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INTEGRATED RESOURCE DEVELOPMENT OF THE SUNDARBANS RESERVED FOREST

BANGLADESH

INTEGRATED RESOURCE MANAGEMENT PLAN OF THE SUNDARBANS RESERVED FOREST

VOLUME 1
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UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Dhaka, The Peoples Republic of Bangladesh, March 1998

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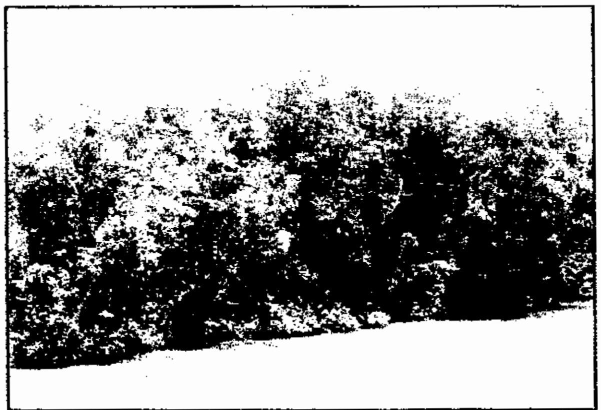
This technical report is one of a series of reports prepared during the course of the project BGD/84/056. The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.

Plate 1


Keora at Katka


Sundri and Kakra


Sundri Forest


Sundri Top-Dying


Rhizophora Sp.


Goran and Gewa – West SRF

EXECUTIVE SUMMARY

This Integrated Resource Management Plan (IRMP) uses extensive information, derived from the fieldwork of the Forest Department (FD) and FAO in UNDP Project BGD/84/056, to formulate scientifically sound options for improving the sustainable management of the Sundarbans Reserved Forest (SRF). The plan is an advisory document for decision makers and managers which provides balanced guidelines and strategies to improve management of all aquatic and terrestrial resources.

The plan provides an holistic assessment of resource statuses of the entire ecosystem for *the first time*. This is a valuable baseline for future research, working plans and development. It could not incorporate a traditional forestry plan since the necessary inventories and stock assessments were not available. However, it provides details of new inventory survey methodology and discusses gaps in the data. The wood resource and non-wood resources and their management were carefully researched to form part of the technical background to the plan, using an integrated systems approach.

It also includes guidelines for practical biodiversity conservation with emphasis on the potential for income and employment generation for disadvantaged groups living near the SRF. Inter-sectoral co-ordination, development of ecotourism; participatory planning, institutional capacity building and the protective role of the coastal forests are among the plan's components.

There are three parts:

Volume 1	:	Part 1 The past and current situation and Part 2 future management.
Volume 2	:	Appendices giving further details.
Volume 3	:	Maps prepared from GIS and hydraulics data bases.

Information is provided on history, meteorology, geology, physiography, hydrology, soils, land use, flora, fauna, forestry, fisheries, wildlife, tourism, apiculture, harvesting and marketing, economics and socio-economics. For full details of separate technical reports refer to Appendix A15 (Vol 2).

The plan is framed round the following broad topics, some of which stem from the Forestry Sector 1980-1985 Five Year Development Plan:

- Ecosystem analysis covering the biotic and abiotic resources of the Sundarbans Reserved Forest.
- Scientific management of forest resources for the maintenance of the ecological balance and sustained production of timber, fuelwood and other forest products.
- The sustainable use of terrestrial and aquatic resources.
- Improvement of the technical capability of the institutions operating in the forest area.
- Practical approaches for long-term conservation of biodiversity and intrinsic values of the fragile and threatened coastal mangrove ecosystem.
- Increase or improvement in wood and non-wood products to meet the needs of an expanding population.
- Establishment of a data base as a basis for resource management.
- Provision of accurate socio-economic information and policy guidelines to ensure greater income and employment opportunities for people who depend on the resources of the Sundarbans for their livelihood without adversely effecting the ecosystem.
- The promotion of socially and culturally beneficial tourism without degrading the ecosystem.
- Investment opportunities for sustainable development.

The plan includes:

(1) The status of the ecology of the Sundarbans based on the work of three consultants, Sukardjo (1993); Grepin (1994/95) and Rahman (1994/95). These confirm that the Sundarbans Reserved Forest still retains most of the attributes of locally disturbed climax mangrove vegetation with little human encroachment. On the other hand there are signs that gross changes are occurring in the ecosystem, reflected in alterations in vegetation associations and plant succession. It appears that these are

caused by reduction in freshwater flushing, increasing duration of higher levels of salinity, increasing sedimentation and subtle intrusion by people.

(2) A draft zoning scheme is proposed for different conservation or production purposes. The exact nature and intensity of management will follow from the inventory data which will be obtained in the IDA Forest Resources Management Project (FRMP) 1996/97. A ten-year implementation schedule indicates priorities, activities, timebound targets and financing. A GIS data base has been developed so that accurate spatial information is immediately available.

(3) By definition the SRF land use category is for forestry and it is to the great credit of the Forest Department that the area has retained the integrity of its borders and the nature of the enclosed mangrove ecosystem for over a hundred years despite unabated pressure from the public. The forest produces about 45% of the sector's total revenue.

The FD has a field staff to manage the SRF consisting of a Conservator, Khulna Circle, three DFO's and about 1000 of other ranks operating on an annual revenue budget of about Tk 34 million which is only 37% of an internationally recognised standard for species protection alone and is 5% of the total FD annual expenditure account. This is also less than 25% of the mean annual revenue for the SRF. The emoluments and terms and conditions of the FD staff working in the special conditions of the SRF should be the subject of separate and urgent GOB review aimed at improving these to levels commensurate with the unusually difficult working environment and unusually high level of responsibility and risk that all field staff face.

Proposals are made now for practical integration of multisectoral ecosystem management, protection, research, training and monitoring and evaluation (M&E) activities essential for sustainability in what amounts to a Managed Resource Area (IUCN classification).

The functional unit needed by the Forest Department (FD) for continuity in multiple resource research, technical training and capacity building is the operational unit (OPSUNIT) which was established at Khulna. Its structure is set out in Figure 9.

(4) Recommendations are made for improving institutional and fiscal arrangements. At present there is a strong case for short-term funding and finding the means for linking the OPSUNIT to the Forest Department's Resource Information Management System (RIMS) based in Dhaka, Headquarters whilst maintaining its long-term role in Khulna. Continuity is a major structural problem and the two-tier system of professional and technical foresters approved by the Secretaries Committees may help attain essential stability and continuity which are discussed in Section 26.

(5) The plan includes a soil-cum-vegetation map of the Sundarbans depicting the spatial variation in species composition and associations. This builds on the ODA 1985 1 : 50 000 vegetation maps and shows the clear relationship between soils, salinity and vegetation types (see volume 3).

Guidelines for the fishery and wildlife are drawn up based on the findings of Chantarasri (1994) and Tamang (1993). At the moment there is minimal management of these resources. Indications are that there is widespread over-exploitation of the fish stocks as well as a detrimental impact upon the environment. Unfortunately there is inadequate information at present on which to make management decisions.

(7) Reports on the statuses of important wildlife species have facilitated the inclusion of an outline wildlife management plan. The wildlife plan is supplemented with information on sustained yield harvesting, biodiversity management, reintroductions of extirpated species and the requirements not only for research and monitoring but also for proper commercial appraisal and sustainable utilisation of an undervalued resource. Protection of vulnerable and endangered species and uncompromising maintenance of wilderness values for ecotourism are considered to be high priorities for future implementation.

(8) The plan introduces a programme for investment in development:

Proposals are made in an indicative investment programme (volume 1) for follow on implementation including, strengthening the Forest Department itself, management of wood resources, non-wood resources, fisheries, tourism and recreation, apiculture, wildlife sustained yield harvesting, extension programmes, employment diversification, small-scale industries and enhancement of opportunities for development for women and other stakeholders, all aimed at improving management, poverty alleviation and more effective resource utilisation. Details are given in Section 27 and Table 73.

(9) A functional communication system consisting of boats, launches and wireless sets with necessary support services for maintenance and repairs is essential to efficient resource management over large areas such as the SRF. Substantial investment will be needed in additional equipment and training. Recommendations are made for inter-sectoral collaboration, for inter-netting between users, for use of photovoltaic power and for training operators.

(10)Harvestable wood and non-wood resources were studied and reported on in specialist reports (see Vol 2) and planning guidelines are based on their conclusions:

- Results from analysis of 69 PSP's and felled sample trees indicate that the timber resource may have been incorrectly estimated (Leech, 1995) in the past in the ODA inventory and that the harvestable volume of Sundri ***Heritiera fomes*** and Gewa ***Excoecaria agallocha*** may have increased since the last PSP measurements 7.5 years ago, confirming the benefits of the Moratorium. A parallel finding has been that, in recent years, volumes from salvage fellings of Sundri have reached pre-Moratorium levels (Mitchell, 1995) and that the total harvest may be as high as 40% above the official harvest (Larsen, 1994). Thus recommendations are made to ensure that the forest does not veer again towards depletion.
- Analysis of the PSPs indicates that the standing volume of Sundri as a proportion of the total appears to have remained constant at 53.4% in 1986/87 and 53% in 1994/95. This suggests that in the theoretical conditions of untouched forest under the Moratorium the proportion of Sundri is not changing. Yet the 1985 inventory compared the areas of Forest Types at 1960 and demonstrated that the area of pure Sundri forest had actually declined and that the area of Sundri-Gewa had increased over the period. This might imply that management practices have had a negative impact upon the standing value of the forest and there is a discernible impact upon natural succession. The areas of Sundri-Gewa and Gewa-Sundri were 1232 Km^2 and 600 Km^2 respectively in 1985.
- Based upon the same analyses of remeasured plots and consistent volume estimation methods, it seems that the proportion of Gewa has increased slightly from 38.1% to 39.0% over the same period. The provisos in accepting these conclusions are that the PSP's have been excluded from official harvesting. It is virtually impossible to ascertain total consumption. They therefore do not necessarily provide a true measure of change in the production forest resource.
- That information from the data made available to or obtained during the preparation of this plan are inadequate to make detailed operational plan management prescriptions for the wood resource. This will only be possible once the results of the impending 1996/97 FRMP inventory are known after which the Moratorium should also be reviewed.

- Results show that 131 000 fishing boats of all sorts were licensed to enter the SRF in 1994 and that estimates of the total landed harvest, including the offshore fishery, are extraordinarily variable ranging between 75 000 t (MARC, 1995); 55 000 t (Ahsanullah, 1995) and 12 000 t (Forest Department, 1995). The most important finding is that finfish, shrimps, crabs and oysters are intensively harvested at the Maximum Social Yield level (Pena, 1994) and that this is unsustainable and requires properly directed management of breeding areas, fishstocks, and methods of harvesting. This matter is substantially complicated by lack of training in fishery management and inadequate inter-departmental co-ordination.
- There is increasing inability for supply to meet demand causing unsustainable over-exploitation. More regulation and better control systems are needed, taking due account of socio-economic and land use factors outside the SRF.

- That no increase in harvest levels should be permitted and that for fish, shrimps, crabs, oysters, other wildlife, golpatta and goran immediate attention should be paid by the FD to consider new harvesting and marketing systems and to improve existing systems.

- That development of community participation in planning, decision making and management, requires considerable forward preparation in which the FD should take a lead role beyond the capacity of current staffing. Investment and proposals to strengthen the management capability are made as part of the ten-year follow on programme.

- Properly managed SRF ecotourism, as part of a one-week Bangladesh module which would aim to capture 2% of the regional market, could lead to the development of an industry worth at least US$100 million pa is described among other development projects.

(11)Institutional development proposals are outlined to support the FD's management capacity. There are several alternative schemes and two are outlined. Assumptions are made which are common to all:

- The current management structure requires strengthening and reform to meet modern demands and new challenges.
- That the existing FD infrastructure, fleet of launches and vehicles and nearly the whole network of field offices requires either up-grading or replacement requiring a modernised management organisation.
- That any change must be intended to be permanent and that the new organisation must be wholly supported by GOB or be self financing and not dependent on donor finance.
- That by improving efficiency, accountability and transparency the return from the resources of the SRF will be nearer their full economic value thus justifying higher expenditure on management.
- That there must be a capability for continually collecting data and monitoring the resource so that an up to date information is available at all times for the preparation of management plans.
- That the recommendations regarding changing the revenue system will be implemented to achieve the expected increase in revenue.
- That there should be no major retrenchment of existing staff and that terms and working conditions for the Forest Department will be significantly improved.

Option 1: This improves the existing management structure by up-grading the FD's *status quo* technical capabilities by providing requisite capital investments in training, infrastructure and equipment. The proposed structure is illustrated in the organogram in Figure 6.

Option 2 : The structure enhances the FD's role as the pivotal organisation involved in administering and managing the SRF but changes the *status quo* through receiving direction from a top level National Mangrove Committee (NMC) - steering committee and by the addition of the OPSUNIT and Integrated Management Committee for multi-sectoral technical functions. This arrangement offers the first methodical step towards genuine integrated resource management.

Attributes of option 2 are:

- Control and implementation of management plans would remain with the FD. The department would recruit specialists to manage fisheries, wildlife utilisation, tourism and community development in the border area. It facilitates cross-sectoral technical co-operation at all levels.
- It helps draw upon expertise in areas where the FD is not skilled or outside its mandate.
- To strengthen co-ordination and integration with other concerned ministries and agencies formation of a National Mangrove Committee (NMC) is recommended. The purpose of the NMC would be to formulate policy and legal reforms, arbitrate monitoring and ensure operational transparency.

The proposed structure is illustrated in the organogram in Figures 7 and 8.

Technical conclusions on which this plan is based are listed below:

1. The biophysical environment:

It is confirmed that major changes are occurring in the mangrove ecosystem. These are :

- Reduction in freshwater inflow from the upstream catchments.
- Increased rate of sedimentation in some places.

- An increase in the duration in most places of higher levels of salinity than measured in the past and that the area of greatest fluctuation in total salinity level is in the central part of the SRF. Information based on the project's pioneer hydraulic modelling studies of the mangrove system.
- Global warming indicates a sea level rise which could ultimately have a serious impact upon the ecosystem.
- Industrial, maritime and agricultural pollution from upstream sources and tidal flows from the Bay of Bengal may become critical to the biota.
- Without access to the 1995 FRMP aerial photographs it has not been possible to detect gross changes in plant associations and forest types measured in terms of total relative areas.
- The occurrence of the condition known as Sundri Top-dying is widespread and no single causal factor has been detected Rahman (1995)and Ciesla (1994). It is generally thought that the cause is likely to be a mixture of several factors acting together which in any case cannot be rectified; improvement in management and control of removals are required.
- In 1985 a change was detected in the total standing volume of Sundri and also that the number of trees per ha had declined since 1960 and this could ascribed to inappropriate application of the selection management system. It has not been possible to ascertain whether this trend has continued for Sundri since that time but for Gewa the same management technique is still used to the probable detriment of the Sundri stock.
- The species populations of the larger animals especially tiger, spotted and barking deer, Rhesus macaque, wild boar and dolphins are either stable round mean density levels or declining.
- The avifauna is rich in species but populations generally exhibit unusually low densities.
- Fish, shrimps, prawns and crabs are over-harvested at all stages in life cycles and unusual fluctuations in their densities were observed in 1994/95.
- Crocodiles, turtles, monitor lizards and snakes are widespread in their occurrence but densities are low.

2. Wood production

- There appears to have been an understandable small total net increase in standing volume of commercial timber species since 1987 but this will need to be verified.
- Despite the timber Moratorium the volume of removals of Sundri, Gewa and Goran are at pre - Moratorium levels.
- The official wood harvest for all species was estimated at 243 000 m^3 ; undetected harvesting may have added a further 40% to this.
- Wood production at the combined current official and unofficial level could be leading to a depletion in the forest but this will not be known until the 1995/96 inventory results are analysed.

3. Non-wood production

- The total Golpatta harvest is said to have averaged 69 000 t over the last 10 years and the FD revenue in 1993/94 was Tk 5.9 million. From socio-economic and other evidence this harvest may be higher by up to 40% .
- The total landed fish harvest estimates range between 12 000 t and 50 000 t. The latter is considered the most probable.
- The total honey and beeswax harvest is unknown but is likely to be to the order of 600 t and 150 t respectively, three times the officially recorded levels, and are valued at Tk 2.2 million.
- The total harvest of shrimp fry was recorded by the FD at 231 million in 1993/94 accruing Tk 11 million in revenue but this harvest is exceptionally difficult to record and is probably under-estimated.
- The total harvest of shells is about 3200 t for which the annual revenue is about Tk 86 000.
- The total number of international tourists visiting the SRF is thought to be about 300 and the total number of domestic tourists is estimated at about 5300 with a combined average revenue to the FD of about Tk 31 000 per year over the last seven years.

4. Socio-economics

- The human population living in the border area is about 2 million and will double at the present rate of 2.04 % pa in 34 years.

- At least 25 % of this population is probably engaged in some form of full-or part-time activity in connection with produce from the SRF and if all members of families are included this figure could be much higher.
- The dependence of people on the mangrove ecosystem is high (MARC, 1997)with about 46 % of all local income being derived directly from SRF resources.
- Those involved in timber and Golpatta harvesting are known as Bowallis and those involved in honey collection are known as Mowallis. Both communities do not appear to receive equitable benefits for their labour.
- Lack of personal security, and unfair treatment were stated to be the foremost local concerns.
- Investments in post-harvest technology, credit facilities, social forestry, wildlife management, tourism, apiculture and aquaculture in the 10 Km border area, could do much to create new employment opportunities for women and disadvantaged groups and thereby help relieve pressure on the products of the SRF.

5. General

- Administrative responsibility rests in the hands of the Forest Department but sustainable development cannot occur in isolation. It is necessary for the Department's capability to be strengthened through dialogue and co-operation with other concerned agencies. It is widely acknowledged that conservation of natural resources cannot be successful against a background of widespread poverty. Management of the SRF should encompass this reality and recommendations are made which promote better protection in conjunction with social equity.
- With better resources, information and education in the border area, the Forest Department could readily move away from people's perceptions of a custodial and confrontational stance. This could be done by demonstrating a commitment to the principle defined at the UNCED conference in Rio de Janiero 1992 Agenda 21, that there is little future for conservation without social justice. Following the reforms described in this plan the FD could manage the SRF in the certain knowledge that its actions accord with the multifarious needs of society and that its technical base has the backing of other specialist agencies.
- Ecological changes are occurring in the physical environment, most of which have their origins outside the SRF. These are outside the control of the FD but which should be researched and monitored through continuous survey using modern technology, GIS, hydraulics and remote sensing.
- Impediments to the FD's management capability, in the face of increasing population pressure on the environment and its resources, indicates a need for capacity building with considerable investment in resources and training.
- The widely held belief that the SRF resource is in decline is correct but the situation is not irretrievable; factors relating to management can be accommodated; others, such as sea level rise, cannot.
- The consequence of not implementing the actions, recommended and set out in this plan to improve management of all resources by investment in integrated strategies, will be an accelerating decline in the value of the SRF ecosystem and consequential increasing loss of social and economic benefits to the nation as a whole.

Twenty recommendations for integrated resource management are highlighted in the body of the plan and listed in Section 30. These are summarised below:

R1 Conservation, integrated management and development

In order to ensure optimal utilisation of resources without disturbing the ecological balance inter-departmental co-operation and co-ordination of functions will be needed. It is recommended that future institutional and structural planning should clearly define areas of mutual interest and responsibility.

R2. Management Committees

It is recommended that regular meetings between concerned ministries, departments and other agencies should be structured by inter-ministerial agreement which would steer and direct the implementation of the IRMP and future management of the SRF. The following should be should be considered:

- The National Mangrove Committee (NMC)
- Sundarbans Integrated Management Committee (IMC)
- Sundarbans Tourism Advisory Sub - Committee

R3. Institutional framework : administration and management

It has been concluded that the institutional structure for improved management of the SRF requires some adjustment. It is recommended that an early decision be made by the government on the best way forward to meet future management goals. Details are in Sections 26 and 27.

R4. The Operational Unit

It is recommended that an Operational Unit for research, monitoring and capacity building, illustrated in Figure 9 and described in Section 26 in Options 2, should be maintained as the first follow-on project in the IRMP. Financial arrangements are detailed in Appendix A17. If interim funding becomes available it is recommended the unit should be linked administratively and functionally to the ongoing FRMP RIMS operations.

R5. Integrated planning system

In the absence of inventory data which are to be acquired in 1996-97 by the FRMP IDA project, it has not been possible to prepare a new detailed Working Plan for the SRF and it is recommended that the new forest inventory data should up-date and add to the existing multiple-resources data on a continuous basis using the methodology defined in this plan (section 9.1) and that these should form part of a future annual operational plan within the IRMP which should be up-dated annually.

R6 Environmental and ecological parameters for follow-on activities

It is recommended that priority topics for follow-on applied research on the mangrove ecosystem should be to focus initially on the broad fields listed below on which work has started but is far from complete:

- Comparative vegetation mapping 1933, 1960, 1985,1996
- Meteorology - new SRF ecological research stations
- Hydrology - shared waters and pollution
- Soils, erosion and accretion
- Biodiversity, fish stocks and other wildlife
- Stakeholders' participation - people's organisations, NGO's and donors
- Baseline surveys of biodiversity in the wildlife sanctuaries and border zone
- Analyse prospects for investment in economic developments in the 10 km border area especially tourism, cottage industries and post-harvest technology
- Studies on the impact of land use practices in surrounding and upstream areas
- Detailed studies of resources, ecology and protection of the 12 nautical mile Marine Zone.

R7 Future field survey

It is recommended that the Forest Department should change from a stratified random sampling methodology to continuous survey systematic sampling Leech (1995).

R8 The wood resource

Although the project was able to measure 69 of the Permanent Sample Plots it was not able to complete the task. It is recommended that the remaining plots be measured as soon as possible. Likewise the environmental/site parameters which have been recorded also should be analysed and used to develop baseline data against which future measurements can be made. It is recommended that this activity should be carried out by the continuous survey team working with the FRMP team as a matter of high priority using the methodology derived by the project (Leech,1995).

R9 Production forest resource management

It is recommended that the following key issues be addressed in determining priorities for production forest management:

- The FRMP inventory to assess the current status of the wood resource is required. It is recommended that this should follow the TSP/ PSP survey system proposed by Leech (1995).
- Following the results of the new inventory design and implement a production management plan outlined by Leech (1995).
- Develop a new system for measuring all wood removals. It is recommended that timber sizes should be based on the metric system, firewood on metric stack measurements and pulpwood based on metric weights as it enters the mill (Mitchell, 1995).
- A new system of passing the removal records up the line for collation needs to be developed, so that all the information by the lowest level of resolution can be centrally processed.
- A new system of continually up dating compartment records should be devised.
- Institute a system of periodical independent random auditing of all revenue systems.
- Improve silvicultural practices.
- It is recommended that the timber Moratorium should continue pending the results of the FRMP inventory.
- It is recommended that all Sundri logs be graded for auction.
- Privileged selection of REB poles from the forest should be discontinued.
- Trials of enrichment planting and large scale plantations should be implemented.

R10. Products : management, harvesting and economics

It is recommended that early consideration be given to reorganising the revenue system and that the system of measuring produce which should be standardised using metric units.

R11. Wood products

After completion of the FRMP inventory priority consideration should be given to the following for improvement of yields and management of wood products:

- Re-define the harvesting criteria applied to Top-dying Sundri if the Moratorium is to remain.
- Assess the cost-benefit of utilising species such as Baen ***Avicennia officinalis*** and Jhanna ***Rhizophora mucronata*** for poles and piles currently wasted and only harvested unofficially.
- Assess the cost-benefit of harvesting wind-blown and fallen trees.
- Gewa is harvested as an exception to the moratorium for use by the Khulna Newsprint Mill. In the event that the mill becomes uncompetitive and faces closure alternative use for Gewa must be researched.

R12. Non-wood resources

The Department has barely had the means for managing the timber resources and thus a big shortfall in capacity exists in its ability to handle the new, often highly specialised requirements, of modern management of both plant and animal based NWFPs. It is recommended that this matter be given priority attention in future investment programmes especially for fish, crabs, shrimps and other wildlife.

For future improvement in NWFPs management, it is recommended that the FD work with NGOs, the civil administration and all other relevant parties. Steering this should be one of the preliminary functions of the IMC.

R13. Plant based NWFP'S

In the order of priorities it is recommended that Golpatta, Hantal and Bhola are given priority attention in terms of making a proper determination of their distribution and statuses.

R14. Animal-based NWFP'S

The Fishery : management of the Sundarbans fishery involves issues which affect the wildlife sanctuaries, forest resource conservation, socio-economics, international boundaries and border area agriculture. This matter involves many agencies and areas well beyond the SRF. It is recommended that avenues are sought for integrating existing complementary functions, skills and responsibilities to mutual benefit under the auspices of the FD where appropriate.

It is recommended that early attention be paid to establish co-ordinated management involving agencies concerned with research and management especially of straddled fish stocks, the Marine Zone and migratory fisherfolk. It is recommended also that immediate management attention should be given to new regulatory systems, including new revenue controls, closed seasons, net mesh limits and stock conservation rules should be established as a matter of urgency by co-ordination of responsibilities and management, in and outside the SRF.

Wildlife: it is recommended that early implementation of wildlife management plans and conservation and research programmes should be instituted in consultation with the IMC. Particular attention should be paid to defining clearly the areas of responsibility and integration of activities of all the DFO's working in the SRF especially overlapping functions. Other wildlife related matters on which recommendations are made include:

- Zoning
- Vegetation studies
- Legislation and Regulations
- Saltwater crocodile
- Boundary delineation
- Deer and crocodile farming
- Ecology of tigers
- Re-introduction of lost species

R15. Tourism and recreation

Recommendations for socially and culturally acceptable tourism and recreation are based upon implementation of a Ten-year Developmen. ian referred to as the TYDP which makes proposals for ecotourism development, investment and management. Optimum use of the wilderness asset is proposed for high cost low volume tourism.

It is recommended that a Tourism Advisory sub-Committee be convened as soon as possible to examine and co-ordinate tourism operations and prioritise development. Early attention should be given to defining functions of the Public Sector, Parastatal organisations and the Private Sector, especially integration of the roles of the Forest Department, the Parjatan Corporation, the Tour Operators' Association of Bangladesh (TOAB) and private investors.

Other tourism matters covered in the plan on which recommendations are made include :

- Training
- Common objectives, commitment and policy
- Prioritise product development
- Prioritise development plans
- Publicity and marketing
- Development without destruction
- Tourism targets
- Regulation and monitoring

R16. Apiculture

Honey has been collected in the Sundarbans by Mowallis from time immemorial but the interests of this subsistence user group have never featured highly in traditional management plans. It is recommended that the entire system of apiculture management be reviewed and that arrangements should be made for more equitable access to the resource on the one hand and better resource management on the other.

It is also recommended that a plan for effective utilisation of the honey processing equipment which will be transferred to the FD should be prepared. Joint management between the Forest Department and an NGO should be approved to ensure that the processing plant is used to assist Mowallis and local producers, especially women and other disadvantaged groups.

R17. Socio-economics : resource utilisation and community affairs

Preliminary findings (MARC 1997) confirm firstly the growing number of people, probably at least half a million, who participate to a greater or lesser extent in SRF resource utilisation and secondly the need to revise some harvesting and marketing practices which do not satisfy criteria for social justice.

Whilst many people consider that their food and clothing needs are met personal security is reported to be the single most important concern for people who access the SRF. This is a matter which should be given high priority in future development planning.

R18. Integrated management strategy : the common goal

Integrated multiple resource management implies setting and agreeing common goals. It is a tenet of modern management that separate specialised technical departments and agencies should work together where a common need justifies combined effort, pooling of resources and economies of scale.

It is recommended that the aims of the IRMP are carried through with full cross-sectoral technical agreement since expectations have been heightened and the pressures at all levels are acute. It is recommended that steps be taken by UNDP/FAO and GOB to ensure the continuity of the OPSUNIT as the base for future long-term research, monitoring and evaluation. It is also recommended that the scope of the Forestry Master Plan, FRMP/IDA, includes adequate training of Forest Department staff in integrated resources management.

A further key recommendation is that the FRMP inventory results are added to existing data to enable the prescriptive part of this plan to be completed.

R19. Implementation, development and investment

Proposals for investment leading to follow-on projects and development assemble all the different components of the SRF and together they form a plan for phased and sustainable development with capital and recurrent expenditure over 10 years estimated at least US$ 30 - 40 million. Each is discussed in Section 27 and it is recommended that these are given early consideration by MOEF and the FD so that detailed financing and implementation can follow with minimum delay using the guidelines for priority requirements listed below:

- Forest management
- The operational unit
- Fisheries
- Institutions
- Wildlife management
- Tourism
- Wood resource
- Non-wood resources
- Socio-economics

There are three target clusters in a Ten Year Follow on Implementation Schedule which will require different approaches to implementation and investment profiles are provided for some:

1. Projects which concentrate on management within the SRF.
2. Projects which affect both the SRF and the Border Zone.
3. Projects which have regional or broader international dimensions.

R20. Official commitment

To achieve sustainable development much will depend upon official commitment, investment and strategic planning and further technical assistance.

It is recommended that the feasibility studies to augment policy decisions be implemented as soon as possible against the targets of the Indicative Investment Programme outlined in Table 77 of the plan once policy decisions on institutional and legal reforms are complete.

ACKNOWLEDGEMENTS

The Food and Agriculture Organisation is greatly indebted to all those many people, especially the members of the Forest Department of Bangladesh who assisted, directly or indirectly, in the implementation of this project by providing support at all levels, information, advice and facilities.

"Protected areas are meant to conserve biodiversity of species (both plant and animal) as well as the genetic variation within them; maintain the productive capacities of ecosystems; preserve historic and cultural features of importance; secure landscapes and wildlife which enrich human experience through their beauty; provide opportunities for community development, scientific research, education, training, recreation and tourism; and serve as sources of national pride and human inspiration."

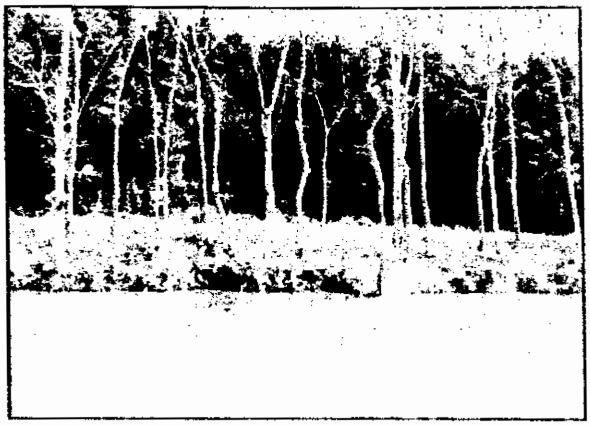
Unasylva, FAO 1994

"Environmental protection cannot be separated from social justice."

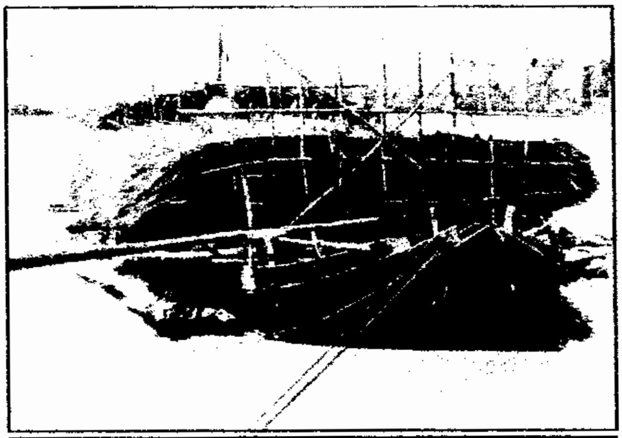
BBC Earthfile 08 February 1995

Plate - 2

Golpatta and Sundri

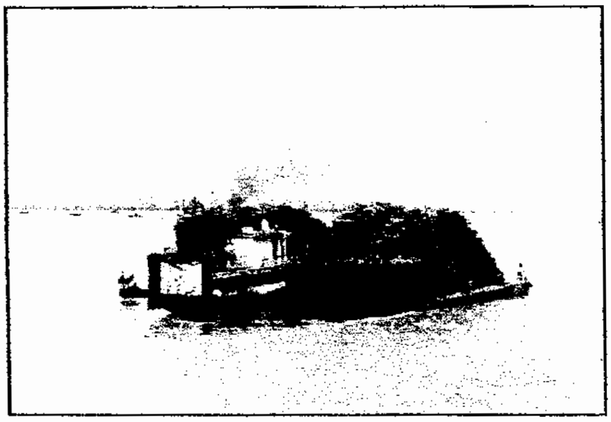


Forest Plantation



Golpatta Transportation

Forest Department Coupe



Gewa Transportation by KNM

Community Consultation

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accretion, administration, Allowable Cut, angling, apiculture, auction, audit, avifauna, Bangladesh, Bay of Bengal, beat, bees, beeswax, BFRI, biodiversity, bird sanctuary, block, border zone, Bowalli, circuit, climate, communications, community, compartment, conservation, coupe, crab, crocodile, CST, cyclone shelter, cyclones, deer, DFO, diseases, Divisional, domestic, ecology, economics, ecotourism, endangered species, erosion, expenditure, fauna, finance, fish stock, fish, fishery, fishing, fishing gear, flora, forest, forest inventory, forest station, Forest Department, forestry, gazetteer, geology; Gewa, GIS, Golpatta, Goran, growing stock, harvesting, honey, hunting, hydrology, hydraulic, increment, IDB, infrastructure, Integrated Data Base, inventories, IUCN, khal, KNM, Khulna, law, mangrove ecosystem, marine, marketing, markets, monitoring, moratorium, Mowalli, navigable, NGO, NPD, offshore fishery, OPSUNIT, oyster, Permanent Sample Plots, pests, plantation, plants, pollution, potable water, precipitation, primates, protected area, protection, range, recreation, research, reserved forest, revenue, rotation, salinity, sampling, security, sedimentation, shrimp, silviculture, socio-economics, species diversity, Sundri, systematic sampling, temporary sample plot, tides, tiger, top-dying, tourism, training, transportation, turtle, wild boar, wildlife, Wildlife Sanctuary, women, working plan, yield, zone

LIST OF APPENDICES - VOLUME 2

CONVERSION FACTORS AND WEIGHTS AND MEASURES

Monetary:

1 USD	=	40 Taka (Tk)
1 Tk	=	0.025 USD
Lakh	=	100 000
Crore	=	10 000 000

Metric to English/American:

1 cm	=	0.3937 in.
1 m	=	3.28 ft. 1 m = 3.281 feet (ft)
1 m3	=	35.3 cft (cubic feet - true volume)
	=	27.7 Hp ft (Hoppus, approximate)
1 m3	=	35.315 cubic feet (cft)
1 m3	=	27.736 Hoppus feet (Hp ft)
1 m3	=	0.353 cunit
1 m3	=	70.629 stacked cubic feet (cft stk) (assumes 50% of the stack is air space)
1 ha	=	2.471 ac 1 ha = 2.471 acres (ac)
1 kilometre (Km)	=	0.62 mi 1 Km = 0.594 nautical miles

English/American to Metric:

1 inch (in)	=	2.54 cm
1 foot (ft)	=	0.305 m
1 cft	=	0.0283 (m^3)
1 Hp ft	=	0.0361 (m^3)
1 cord	=	3.625 m^3 (stacked)
1 acre (ac)	=	0.4047 ha
1 mile (mi)	=	1.61 Km
1 nautical mile	=	1.8532 Km or 1 minute of longitude measured along the Equator

Bangladesh Units:

1 seer	=	2.057 lbs
	=	0.933 kg
1 maund (md)	=	40 seers 1 maund =37.324 kilograms (kg)
	=	37.3 kg
1md	=	3 cft stk air dry wood (Larsen, 1994)
1md	=	2 cft stk green wood (Larsen, 1994)
1 tonne (t)	=	26.8 md (1 000 kg)
1 tonne (t)	=	26.792 maund (md)
1 cunit	=	100 cubic feet (cft)
1 pon	=	80 pieces

LIST OF ACRONYMS

AAC	Annual Allowable Cut
ADB	Asian Development Bank
BCAS	Bangladesh Centre for Advanced Studies
BGD	Bangladesh
BIWTC	Bangladesh Inland Water Transport Corporation
BOD	Biological Oxygen Demand (the amount of oxygen required to stabilize the demands from aerobic action in the decomposition of organic matter)
BPC	Bangladesh Parjatan Corporation
BSCIDc	Bangladesh Small and Cottage Industries Development Corporation
BWDB	Bangladesh Water Development Board
CCF	Chief Conservator of Forests
CDC	Commonwealth Development Corporation
CHMT	Continuous Hydrological Monitoring Team
CIDA	Canadian International Development Agency
CITES	Convention on International Trade in Endangered Species
CST	Continuous Survey Team section of OPSUNIT
DEZ	Day Excursion Zone
DFO	Divisional Forest Officer
DOE	Department of the Environment
DOF	Department of Fisheries
FAO	Food and Agricultural Organisation of the United Nations
FAP	Flood Action Plan
FD	Forest Department
FMP	Forestry Master Plan Project 372001/30 1992
FPCO	Flood Plan Co-ordination Organisation
FRMP	Forest Resource Management Plan
FYDP	Five Year Development Plan
GIS	Geographic Information System
GOB	Government of Bangladesh
GPS	Global Positioning System
IDA	International Development Agency (World Bank)
IDB	Integrated Data Base
IMC	Integrated Management Committee
IRMP	Integrated Resource Management Plan for the SRF
ITTO	International Tropical Timber Organisation
IUCN	International Union for the Conservation of Nature (World Conservation Union)
KNM	Khulna Newsprint Mill Ltd.
LANDSAT	A series of satellites launched by NASA
LARST	Local Application of Remote Sensing Techniques
MIKE - 11GIS	An integrated MIKE 11/GIS modelling tool to support river and flood plain management
MIKE - 11	Software developed by Danish Hydraulic Institute for the simulation of flow, sediment transport and water quality.
MPHA	Mongla Port Harbour Authority
MRA	Managed Resource Area
MSD	Mangrove Silviculture Division - BFRI
MSY	Maximum Sustainable/Sustained Yield
NACOM	Nature Conservation Movement
NASA	National Aeronautics and Space Administration of the United States of America
NCS	National Conservation Strategy
NEE	North-eastern Extension
NEMAP	National Environment Action Plan
NERP	North-East Regional (water management) Project
NGO	Non-government Organisation
NOAA	National Oceanic and Atmospheric Administration of the United States of America
NPD	National Project Director
NTO	National Tourism Organisation synonymous with BPC
NTP	National Tourism Policy
ODA	Overseas Development Administration

OPSUNIT	Operational Unit
PA	Protected Area
PSP	Permanent Sample Plot
REB	Rural Electrification Board
RIMS	Resource Inventory Management System
RRI	River Research Institute
SBC	Sundarbans Circuit
SC	Southern Circuit
SCMPA	Sundarbans Coastal and Marine Protected Area
PARRSO	Space Research and Remote Sensing Organisation
SPOT	Systeme Probatoire d'Observation de la Terre, the French satellite with panchromatic and multi-spectral scanning capabilities
SRF	Sundarbans Reserved Forest
SWMC	Surface Water Modelling Centre
SWRM	South-West Regional Model (hydrology)
TFAP	Tropical Forest Action Plan
TM	Thematic Mapper
TOAB	Tour Operators' Association of Bangladesh
TSP	Temporary Sample Plot
TYDP	Ten Year Development Plan
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
USP	Unique Selling Point
UTM	Universal Transverse Mercator Projection
WB	World Bank also IDA

THE INTEGRATED RESOURCE MANAGEMENT PLAN

PART 1 : CURRENT SITUATION

1 INTRODUCTION

This Integrated Resource Management Plan (IRMP) uses information derived from the fieldwork of the Forest Department (FD) and FAO in UNDP Project BGD/84/056, to formulate scientifically sound options for improving the sustainable management of the Sundarbans Reserved Forest (SRF). The plan is an advisory document for decision makers and managers. It sets out guidelines and strategies to improve management of all aquatic and terrestrial resources.

The plan provides an holistic assessment of resource statuses of the entire ecosystem for the first time. This is a valuable baseline for future research, working plans and development. It could not incorporate a traditional forestry working plan since the necessary inventories and stock assessments were unavailable. However, it provides details of new inventory survey methodology and discusses gaps in the data. The wood resource and non-wood resources and their management were carefully researched to form part of the technical background to the plan, using a balanced integrated systems approach resulting from the studies of 26 experts from multiple disciplines.

It includes guidelines for practical biodiversity conservation with emphasis on the potential for income and employment generation for disadvantaged groups living near the SRF. Inter-sectoral co-ordination, development of ecotourism; participatory planning, institutional capacity building, monitoring and evaluation and the protective role of the coastal forests are among the plan's components.

There are three parts:

Volume 1 : Part 1 The past and current situation; Part 2 future management.
Volume 2 : Appendices giving further details.
Volume 3 : Maps prepared from GIS and hydraulics data bases.

The plan is based upon detailed studies of the mangrove forest ecosystem and focuses on sustainable conservation and management of terrestrial and aquatic resources taking into account ecological and environmental changes (refer to Vol 2, Appendices for further information on the Project design and multi-disciplinary technical reports).

The plan provides guidelines for multiple-use management of the Sundarbans and finds ways to increase opportunities for people's participation in wood and non-wood cottage industries, including socially and culturally beneficial tourism and recreation. It demonstrates how a greater contribution could be made to the overall objective of socio-economic development, envisaged in the Forestry Sector's Five Year Development Plan(FYDP). Strategies are devised to enhance production of timber, firewood, aquatic and wildlife resources and policies are discussed for establishing long-term conservation of biodiversity and the intrinsic values of the coastal ecosystem.

Proposals are made for sustainable utilisation and management for all products, especially Sundri ***Heritiera fomes***, Gewa ***Excoecaria agallocha*** and Goran ***Ceriops decandra*** and non-wood products, particularly Golpatta ***Nypa fruticans***, fish, shrimp, oysters, crabs, wildlife and tourism.

Recommendations are made in the realisation that there is unsustainable pressure on all resources within the SRF. Changes are occurring in upstream hydrology, marine pollution, sedimentation, the climate and sea level. These environmental factors combined with competing economic interests require cross-sectoral scientific management, embracing a host of matters beyond the capacity or mandate of the present management system. It was perceived that effective management of the SRF in future would require investment in staffing, training, equipment, rural development and an expanded institutional capacity. This strategy recognises the Forest Department as the management agency within the SRF and incorporates national and international considerations which affect the entire ecosystem, extending from the peripheral agricultural lands, through the inter-tidal mangroves, to the territorial waters in the Bay of Bengal .

1.1 The Sundarbans Reserved Forest

The Sundarbans Reserved Forest is the most diverse and richest natural resource area in the People's Republic of Bangladesh encompassing about 6000 Km^2 of mangroves. The country has an area of about 144,000 Km^2. lying between latitude $20^0$34' and $26^0$33' North and longitude $88^0$01' and $92^0$41' East. It forms an important corridor south of the Himalayan massif, between the sub-continent of India to the west and the sub-continent of Southeast Asia to the east. The Sundarbans Reserved Forest is located on the coast in the extreme south-western corner (Map 1).

From almost every point of view the SRF is recognised as the most valuable forest in the country. It constitutes 51% of the total reserved forest estate, contributes about 41% of total forest revenue and provides employment and income for at least half a million people. It is the single largest source of forest produce in the country accounting for about 45% of all timber and fuelwood output.

The national population is about 120 million, estimated to rise to 140 million by the year 2000 with a density between 700 and 1300 per square kilometre. Of these there are at least 2 million people who live near the SRF. This population is growing at the rate of 2.04% per year and will double in 34 years.

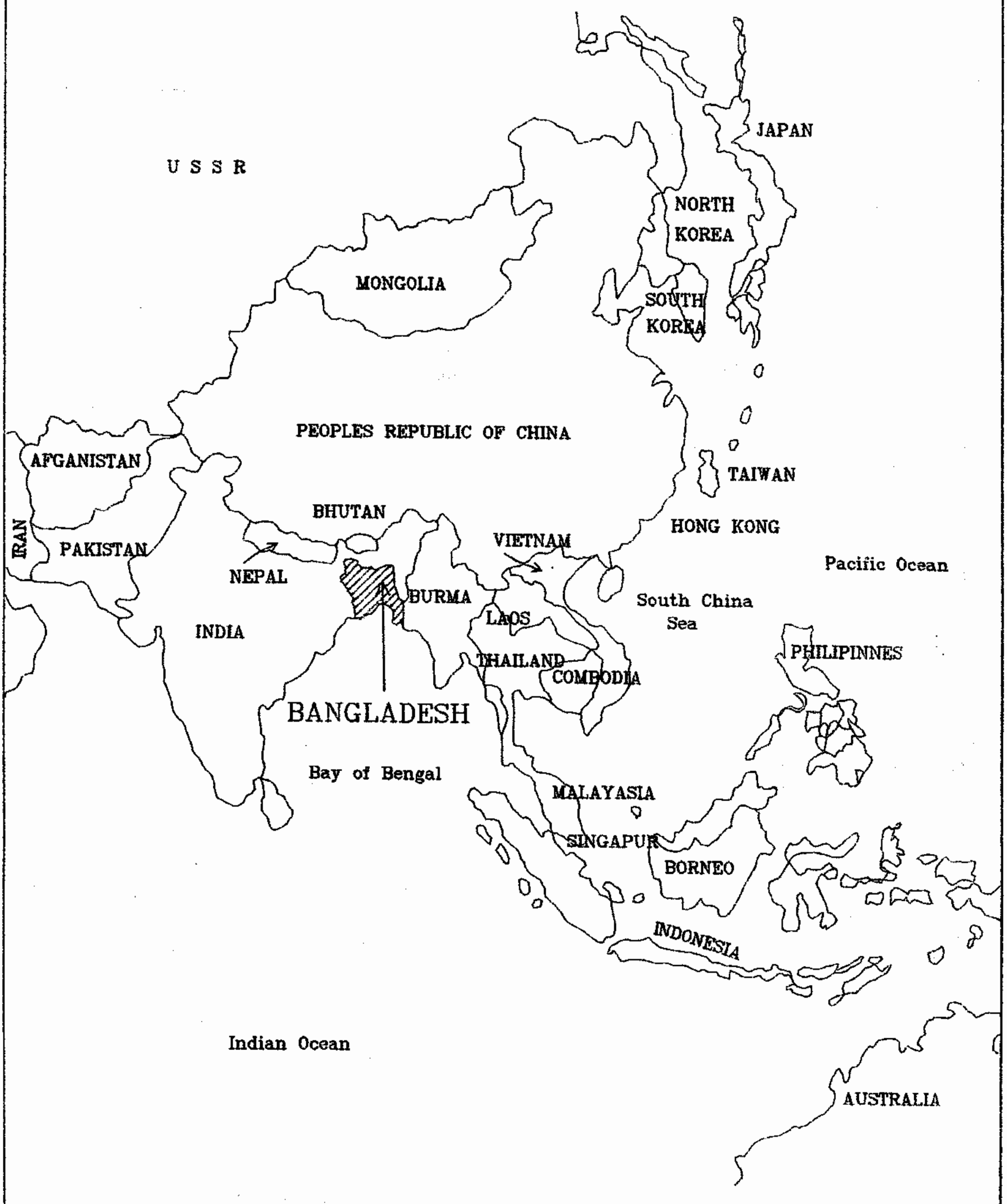
Since approximately 60% of the country is either permanent water, deeply flooded or experiences shallow inundation, water is the formidable force which forms the landscape and dictates the rhythm of the lives of all the people. It is estimated that there are 24 000 Km of river channels within the borders of Bangladesh (Akonda, 1989) and there is a remarkable versatility in the way water is managed and utilised. For the Sundarbans, the ebb and flow of the tides, circadian changes in water depth and its biochemical constituents and the seasonal influence of freshwater from the rivers which shape the delta, make the basis on which all life here depends.

Apart from ranges of hills along the Burmese and Indian borders, to the south and north-east, the entire country is an enormous deltaic plain flanked by the Ganges (Padma), Brahmaputra (Jamuna) and Meghna rivers. These rivers are among the largest in the world and with their floodplains and tributaries make a myriad of meanders, lakes, ox-bows and water meadows, creating an intricate network of large and small channels which flow through an attractive countryside of agricultural land to the sand bars, islands and beaches on the Bay of Bengal (Map 2).

The Reserved Forest sits astride these river deltas which, combined with the portion in West Bengal in India, constitutes the largest contiguous mangrove forest ecosystem in the world, with a total area of about 10 000 Km^2. In Bangladesh the land is mostly free of permanent human habitation and retains a forest closure of about 70% according to the Overseas Development Administration (ODA) in 1985.

The area was described recently by UNDP as "the most important mangrove formation in the world" and this provides the overriding rationale for its careful conservation for the present and all time. The natural forest produces protein, fuel and raw materials for industry and these, combined with the attraction of wildlife and wilderness, form an incomparable source of profit, pride and prestige for local people and the whole Nation.

LOCATION OF BANGLADESH WITHIN THE CONTEXT OF ASIA



Ecological Considerations

The whole area lies within a zone of cyclonic storms and devastating tidal bores which occur during early summer, April and May or late rains, September to November. During the past three decades catastrophic storms with winds reaching 240 kmph have devastated coastal areas (Rashid, 1991). Extensive damage is done not only to large numbers of people and their property but to the environment and wildlife as well and although the mangroves provide a powerful buffer against these violent forces, a physical price is always paid by the ecosystem which has yet to be properly measured.

Furthermore, if global warming and the greenhouse effect cause climatic changes and result in a rise in sea water levels, then Bangladesh will be seriously affected, coastal areas such as the Sundarbans in particular. Whilst such matters may not impinge upon immediate management it would be irresponsible to neglect an issue which may be of profound consequence not only to the mangrove forests, which will be the first area to be affected, but to the country as a whole. Projections suggest that with a rise in level of one metre, by the year 2050 Bangladesh could lose at least 11.5% of its land surface where some 8.5 million people reside and that mangrove areas will be reduced by up to 75% (Rahman and Haq, 1989; Nishat, 1989; BIDS, 1993; Kennedy, 1993; IUCN, 1994).

This thought must be weighed in short and even medium-term management planning. The normal life cycle for example of Sundri is some 130 years and harvestable timber requires about sixty years to reach a harvestable size whereas high economic returns from fish culture in the same environment may be achieved in a small fraction of that time. The sustainablity of both options today remains the subject of intense debate at all levels and in most sectors of the scientific and lay community.

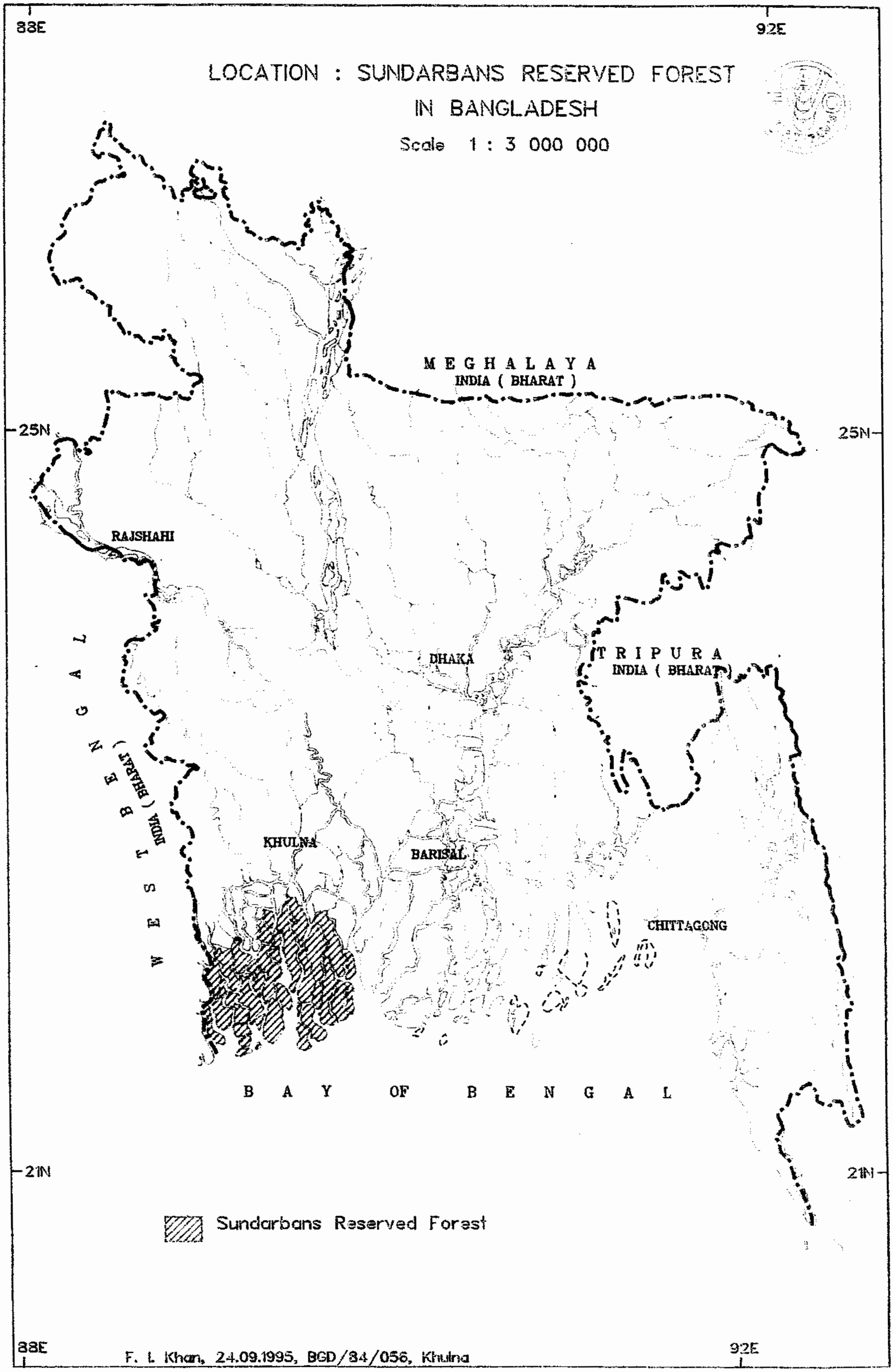
Much has been written about the Sundarbans biome and reports have been commissioned on forestry, wildlife and ecology, sometimes for their own sake and sometimes as part of background studies to consider resource values, especially timber production or as a tourist attraction and venue for recreation activities (Seidensticker and Hai, 1983; Blower, 1985; Salter, 1984; Phillipson, 1988; Dean and Treygo, 1989; IUCN, 1989; Tamang, 1993).

Whilst the physical boundary of the Reserved Forest has hardly changed since it was first demarcated in 1875, the Sundarbans today is wholly surrounded to the landward side as an island by human communities and their agricultural and commercial activities. The energy flux of the ecosystem is governed by tides, the intensity of the annual floods and the sediments they bring with them and differing levels of salinity (see Map 3). Together, this dynamic amalgam of physical factors influences the distribution of plants and animals and leads to development of fascinating physiological adaptations. Pollution from Mongla Port and the expansion of industries located on the Hoogly and Padma river systems pose a serious threat to the ecosystem.

It is to the great credit of the Forest Department that the area remains relatively intact despite encompassing threats and the severe strain imposed upon the Department's resources by intensive harvesting of wood and non-wood resources that occurs almost everywhere. Among the ecological functions and other values ascribed to mangrove forests are:

- Coastal protection from cyclones and tidal surges.
- Production of wood for commercial and subsistence purposes.
- Habitats for reproduction and growth for fish harvested in the local and offshore fishery.
- Essential elements in shrimp production in onshore agro-fisheries.
- Habitats for wildlife.
- Tourism and recreation.
- Special habitat for the Royal Bengal Tiger ***Panthera tigris.***
- A major pathway in nutrient cycling and pollution abatement.

Forest inventories have commented upon changes in the state of forest. (Curtis 1933, Forestal 1960 and ODA 1985). As a result of the findings of the ODA inventory, which revealed a decline in standing volume of the two main commercial species, Sundri and Gewa, by 40% and 45% respectively, a moratorium was placed in 1989 (also 1990 and 1993) on all extraction with exceptions made for Sundri affected by the Top-dying syndrome, Gewa, Golpatta and Goran.


88E
92E
LOCATION : SUNDARBANS RESERVED FOREST
IN BANGLADESH
Scale 1 : 3 000 000
MEGHALAYA
INDIA (BHARAT)
25N
RAJSHAHI
WEST BENGAL
INDIA (BHARAT)
DHAKA
TRIPURA
INDIA (BHARAT)
KHULNA
BARISAL
CHITTAGONG
BAY OF BENGAL
21N
Sundarbans Reserved Forest
88E
92E
F. I. Khan, 24.09.1995, BGD/84/056, Khulna

Likewise there is a total ban on killing or capture of wildlife other than fish and some invertebrates. Despite these measures there is a pattern of declining forest quality, depleted biodiversity, loss of species, notably at least six mammals and one important reptile this century and that the "ecological quality of the original mangrove forest is declining" (IUCN, 1989) These are the major issues which this plan addresses.

On the positive side the Forest Department is active throughout the forest. It has 1038 staff to police and control all commercial timber harvesting and collection of other forest produce. The immediate impression is that here is a tranquil area of natural forest and true wilderness which may be under external threat but retains its intrinsic ecological values within.

Unfortunately, this impression masks the difficulty which is faced by the Forest Department in that not only is forestry seen as competing for valuable land, which is often mooted to be better used for other purposes, such as shrimp farming but also that most of the people who access the forest to harvest its produce live below the subsistence line. It appears that there is scant formal concern for their impoverished lives which could be much improved by more equitable sharing of benefits (MARC, 1997; Bhuiyan, 1995) thereby assisting future sustainability.

Compared with many other natural areas, mangrove forests are not well known to the general public for reasons of inaccessibility, lack of facilities and in many respects a hostile environment for the ordinary traveller. Paradoxically, it is from these manifestly negative aspects that the Sundarbans gathers its real strength since the mangroves are uniquely adapted to an extreme environment which is classified as virtually impossible for conventional agriculture, from which natural produce is difficult to harvest, imposing intrinsic limits to exploitation, and remains an area of "outstanding biological interest, and provides incomparable opportunities for outdoor recreation, scientific research and conservation education" (Unesco 1978). The significance of the Sundarbans is reflected not only in the extensive literature regarding forestry and wildlife but also in the various proposals which have been made to establish the area as a national park, special conservation area and most recently as a possible World Heritage Site (IUCN, 1989; ADB, 1992). Added to this, the area's rich ecology and wilderness values could provide the foundation for sustainable low volume high cost ecotourism and to a lesser extent as a venue for a wider less affluent mass market.

The SRFs ecological and commercial importance are well documented. In 1978 its multiple use status was described by Unesco : "The multiple use concept is being applied in managing forests...and wild life resources are managed by maintaining proper habitats, conserving and propagating the wild life in the areas. The famous Royal Bengal Tiger is a valuable wild life resource in this ecosystem which is being preserved with utmost care. Much has yet to be done to develop tourism in this environment, the potentiality of which is very high".

1.1.1 Location

The Sundarbans Reserved Forest is shown in location text Map 2. It is situated in the South-West corner of Bangladesh between latitudes 21°27'30" and 22°30'00" North and longitude 89°02'00" and 90° 00'00" East in Khulna administrative division and includes parts of Khulna, Satkhira and Bagerhat districts. The western boundary follows the Harinbhanga-Raimangal-Kalindi rivers and abuts with the Indian Sundarbans. To the south the Forest meets the Bay of Bengal and two boundary lines (the approximate Curtis line and the national marine boundary line) have been defined in the GIS data since there is no legally tenable description at present; to the east it is bordered by the Baleswar river and to the north there is a sharp interface with intensively cultivated land, all of which is intersected by a network of tidal rivers, canals and streams.

Although virtually surrounded by India on three sides and the Indian Ocean to the south, Bangladesh's strategic situation offers immense opportunities as a hub for traders and travellers for the entire region and the Sundarbans form the powerful natural bastion to the south.

Impact of Gorai Inflow on Maximum Dry Season Salinity

Decrease (ppt)

Less than 2	4 - 5
2 - 3	More than 5
3 - 4	Not mapped

INTEGRATED RESOURCE DEVELOPMENT OF THE SUNDARBANS RESERVED FOREST

FAO/UNDP Project BGD/84/056

HYDRAULIC MODELLING STUDY

SWMC

1.1.2 Area

The Forest has an area today of some 6017 Km^2 (7620 Km^2 including the proposed marine zone) determined based on 1989 SPOT imagery. The SRF comprises about 62% of the total mangrove ecosystem shared between the State of West Bengal in India and Bangladesh.

As shown in Table 1 the total land area is 4143 Km^2 (including exposed sandbars 42 Km^2) and the remaining water area of 1874 Km^2 (Curtis boundary) encompasses rivers, small streams and canals. If this is extended to the national marine border to the south, stretching 12 nautical miles (22.24 Km) into the Bay of Bengal, a further 1603 Km^2 would be added to form a total area of 7620 Km^2.

Ratification of these boundaries is a national management issue which should be formally addressed since it underlines the importance of the offshore fishery and consequent implications of extension of responsibilities in this area for the Forest Department. Petroleum and mining exploration are already activities said to be going on in the area (Azam, 1995).

Table 1 Major Physiographic Areas of Bangladesh and the Sundarbans

(Phillipson, 1985)

DESCRIPTION	Area km²	% of total area	Cumulative total (%)
Rivers, canals, streams	8,300	5.76	5.76
Estuarine, brackish water	1,828	1.27	7.03
Floodplain	112,010	77.76	84.79
Wetlands (beels and haors)	2,930	2.03	86.82
Freshwater ponds and tanks	794	0.55	87.37
Artificial lakes	906	0.63	88.00
Hill areas	17,286	12.00	100.00
TOTAL $\propto$ (Bangladesh)	144,054	100.00	_
FOREST (managed by FD in Bangladesh)	14 609.67	10.14[1]	
RESERVED FOREST (RF)	11 776.77	80.61[2]	
THE SUNDARBANS RF (SRF) land area including sand bars	4142.80		
SRF MARINE ZONE	1603.24		
RIVER CHANNELS, STREAMS, CANALS	1874.30		
TOTAL AREA OF SUNDARBANS (SRF) **excluding marine zone** **including marine zone**	 **6017.10** **7620.34**	 **51 .09[3]** **64 .70[3]**	

Forests and Sundarbans Percentages: (1995 BGD/84/056 GIS)

1 of total area of Bangladesh
2 of total forest area
3 of total Reserved Forest in Bangladesh

1.1.3 Legal status of the Reserved Forest and its administration

There is a long and varied chronicle of the legal status of the Sundarbans recorded as far back as the Mughal period (1203-1538) when the area was leased to local kings (IUCN, 1994). Records on reclamation, forest clearing and settlement stem from the late eighteenth century and the first management legislation was the Charter of Indian Forests and Forest Act which declared the Sundarbans a 'Reserve Forest' made by the Government of British India in 1855. Subsequently systematic management became official policy and Heinig (1892) in his Working Plan records important events in the legal background to what eventually became the Forest Act of 1927 which makes provision for Reserved Forests and their legal position.

According to Heinig (1892) the early legislation reserving the Sundarbans Forest was enacted as follows:

1875 The Bagerhat forest (area 500 square miles) and the north part of the Khulna Forest (area 385 square miles) were notified under section 2 of Act VII of 1865 on the 15th February 1875 in the Calcutta Gazette of the 17th idem.

1876 The Satkhira forest (area 382 square miles). was notified under section 2 of Act VII of 1865 on the 1st August 1876 in the Calcutta Gazette of the 2nd idem.

1879 The whole of the above was again notified under section 34 of Act VII of 1878 on the 23rd January 1879 of the 29th idem.

1890 The following areas were excluded under section 26 of Act VII of 1878:
Bagirhat forest - lot 240 (6 square miles)
Khulna forest - part of lot 209 (7 acres)

At this stage the Reserve had a total area of 2092 square miles (5418 square kilometres). The definition of the boundary of the Sundarbans Forest Reserve was described as follows:

North	-	by settled lands.
East	-	by the Bhola and Baleswar rivers.
South	-	by the Bay of Bengal.
West	-	by the Raimangal and Jamuna rivers.

In 1915 the whole area was re-notified under Gazette notification 1439 for Khulna and the reserved area was increased to 5 950 Km^2 (2 927 square miles). The boundaries of the reserve were all natural with minor exceptions.

By 1894 the National Forest Policy was promulgated and this provided the foundation for all future Acts and Rules which to this day are used to govern the administration of the SRF. The principal policy directives and legislation which affects integrated forest management are:

- The Forest Act (Act No.XVI) of 1927
- The National Forest Policy of Pakistan, 1955
- The National Forest Policy of Bangladesh, 1979
- The Wildlife Ordinance 1973 and Wildlife Act, 1974
- The Brick Burning Act, 1991
- The East Bengal Protection and Conservation of Fish Act, 1950
- The Protection and Conservation of Fish (Amendment) Ordinance, 1982
- The Protection and Conservation of Fish Rules, 1985
- The National Environment Policy and Environment Act - NEMAP (under preparation)
- The National Conservation Strategy - NCS

The laws and rules which dictate the activities of the FD in the SRF are discussed in Section 8.2.

2 HISTORICAL BACKGROUND

The history of changes in legal status boasts a number of unique features including the distinction of being the first mangrove forest in the world to be brought under scientific management. The area was mapped by the Surveyor General as early as 1764 following soon after proprietary rights were obtained from the Mughal Emperor, Alamgir II, by the East India Company in 1757 (Hunter, 1876). The first Forest Management Division to have jurisdiction over the Sundarbans was established in 1869 and the first management plan was introduced in 1892.

Conservation and management have long been partners in moulding the legislation which has supported both protection and production in the Sundarbans and as early as 1874 -75 in a Resolution on the Annual Progress Report of Forest Administration in Bengal it was stated that "The object of Government in forming the reserve has not been so much the realisation of profit as the preservation, for the public benefit, of valuable property which was being recklessly destroyed, and which ministered to needs which could not well be supplied from any other quarter".

Various opinions were expressed on the amount of land which should be secured and the abundance and likely sustainablity of the harvests of forest produce. It was proposed by the Lieutenant Governor that the "reserved tract should be limited to the smallest area compatible with the effectual preservation of the valuable Sundri timber" ... and that following the findings of the Annual Progress report of 1873-74 that no restrictions whatsoever should be placed on the export of produce from the "extremely rich" forest assuming these to be inexhaustible. This view was changed soon when it was realised that fuel cutters were making excessive removals in areas to the west, adjacent to Calcutta, forcing them to extend their activities further to the east where unrestricted harvesting of quality timber for firewood was damaging the stock of Sundri which was much sought after for boat-building.

In consequence, the first Working Plan for the Reserved Forest was formulated dividing the Reserve up into three blocks and imposing size restrictions and fees to be paid for extraction of timber and other products including firewood, wax and honey and all other "minor products" (Heinig, 1892).

From this early beginning, principles, which have become enshrined in subsequent legislation, Working Plans and management guidelines, have invariably considered three main issues :

- Conservation of resources.
- Levels and methods of harvesting.
- The interests of the human population.

In effect, historically the ecological and socio-economic values of the area have been cornerstones in developing management plans for the SRF. This policy formed the basis of the Five Year Forestry Sector Development Plan.

Today with changing values and increasing pressures it is no longer a matter of preparing another forest inventory in its conventional sense of timber stock calculations, increment and harvesting prescriptions but more an inventory of all the area's assets and their relative positions in terms of sustainable harvests of all kinds and co-ordinated management requirements.

The main considerations for integrated management planning for the SRF are substantially more complex than those demanded in previous forest inventories and working plans and this complexity is illustrated in Table 2 which outlines the main components. To conserve and develop the Forest and all its diverse resources, the forest manager of today must consider a host of factors which range from the macro-economic goals of GOB to the effects on the food chain of intensive harvesting of mud crabs.

Each should be examined in its totality as an holistic part of a matrix of interdependent functions. Integration is required throughout, incorporating conservation imperatives weighed against development and production objectives, keeping in mind exactly how the actions of the Forest Department will benefit the environment itself, dependent people and the economic targets of the nation. The stratum and resolution levels will depend entirely upon user needs.

Table 2 Components of integrated management of the SRF

		GOB		
THE PROJECT AREA		THE FOREST DEPARTMENT	KHULNA DIVISION	
MANGROVE FOREST	SUNDARBANS RESERVED FOREST		KHULNA- BAGERHAT- SATKHIRA DISTRICTS	
BIOTIC & ABIOTIC COMPONENTS				OTHER AGENCIES and the SRF
CLIMATE	FOREST PRODUCTS - WOOD	FOREST MANAGEMENT	FOREST PRODUCTS - NON-WOOD	
PHYSIOGRAPHY		IRMP		CIVIL ADMINISTRATIONS
GEOLOGY	Sawmill Timber		Fish, Shrimps,	POLICE
SOILS	Firewood	FORESTRY	Crabs	NAVY
HYDROLOGY	Pulpwood	FISHERIES	Honey	MPHA
FLORA	Hardboard wood	WILDLIFE	Molluscs/Lime	BWDB (water)
FAUNA	Poles	APICULTURE	Tourism & Recreation	BIMAN
				BPC tourism
DISEASES	Matchwood	TOURISM AND RECREATION	Thatching grass	DEPARTMENT OF FISHERIES
PROTECTED AREAS	Barks	SOCIO-ECONOMICS	Palm leaves	BFRI
ZONES		MARKET RESEARCH	Wildlife (Other)	KHULNA UNIVERSITY
SOCIAL/CULTURAL FACTORS		EXTENSION SERVICE	Medicinal Plants	SRDI (soils)
ECONOMIC FACTORS & FINANCE		LAW AND ORDER	Wild Fruits	IUCN
				KNM
LEGAL & ADMINISTRATIVE		ADMINISTRATION	Clay for pots	TOAB
DEVELOPMENT OPTIONS	SAMPLING AND SURVEY	OPSUNIT	Sand	BSIC
IRM PLANNING	LABORATORY AND LIBRARY	ANALYSIS		NGO'S
IMPLEMENTATION	DATABASES - GIS, HYDRAULIC, IDB	INFORMATION		RRI SWMC (water)
RESEARCH AND MONITORING	ADVISORY COMMITTEES	PRESCRIPTIONS		BFIDC
FOREST DEPARTMENT— KHULNA CIRCLE - - - INTEGRATED RESOURCES MANAGEMENT				

3 PHYSICAL FEATURES

3.1 Climate

The climate is humid maritime tropical with a marked seasonality shared between heavy monsoon rains and a dry, relatively cool winter. The monsoon coincides with the arrival of the moisture-laden South-West trade winds during the period May to October. This is a time when mean temperatures reach 35°C, with maxima of over 40°C, and high humidity peaking at around 95%. Although for field managers heavy and prolonged rains and cyclonic conditions bring with them seasonal constraints on fieldwork which are especially pronounced in mangrove environments, the same constraints apply to all forms of incursion into the forest thus offering some seasonal relief to flora and fauna.

The monsoon declines with a change in wind direction to the North-East ushering in cool dry winters which last until March. During this time the days are sunny, skies clear and temperatures equable. This is the period of greatest activity by people within the forest and for as yet undeveloped tourism it is fortuitous that this pleasant time of the year happens to overlap with the cold north-temperate winter from which many people try to escape to warmer tropical places.

The seasons may be summarised as follows:

- Dry season from November to April - Rainfall is infrequent under the influence of the dry air carried from the north and Northeast. Humidity gradually decreases during this period, reaching a minimum of 60% to 70% in March and April. This followed by a gradual rise in temperature to levels often above 35°C in April and May which introduces low pressure systems and monsoonal conditions of the rains.

- Wet season from June to September - This season brings with it heavy rainfall under the influence of the Southwest monsoon with 75% of the annual total occurring in this period. Storms are usually of several days duration and rainfall is steady at moderate rates. The mean temperature is 28°C and humidity averages about 85%.

- Transitional months of May and October - The pre-and post monsoon months of May and October are noted for violent, short-duration thunderstorms over the land masses and severe cyclonic storms generated in the Bay of Bengal. Nearly 80% of the major storms which strike the Sundarbans occur during these months.

Details of temperatures for selected locations are provided in Table 3 Mean precipitation for Khulna during the period 1947 to 1978 was 1836 mm, with the highest month being June (349 mm) and the lowest being December (15 mm).

Meteorological data for the Sundarbans have been derived from sources located around the periphery since there are no weather stations within the Forest. There are 7 evaporation and climatic data stations and 46 rainfall and 24 ground water stations in the south west region maintained by Bangladesh Water development Board (BWDB) and their deployment is shown on Map 12. Climatic details are shown in Tables 3-8 and variations in mean monthly values are illustrated Figure 1.

Figure 1 Meteorological Data

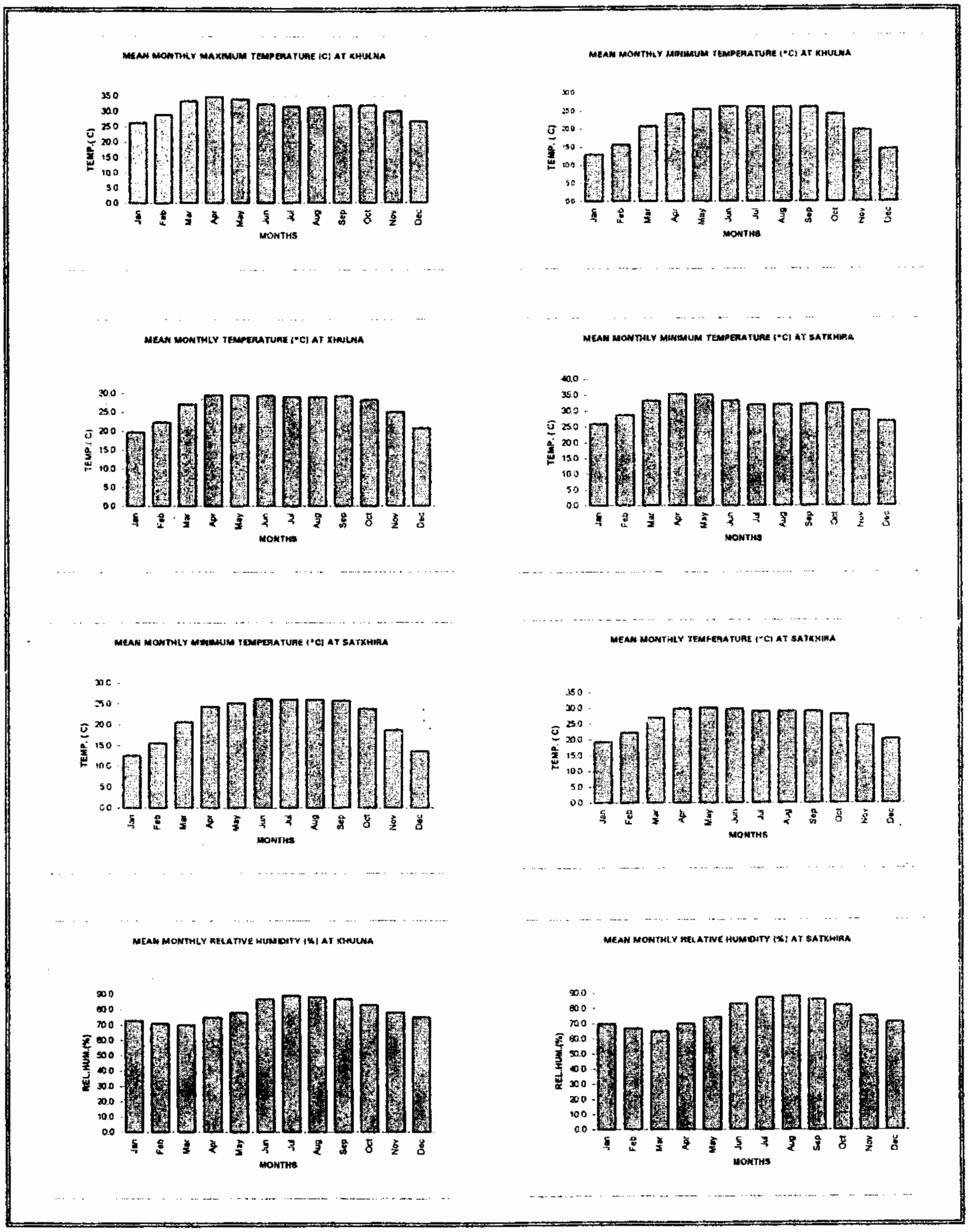
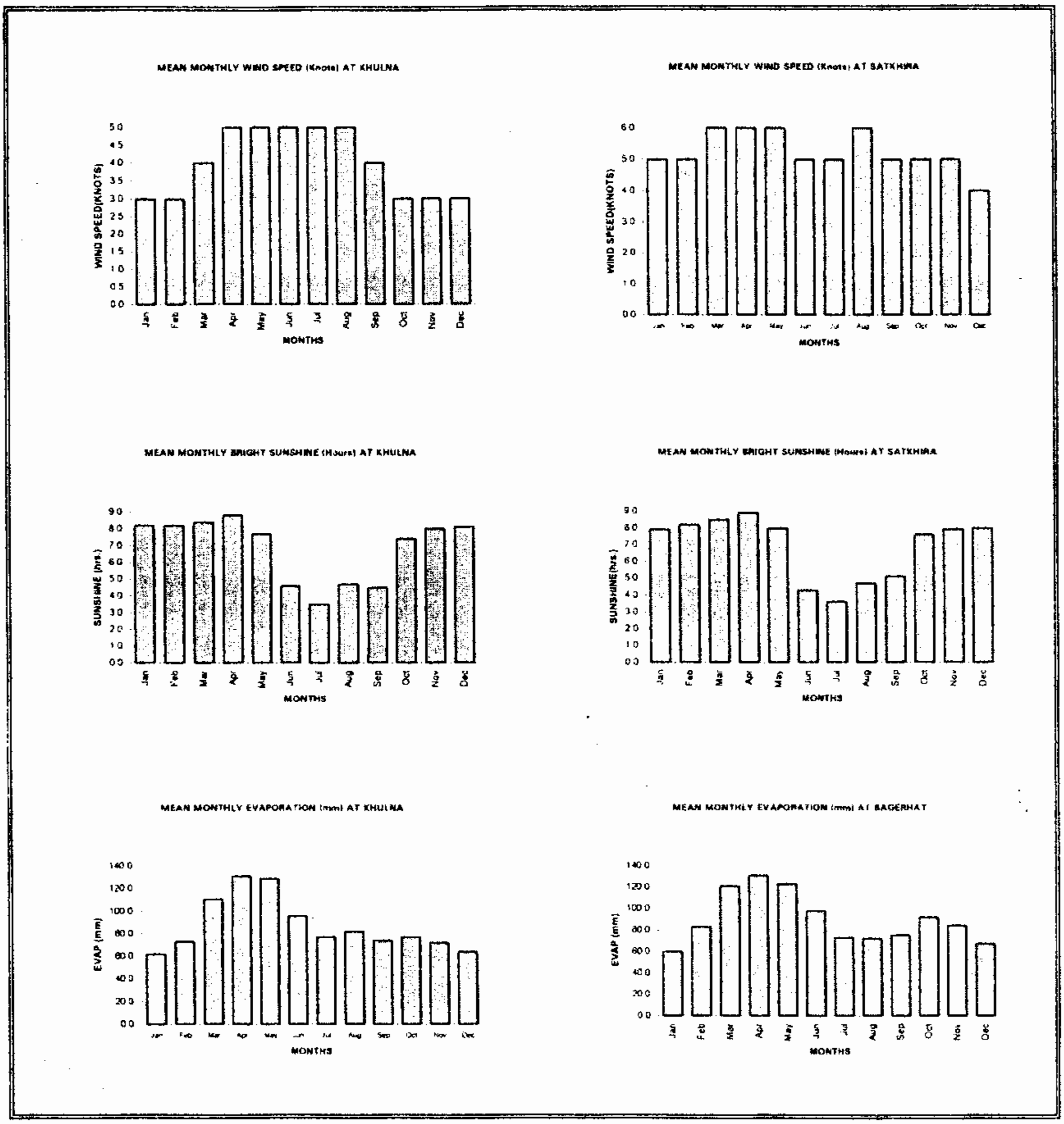


Figure 1 Meteorological Data (Cont'd)



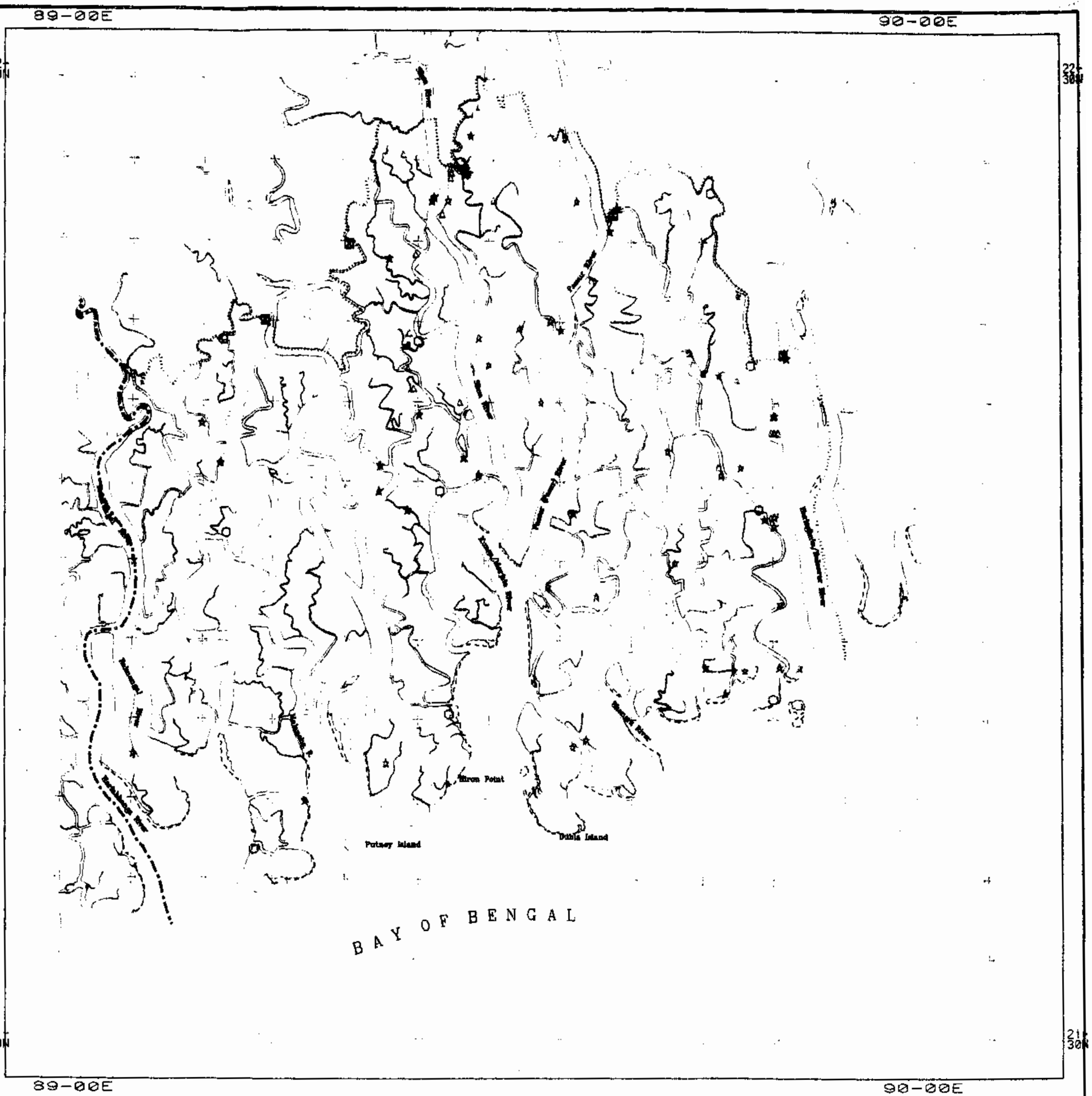
FAO/UNDP PROJECT BGD/84/056, KHULNA, BANGLADESH

INTEGRATED RESOURCE DEVELOPMENT OF THE SUNDARBANS RESERVED FOREST

MAP SHOWING THE SOIL SAMPLE SITES

Scale 1 : 500 000

Km 4 2 0 2 4 6 8 10 Km



LEGEND

- Land/Water Boundary
- Sand Bar
- International Boundary
- Reserved Forest Boundary (after Curtis, 1928)
- ★ Dr. Bhuiyan's Soil Sample Sites (52 sample sites)
- ○ Dr. Karim's Soil Sample Sites (11 sample sites)
- △ ODA Siol Sample Sites (20 sample sites)
- ⊠ BFRI Soil Sample Sites (4 sample sites)

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F.I. Khan, 26.06.1995

Table 3 Summarised details of Climatic Data 1986-1995 for places adjacent to the SRF

(Wahid, 1995)

Station	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.*
	Mean Monthly Maximum Temp. (^{0} C)	26.4	28.9	33.3	34.7	34.1	32.5	31.7	31.5	32.0	32.0	30.1	26.8	26.6
Khulna	Mean Monthly Minimum Temp. (C)	13.1	15.8	20.8	24.2	25.5	26.3	26.2	26.2	26.1	24.2	19.8	14.5	21.9
	Mean Monthly Temp. (C)	19.8	22.4	27.1	29.5	29.5	29.4	29.0	29.0	29.2	28.2	25.0	20.7	26.6
	Mean Monthly Maximum Temp. (C)	25.9	28.7	33.2	35.3	35.1	33.2	31.9	32.0	32.1	32.3	30.2	26.8	31.4
Satkhira	Mean Monthly Minimum Temp. (C)	12.6	15.6	20.6	24.3	25.2	26.2	26.0	26.0	25.8	23.8	18.7	13.6	21.5
	Mean Monthly Temp. (C)	19.4	22.3	27.0	29.8	30.1	29.7	29.0	29.0	29.0	28.1	24.5	20.2	26.5
Khulna	Mean Monthly Relative Humidity (%)	73.0	71.0	70.0	75.0	78.0	87.0	89.0	88.0	87.0	83.0	78.0	75.0	80.0
Satkhira	Mean Monthly Relative Humidity (%)	70.0	67.0	65.0	70.0	74.0	83.0	87.0	88.0	86.0	82.0	75.0	71.0	77.0
Khulna	Mean Monthly Wind Speed (Knots)	3.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	4.0	3.0	3.0	3.0	4.0
Satkhira	Mean Monthly Wind Speed (Knots)	5.0	5.0	6.0	6.0	6.0	5.0	5.0	6.0	5.0	5.0	5.0	4.0	5.3
Khulna	Mean Monthly Bright Sunshine (Hours)	8.2	8.2	8.4	8.8	7.7	4.6	3.5	4.7	4.5	7.4	8.0	8.1	6.8
Satkhira	Mean Monthly Bright Sunshine (Hours)	7.9	8.2	8.5	8.9	8.0	4.3	3.6	4.7	5.1	7.6	7.9	8.0	6.9
Khulna	Mean Monthly Evaporation (mm)	62.0	73.0	111.0	131.0	129.0	96.0	77.0	82.0	74.0	77.0	72.0	64.0	1049.0
Bagerhat	Mean Monthly Evaporation (mm)	60.0	83.0	121.0	131.0	123.0	98.0	73.0	72.0	75.0	92.0	84.0	67.0	1079.0
Khulna	Mean Monthly Rainfall (mm)	12.7	28.4	35.4	88.6	190.3	347.7	345.6	342.5	244.0	141.7	33.9	1.6	1822.4
Satkhira	Mean Monthly Rainfall (mm)	19.8	33.3	35.8	91.0	124.9	331.2	370.0	329.6	297.9	132.5	31.4	10.8	1808.2
NOTE	* Ann. - Average of mean monthly values													

3.1.1 Temperature

The mean temperature in the SW region varies from a minimum of 19°C in January to a maximum of 30°C in May. Variation across the region is of the order of 1°C. Analysis of records from 1965 onwards show that the mean monthly maximum temperature at Khulna and Satkhira varied between 26.4-34.7°C and 25.9-35.3°C respectively whereas the mean monthly minimum temperature at these locations varied between 13.1-26°C and 12.6-26.2°C.

Table 4 Monthly maximum and minimum temperature at Khulna (0°C)

Name of Station	Temp.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khulna	Max Min	32.2 7.2	36.1 7.2	39.4 10.0	40.6 17.08	41.7 18.3	39.4 21.7	37.2 21.7	36.1 22.2	37.2 22.8	36.1 17.8	34.4 11.7	31.2 7.3

3.1.2 Rainfall

The mean annual rainfall increases from about 1900 mm in the Northwest to about 2500 mm in the Southeast of the Sundarbans. Long term simulation of rainfall-runoff covering the period from 1965-1990 shows that the annual precipitation over individual catchment ranges from 1810 mm in the southernmost peripheral catchment (SW-22) to 2076 mm in the northernmost peripheral catchment (SW-24) while for the Sundarbans catchment (SW-27) the annual rainfall is 2133 mm.

In absence of hydro-meteorological stations inside the Sundarbans and limited knowledge on the overall drainage pattern, of the area these values should be taken as an approximation only of the distribution of precipitation. Details of comparative rainfall for places near the SRF are provided in Table 5.

3.1.3 Humidity

The region has high relative humidity and ranges from a mean annual relative humidity of 80% at Khulna to 77% at Satkhira. Records from 1965 indicate that the region seldom experiences relative humidity below 75% and during the monsoon higher values are normal.

Table 5 Mean Monthly and Annual Rainfall (mm) at places adjacent to the Sundarbans: 1902 - 1974 Khulna District

(Rahman, 1995)

Station No.	Name of Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
501	Bagerhat	8.2	22.6	51.3	81.2	146.1	313.7	372.2	326.6	208.7	127.6	27.8	5.9	1691.0
502	Beneporta	19.3	21.5	42.3	63.3	85.3	294.4	294.0	343.2	239.1	131.8	22.1	19.3	1575.5
504	Dumuria	15.1	21.4	37.9	83.7	150.8	297.3	321.5	310.6	233.1	126.5	19.8	7.4	1625.5
505	Islamkati	10.2	18.2	34.0	63.0	131.3	289.5	304.0	265.1	208.9	115.7	19.6	6.4	1465.5
507	Kalaroa	11.8	24.4	43.1	72.4	155.2	279.3	328.8	298.6	205.3	121.0	14.2	3.6	1557.8
508	Kaliganj	11.5	28.5	38.2	62.2	143.0	312.0	388.2	354.8	241.5	135.3	24.6	5.3	1745.6
510	Khulna	14.6	22.3	40.9	90.6	173.9	318.3	359.4	309.8	213.8	138.0	27.6	6.3	1715.8
511	Mollahat	9.8	28.4	49.9	110.5	190.6	337.0	416.7	360.7	234.9	129.1	19.8	10.0	1897.7
512	Morrelganj	11.5	21.7	42.3	76.4	164.3	401.6	494.4	435.3	284.6	168.3	29.2	7.1	2136.8
513	Nakipur	11.0	21.3	39.3	61.6	130.7	303.0	341.4	324.9	239.8	147.4	25.6	7.5	1653.7
515	Paikgacha	15.2	25.9	46.7	76.0	151.7	324.4	389.9	343.8	228.7	136.0	29.9	15.3	1783.3
516	Rampal	10.0	27.1	44.4	72.4	171.7	303.8	379.7	351.1	232.0	138.1	30.9	11.0	1772.5
518	Satkhira	18.8	24.7	40.7	71.5	163.8	315.9	361.5	308.7	235.9	131.9	23.2	5.6	1698.8

Source : Agro-climatic Survey of Bangladesh 1975.

Table 6 Relative Humidity % at 0900 hrs and 1800 hrs at Khulna and Satkhira

Khulna	9 AM 6 PM	73 62	71 55	73 55	76 65	78 74	83 82	86 84	85 84	83 83	78 78	72 69	72 67
Satkhira	9 AM 6 PM	79 60	80 50	73 52	74 63	78 70	84 80	87 81	88 82	85 81	81 75	78 68	74 65

Evaporation is measured by BWDB using a modified Class A Pan which has an additional 5 inches of freeboard above the water surface as compared to a normal Class A pan. A pan coefficient of 0.7 is used by BWDB to convert pan evaporation to open air evaporation. Evaporation in the nearest measurement locations of the Sundarbans at Khulna and Bagerhat shows an annual rate of 1049 mm and 1079 mm.

Table 7 Mean monthly and annual evaporation (mm) near the SRF

Beneporta	63.9	83.4	141.6	152.3	161.4	117.5	101.9	90.3	97.0	90.9	72.2	61.4	125.5
Khulna	77.6	91.6	136.0	154.0	172.1	102.6	97.8	80.2	88.7	93.4	84.6	73.8	125.7
Satkhira	69.8	88.6	121.3	136.4	144.0	125.5	108.7	101.8	100.9	92.8	84.2	74.1	124.3

3.1.4 Wind

The wind speed data are reported as an average for the day in knots for the predominant wind direction at 10 m height. The records indicate a significant variation in the mean wind speed across the region. At Khulna, the mean annual wind speed is 4.0 knots whereas the mean at Satkhira is 5.3 knots. The mean monthly distribution of wind speed at Khulna shows little mean variation. The wind speed distribution at Satkhira to the west has two peaks in April and August.

3.1.5 Insolation

Distribution of unimpeded sunshine hours shows little mean annual variation between Khulna and Satkhira (6.8 and 6.9 hours respectively) but as would be expected the sunshine hours in the monsoon is much lower than during the rest of the year when 8.5 hours per day of sunshine are often exceeded.

3.1.6 Cyclones and extreme conditions

The SRF is located at the apex of the Bay of Bengal and its geographical position places it in the immediate path of cyclonic storms generated over the sea or down from the Himalayas. These are accompanied by heavy rain, floods and tidal bores which combine in this part of the continental coastal belt making it the recipient of many natural disasters. These violent weather conditions tend to strike fast and unexpectedly. Major cyclones have been reported for centuries as the cause of loss of human life and devastation to vegetation in the Sundarbans.

During the last 125 years more than 42 cyclones have crossed the coastal belt of Bangladesh, of which eleven tracked through the Sundarbans. The most severe recent ones were in November 1970, May 1985, November 1988 and April 1991. The November 1988 cyclone that hit the Sundarbans coastline had a wind speed of 160 km/hour produced a 2.8 m wave surge above normal tidal level at Mongla and killed much wildlife and devastated other forest resources (Statistical Yearbook of Bangladesh, 1990).

The cyclonic winds rotate anticlockwise, producing the highest winds and surge conditions on their right side. Thus most of the Sundarbans can expect moderate damage compared with severe effects in the lower Meghna estuary. Records available at the SWMC show that cyclone occurrences have averaged 1 every 5 years in the area since 1882, although there is a gap in the records from 1926 to 1941. Their frequency appears to be increasing this century from 1 in 3 years in 1950 to less than 1 in 2 years now. This increase could be attributed to climate change or improved detection. The frequency of severe cyclones has been the same for pre (April-June) and post (September-December) monsoon period.

Studies conducted by the Cyclone Protection Project II (FAP-7) commented on the role of the mangroves in dampening tidal surges and pointed out that 100 to 200 m wide strip of dense mangrove can reduce wave energies by 20 to 25%. In addition FAP-7 highlighted the need for disaster preparedness, to continually update of plans; consider cyclone resistant housing; give careful consideration to environmental impacts; and to undertake extensive mangrove planting.

Apart from coastal protection, this practical forest development creates employment opportunities for the poor, generates wood for many purposes and has many benefits for the mangrove ecosystem. The Flood Forecasting and Warning Project (FAP-10) is expected to develop an early warning system which, combined with mangrove afforestation, could do much to help protect life and property. **The FD staff should be conversant with maritime signals and hold meetings with the people living in the border zone so that they learn the meaning of the warning signals and pay proper heed to the impending disaster.**

Greenhouse Effect:

There is growing literature and extensive research on the global phenomenon referred to as the "Greenhouse Effect" and in Bangladesh this is being taken seriously since the country has been listed as heading the league of the twenty seven most vulnerable low lying countries which might suffer as a consequence of climate change and rise in sea level (IUCN, 1995 citing Delft Hydraulics, 1989). Arguments range between a relaxed lack of concern relying on the idea that "possible" events are so drastic and so unpredictable that it seems impossible to plan for them (Stewart, 1989 in CARDMA, 1989) and a more sanguine view which affirms that " climatic change looms as our most serious global environmental issue" (Warkick and Jones, 1989 in CARDMA, 1989), a view which is echoed by IUCN (1995) quoting WHOI (1986) which states that " the expected sea level rise (SLR) at the calculated rate of 51.8 cm/100 cal yr or 83 cm by the year 2050 is expected to be disastrous for the Sundarbans".

What appears clear is that current trends in climate change, extrapolated to the middle of the next century, predict a serious impact upon coastal mangroves but which could be ameliorated by isostatic movement, increased delta building or a reversal of the trends themselves. Models of climate change are possibly not yet accurate enough to provide more than a warning that the matter should not be overlooked by planners and that probabilities should be included in making planning decisions. Researchers at the Woods Hole Oceanographic Institute (WHOI) and the Climate Research Unit, University of East Anglia, UK predicted that absolute rise of sea level by the year 2050 and 2100 in an average scenario will be 83 cm and 220 cm respectively but the problem of eustatic sea level rise due to the Greenhouse Effect could be made worse in the Sundarbans through the following factors:

- Compaction of deltaic sediment in the upstream catchment basin followed by subsidence of the land surface.
- Excess withdrawal of ground water for irrigation and potable water use in the SW region as a whole due to rapid growth of the human population causing additional subsidence of the downstream delta.

Table 8 Dates of major cyclonic storms and tidal surges in the Sundarbans

(Wahid, 1995)

Year	Month and date	Affected area	Form of cyclone	Estimated damage	Max.wind (km/hr)	Storm surge height (m)
1895	October	Sundarbans	Cyclone and storm wave	Bagerhat affected		
1901	November	Western Sundarbans	Cyclonic and storm waves	Damage report not available		
1917	May	Sundarbans	Ditto	Ditto		
1942	October	Sundarbans	Severe cyclonic storm	No known damage		
1960	May 25-29	Sundarbans coast	Cyclonic storm	Ditto		
1967	October 11	Khulna and Sundarbans	Ditto	Ditto		2.0-8.5
1969	October 11	Khulna coast	Ditto	Ditto		2.5-7.0
1970	October 23	Khulna	Severe with storm surge	No heavy damage		
1971	November 28-30	Sundarbans coast	Khulna winds 60-70 mph. Storm surge 2 ft.			
1973	December 6-9	Sundarbans coast	Severe at Patuakhali and offshore islands inundated		122	1.5-7.5
1974	August 13-15	Khulna coast	Severe cyclonic storm 50 mph		97	1.5-6.5
1975	May 9-12	Khulna	Severe cyclonic storm 60-70 mph	41 people killed		
1977	May 9-12	Khulna and offshore islands	Cyclonic storm 70 mph		122	
1978	Sep 30 to Oct 3	Khulna and Sundarbans	Cyclonic storm 46 mph			
1988	November 29	Khulna coast near river Raimangal	Severe storm with core wind speed 160 km per hour storm surge 14.5 ft at Mongla point	People killed 5708 Deer killed 15000 Tiger killed c.9	162	1.5-3.0

Source : 1990 Statistical yearbook of Bangladesh
Multi-purpose Cyclone Shelter Programme, Final report, Part 1, Volume 1, Main Report
Cyclone in Bangladesh, Report on Field study & investigations on the damage caused by the cyclone in Bangladesh in 29-30 April 1991 Organised by United Nations Centre for Regional Development, Nagoya, Japan

Studies in Bangladesh conducted by FAP-4 detected a trend of sea level increase between 0.75mm/year to 1.4 mm/year in the Sundarbans. A simplified simulation of the SLR with an assumed sea level increase of 35 cm was carried out for preliminary impact analysis. The impact of the assumed SLR on flooding was assessed by simulating increased flooding during the peak flood time of August - September.

Results indicated that during the dry season the rivers between Arpangasia and Baleswar will experience a 35 cm increase in water level during a high tide while the rivers to the south of Arpangasia will experience a increase of about 30 cm due to a SLR of 35 cm.

For salinity the study indicated that due to a 35 mm SLR the salinity front will move only marginally. Whilst this study was limited in its scope use of the hydraulic model enables assessments of likely outcome of SLR especially;

- Change in current and water characteristics such as temperature and density.
- Loss of breeding and nursery grounds for fish and shrimps.
- Saline precipitates on the forest floor due to increased evaporation.

Whilst it may be that the Greenhouse Effect and SLR may not be of immediate concern, nearly all the evidence suggests that it would be unwise to disregard informed opinion on the subject.

3.2 Physiography

The mangrove forest today extends about 80 km inland from the coast and about 100 Km at the widest point between the Raimangal river on the Indian border and the eastern bank of the Baleswar river to the east. Mangroves along the Bay of Bengal seaface have evolved over the millennia through natural deposition of upstream sediments accompanied by intertidal segregation. The major physiographic areas of Bangladesh and the relative importance of the SRF mangrove system are shown in Table 1.

The Sundarbans mangroves extend along the coast forming an overwhelmingly prominent environmental unit wholly different from any other in the hinterland extending from the seaface to the approximate edge of the inter-tidal zone. In transverse profile - from the mainland to the sea - the physiography is dominated by deltaic formations which include innumerable drainage lines associated with surface and sub-aqueous levees, splays and tidal flats. There are also marginal marshes above mean tide level, tidal sand bars and islands with their network of tidal channels, sub-aqueous distal bars and proto-delta clays and silt sediments.

The physical developmental processes along the coast are influenced by a multitude of factors, comprising wave motions, micro and macro- tidal cycles and long shore currents typical to the coastal tract which vary during the pre-monsoon, monsoon and post-monsoon periods. These are also affected by cyclonic action. Erosion and accretion through these forces maintains varying levels, as yet not properly measured, of physiographic change whilst the mangrove vegetation itself provides a remarkable stability to the entire system.

Biotic factors here play a significant role in physical coastal evolution and for wildlife a variety of habitats have developed including beaches, estuaries, permanent and semi-permanent swamps, tidal flats, tidal creeks, coastal dunes, back dunes and levees. The mangrove vegetation itself assists in the formation of new land mass and the intertidal vegetation plays an important role in swamp morphology. The activities of mangrove fauna in the intertidal mudflats, develop micro-morphological features which trap and hold sediments to create a substratum for mangrove seeds. The morphology and evolution of the eolian dunes are controlled by an abundance of xerophytic and halophytic plants. Creepers and grasses and sedges stabilise sand dunes and uncompacted sediments (Bhattacharya and Chowdhery 1985).

The form of the delta is shaped by the complex drainage structure which physically links innumerable islands clothed in mangrove vegetation by waterways of varying dimensions. These islands appear to retain a remarkable stability through the immensely resistant sub-surface mesh of mangrove roots and pneumatophores which distinguish mangrove forests from all others. Whilst sediments provide the substrate on which the littoral vegetation grows the entire physical environment is held together by soil fractions which to some extent consolidate as a matrix strongly stabilised by the mangrove plants themselves.

Topographical variation compared with upland environments is negligible, the SRF floor being 0.9m to 2.11 m above sea level (Katebi and Habib 1987) and local variations in elevation have been demonstrated for the first time in the SWMC hydraulic model. Map5 illustrates the Digital Elevation Model at a resolution of 0.1M (DEM) of the SRF. The model will be considerably improved for more precise resolution after further data have been obtained in the field and this aspect of research must be considered a high priority in future research programmes.

The whole low-lying physiography of the area may owe its form to either insufficient deposition of sediments or subsidence, with claims of tectonic activity being responsible for lowering of levels by up to 11m within the forest at Shekertek ruins, Compartment 39, during geologically very recent times (Rashid, 1991).

What seems certain is that the area has been greatly affected by the migration eastwards of the main course of the Ganges, causing the dislocation of the confluences of the principal western rivers, such as the Raimangal and Arpangasia, and thus the building up of the estuarine area has not yet progressed to any significant extent. **Added to this is perhaps the more important effect of the twice daily tidal inundation which the whole area receives and which keeps its gross ecology in a state of dynamic activity.**

3.2.1 Structure of the Delta

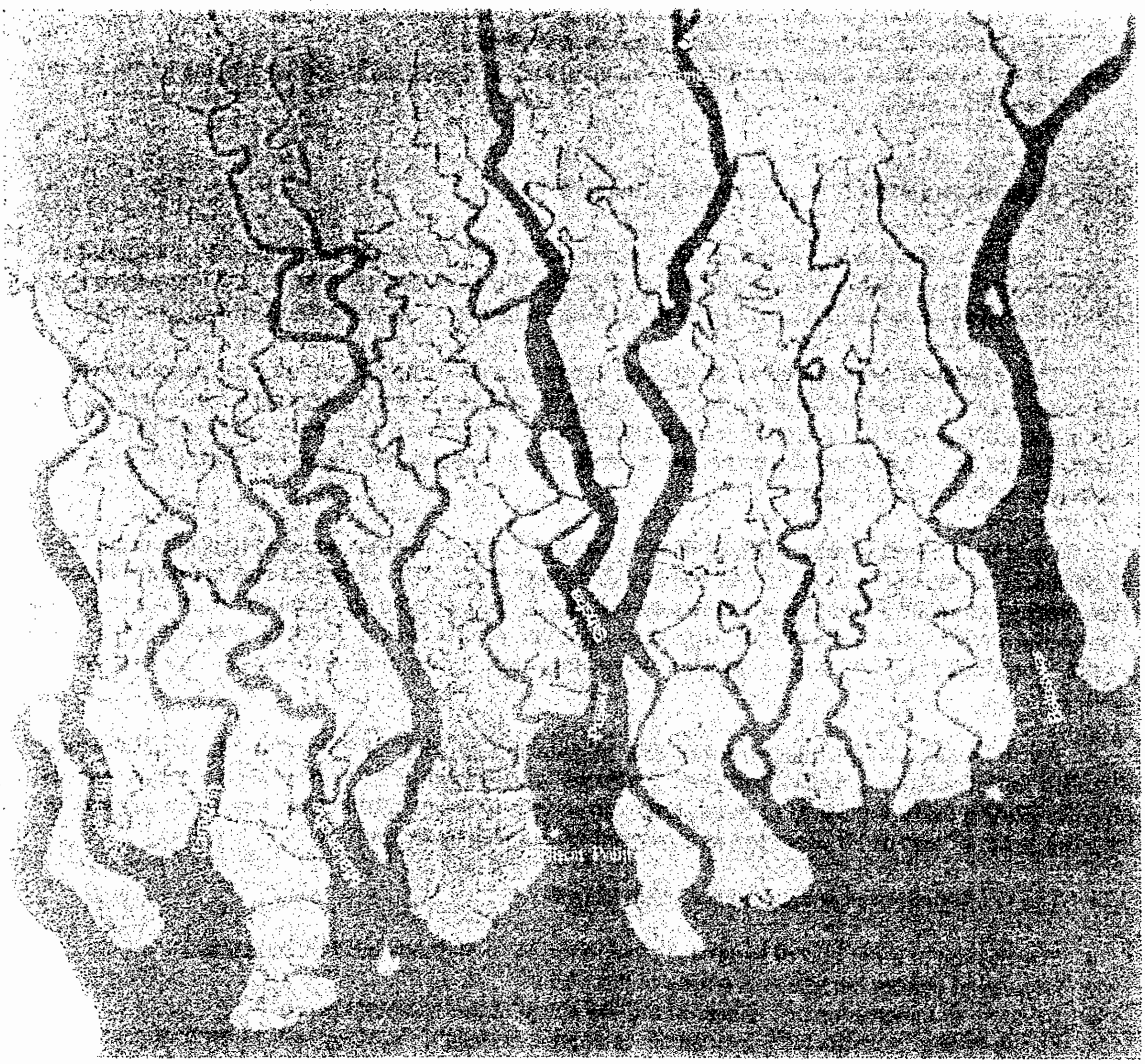
The entire delta is the formed by the estuarine sediments of the Ganges, Brahmaputra and Meghna rivers in Bangladesh and the Hoogly and its distributaries in India which combined in geologically recent times. The geomorphological and other conditions which have been responsible for the structure of the delta and the vegetation which it supports are :

- Topographic position
- Drainage lines
- Proximity to the sea
- Salinity
- Tidal periodicity
- Tectonic activity
- Freshwater flushing
- Sedimentation
- Temperature
- Humidity
- Land use in upland watersheds
- Extreme stress inducing factors

The origin of most of the sediments is far to the north and these alluvial deposits have formed what is referred to as the Gangetic Plain (Khan, 1991). These are supplemented by tributaries of the rivers whose catchments mostly now lie to the south of the main Ganges channel, notably the Kolpetua-Arpangasia, the Kobadak-Bal and the Passur/Sibsa-Kunga. The delta has four principal estuaries: the Bangra, Kunga, Malancha and Raimangal depicted in Map 8.

The combined sediment load of the rivers that flows through the Sundarbans has also created a large submarine fan which slopes almost uniformly southward for about 300 km. The enormous quantities of sediment carried into the sea by the river is distributed between the delta fan and coastal areas. Discharge to the delta fan takes place through submarine canyons at the head of the bay. Situated south of the Raimangal-Malancha estuary is the "Swatch of No Ground" where shallow water of 5-10 fathoms suddenly changes to depths of 200-300 fathoms. The sediments are distributed by currents which run mainly from north to south. These sediments have accumulated in places to a thickness of 15 km.

Digital Elevation Model of The Sundarbans



Elevation (m)
PWD Datum

1.0 - 1.1	1.4 - 1.5	1.8 - 1.9	2.2 - 2.3
1.1 - 1.2	1.5 - 1.6	1.9 - 2.0	2.3 - 2.4
1.2 - 1.3	1.6 - 1.7	2.0 - 2.1	2.4 - 2.5
1.3 - 1.4	1.7 - 1.8	2.1 - 2.2	Above 2.5

INTEGRATED RESOURCE DEVELOPMENT OF THE
SUNDARBANS RESERVED FOREST FAO/UNDP Project BGD/84/056
HYDRAULIC MODELLING STUDY **SWMC**

A historical review carried out by FAP-4 studies made a comparison between the coastal outline obtained from 1989 1:50,000 SPOT satellite images and selected charts dating back to Rennell's Map of 1779. Notable conclusions were:

- The coastline from the centre of the Sundarbans towards the east has remained virtually unchanged over the last 200 years; this suggests a remarkable stability in the coastal area, possibly due to the mangrove forest's protective effect.
- There have been some detectable changes to the lateral channels linking the main north-south tidal rivers.

3.2.2 Inshore and offshore islands and accretion

Land formation is complicated and variable since it is dependent upon the vagaries of sediments which are initially introduced through the Ganges System in the Bay of Bengal where they are probably finely sorted and brought back by again by tidal currents inside the SRF (Grepin, 1995).

This results in irregular rates of sedimentation and in some places may be responsible for rapid changes in the floristic composition of the mangrove forest where variations in soil elevation plays an essential part. An important consideration in short and long-term management is the propensity not only for continuous accretion and erosion along the riverlines but the also the emergence of new land or chars.

Land is formed by huge beds of shifting silt and sand sometimes more than a kilometre long and travelling at rates up to 600 metres per day (Custers, 1992). These are carried downstream and deposited by the rivers in places where water velocity drops on meeting relatively slow moving tidal water in the delta. **New accretions, opportunities for afforestation, wildlife management and coastal zone development are all matters requiring monitoring and co-ordinated management planning.**

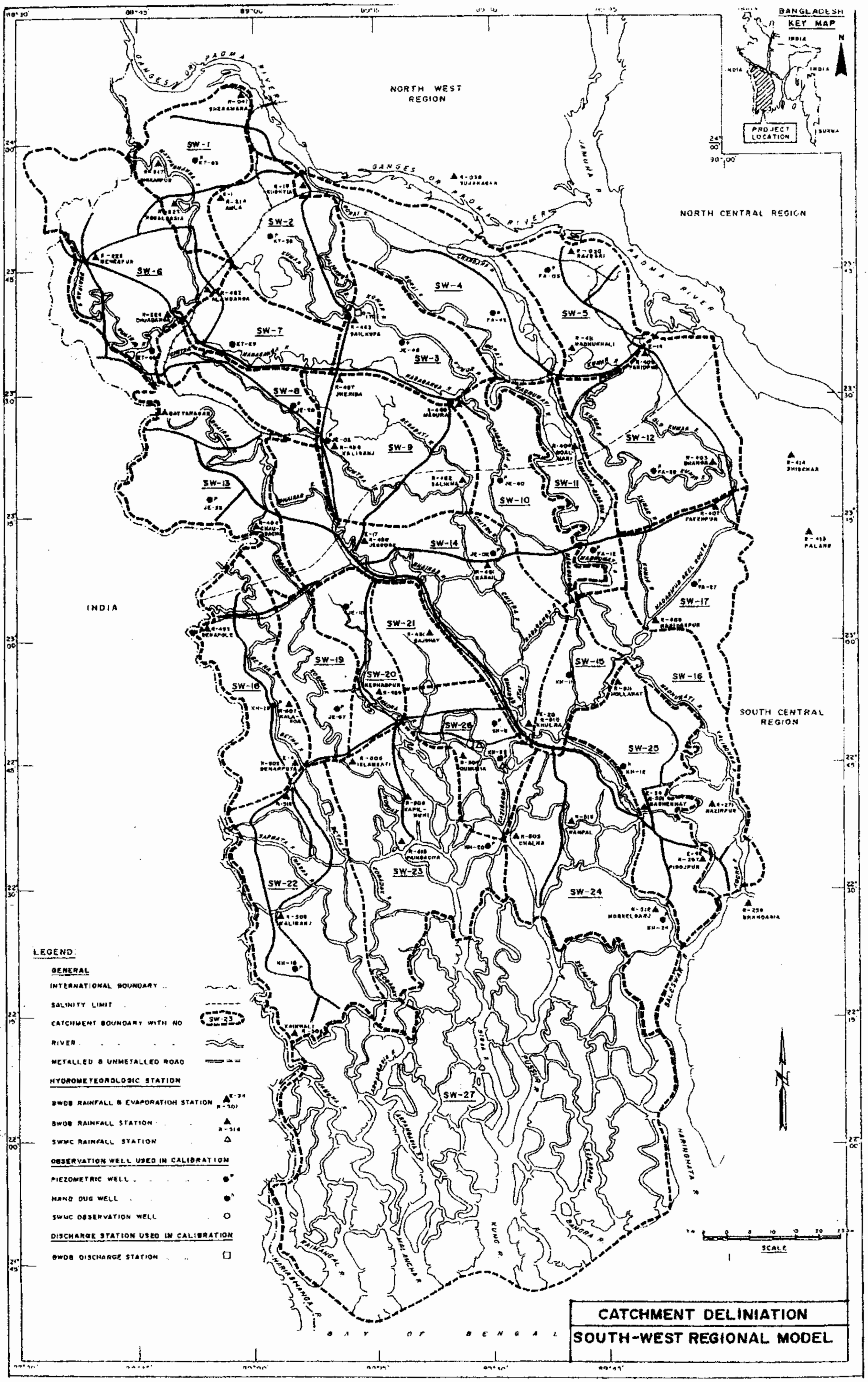
As in other deltaic mangroves, the vegetation of the SRF is a mosaic of species reflecting differences in soil elevation, drainage and salinity. Continuous introduction of nutrients during sedimentation is essential to maintain primary production and rates of growth since the greater part of all biomass is exported to the sea by tides.

The usual pattern of sedimentation is as follows:

- Emergence of a flat bed of sediment often in the form of gently inclined mudflats.
- Deposit of coarse particles on edges of the bed.
- Creation of raised areas or levees along the shore of the sediment patch.
- These levees enlarge with deposition of coarse particles, isolating central area depressions which fill with fine particles of silt and clay. Rain water and tidal flows caive the soft sediments in an arborescent pattern of small dichotomised channels (see Base Map 10) reproducing the same zonation and landform to create basins and backswamps :

Raised area	: sandy, hard, well drained soil
Lower area	: silt, clay, soft, waterlogged soil

This pattern appears to be repeated throughout the SRF and the limits and ecological conditions for each have never been ascertained but undoubtedly these have considerable bearing upon the distribution and quality of plant associations with attendant opportunities for management and development.


BANGLADESH
KEY MAP
PROJECT LOCATION
INDIA
NORTH WEST REGION
NORTH CENTRAL REGION
SOUTH CENTRAL REGION
GANGES OR PADMA RIVER
PADMA RIVER
JAMUNA R
SW-1
SW-2
SW-3
SW-4
SW-5
SW-6
SW-7
SW-8
SW-9
SW-10
SW-11
SW-12
SW-13
SW-14
SW-15
SW-16
SW-17
SW-18
SW-19
SW-20
SW-21
SW-22
SW-23
SW-24
SW-25
SW-26
SW-27
B A Y O F B E N G A L
LEGEND:
GENERAL
INTERNATIONAL BOUNDARY
SALINITY LIMIT
CATCHMENT BOUNDARY WITH NO
RIVER
METALLED & UNMETALLED ROAD
HYDROMETEOROLOGIC STATION
BWDB RAINFALL & EVAPORATION STATION
BWDB RAINFALL STATION
SWMC RAINFALL STATION
OBSERVATION WELL USED IN CALIBRATION
PIEZOMETRIC WELL
HAND DUG WELL
SWMC OBSERVATION WELL
DISCHARGE STATION USED IN CALIBRATION
BWDB DISCHARGE STATION
SCALE
CATCHMENT DELINIATION
SOUTH-WEST REGIONAL MODEL

BGD/84/056

3.2.3 The Sundarbans Reserved Forest as part of the delta

The delta is recognised as one of the four main physiographic regions of Bangladesh (Khan, 1991) covering about 32% (46 000 Km^2) of the entire country and nearly a quarter of this is covered by the SRF. Historically the intertidal zone occupied almost double the area (see Maps Appendix A28 and volume 3) (Prain, 1902) and LANDSAT imagery (1984) and all but the mangroves in the Reserved Forest in Bangladesh and that part of the delta which lies between the Raimangal western border and the Hoogly river in India. The Sundarbans in Bangladesh contrasts strongly in many respects with the Indian portion especially in that it is free from permanent human settlement (in the Indian portion there are three towns and 1 060 villages) and has lower salinity levels for most of the year over much of the area.

Both are surrounded by high density human populations and intensive agriculture and although loss of the landward mangroves occurred in the last century, increasing human settlement, poldering and flood protection embankments, impeded and reduced freshwater flushing and industrial pollution, pose immediate short-term threats to the remaining part of the ecosystem.

In the longer term, yet within the timespan of a single generation, the SRF could face the daunting prospect of permanent inundation by sea-level rise. Conservative projections on current trends suggest a possible loss of up to three quarters of the forested area and the process is ongoing.

Nevertheless at present the SRF provides a strong and stable natural bastion for the settled hinterland against the impact of storms and tidal surges which devastate areas that do not have the protection afforded by coastal swamp forest (Blasco, Bellan and Chaudhury, 1992).

The economic value is enormous for this function alone. The Southwest Area Water Resources Management Project (1993) estimated that the coastal defences that would be required in the absence of the Sundarbans would be 2 200 Km of flood defence embankments costing about US$ 4 billion (Tk 160 billion).

3.3 Geology

The geology of the SRF has not been studied in detail There is a sharp interface between superficial sediments of recent origin and the sub-surface edge of the continental shield and land mass.

The surface geology consists entirely of Quaternary sedimentary layers of sand, silt and clay. Some recent studies (Umitsu, 1991) in adjacent areas of Khulna and Barisal confirmed earlier views that there was a sea level regression about 12 000 years ago but there is now a trend in sea level rise, the effect of which may be exacerbated by relative stability to the west compared with active sedimentation accompanied by tectonic activity and ongoing subsidence, to the east.

The present delta is thought to be a combination of the Ganges delta, the Old Brahmaputra-Meghna delta and the Ganges-Jamuna-Meghna delta which is the existing Ganges-Brahmaputra-Kunga delta. It is difficult to determine the geomorphological contacts of these deltas since these are obscured by deep sediments which are overlain by very recent sediments. The Ganges is by far the greatest builder of the delta with estimates which suggest that 80% of the surface sedimentation comes from this source alone (Khan, 1992).

The mangroves thus grow on soil of recent origin which overlie uncompacted sediments derived from the upper catchment by deposition from the Himalayas and the Ganges-Brahmaputra floodplains.

Maximum Salinity, Dry Season Spring Tide - February 1995

Salinity (ppt)					
	0 - 2	8 - 10	16 - 18	24 - 26	Not mapped
	2 - 4	10 - 12	18 - 20	26 - 28	
	4 - 6	12 - 14	20 - 22	28 - 30	
	6 - 8	14 - 16	22 - 24	Above 30	

INTEGRATED RESOURCE DEVELOPMENT OF THE
SUNDARBANS RESERVED FOREST FAO/UNDP Project BGD/84/056

HYDRAULIC MODELLING STUDY **SWMC**

The most important events in geological times caused by sub-surface geological activity which continue to affect and threaten the shape and nature of the SRF appears to be the shift in delta building from west of present-day Calcutta to the east as a consequence of a gradual eastward migration of the main Ganges drainage line. As recently as the mid-eighteenth century the Ganges had no connection with the Brahmaputra or Meghna rivers.

Earthquakes in 1762 and 1782 were followed by severe floods which resulted in the formation of the Brahmaputra confluence with the Ganges to create the enormous river Padma. It seems therefore that these very recent geological events have greatly influenced the phases of sedimentation, erosion, accretion and erosion. Frequent comments upon the fragility of the system tend to focus on land use pressures, alterations in salinity gradients and perceived changes in vegetation and management systems whereas in many senses there is an underlying stability in the mangroves themselves but this should be weighed against an immense threat from sea level rise and sudden tectonic upheaval.

3.4 Soils

Although it is hardly surprising that soils of the SRF show practically no profile (Bhuiyan, 1994; IUCN, 1994), studies indicate that there are recognisable variations in characteristics at different depths depending upon the same repeated local topographical and drainage patterns. On account of constant circadian tidal agitation, sedimentary segregation of organic and mineral fractions and salinityl, soils are often featureless, hydromorphic and semi-fluid, demonstrating layering with highly variable physical and chemical composition.

A complete soil survey has never yet been accomplished but research at recorded points and along non-random transects by Bhuiyan, 1994; Karim, 1988; Chaffey *et al.*, 1985; Hassan, 1982 offered data which are sometimes conflicting particularly in relation to the phenomena of Top-dying of Sundri and occurrence of acid sulphate but are of help in describing soil types and associated vegetation. These data are presented in Map 14 and the soils data in Bhuyian (1995) should be compared with the vegetation maps, Volume 3 Maps 35 (1-15) for further information.

Apart from local variations in ground elevation, for which mapping has only recently begun by the Surface Water Modelling Centre, River Research Institute (see Map 5 Digital Elevation Model, SWMC), other overriding factors which affect the nature of SRF soils are the marked seasonality of precipitation and fluctuations in water depth, duration of flooding and salinity levels. None of these is static and all continuously alter their spatial and temporal positions. In a preliminary analysis made by Rahman and Bhuiyan(1995) of soils and water salinity, the results a remarkable lack of correlation between salinity concentrations in water and surface soils.

Previous analyses which presented fixed isohalines (ODA, 1985; BFRI, 1982 and Curtis, 1933) tended to lump parameters together for convenience and underplay the marked and significant variations which have been recorded throughout the SRF and are now beginning to emerge from new data. The Surface Water Model illustrates this over-simplification very clearly (see Volume 3 Maps 15 - 27 This work on a highly complex hydrological and salinity regime will provide ecologists and ecosystem managers a much truer picture of factors which limit distribution, species compositions of communities and rates of biomass production, than anything which has preceded these pioneer studies.

Under moist forests, a partial compaction due to the short period of drying out in the dry season gives these soils a high bulk density. Usually attributes of the pedogenic factors are not recognisable in these soils. The characteristics of the parent material dominate in the soil morphology which are always influenced by prevailing local hydrological conditions. The soils of the tidal mangrove swamps do not fulfil the requirements of a cambic horizon as defined in standard soil taxonomy reflected in distribution of organic carbon and content of Fe-Mn concretions. Such soils were therefore classified as Entisols by Hassan, (1983).

Pedologically soils of the Sundarbans are very young, very poorly drained uncured sediments having no diagnostic horizon. Unless artificially drained, these soils are poorly oxygenated.

Seasonality has a marked effect and sometimes deceptive effect. In the monsoon there is excessive flooding and the scope for vertical leaching is limited. Horizon differentiation therefore is not noticeable. No appreciable movement of clay colloids has been noticed and under these circumstances the development of any healthy soil profile according to Bhuiyan (1994) is not feasible.

Sundarbans soils also were classified as Typical Haplaquents by Gopalswamy and Raychowdhury (1970). FAO (1971) correlated and classified these soils according to order : Tidal Mangrove Swamp Soils: Entisols; Sub-Group Type : Fluvaquents and General Soil Type : Calcarious Grey Floodplain Soil.

3.4.1 A description of the soils

Soils of the SRF are derived from a mixture of deltaic floodplain deposits and tidal marine deposits. The surface soil is a silty clay loam overlying alternating layers of clay and sand. In general, soil fertility decreases from east to west and from north to south (Choudhury 1962). In the north and east portions of the Sundarbans, relatively high fertility is maintained by annual silting. This matter will require proper quantification in future.

These soils are slightly saline, silty clay loam and the sub-soil consists of alternate layers of clay and sand. Silt appears to be the most common textural class and grain size is larger in the eastern forest than in the west. Pyrite may occur in localised depressions containing higher amount of organic matter. Presence of biotite, carbonates and feldspars may protect the soil from becoming acid sulphate where drainage is not impeded (Bhuiyan, 1994).

Hassan, (1982) described the soil of the Sundarbans delta as unripened, slightly calcareous, tidally flooded, grey, massive, alkaline, clayey muds with low (<2%) organic matter content and saline, uncured or partly cured grey clayey deposits which are homogeneous in vertical and horizontal directions (Hassan and Mazumder, 1990).

Organic matter - OM

The soils of the Sundarbans being formed entirely of the fine silt and sediments carried by the Ganges or the Padma, contain a high percentage of calcium carbonate and therefore fall essentially under the Pedocal group.

The percentage of organic matter appears to be generally low and Bhuiyan (1994) found variation in the range 0.8 to 3.3.% in top layers and 0.2 to 2.9% in bottom layers. The highest percent of organic matter was found in the top layer of compartments 36 and 39. The lowest percent of organic matter was found in the bottom layer of compartment 24. OM was found to vary by Karim and Islam (1983) who recorded oven dried soil percentages of 4 - 10% which are considerably higher than those determined by Bhuiyan (1994).

Soil pH:

It was observed that the soil pH varies from 6.8 to 8.4. But most soils falls in the alkaline pH range between 7.0 - 8.0 throughout the SRF.

Mineral composition:

Results obtained from mechanical analyses of different samples showed that the silt fraction varies with depth. The clay fraction varies from 24 - 44%; sand fraction varies from 8 - 30% and silt varies from 40 - 62%. It was found from the particle size analyses the following different textures were readily discernible and could be used as a basis for classification: silt loam, silty clay loam, silty clay and clay loam.

Chloride:

Chloride is said to be the most common anion in coastal soils of Bangladesh ranging from 5.7 me/100 g to 23.2 me/100 in ovendry soil with significant gradation in proportion to distance from the sea and from perennial freshwater flushing especially to the east (IUCN, 1994).

Sodium and calcium:

Content of these two was found to be highly variable in all studies ranging between 5.7-9.8me/100 g of oven dried soil with variations along north-south and east-west gradients. Bhuiyan's results for calcium ranged from 0.50 me/100 g for subsurface soil to a maximum of 12.4 for surface soil in compartments to the North-East and Sodium 1.8 to a maximum of 9.3 me/100 g of oven dried soil in compartments 6 and 8 in the south-west near the sea..

Sodium adsorption ratio - SAR:

This measure of the exchangeable sodium percentage also shows considerable variation and was found by Chaffey et al., (1985) to vary between 1.3 and 31.6% in surface soils and 6.4 and 40.7% in subsurface soil.

Cation exchange capacity:

The cation exchange capacity of the soils have been presented in Appendix A35. The highest CEC of 22.87 me/100g was found in the PSP No. 16 of compartment No. 1 and the lowest CEC of 9.94 me/100g was found in the compartment No.54. These figures accord with Karim (1988) and Chaffey et al., (1985) who found variations at their sites of 12-23 meq/100g of soil with little difference between wet and dry seasons.

Aeration

An additional factor, of considerable significance to plant growth, is the level of oxidising and reducing substances exhibited by a given system and referred to as the redox (Eh) potential (IUCN, 1994). Anaerobic soils which may result from prolonged inundation tend to show negative Eh values in which the aqueous solutions of divalent iron or manganese are toxic to plants (Etherington, 1975). Such conditions may prevail in waterlogged backswamp areas where it is likely that calcium and magnesium may be mobilised, thereby increasing carbon dioxide in solution. Equally other cations such as potassium may be leached under these conditions affecting the growth potential of species.

Aeration measured as Eh, has the tendency to receive or supply electrons and is profoundly important in the assessment of environmental quality for primary and even secondary production. For the SRF it is believed that the redox potential varies between +200 mv to - 180 mv (IUCN, 1994). Effects upon specific plant growth may be revealing and of great value in making management decisions, especially where plantations or forestry management actions may be considered.

Soil characteristics affect natural and artificial regeneration and plants in the intertidal zone are exposed to many short and long-term stresses especially :

- Salinity level and physiological stress.
- Poor drainage, waterlogging and low Eh levels and possibly anaerobic conditions.
- Poor compaction or even fluidity creating an unfavourable substrate for plant growth.

3.4.2 Soil and vegetation

There is an overall pattern of apparently higher productivity in eastern parts of the SRF compared with the west, although recent reports (Grepin, 1995; Leech, 1995; Mitchell, 1995; Maniruzzaman, 1995 and Rahman, 1995) suggest that forestry management and tree removal practices in particular may accentuate apparent changes in species composition and size/site classes. The link between the soil catena with the plants it supports is unambiguously recognisable on the ODA, (1985) 1:50 000 vegetation map, now included in the GIS data base and listed in Appendix A28, but future work will need to determine at a higher level of resolution, and for plant species associations especially, exactly how combinations of physical characteristics are distributed throughout the SRF..

In backswamps, where little commercially harvested vegetation develops, pH was found to be appreciably lower than elsewhere in the range 6.4 - 5.3 and vegetation in the SRF substantially indicates that where there is hypersalinity resulting in strong negative osmotic pressure of soil water there is a progressive stunting of the mangrove canopy reflected in all species across the SRF salinity gradients from east to west and from the seaface inland.

Recent observations of river banks by Grepin (1995) at the beginning of the monsoon showed significant variation in phenological stages of Gewa. Gewa trees growing on the upper part of banks in the eroded side of the river loops were losing their leaves (red leaves). Gewa trees in depressed areas at the same time were without leaves and Gewa on newly accreted banks behind Keora or along linear banks were growing new leaves.

It seems that Sundri trees immediately behind the Gewa fringe on eroded sides were more intensely affected by Top-dying; Gewa trees losing their leaves in early June were located on raised and more sandy soils with probably low water holding capacity. Further observation at the end of the rainy season showed that all raised areas were dry and cracked along the river banks and the soil in some places had saline efflorescences. This confirmed a possible stress syndrome for tall trees in circumstances of increasing salinity.

3.4.3 Salinity and forest type classes

Mangroves are described as facultative halophytes and salinity not only affects and indeed dictates the floristic composition of mangrove communities but the efficiency with which each species deals with high salinity. This determines firstly its position in the intertidal zone and secondly its rate of growth and ultimately size and height. There appears to be an optimal salinity range for maximum growth(Saenger et al., 1983).

For the SRF it has long been accepted that salinity levels are generally higher in the west than in the east and that Goran seems to be a highly successful dominant to the west of the Arpangasia river; Gewa and Sundri are co-dominants in the centre and Sundri a dominant to the east. Local variation in duration of inundation, drainage and freshwater flushing are as important, if not more so, in distribution of specific stands and their quality (Grepin, 1995).

Hassan et. al. (1988) classified soils having <2.0 mmhos of electrical conductivity as non saline; 2.0 - 4.0 mmhos of electrical conductivity as slightly saline and >4.0 mmhos of electrical conductivity as moderately saline.

The conductivity of soil has wide variation from between compartments and Bhuiyan's (1994) analyses determined a conductivity range between 1.0 - 7.0 mmhos/cm.

In the BFRI study March-May soil salinity remained between 2000 and 4500 mmohs in most parts of the Sundarbans. Peak salinity level was reached in April-May and dropped gradually in soil and abruptly in water after June with the beginning of the monsoon (Hassan, 1984).

3.4.4 Soil characteristics and Top-dying Sundri

Sundri Top-dying has been a subject of study for several years and although no causative factor which can be positively managed and reversed has been identified, it is clear that ***Heritiera fomes*** is able to grow in saline areas but that the full development of the species is only found in areas where freshwater flushing occurs. This was remarked upon by Curtis in 1932 and further substantiated by ODA in 1985 and during recent field studies by (Grepin, 1995).

It can be observed from the condition of Sundri and data on electrical conductivity,(EC), of Sundarbans soil that no Top-dying was found in the areas where the EC was 1.00 - 2.00 mmhos/cm. But moderate to extreme Top-dying was found in areas where the electrical conductivity was above 3.00 mmhos/cm. Bhuiyan (1994) found moderate to severe Top-dying in areas where soil salinity was relatively high and in areas of lower salinity there was evidently no Top-dying.

Therefore it could be argued from electrical conductivity measurements of salinity, (Bhuiyan 1994) that there could well be a link between this and the rate of Top-dying, but not necessarily a direct cause.

On the other hand since soil salinity varies considerably between seasons and since most of Bhuiyan's soil samples were collected in the rainy season, it would be unwise to draw a definite conclusion regarding causal relationships between salinity levels and Top-dying.

A major physiological factor which deserves detailed qualified research was postulated by Grepin during ecological studies. He noticed that any apparent equilibrium may be fragile, particularly for tall trees in areas where salinity is high. In these circumstances, when trees reach a particular age, it could be that the amount of energy required to pump sap to the top of a tree is unable to compensate for osmotic pressure and is not sufficient to pump fresh water out of the ground to the top of the tree, thus creating a damaging level of physiological stress. Top-dying may ensue leading eventually to the death of the whole tree (Grepin, 1995). This theory would accord with Curtis (1933) who found that Sundri trees appeared to show signs of senescence and dieback at the peak of their growth and earlier than might be expected under less saline conditions.

3.5 Hydrology

The inter-tidal habitat of mangroves is wholly dependent upon water resources and their particular characteristics. The scientific study of hydrology for coastal mangroves is therefore fundamental to all other disciplines and nowhere is this more important than in ecosystems, such as the Sundarbans of India and Bangladesh, which are under threat from man-made changes in hydrological regimes and water quality. Accordingly, the subject is given substantive attention. Further detailed information may be obtained from technical reports of Wahid (1995) and SWMC (1995).

The Sundarbans open hydrological system encompasses international, regional, national and local factors associated with shared catchments, shared access and global hydrological cycles. This holistic view of hydrology leaves it inextricably linked to upstream watersheds, shared drainage lines and natural and man-made processes in the Bay of Bengal and along the SRF's long western boundary.

Faced by the enormous task of achieving even a modicum of understanding of the ecosystem's water relations a surface water model was developed for this plan as an extension of the national south-west regional model.

Understanding streamflow and water dynamics in this system is complicated on account of variable tides and salinity fluctuations. The underlying dynamics of the hydrological system are controlled by three major factors discussed by Wahid (1995) :

- River inflows/discharges into the SRF at the northern head of the system.
- The tidal inflows at the river mouths.
- The topography of the area.

Productivity and survival of mangrove communities relies upon fresh water inflow; micro-topographic changes and the condition of vegetation succession. It is therefore essential to quantify and model freshwater and saline water inside the system. Computer modelling facilitates the testing of different hydrological regimes, such as an increase in water diversion or consequences of extended duration of flooding. It helps predict the possible outcome of the effect of changes in flow patterns. This is an invaluable aid for long-term planning of forest management, silviculture, plantations, Top-dying removals, zoning schemes and other proposed management actions.

3.5.1 The drainage system, water bodies and catchment area

The special feature of coastal mangrove ecosystems is their dependence upon the dynamics of three sources of water : precipitation, upstream catchments and the sea. Nowhere is this more relevant than the SRF which has an enormous upper catchment shared between four countries (India, Bhutan, Nepal and China) with sources in the largest and highest mountain range in the world. The middle catchment is formed by the floodplains of the three big rivers, the Brahamaputra, Ganges and Meghna and the proximate catchment, which has the most bearing upon water relations is the south-west region's Ganges-Gorai drainage lying to the east of the Hoogly and west of Meghna. Together these sedimentary plains are known as the Bengal Basin.

The SRF drainage system has three sub-systems to the east, centre and west which formed the estuaries of the Bangra, Kunga, Malancha and Raimangal. The whole area is dissected by large tidal rivers, notably the Baleswar, Pussur, Kobadak-Sibsa, Arpangasia and Raimangal together with innumerable small channels and creeks. The main south-west catchment together with the sub-catchments are referred to as SW - 1 to SW - 27 and these are illustrated in Map 6.

The physics of the inter-tidal zone is immensely complex and past attempts to define nearly perpendicular high, medium and low isohalines (ODA, 1985) with rigid interfaces were efforts to rationalise the perceived west-east gradient and transition between the freshwater of the rivers and the saline water of the oceanic tides. Conclusions were drawn without having the benefit of detailed field research and computerised hydraulic modelling (Grepin, 1995).

Water is the main force which shapes the coastal landscape and although the forest and the dissected low lying land surfaces dissipate much of the energy of the tides and river flows, water remains the powerful architect of this environment. Future water management will require improved methods to detect changes in dynamics so that rational long-term management plans for the SRF and indeed the entire coastal area, may be made bearing in mind the following:

- Reversal of freshwater flow due to tidal action experienced throughout the Sundarbans.
- The average tidal range in the area varies approximately 3.0 m on the coast at Hiron Point. The time difference between high water at Hiron Point and high water at Nalian is approximately 2.5 hours. In addition to circadian tidal fluctuations there are half yearly variations in sea level of 600-800 mm in the northern part of the Bay of Bengal due to seasonal changes in salinity and atmospheric pressure.
- Stream and tide flows carry sediments with varying velocities and currents which govern the nature and form of accretion and erosion in the area.
- Sea level rise (SLR) coupled with land subsidence will cause changes in tidal flows, salinity and sedimentation patterns throughout the area.

The rivers in the Sundarbans are classified in three different series and information provided here helps understand the systems hydrology and is a benchmark for future studies.

(1) Raimangal-Sibsa Series

The Raimangal is a broad deep river which carries cross boundary flow from India and discharges into the Bay of Bengal. The main flow which enters from this river into the Sundarbans is through Jamuna at Kaikhali. The river Jamuna is also a broad deep channel with well marked shoals. It issues a large part of its flow into Malancha river through Firingi Khal. The tides ebb and flow through this Khal which is in reality a large river. The Malancha is connected with the Arpangasia river through Araibeki river.

Model simulations show that the flood tide pushes the flow from Malancha to Arpangasia through Araibeki and reverses at the beginning of the ebb tide in the dry period. The linkage between Arpangasia and Sibsa is the Chalki-Sonakhal-Taldup river. Through this river, the flow movement is towards Sibsa and ebb direction towards Arpangasia. This linkage appears to be morphologically stable. The Arpangasia upstream joins with the Kobadak which brings in a significant runoff from the upstream catchment basins. The Kobadak and Sibsa have the same tidal phase.

(2) Pussur-Sibsa Series

The Pussur-Sibsa system is much cross-connected. The tidal flood water flowing up the Pussur and Sibsa penetrates into numerous small rivers and khals. Strong tidal dominance of water induces net tidal circulation with a strong spring-neap variation between the two major rivers. The Sibsa is connected with the Pussur through Bishanbari Khal and the Mara Bhadra-Manki system within the SRF. Freshwater discharge to the river system is provided by local rainfall and tributary flow from the Ganges into the Gorai-Madhumati river. The main freshwater source in the system is the inflow from the Gorai through the Halifax Cut. For the purpose of assessing the freshwater received by the system, the total upstream catchment area that contributes to the runoff to the system is sub-divided and grouped as Q1-Q4 and described in Table 9.

Table 9 River sub-catchments associated with the SRF hydrological system

(Wahid, 1995)

GROUP NO	DESCRIPTION	CATCHMENTS NO	AREA (km^2)
Q1.	Inflow to Nabaganga-Atai-Rupsa	SW - 2,3,7,8,9,10,14,15	5790
Q2.	Inflow to Gorai-Madhumati	SW - 11	445
Q3.	Local inflow to Sibsa	SW - 20,21,26,23 (50%)	1997
Q4.	Local inflow to Pussur	SW - 24 (25%)	334

During the monsoon about 80% of the Gorai flow passes through the Halifax Cut near Bardia to the Pussur-Sibsa system. In the wet season this amounts to 3,200 - 4,800 m^3/sec whereas the inflow from January to May is almost negligible. Along the way the contribution of Group Q1 catchment is received. The net flow that reaches the confluence at Jalma is divided into approx. 20% flowing towards the western polder area through the Lower Solmari river and the rest 80% of the net flow through the Kazibacha river. The percentage of net flow diverted to the Jhapjhapia river during the monsoon is about 30% of the net flow coming southward through Kazibacha.

The net flow in Kazibacha changes direction going eastward during the dry season. A similar pattern occurs in Chunkuri river near Chalna where the net flow reverses from the dry season to the monsoon season. There is an interaction between strong upstream tidal flow in the Sibsa river pushing water eastward in connecting channels to Pussur river. Thus with the ebb tide some of this water moves downstream in the Pussur river. Simulation studies conducted at SWMC have shown that the net discharge at Mongla is about 2000 m^3/sec at the end of July. The Sibsa river at Nalianala shows a net flow of the same magnitude for the same period.

(3) Pussur-Baleswar Series

The major rivers in the series in between Pussur and Baleswar are Bara Siala Gang, Mirgamari-Sela Gang and Bhola-Supoti systems. There is no major exchange of flow between these two rivers except minor flow through the Mirgamari-Sela Gang-Pathuria rivers. Model simulations show that flood tide comes in Pussur much earlier than in Baleswar. During flooding in the Pussur river, water in the Bara Siala river discharges into the Pussur with a tidal meeting point in Pussur Khal. This has resulted in a condition of 'flow stagnation' in the Pussur Khal and subsequent siltation of the Khal. The Mirgamari receives water from the Pussur during ebb tide condition in the later. This water flows into the Sela Gang which diverts some of its flow into the Pussur through the Armal Khal and some to the Baleswar through the Patakata and Badumtala rivers.

3.5.2 Tidal behaviour

Tides affecting the SRF are predominantly semi-diurnal with a tidal period of about 12 hours 25 minutes. It takes approximately 2.5 hours for the tide to traverse the SRF. From the coast the tide flows up the main estuaries; the Raimangal, Jamuna, Malancha, Passur, Sibsa, and Baleswar. From these main rivers, the tidal waves spread into the smaller tidal channels.

Flows in the smaller cross channels obviously depend on the timing and magnitude of high water in the channels they connect. In some cases, the difference in timing may cause a net flow of water from one estuary to another, which may vary in direction depending on the prevailing hydraulic conditions. In other cases, the timing and magnitude of the incoming tidal waves in the connecting channels may coincide, forming complex interference patterns, and stagnation zones with low water velocities. Such zones are important as they constitute possible areas where channel siltation may be taking place (SWMC, 1995) and also must play a significant part in the distribution pattern of plant-soils associations. The irregularity in these confounds simple low resolution mapping.

The duration of ebb tide in a tidal river is longer than that of the flood tide. As the same quantity of water must ebb out as flowed in, it follows that the average velocity of ebb is less than that of flood tides. The capacity of water to transport silt depends upon its velocity. The ebb tide generally fails to transport back fully the silt that has been carried up these tidal rivers by the flood tide causing sedimentation.

In some places even small depositions of silt may accumulate leading ultimately to channel deterioration. This in turn impedes tidal flow causing further deterioration, establishing a vicious circle until the channel is completely silted up. If it is necessary to maintain the life of a particular river in the SRF, for deep water shipping for example, there must be an adequate flow of water with sufficient velocity to supplement the tidal flow during the ebb to scour out fully the silt that has been admitted into the river by the flood tide. The dependency upon upstream catchments and net inflows to the system is clear and at the same time forward planning is greatly assisted by accurate measurements and resulting predictions, now possible with the surface water model.

The overall picture in the dry season is that the system is flood dominated with peak discharges, and hence sediment transport is greater during flood than ebb. In the wet season the situation is less pronounced or reversed. Annually the dry season effects appear to exceed the wet season effect making the system a net importer of sediment but this important topic requires further verification with the aid of the sediment transport model.

The inland tidal condition is also subject to changes caused by major human intervention in the river system. Simulations verified by historic measurements for Mongla (D.H.I. 1992) show that the tidal range has increased and tidal discharge decreased following the large scale construction of polders under the Coastal Embankment Protection (CEP) scheme in the 1960s and '70s. The ecological impact upon the mangrove ecosystem could be considerable but has yet to be measured properly.

3.5.4 Upstream hydrology and the South-West Regional Model

When the upstream rivers, Kumar, Nabaganga, Chitra, Bhairab and Kobadak were active distributaries of the Ganges, sediment laden water flowed into the sea in a south easterly direction. Under normal conditions sediment that reached the sea would be returned at high tide and be deposited over tidal spill areas. During the wet season the rivers would be carrying large volume of material and would increase the height of their bed and banks. During the dry season the tide would break through the raised banks and deliver silt to the low lying areas, thereby causing a general increase in levels of the inter-channel lowlands. In this way a gradual raising and seaward progression of the delta was taking place.

With the migration of the Ganges eastwards the flow from the Ganges into the upstream rivers first diminished and then ceased altogether. At this time there was probably insufficient sediment reaching the sea from the inland rivers to cause further seaward movement of the coast. Instead tidal action continued to move material inland, thereby advancing the shore ridge landward and further raising the old river beds. In time sediment reaching the low lying junction between tidal and river deposits diminished and permanent low lying bowl-shaped areas were created as can be found in the Sundarbans today. The low lying coastal ridge where salt and fresh water meet provided the condition necessary for extensive mangrove forests to grow in the Sundarbans.

The delta in the Southwest Region is now undergoing a period of transition from being an active deltaic system with large Ganges fresh water flows mixing with tidal incursions, to a system with much smaller local fresh water flows but similar tidal incursions. This transition involves the gradual siltation of tidal inlets until they reach a size which is in equilibrium with the reduced fresh water flows. The point at which the system will stabilise is not known but total decay of the delta is not likely to occur.

A review of historical charts has been carried out by FAP-4 studies and comparison between the coastal outline obtained from the 1989, 1:50,000 SPOT satellite images and selected charts dating back to Rennell's Map of 1779. The most notable points concerning coastal formation in the Sundarbans are:

- The coastline from the centre of the Sundarbans towards east has remained virtually unchanged over the last 200 years.
- There have been some changes to the lateral channels linking the main north-south tidal rivers

3.5.5 Extreme floods and cyclones

Cyclones and tropical depressions are common occurrences in the Bay of Bengal. They are often associated with strong winds and low barometric pressures, which combine to form a build up of the water level along the coast in the form of a surge. The surges propagate up the tidal channels, causing widespread inundation, damage to property and crops, and loss of life. The ameliorating effect of the mangrove forest upon these forces is remarked upon throughout this plan and provides a strong case for careful long-term maintenance of the coastal core area Protection Zone discussed in Part 2.

3.5.6 Salinisation

As for hydrological regimes, levels of salinity play dominant roles in the gross and micro-ecology of mangrove ecosystems and until recently the extreme difficulty in measuring fluctuations in levels and their dynamics has led to broad and sometimes contradictory opinions on salinity levels and their temporal and spatial variations (Grepin, 1995). This is such an important and controversial subject for the Sundarbans that it is dealt with in some detail below and for further more technical supporting information reference should be made to SWMC (1995).

During the course of data gathering for this plan the salinity model prepared by the SWMC was used to determine the fluctuations in salinity in the rivers of the Sundarbans. The results are based on monsoon and dry season hydrodynamic simulations based upon records of salinity measurements at the coastal boundaries and spot salinities measured in the rivers during recent hydrological studies (Wahid, 1995). These studies have made a considerable advance in knowledge of salinity distribution and both daily and seasonal variations which are shown to be far more varied and complex than previous less definitive research had indicated (Grepin, 1995).

Salinity in the SRF is highly dependent on the salinities at the coast and the volumes of freshwater flows discharging from upstream. Salinities on the coast and in the forest channels vary over a number of different timescales (SWMC, 1995) as follows:.

- Semi-diurnal variations

Tides in the Bay of Bengal are semi-diurnal. The arrival of high water at the coast generally coincides with the peak in daily salinity and the daily range of salinity concentrations at the river entrances varies with the season.

- Spring neap tide variations

Tidal amplitudes during spring tides are around 2.5 to 3 times higher than during neap tides. The higher water levels occurring at the coastal boundaries cause greater volumes of saline water to enter the forest than during neap tides. The dilution effect of any freshwater flows in these channels is consequently weaker during spring tides. As a result, maximum salinities occurring during spring tide are generally higher than neap tide concentrations.

- Local effects can however alter this general pattern for example for the Malancha river entrance in September salinity generally increases during the month due to the declining volume of freshwater discharging into the Bay of Bengal as the monsoon comes to an end. The freshwater net flows occurring during the monsoon spring tides in the Arpangasia river are apparently sufficient to dilute the salinity at the river entrance by several ppt.

- Seasonal Variations

Salinity levels on the coast are also affected by the volume of freshwater discharging through the lower Meghna estuary and that the effect diminishes with distance from the Meghna. Average salinity concentrations at the coast are therefore higher in the dry season than in the monsoon. Measurements at Hiron Point and Kaikhali between August 1994 and February 1995 indicate that salinity increases almost linearly from the beginning of October. This rise will generally continue until the start of the monsoon.

This complexity is further compounded through seasonal variations in relation to measured daily variation. This is clearly illustrated in Table 10 which shows the semi-diurnal salinity ranges at the entrances to the Jamuna and Baleswar Rivers during September 1994 and January 1995.

Table 10 Daily Variation of Salinity in the Sundarbans

(Wahid, 1995)

Location	Monsoon		Dry Season	
	Measured Salinity (ppt)	Range	Measured Salinity (ppt)	Range
Jamuna Entrance	6-10	4	20-21	1
Baleswar Entrance	0-2	2	3-9	6

From Table 10 it can be seen that the Jamuna entrance experiences the greatest variation in daily salinity concentrations in the monsoon, whereas at the Baleswar entrance, the highest variation occurs in the dry season. The daily variation in the salinity at the river entrances is dependent on the salinity of the sea water as it enters the river during flood tide, and the relative volume of this water compared to the volume of fresh water available for mixing inside the river system.

In the monsoon, flood tides entering the Jamuna river contain relatively high concentrations of salt. This is diluted by the freshwater inflows into the western Sundarbans which result partially from runoff from the polder areas, and partially from flows in the Gorai River. The result is that the salinity of the ebb flows is reduced by about 4 ppt compared to the original flood flow.

In the dry season, the situation is quite different. Now the salinity of the flood tide is very high. With negligible freshwater inflows in the upper reaches of the Jamuna available to dilute the salt water, the salinity concentrations during tidal ebb remain virtually unchanged from those in the flood tide.

At the Baleswar entrance, the conditions in the monsoon are affected by the high freshwater discharges in this river and in the adjacent Meghna estuary. These are sufficient to push the salinity front far out into the bay, with the result that salinity concentrations at the river entrance are very low, around 2 ppt. Consequently, there is little scope for a further reduction in salinity during the mixing processes which occur inland during flood tides. In the dry season, the freshwater flows in the Baleswar are reduced and salinity at the coast is higher, a situation similar to that occurring at the Jamuna Entrance in the dry season. The mixing of the saline water carried inland during flood tide with the freshwater that is available, results in a decrease of about 6 ppt in the ebb flow.

- Salinity Distributions - Existing Conditions

The spatial distributions of salinities in the Sundarbans as simulated by the model have been presented as a series of salinity concentration maps, overlain on a topographic map of the Sundarbans Reserved Forest - see Appendix A28. Maps showing the maximum and minimum salinity concentrations in the SRF have been produced for both neap and spring tide conditions. Each map represents the maximum or minimum simulated salinity concentration reached during 13 hour simulations periods on the dates shown in Table 11.

Table 11 Dates Corresponding to Salinity Maps

	Monsoon	Dry Season
Neap	14th September 1994	10th February 1995
Spring	7th September 1994	17th February 1995

Monsoon Spring Tide:

During the monsoon spring tide simulation, salinities at the boundaries varied from 10 ppt at Kaikhali, 13 ppt at the Jamuna entrance, decreasing to almost zero at the entrance to the Baleswar river. Furthermore, freshwater inflows to the Sundarbans range from 60 m^3/sec in the Kobadak, to 5000 m^3/sec in the Baleswar. The effects of high freshwater flows and low coastal salinities in the eastern Sundarbans combine to restrict the salinity in the tidal channels east of the Arpangasia river to the range 0-6 ppt. This contrasts with the situation in the western Sundarbans, where higher coastal salinities and small freshwater inflows give rise to high salinities, in the range 8-16 ppt. The resulting salinity distribution at spring tide is shown on Maps in Appendix A28. The plates show the maximum and minimum salinity distributions in the Sundarbans over the 13 hour period for which the simulation was run. The decrease in salinity from west to east is clearly shown but not the duration.

Monsoon Neap Tide:

Maps in Volume 3 show the salinity distribution for the neap tide on 14 September 1994. The situation compared to the spring tide is mostly unchanged. The exception is at the Malancha river entrance where the reversal of net flows in the Arpangasia river during neap tides leads to an increase in the salinity at the boundary. The effect appears very localised however, as the simulated salinities immediately inland of the boundary are 2 ppt lower, due to the large freshwater net flows emerging from the Malancha river.

Dry Period Spring Tide:

Salinity levels at the coastal boundaries gradually increase from their monsoon flows from around September until the monsoon river flows commence again in May-June. Assuming a linear increase in salinity from the beginning of October to the end of May, the coastal salinity concentrations in February are estimated to be 7-12 ppt lower than their peak values, and this should be taken into account when analysing the model results.

In February 1995, salinities at the coastal boundaries ranged from 25 ppt at the Jamuna entrance, decreasing to 20 ppt at Katka, west of the entrance to the Baleswar river. As in the monsoon, this gradient is due to the volume of freshwater discharging into the Bay of Bengal from the Meghna estuary. However the magnitude of this discharge, and those in the rivers which enter the Sundarbans, are greatly reduced from their monsoon values. The net flows in February in the Kobadak and Kholpetua rivers are almost negligible, while in the Baleswar, the net flow is reduced to 800 m^3/sec from a monsoon figure of 5000 m^3/sec. These factors lead to a general increase in salinity along the coast and in the forest in the dry season.

Maps in Appendix A28 illustrate the maximum and minimum salinity distribution during the spring tide of 17 February 1995. As in the monsoon, the highest salinity concentrations (26-28 ppt) are to be found at the western edge of the forest, while the lowest salinities (6-8 ppt) are found inland in the east along the Baleswar River.

Dry Period Neap Tide:

During the neap tide, the volume of saline water flowing into the forest from the sea is reduced compared to spring tide conditions. The dilution effects of the freshwater flows are increased, leading to a general reduction in salinity. Maps in Appendix A28 show the maximum and minimum salinity level during the dry period neap tide on 10 February 1995. Maximum salinity levels are generally reduced by about 2 ppt from the spring tide maximum. It should be noted that these maps do not provide the all-important information on duration, which should be the next and most important stage in modelling.

The salinity maps allow the salinity distributions in the Sundarbans to be easily visualised. The areas of forest exposed to the different salinity ranges shown on the maps have been computed from the GIS as shown in Table 12. The salinity interval has been increased from 2 to 4 ppt to produce a clearer picture of the situation. The areas are calculated at the maximum salinity condition and expressed as a percentage of the total forest area. The calculated figures correspond to the situations depicted in the salinity maps as indicated at the bottom of the table.

Table 12 Spatial Salinity Distribution in the Sundarbans (% of Total Forest Area)

(Wahid, 1995)

Range (ppt)	Monsoon		Dry Season	
	Spring	Neap	Spring	Neap
0-4	62.4	62.1	5.7	7
4-8	18.3	17.1	3	2.5
8-12	13.6	15.4	6.2	8.7
12-16	5.7	5.4	17	20.3
16-20			25.6	28.3
20-24			30.1	23.9
24-28			12.4	9.5
Plate No.	*4.1*	*4.3*	*4.5*	*4.7*

Changes in Salinity between Monsoon and Dry Season:

The GIS used to display the results of the salinity model simulations has been used to construct a difference map to illustrate the difference between monsoon and dry season salinity concentrations. As a basis, the maximum spring tide salinities have been used. The difference maps show the reduction in the maximum salinity concentrations between the dry season spring tide maps.

These show that the greatest changes between monsoon and dry season salinities are adjacent to the Passur-Sibsa system in central SRF, a matter not defined clearly in previous reports. Monsoon salinities are reduced in this area by 14-16 ppt in the north to 18-20 ppt near the river mouth. **The river systems to the west receive very little freshwater flows in either season and hence the salinity levels remain relatively high at about 10 ppt to as much as 28 ppt for much of the year but the exact duration of levels critical to the plant communities has yet to be determined.** The reduction in salinity in the monsoon along the Jamuna River is 8-10 ppt. At the other extreme, freshwater flows in the Baleswar in the east are maintained the year round with relatively low salinities in most, but not all, parts of this region. Changes between dry season and monsoon salinity levels in this area are in the range 0 ppt - 4 ppt.

- Salinity Distribution - Gorai Inflow of 200 m^3/sec:

The Gorai river is an offtake of the Ganges. It represents the only major dry season source of freshwater flow to the western part of South West Region. In recent years, dry season flows in the Gorai have reduced dramatically, partially due to the withdrawal of water from the Ganges, and additionally by the gradual siltation of the offtake. In the past 2 years, the mouth of the offtake has closed completely in the dry season, cutting off freshwater flow downstream. The FAP 4 study has concluded that unless preventive measures are carried out in the near future, the Gorai could be completely abandoned and become an inland river carrying only local runoff.

The effect that freshwater flows in the Gorai have on the salinity distribution in the region as a whole has been thoroughly investigated by FAP 4. The effects on the salinity in the SRF have not been studied in detail to date but should be included in CST activities discussed in Part 2.

The calibrated model was used to determine the impact of increased Gorai flows on dry season salinity levels. A constant Gorai inflow of 200 m^3/sec was selected for the simulation. This figure was based on average dry season discharge for 1965-70 of 1675 m^3/s at Harding Bridge on the Ganges, and the assumption of an 11% flow split to the Gorai.

The model simulation was carried out for a 5-week period from 1st Jan 1995 which was necessary to allow the salinity levels to stabilise. Results are presented in the Gorai maps which illustrate maximum and minimum simulated salinities.

The impact of the increased Gorai inflow can be seen more clearly which illustrating the reduction in maximum dry season spring tide salinity produced by the increased Gorai flow. It should be noted that the data can also be interpreted as the increase in salinity caused by the reduction in Ganges and Gorai discharges after 1972. The greatest impact is visible along the Passur-Sibsa system which, of all the rivers entering the Sundarbans, receives the greatest contribution from the Gorai. The reduction in salinity concentration varies from 4-5 ppt along the Passur Sibsa system, to less than 2 ppt in the western and eastern regions of the forest.

3.5.7 Sedimentation

During the rainy season sediments which have accumulated in river beds are flushed to the sea by rivers which pass through the SRF and annually deposition occurs on the forest floor but the pattern is far from simple since a significant proportion of the sediments which are swept out to sea are probably brought back by tide currents inside the Forest (Grepin, 1995; IUCN, 1994 and SWMC, 1995). Streamflow, currents, turbulence, tidal effects and seasonal flooding modified by impoundments, poldering and extreme events all affect the rates and locations of sedimentation.

It has been observed that in deltaic situations dissolved organic and inorganic material deposited in areas where salinity is about 2-3 ppt through mass flocculation and at the same time clay particles become clumped and combine with silt and organic particles to settle out upon the forest floor (IUCN, 1994). In mangroves these sediments are trapped by the sheer density of vegetation and associated roots and pneumataphores.

Although it has not been possible to make reliable quantitative assessment of rate and pattern of sedimentation within the SRF there is evidence gathered for the Chalna, Mongla and Kharma Khal areas which indicate that with the increasing reduction of fresh water inflow from upstream due to human activities, the annual silt load is not being flushed down during the monsoon and many rivers are silting up. There is every possibility that there is an increasing rate of sedimentation and this could be resulting in fast changes in the floristic composition of the mangrove Forest due to soil elevation (Grepin, 1995).

It seems apparent that in the medium term, 5 - 10 years, the sedimentation problem will become prominent with consequential changes not only in the nature of the mangroves but of the entire environment opening up new options of land use and resource management.

For example recent studies in the Kharma Khal area (see Plate 6) raised forest land near the Khal in Compartments 27 and 28 in the North-East of the SRF have a reduced channel network linking the Khal and the forest due to siltation. The evident low forest productivity of the adjacent areas appeared to be the consequence of soil elevation through sedimentation combined with excessive unofficial cutting and lack of effective silvicultural practices.

The Kharma Khal was completely silted up in less than 10 years: the FD's main launches (draught: 2 m) were crossing this Khal at high tide in 1986 - 1987. Aerial photography and field survey, (1990 - 1995) showed total siltation and today even small wooden canoes with less than 40 cm draught cannot use this Khal.

Management decisions for the area are complicated by the fact that it is doubtful that dredging of the Kharma Khal without any other changes in the adjacent channel or river system would be successful in the long run. The siltation experienced in the last 7 years (200 - 250 mm/year) would soon close the Khal again. The silt is brought by the tide from the Passur and the Bay of Bengal. To flush the excess silt, it would be necessary to reopen waterways tapping waters upstream on the Passur and excess of rainwater collected in the adjacent polders. There would be a need for a detailed cost benefit analysis with little assurance of ultimate success, in the face of ongoing sedimentation and population pressure, for any of the options currently available.

Other important effects of siltation have been observed exceptionally in coastal areas where massive siltation up to one metre may have occurred over the short term leading to the virtual burial of stands of 2 - 3 year old mangrove trees and pneumatophores of older trees in coastal areas (Conchie, D.M.C, 1990).

"Roots and stems of Sundri trees in fair preservation have been found at Khulna, 18 feet, at Mutlah 10 feet, and at Cacultta 30 feet, below the ground, underlying strata containing no trace of former land surface" (Heinig, 1892).

During the hydrological studies a newly accreted site of this type was discovered during TSP surveys at 22° 25' 00 N - 89° 24' 48 E where dead and Top-dying Sundri had been replaced by a healthy stand of 10 - 15 year old Kankra growing on fresh sediment overlaying a strata of degraded organic matter which was producing H_2S (Grepin, 1995).

Other phenomena which may be widespread in the SRF and which should be researched in more detail during future studies relate to sudden siltation and water logging. It has been observed (Grepin, 1995) that tall Sundri trees are often found in low lying areas (but not swamp areas) behind levees. These areas are subject to prolonged inundation and during tidal surges are exposed to sudden and excessive siltation. Prolonged waterlogging up to 4-6 weeks is known to kill most mangrove species (Saenger, 1987).

Increased siltation from the Bay of Bengal due to reduction of freshwater flushing has extended the period where the mangrove area is not flushed by tide. In this condition raised areas which cannot store freshwater (non sandy or silty sediments) are suffering an extended period of drought.

Areas rich in silt and sand store freshwater and these are more suitable for fresnwater species such as rain tree ***Samanea saman***. Low lying areas isolated from tidal flushing are turning to swamp and unsuitable for Sundri growing or regeneration especially when waterlogged for long periods.

3.5.8 Water pollution

Water pollution has been endemic in the south-west region and become widespread in recent years with possible impacts upon the SRF which have not yet been measured. All kinds of wastes - either in solid or liquid form - are dumped into rivers and ultimately find their way into the Bay of Bengal through the Sundarbans which can produce a change in the physical characteristics of the ecosystem (Wahid, 1995).

Pollution originates from specific places such as a particular industrial source or have diffuse origins such as ocean currents or agricultural runoff. Water pollution from diffuse sources can be highly damaging to the environment and flora and fauna through the concentration and accumulation of toxins in the water, in sediments and ultimately organic tissues.

Within the south west region, industries are concentrated along the roads between Khustia-Jessore-Khulna and along the rivers. There are about 165 iin Khulna alone. These discharge untreated waste into the Bhairab-Rupsa river system. In addition, several match factories, the Khulna shipyard and fish processing units in the Rupsa industrial area discharge their effluent into the Rupsa river. Khulna Newsprint Mill, Goalpara Power Station, some jute, hardboard and steel mills in the Khalispur industrial belt also discharge their untreated wastes into the Bhairab river.

According to ESCAP (1987) a newsprint mill continuously discharges nearly 4,500 m^3 /ha of waste water containing high level of suspended solids (300-500 mg/l) and sulphur compounds. Biological Oxygen Demand (BOD) data are not available, but it is assumed to stand at 2,500 kg/year for the factory's chemo-mechanical process. Thus the Bhairab river has become an important artery receiving untreated water from industrial discharge. These pollutants find their way to the SRF through the Pussur-Sibsa system to well below Mongla Port which is one of the country's major ports and is itself a significant source of water pollution (Wahid, 1995).

Oil pollution may be affecting the SRF (Wahid, 1995; Grepin 1995). Bilgewater and crude oilslicks derived from ocean going freighters, mechanised boats, fishing trawlers and passenger launches travel along the Pussur River for a distance of about one hundred kilometres via the SRF to Mongla Port. In the last few years, two severe oil spillages occurred accidentally within Bangladesh's territorial waters. This caused an oil slick for about 64 Km inland along the SRF seaface area (SWEDMAR/BOBP, 1994). ESCAP estimated in 1988 that accidental oil spillage, oil slicks, ballast and bilge water discharges would increase four-fold by the year 2000 under present operating rules.

Another important issue is the extent to which pollution from the Hooghly river in India reaches the Sundarbans ecosystem. SWEDMAR conducted an environmental assessment of the Bay of Bengal in 1994 which stated that " The Hoogly estuary in West Bengal is probably the most polluted estuary in the world ... discharging about half a billion litres a day of untreated wastes." On the other hand it was noted that the environmental conditions in the estuary in 1960 and 1988 showed "surprisingly, there were no significant change in the chemical parameters in the estuary during the two decades. The regular flushing by tidal water had evidently taken most wastes out to sea and the estuary itself had not changed significantly." This implies that with flood tides in the Sundarbans there is a possibility that pollution discharged from the Hooghly estuary into the sea could be carried far into the SRF (Wahid, 1995).

Ground water contamination especially in the Border Zone is unknown and should be studied as a matter of high priority together with problems relating to agricultural pollution for the following reasons:

- the accumulation of nutrients from fertilisers, especially Nitrogen and Phosphorus, which contribute to the eutrophication of rivers;
- the toxic effect in the food chain of certain pesticides and herbicides which are known to concentrate in organisms and in the environment.

Present rates of agrochemical use in the greater district of Khulna demonstrates the problem. While the area of land under cultivati‹ ,·. between 1983 and 1989 remained almost constant at about 438 000 ha, during the same period fertiliser use increased from 44.95 kg/ha to 246.52 kg/ha. The trend for increasing use of chemicals is expected to continue as more land is brought under irrigation and a change to HIV rice is occurring, probably in proportion to the increase in the human population.

Toxins accumulated in soils can lead to hindrances in microbial processes and mineralization, thereby impeding plant growth, or may be directly taken up by plants in toxic quantities. Study conducted by SWEDMAR as part of the "Bay of Bengal Programme" pointed out that oil pollution alone can damage the mangrove ecosystem as well as other coastal and marine resources and cause defoliation and mortality to mangroves, river breeding grounds and nurseries of fish and crustaceans. Also the pneumatophores (breathing roots) of mangroves become covered by oil and tar resulting in defoliation and death.

Coastal and marine fisheries are affected through the food webs leading to a depletion in the fish stocks. Qualitative deterioration also reduces the nutritional value of fish. The thin layer of oil on the water surface hampers light penetration and air-sea gas interaction, affecting the multiplication of planktonic food organisms. This effects physiology of marine fish living on planktonic organisms and interferes with growth and reproduction. Fish can also absorb oil directly with their feeding, resulting in the tainting of fish tissue. Also, the aromatic hydro-carbons present in crude oil are persistent and carcinogenic. Since they have a tendency to be biologically accumulated in fish tissues, they can pass into organisms of higher trophic levels in the food chain.

Since plants are at the base of the food pyramid, the structure and characteristics of the ecosystem can be completely changed, even to the extent of markedly altering the species composition. In addition to that, once some of the pollutants get ingested by various organisms in the aquatic environment, a major concern is the likelihood that these concentrated pollutants will appear in the marketplace where there are no mechanisms for testing and control, especially of fish and crustaceans.

Although there has not been any systematic study assessing the impacts of pollution on mangrove forest and fisheries, it is likely that the ecosystem may become a sump for pollutants not only because they flow into shallow areas more rapidly than they are exported by natural tide action but also because the normal structure and circulation of currents in the Bay of Bengal tend to prevent the mixing of these shallow waters with the rest of the ocean.

Monitoring industrial pollution and its effect upon the SRF should be considered in more detail in future integrated research programmes . Existing laws relating to the environment are listed in Table 13. These should be updated in light of new research and in the face of increasing threats, environmental legislation should be strengthened.

Table 13 Environmental Legislation in Bangladesh

(Wahid, 1995)

Subject of Legislation	Existing Legislation	Comments and Recommendations
Water pollution	Environmental Pollution Control Ordinance, 1977; Factories Act, 1965	Updated act required
Toxic and hazardous substances	Pesticide Ordinance, 1971 (as amended, 1980, 1983); Environmental Pollution Control Ordinance, 1977.	Existing law to be updated
Coastal resource management	Environmental Pollution Control Ordinance, 1977; Territorial Water and Marine Zones Act, 1974; Factories Act, 1965.	Comprehensive legislation may by required, such as proposed marine Pollution Control Law
Conservation of bio-diversity	Forest Act, 1927 (amended up to 1973), Environmental Pollution Control Ordinance, 1977; Wildlife Preservation Order, 1973; Rules regulating hunting shooting, fishing.	Related laws, ordinances, and rules need integrating and updating.

3.5.9 Potable water

Drinkable water for Forest Department employees and people who enter the SRF to harvest produce is a matter which has concerned managers for a long time but to date no concerted planning or investment has been made to address this important management issue.

In general there is no dependable organised water supply system and at nearly all times and in nearly all locations, the scarcity of potable water is acute. The river water is highly turbid, saline and contaminated with pathogens for most of the year. The current source of potable water is mainly rainwater with some ground water abstraction from the less saline aquifers on the outskirts of the Sundarbans. Collected data show that out of 69 FD offices inside the SRF, only 3 use tubewells for their potable water supply while 66 collect their supply often from distant ponds which traps rainwater during monsoon. At only 3 locations are sand filters available. The SRF FD Inventory of Potable Water Sources is provided in Appendix 30.

The position at present is as follows:

- A hydro-geological system is recognisable which is not similar to the other areas of the SW region. However, due to southward fining of the deltaic sediments and particularly thick upper clay layer, ground water of acceptable quality is not available at relatively shallow depths for easy withdrawal by conventional handpump tubewell.

- In particular, there is severe problem of saline intrusion. Saline fronts are present in deep and shallow aquifers, which will move further inland if abstraction is made from ground water.
- Ground water contamination by river pollution is unknown but could be extensive.
- Ponds used for potable water supply in the SRF are mostly artificial man-made type. Because of the stagnant nature of water, pollution, whether natural or man-made, entering the ponds are partly carried in the seepage and percolation underground and the amount remaining in the pond is subjected to physical, chemical and biological processes such as adsorption, chemical precipitation, oxidation and reduction, biochemical degradation etc. besides being subjected to the important effects of exposure to sunlight, wind, temperature and evaporation.

At FD stations the major difficulty in using of pond water is excessive salt and iron concentrations which impart bad tastes and odours, stain clothes, discolour food and engender a high risk of water-borne disease. Potable water was analysed at different stations using the following criteria:

- Turbid water indicates the presence of iron and manganese contaminants.
- Colour in water is usually due to presence of dissolved organic matter.
- Odour in the surface water is caused by plankton which are free floating microscopic organisms. These organisms liberate traces of volatile essential oils, which give out various objectionable odours.
- Metallic taste is imparted to water if copper, zinc or iron is present in water even at a very low concentration.
- Magnesium and sodium sulphate exert a cathartic action and if present in sufficient quantity imparts a bitter taste to the water.
- Ph value is dependent on the carbon dioxide-carbonate-bicarbonate equilibrium. Ph values exceeding 9 indicates presence of sodium carbonate or sodium bicarbonate.
- Salt content of water indicates the presence of chloride.

Resulting from this and measurements of pH and salt concentration, a quality scale was established as shown in Table 14.

Table 14 Potable Water Quality Criteria : the Sundarbans Reserved Forest

(Wahid, 1995)

	GOOD	MODERATE	BAD
pH	7.0	7.5	8.0
Salinity ppm	500	2000	3000

Distance from the water source is also an important factor in determining suitability. In 40% of the cases FD stations were more than 5 Km from potable water and 13% of these stations have to fetch water from more than 10 km. The remaining 60% of the stations have access to the source within less than 5 km. distance but there are 14 stations out of the 69 where ponds used for potable water supply are located inside the station compounds. Quality determinations indicated that only about 30% of these stations receive good quality water while the staff at the remaining 70% of the locations have to survive on moderate to bad quality water. **Apart from personal security, provision of drinking water of reasonable quality should surely be an early commitment in future SRF capital projects for FD staff with accessibility for the general public also.**

3.5.10 Future Water Supply System

The special circumstances of salinity, unconsolidated soils and exceptionally high year round water tables make potable water supplies difficult to organise and difficult to maintain at acceptable standards in the SRF. Strategies for provision of dependable potable water for all FD stations could be as follows:

(1) Rainwater storage tanks have to be improved and their use extended because of their cheap construction. The tanks will be constructed by excavating the earth on relatively high natural ground and by providing sufficiently strong embankments or linings to store the water. As the distribution of rainfall throughout the year is uneven, the rainwater storage tank will be comparatively large in size. The surface area will have to be sufficiently large for rainwater collection. The volume of the tank V (m^3) and the surface area A (m^2) required for rainwater harvesting can be estimated from the following equations:

$$V = 0.365\ P\ C$$

$$A = (1/24)\ P\ C\ (1/RI)$$

where, P is the number of persons served, C is the per capita per day water consumption in litres and R is the rainfall intensity in mm/hour for the monsoon months from June-September and I is the runoff coefficient (Runoff / Rainfall).

For example, considering, average water consumption (P) for all domestic purposes to be 45 l per capita per day (lpcd), 500 persons served per pond (C), distributed rainfall intensity for the months of June-September 0.55 mm/hour, runoff coefficient of 0.564 (as obtained from rainfall-runoff model) and 30% loss due to seepage, percolation and evaporation, the computed volume of each tank is 8,300 m^3 and surface area required will be 3100 m^2.

In addition to improving the present 14 ponds a further 9 new storage tanks (see Map 12) should be dug at:

1. Adachai Coupe Office
2. Sutarkhali Forest Station
3. Andharmanik Patrol Post
4. Kalabogi Forest Station
5. Patakata Patrol Post
6. Sakbaria Patrol Post
7. Bazbaza Patrol Camp
8. Kochikhali Wildlife Sanctuary
9. Koyra Patrol Post

(2) Slow Sand Filters should be installed at 20 new locations; these include all 9 new storage tank locations as well as 11 old pond sites where filters are not present. Though initial cost of installation is higher compared to other filtration methods, SSF is the best option for the following reasons:

- Skilled supervision is not required.
- Capital cost and cost of operation is low.
- Depreciation is low.

SSF are package type filter units developed to treat usually low saline pond water for domestic consumption. In this system, water from ponds is collected by hand pump and discharged into a reservoir underlain by a sand bed; filtered water is collected through a tap. Construction of SSF at other coastal areas reported 86% removal of turbidity and 95% removal of bacteria in spite of poor maintenance. It is expected that installation of Modified UNICEF type SSF and proper scraping of surface layers of sand every 60 days will ensure 98 to 99% removal of bacteria and suspended matter. Each of these units can serve up to 300 people. .Participation of beneficiaries in routine maintenance work must be ensured for efficient operation of these facilities. All necessary parts and components requiring frequent replacement should be stored among other essentials in the stores of the FD stations where SSF's will be installed.

(3) Charcoal can be used as a superior filter medium instead of sand. The filter medium in this method consists of durable, saturated and organic matter free charcoal which has an effective size between 0.7 to 0.75 mm and an uniformity co-efficient of 1.75. Easy and abundant availability of filter material, sand and charcoal, makes it an attractive option for the SRF. Charcoal filtration leads to a high degree of improvement to the physical, chemical and bacteriological quality of water (Wahid, 1995).

3.5.11 Sea level rise

Predicted sea level rise (SLR) already detected due to global warming coupled with land subsidence will change water depths, tidal flows, salinity and sedimentation patterns throughout the area.

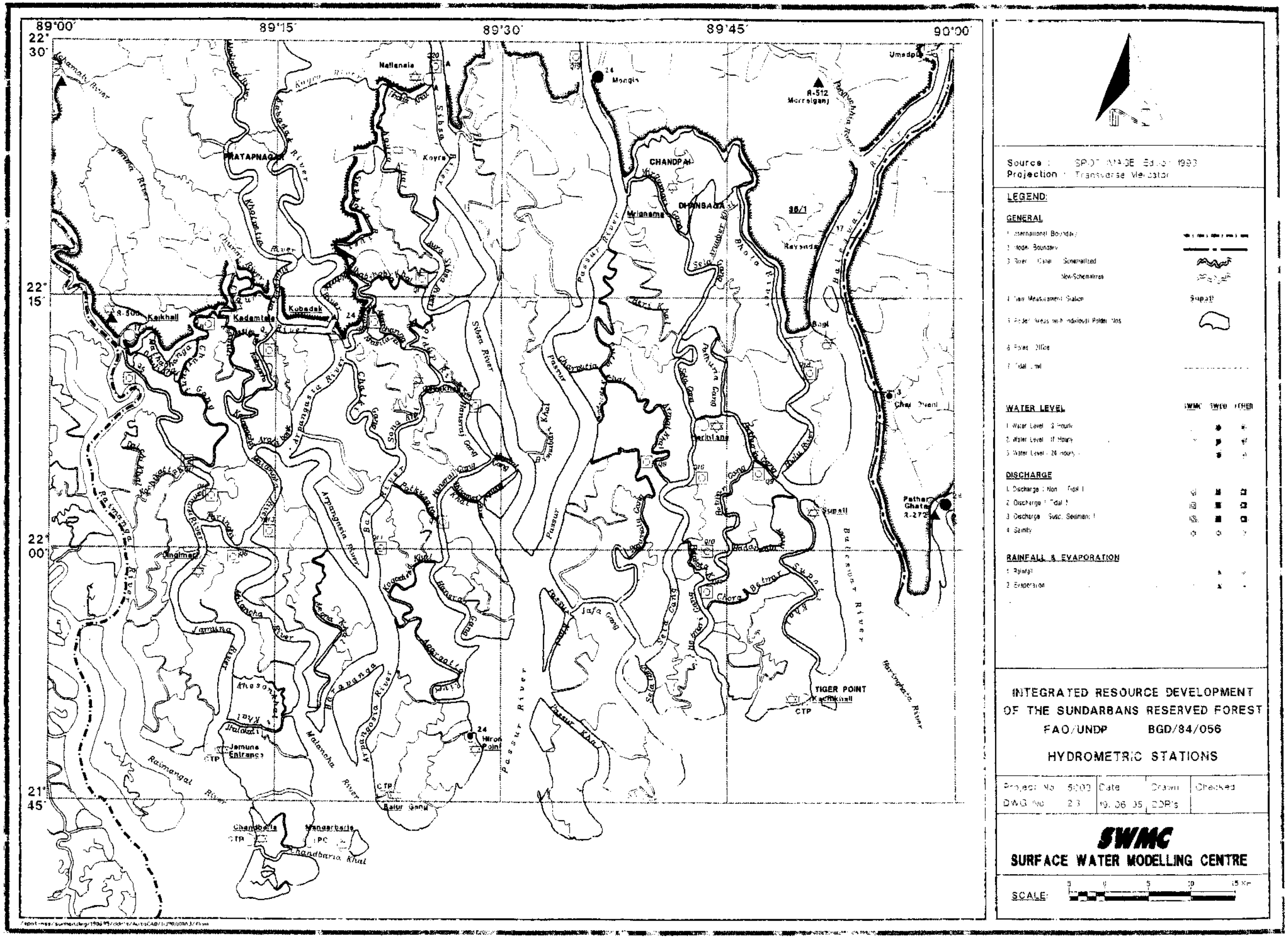
During the last 100 years the climate has gradually become warmer. Top scientists now agree that the earth has already warmed by about half a degree over the last 100 years (CARDMA, 1989).The increased emission of CO_2 and the so called `green-house' gases may in the future give more severe heating effects. Past records show that global mean temperature has increased 0.3-0.6 C over the last one hundred years, with the five warmest years being in the 1980s. Over the same period global sea level has increased by 10 to 20 cm. Though predictive mathematical climate models give varying results on long-term global mean temperatures which ranges between 1-5^0 C according to the joint statement of the US scientist of the National Academy of Sciences, the National Academy of Engineers and the Institute of Medicine (CARDMA, 1989) it is most likely that there is a global move towards higher temperatures, which will cause the polar ice masses to melt and sea level to rise.

3.5.12 The hydraulic model data base

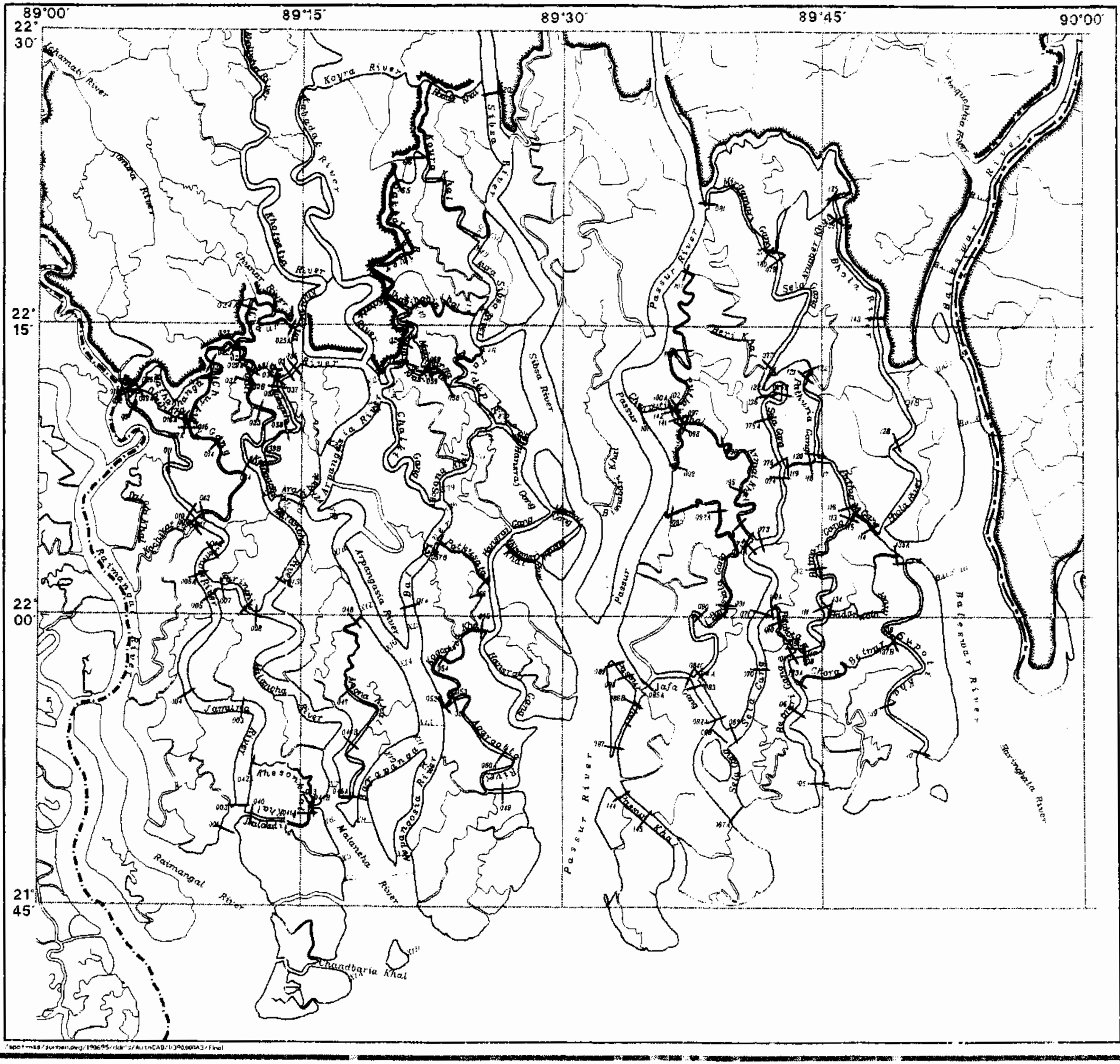
The hydraulic model, which has provided the first systematic data on the hydrological regime of the SRF, was developed by the SWMC and RRI to provide essential up-to-date information for this plan.

The model is capable of simulating all the important hydrological and hydraulic processes in the Sundarbans. The model was refined by including additional river channels using data acquired in a series of field programmes carried out by SWMC. After calibrating the refined models using data acquired at the hydrometric stations and cross-section locations illustrated in Maps 8 and 9, they were used to simulate both historical events and hypothetical scenarios. The results of the model simulations are interfaced with the (GIS). The topographic maps of the Sundarbans provided in volume 3 are suitable for immediate use in the field and as a quantitative baseline for future studies.

The results of the hydraulic model have also been used to briefly investigate the potential for sedimentation in selected channels in the Sundarbans. **Further work with additional data are an essential follow-on project for the SRF and ultimately the model will provide duration data which will be of considerable help in plant and soils association analyses quite apart from the profoundly valuable factual information which will accrue in the IDB on water regimes and general hydrology on which the system depends**



89°00'
89°15'
89°30'
89°45'
90°00'
22° 30'
22° 15'
22° 00'
21° 45'
Source : SPOT IMAGE
Projection : Transverse Mercator
LEGEND:
GENERAL
WATER LEVEL
DISCHARGE
RAINFALL & EVAPORATION
SWMC
Supati
PRATAPNAGAR
CHANDPAI
DHANSAGA
Mriganama
Nalianala
Koyra
Mongla
Morrelganj
Umedpur
Rayenda
Bagi
Supati
Pathar Ghata
Kaikhali
Kadamtala
Kobadak
Sibsa River
Passur River
Arpangasia River
Malancha River
Jamuna River
Raimangal River
Raimangal River
Baleswar River
Haringhata River
Bhola River
Kobadak River
Kholpetua River
Hansraj Gang
Sela Gang
Pathuria Gang
Jafa Gang
Chandbaria Khal
Jamuna Entrance
Chandbaria
Mandarbaria
Hiron Point
TIGER POINT
Kachikhali
Balur Gang
CTP
INTEGRATED RESOURCE DEVELOPMENT
OF THE SUNDARBANS RESERVED FOREST
FAO/UNDP BGD/84/056
HYDROMETRIC STATIONS
Project No
Date
Drawn
Checked
DWG No
19. 06. 95
DDP's
SWMC
SURFACE WATER MODELLING CENTRE
SCALE:



Source : SPOT IMAGE Edition 1993
Projection : Transverse Mercator

LEGEND:

GENERAL

1 International Boundary
2 Model Boundary
3 River / Canal Schematized
Non-Schematized
4 New Measurement Station
5 Polder Areas with individual Polder Nos
6 Forest Office
7 Tidal Limit

Supati

CROSS SECTION

1 Cross Sections (1994)
2 Cross Sections (1991)

INTEGRATED RESOURCE DEVELOPMENT
OF THE SUNDARBANS RESERVED FOREST
FAO/UNDP BGD/84/056

CROSS SECTION LOCATIONS

Project No	5003	Date	Drawn	Checked
DWG No	22	19/06/95	DDR's	

SWMC
SURFACE WATER MODELLING CENTRE

SCALE: 5 0 5 10 15 Km

4 FLORA

The Bangladesh mangrove vegetation of the SRF differs greatly from other non-deltaic coastal mangrove forest and upland forest associations. Unlike the former, the Rhizopheraceae are of minor importance. Differences in vegetation have been explained in terms of freshwater and low salinity influences in the North-East and variations in drainage and siltation.

The Sundarbans has been classified as a moist tropical forest demonstrating a whole mosaic of seres, comprising primary colonisation on new accretions to more mature beach forest, often conspicuously dominated by Keora ***Sonneratia apetala*** and tidal forests. Historically three principal vegetation types have been recognised in broad correlation with varying degrees of water salinity, freshwater flushing and physiography and which are represented in the wildlife sanctuaries:

(1) Sundarbans east, where freshwater and Sundri dominate interspersed with Gewa and Passur ***Xylocarpus mekongensis*** with Kankra ***Bruguiera gymnorrhiza*** occurring in areas subject to more frequent flooding. Here there is an understorey of Shingra ***Cynometra ramiflora*** where soils are drier and Amur ***Amoora cucullata*** in wetter areas and Goran ***Ceriops decandra*** in more saline places. Nypa palm is widespread along drainage lines.

(2) Sundarbans south, where there is evidently the greatest seasonal variation in salinity levels (see Text Maps 3 and 11) and possibly represents an area of relatively longer duration of moderate salinity where Gewa is the dominant woody species. It is often mixed with Sundri, which it is able to displace in circumstances such as artificially opened canopies where Sundri does not regenerate as effectively. It is also frequently associated with a dense understorey of Goran and sometimes Passur.

(3) Sundarbans west, in areas which support sparse Gewa and dense stands of Goran and discontinuous patches of Hantal palm ***Phoenix paludosa*** on drier ground and river banks and levees.

Sundri and Gewa occur prominently throughout the area with discontinuous distribution of Dhundal ***Xylocarpus granatum*** and Kankra. Among grasses and palms ***Portresia coarctata, Myriostachya wightiana, Imperata cylindrica, Phragmites karka***, and ***Nypa fruticans*** are well distributed. Keora is an indicator species for newly accreted mudbanks and is an important species for wildlife, especially Spotted deer ***Axis axis***.

A total 245 genera and 334 plant species were recorded by Prain (1903). Chaffey and Sandom (1985) provide a list of trees and shrubs listed in Appendix A18.

From the point of view of production forestry, Sundri is by far the most important species followed by Gewa and Goran, with Nypa palm being the most valuable of the plant based non-wood resource. The distribution and relative statuses of these species is therefore of paramount concern in determining management practices, silvicultural activities and biodiversity management. The flora of the mangrove forest however has a far-reaching appeal to many other sections of society including research scientists, students, pharmacologists and ecotourists.

Apart from a worldwide interest in botany, especially flowering plants, orchids, grasses and trees the current pervasive fashion for herbal medicines and chemical-free drugs has generated two lines of interest in plants which could be of great value to the SRF:

- Herbal tours - very popular in many parts of the world, even in countries like Kenya and Tanzania where there are powerful alternative attractions of 'big game and beaches.
- The pharmaceutical industry which is searching the world for 'natural products' which could have commercial application. Supply of samples either as extractions or wet material is already being widely practised and where there is a 'hit' substantial revenues can accrue to the source country.

4.1 Mangrove vegetation in south-western Bangladesh

Mangrove vegetation at one time was distributed along much of the coastal belt of south-western Bangladesh but is now confined to the SRF and offshore chars and islands stretching as far east as the relic forest of Chakaria, near Cox's Bazar. Whilst most of the mangroves in other parts of the world are characterised by members of the **Rhizopheraceae, Avicenniaceae** or **Laganculariaceae**, the mangroves of Bangladesh are dominated by the **Sterculiaceae** and **Euphorbiaceae** (IUCN, 1994). Sundri is the dominant species and occurs in suitable localities along the coast of the Bay of Bengal to the Irawaddy delta in Myanmar.

The natural mangroves are halophytic two-storied woodland seldom exceeding 10 m in height with the notable exceptions of Sundri, Keora and Baen. Salinity and water tolerance and specific thresholds govern the distribution of species and at the population and individual levels these factors also influence densities, species associations, ecological separation, succession and growth.

Generally it is considered that forests in the northern and eastern parts of the SRF are better supplied with freshwater and are floristically richer than those in the south and west. Indicators are the quality of Sundri and Nypa which become progressively less frequent and morphologically smaller in the south and west (IUCN, 1994).

4.2 Ecological succession

A detailed understanding of plant succession under varying habitat conditions is essential for ecosystem management, wildlife management and for production forestry. Mangroves, unlike upland forests present the ecologist with a paradox since on the one hand the environment is in a constant state of dynamic adjustment under the influence of tides, flood water and sedimentation and on the other there is a remarkable stability in the mangrove vegetation which is exceptionally well adapted to these unique conditions.

Succession or steady state, like water salinity, only characterise the circumstances which prevail in a particular place within the ecosystem at a particular time (Lugo, 1988). They are not, and should not be deemed as incontrovertible labels. The entire system is undergoing change which is reflected in soil formation, local topography, states of succession of plant associations and species compositions and ultimately the nature of the mangrove forest itself. Change is brought about by reduction in freshwater inflow, increasing sedimentation and the effect of human activities, especially commercial removal of trees and, within the short-term, the effect of probable sea level rise.

Until the advent of systematic sampling and sophisticated computerised hydrological modelling it was difficult, if not impossible, to acquire sufficient spatial and temporal data to be able to define the complexity of the system. Attempts at ecosystem analysis tended to follow perceptions derived from limited vegetation sampling plots and transects with broad extrapolations. These inevitably led to concepts of static salinity zones and schematised vegetation profiles (Grepin, 1995).

There is growing evidence from analyses of satellite imagery and hydraulic modelling data that plant communities are spread throughout the SRF across the soil catena in recurring soil and plant associations modified locally by topography (on which only the recent digital elevation model - DEM has been available), drainage and temporal changes in salinity. A likely future position will be a proper recognition at the 1:50 000 level of resolution or less of mangrove facets or repeated sets of biotic and abiotic components which may be sub-divided for specific management purposes. Introduction of the ODA (1985) data, prepared for production forestry and not ecosystem management purposes, in the GIS data base (see Appendix 28) will greatly assist future ecological analyses beyond the needs of the conventional forest inventory (Leech, 1995). **Zonation in this context will be artificial demarcation to facilitate management controls.**

There is monotonous repetition in the literature of the existence of three static salinity zones with accompanying successional states in the SRFis commented upon by Grepin (1995) who underlines the view expressed in relation to mangroves by Lugo (1980) that zonation and succession are not synonomous and warned about the confusion that exists between these ideas. He states that there is an over-abundance of species zonation descriptions which overlook the cyclic nature of mangrove ecosystems.

In certain parts of the SRF, the northern border areas from east to west in Compartments 27, 28, 32, 35, and 47 especially, succession should be studied by plant ecologists to determine the seral state of the vegetation in relation to changing environmental factors. It is in these areas that the mangroves may be on the threshold of change to upland conditions as a consequence of major environmental changes outside the SRF affecting conditions inside, such as increasing sedimentation and reduced tidal flushing (Grepin, 1995). For example very high salinity levels were found in 1995 in the north-east where, according to past static salinity zoning definitions, salinity is supposed to be constantly very low.

The pattern of vegetational succession in the SRF depends upon the duration of salinity gradients, duration of freshwater flushing, soil type and occurrence of erosion, sedimentation and accretion. The sequence repeated most frequently throughout the ecosystem appears to be ***Sonneratia*** ➔ ***Avicennia*** ➔ ***Nypa*** with ***Excoecaria*** and ***Heritiera*** following as land builds up from exposed sediments and stabilises. The floristic composition of different successions depends upon species tolerance and the physical conditions of each specific site .

4.3 The SRF plant communities

In the past attempts have been made to ascribe one or two species dominants to represent community types and efforts were made to link these to variations in salinity and ground elevation and to define some successional types but with little true quantitative indication of relative frequency (IUCN, 1994). Since there were no composite data on water depth, salinity concentration, duration and distribution, point data only, and no comprehensive elevation data were available, descriptions of the plant communities must be taken as generalisations only. **The vegetation associations and their quantitative spatial distribution in the SRF will only emerge with improved hydrological data and elevation mapping at levels of resolution compatible with needs of ecological site facet analysis.**

Forest types for production forestry however are a different matter since the concern here is to assess individual commercial species dominance in terms relevant to timber production, stems per unit area, volume, height, incremental growth.. Accordingly site class and absolute distribution of commercial species rather than plant associations are key criteria. Tcomparative botanical studies have yet to be done and requisite ecological data, will be acquired by continuing the studies already initiated for this plan.

4.4 Forest types - definition and areas

For timber production purposes, ODA in their inventory in 1985, mapped 14 major Forest Types on the basis of major woody species dominance and identified over 300 sub-types at scale 1 : 50 000. Recent evidence (Grepin, 1995; Huda, 1995 per. comm.) suggest that these in general remain valid and gross changes will only be determined during the FRMP systematic survey anticipated for 1996-1997. The ODA data are now available in the GIS data base and the Forest Types, which, it is emphasised, do not represent the plant community successional statuses, are listed below in Table 15.

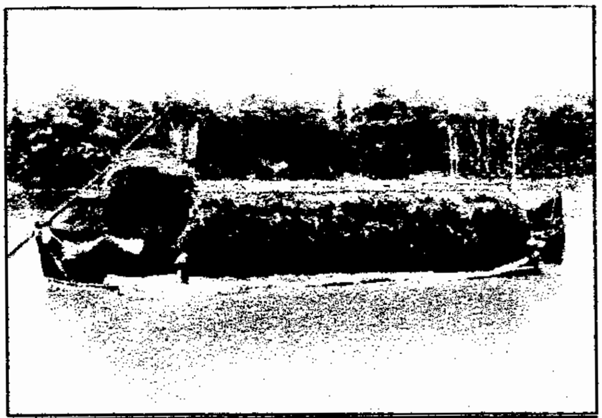
4.5 Exotic plants

There are several species of exotic plants which are distributed throughout the SRF and these should be properly identified and removed from the wildlife sanctuaries since these sanctuaries are intended to be places where the natural vegetation (see Section 8.2.2) of the Sundarnans will be protected for *in situ* biodiversity and genetic conservation.

Table 15 Forest Types : SRF derived from ODA (1985)

(Khan, 1995 GIS data base)

[illegible]	[illegible]	[illegible]	Height [illegible] (m)					Canopy [illegible]			
			≥15m	<15 > 10m	<10 > 5m	<5m	no class	≥ 70%	<70>30%	<30>10%	no density
Baen	27	8.2740						1.3128	5.7419	1.2192	
Gewa	639	185.8622		8.9111	174.7959		2.1552	132.3842	30.6341	20.4656	2.3783
Gewa - Goran	596	376.2483		4.5784	371.4611	0.2088		127.2525	234.1221	14.8736	
Gewa - Mathal	15	8.3546			8.3546				8.3546		
Gewa - Sundri	1042	600.1533	0.1179	86.5844	513.2812		0.1669	421.5060	153.8326	24.6449	0.1699
Goran	277	87.0563			0.3481		86.7083	55.0364	26.9562	5.0637	
Goran- Gewa	657	576.1361		9.1005	564.1295	2.7213	0.1848	194.9746	370.4148	10.7466	
Grass and bare ground	240	45.2841					45.2841	0.3033			44.9808
Keora	183	35.0930					35.0930	15.0372	20.0558		
Passur - Kankra	15	9.3985							7.0749	2.3236	
Passur - Kankra - Baen	15	16.1424						9.9319	3.8687	2.3418	
Sundri	1013	828.4688	622.1382	199.8287	5.9916		0.5103	658.6882	154.3600	14.9103	0.5103
Sundri - Gewa	1209	1232.149	92.9667	988.0191	151.1242		0.0398	1014.693	197.6245	19.7916	0.0398
Sundri - Passur	58	22.1391	6.2635	13.4227	2.4529			5.1035	16.6578	0.3778	
Sundri - Passur - Kankra	43	67.9883	48.4102	19.3420	0.2361			33.7673	31.6072	2.6139	
Tree plantation	19	3.5097					3.5097				3.5097
TOTAL		4102.26									



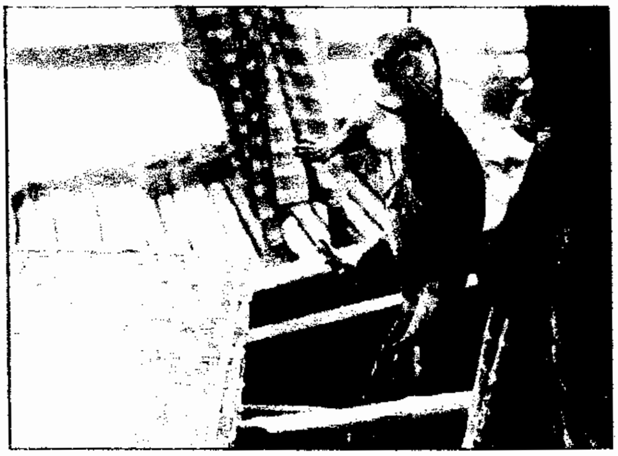
Golpatta Boat

Golpatta - Nypa fruticans

Green Jute – Buffer Zone

Estuarine Crocodile

Tiger Skull



Otter Fishing

5 FAUNA

Although it is clear that the faunal resource of Bangladesh have diminished sharply in recent times (Ahmad, 1981; Hussain, 1979; Khan, 1985; Phillipson, 1985; Seidensticker, 1980; Blower 1985; Tamang, 1993; IUCN, 1994) and the SRF has not been spared from this decline, the mangrove forest retains several good wildlife habitats and their associated fauna. The total mangrove ecosystem, including the Indian portion, has enough space for wildlife to thrive. Under existing management systems there is also abundant scope for wildlife management and even re-establishment of some lost faunal species in due course.

The proposed system of buffer zones, core conservation areas and intensively managed production zones (see Map1?) should help stabilise the decline and over a period of a few years, assuming that new controls function efficiently, there could be a marked improvement in the statuses of all species populations. Habitats exist but at present wildlife management is virtually non-existent and this plan includes guidelines for future action.

The spectrum of species and the importance of the SRF is summarised in Tables 16-17 below.

Table 16 Some Fauna of the Sundarbans in Comparison with Bangladesh as a whole

(de Vere Moss, 1993)

Group	Total Families in Bangladesh	Total Families in Sundarbans	Percentage %*	Total Species in Bangladesh	Total Species in Sundarbans	Percentage %*
Mammals	35	14	40	119	42	35
Birds	64	39	61	660	315	48
Reptiles	20	16	80	124	59	48
Amphibians	04	04	100	19	08	42
Fish	133 (110)	39?	35	474 (260)**	120 (65)***	25*

Khan (1985)
Tamang (1993)
Harvey (1989)
** Rahman (1989),Hussain (1971)
*** Total number of species (65) recorded to date 30/11/93 in BGD/84/056. No definitive list for entire country. Freshwater zone only in brackets (Rahman 1989), marine and estuarine fish, Hussain (1971)

* Percentage recorded for the Sundarbans expressed as a percentage of Bangladesh as a whole.

Faunal species of special significance to conservation are listed selectively in Table17: research, conservation action and ecotourism values are treated subjectively, based on the criteria of obvious immediate biodiversity concern (endangered or vulnerable) or otherwise, and well-known popularity amongst laymen and specialists for either casual interest or research.

Table 17 Selected Animals of the Sundarbans and their Significance to Conservation

(de Vere Moss, 1993)

[illegible]	[illegible] Name	Status	High [illegible] Research	Conservation Action	Ecotourism [illegible]
Greater False Vampire Bat	***Megaderma lyra***	?	No	Not needed at the moment	Medium
Flying Fox	***Pteropus giganteus***	?	No	Not needed at the moment	High
Rhesus Macaque	***Macaca mulatta***	Common	No	Yes. Research	High
Gangetic Dolphin	***Platanista gangetica***	Common	No	" "	High
Common Dolphin	***Delphinus delphin***	?	No	" "	High
Irrawaddy Dolphin	***Orcaella brevirostris***	?	No	" "	High
Plumbeous Dolphin	***Sotalia plumbea***	?	No	" "	High
Little Porpoise	***Noephocaena phocaenoides***	?	No	" "	High
Smooth Otter	***Lutra perspicillata***	Uncommon	Yes	" "	High
Clawless Otter	***Aonyx cinerea***	Rare	Yes	Not imm. but research IDC	High
Bengal Fox	***Vulpes bengalensis***	?	No	Not imm. but research IDC	Low
Jackal	***Canis aureus***	?	No	Not imm. but research IDC	Low
Tiger	***Panthera tigris***	Common	Yes	Yes. Urgent research needed on autecology for tourism etc	Very High
Fishing Cat	***Felis viverrina***	Uncommon	Yes	No. Research IDC.	High
Leopard cat	***Felis bengalensis***	?	No	No. Research IDC	Medium
Jungle cat	***Felis chaus***	?	No	Yes. Research	Medium
Wild Boar	***Sus scrofa***	Common	Yes	Yes. Research	High
Barking Deer	***Muntiacus muntjac***	Locally Common	Yes	Yes. Research	High

Common Name	Scientific Name	Status	High priority Research	Conservation Action	Ecotourism Value
Spotted Deer	***Axis axis***	Common	Yes	Yes research in depth	Very High
Swamp Deer	***Cervus duvaucali***	Extirpated	Yes	Re-introduce	Potentially High
Hog Deer	***Axis porcinus***	Recently Extirpated?	Yes	Re-introduce	" "
Wild Buffalo	***Bubalus bubalis***	Extirpated 1908	Yes	Re-introduce	Potentially Very High
Javan Rhinoceros	***Rhinoceros sondaicus***	Extirpated	Yes	Research	" "
One-horned Rhinoceros	***Rhinoceros unicornis***	Extirpated	Yes	Research	" "
Dugong	***Dugong dugong***	Very rare	No	No, but worth investigating	" "
Marsh Crocodile	***Crocodylus palustris palustris***	Extirpated?	Yes	Yes. Research status urgently	Low
Estuarine Crocodile	***C. porosus***	Uncommon	Yes	Yes. Research status urgently and farm	High
Olive Ridley Turtle	***Lepidochalys olivacea***	?	Yes	Research status thoroughly	Medium
Green Turtle	***Chelonia mydas***	?	Yes	" "	"
Loggerhead Turtle	***Caretta caretta***	?	Yes	" "	"
Hawksbill Turtle	***Eretmochelys imbricata***	?	Yes	" "	"
Leatherback Turtle	***Dermochelys coriacea***	?	Yes	" "	"
Estuarine Terrapin	***Batagus baska***	?	Yes	" "	"
Black Mud Turtle	***Trionyx nigricans***	?	Yes	" "	"
Roof Turtle	***Kachuga tecta***	?	Yes	" "	"
Rock Python	***Python molurus***	Uncommon	Yes	" "	High
Monitor Lizard	***Varanus salvator***	Common	Yes	" "	High

From this it will be noted that the following existing species or groups of animals are particularly important:

• Bats	Strong following among wildlife specialists.
• Tiger	Main national animal therefore of inestimable value; man killing behaviour requires urgent study;
• Fishing cat	Small but common secondary carnivore
• Spotted deer	Continental deer but unusual habitat in mangroves therefore of more than usual value; harvesting may be possible;
• Wild boar	Common and with much commercial potential;
• Barking deer	Rarely seen but well represented therefore good for wildlife specialists;
• Crocodiles	Infrequently seen but important in food chain and ecological stability; farming may be possible;
• Otters	Of great value for biodiversity management and as a unique selling point (USP) tourist attraction with traditional fishermen; deserve special conservation attention in future;
• Turtles	Strong interest among wildlife conservation specialists and deserve special attention in future; wildlife research especially to protect breeding areas and to secure threatened species is now essential for urgent action;
• Python	Infrequently seen but must be well represented. No longer occurs in Indian Sunderbans. Deserves special effort in future conservation and protection measures.
• Dolphin	Indiscriminately harvested. should be researched and actively protected.

Of these the tiger and dolphin are target species for planning wildlife management tourism development. They are high profile and vulnerable mammals living in two contrasting environments and their statuses and management are strong indicators of the general condition of wildlife and its management - see Tamang (1993).

The Sundarbans tiger population is probably the largest single gene pool of the species in the world and it is of supreme value not only to science but as a tourist attraction. It has an all-pervading importance in local affairs, ranging from unabated man-eating behaviour to mysticism. This, combined with its status in international conservation circles , seems to justify early research and management action. Killing of human beings by tigers and uncontrolled killing of tigers by human beings demand early attention and investment in research and conservation programmes.

5.1 Mammals

At least 32 species of mammals are ecorded in the SRF and a further 10 species occur in the total ecosystem (Tamang, 1993 and Appendix A21). A few species, notably spotted deer and wild boar are common and readily seen whereas others are retiring, less conspicuously distributed and are difficult to observe and this applies particularly to tiger which are represented in every compartment but only rarely seen.

Population estimates for the large mammals are either lacking or based upon field studies which will require much further verification and should be taken as indicative estimates only. The systematic surveys proposed in the forthcoming inventory programme could do much to substantiate these figures. Numbers in themselves are of little value in management planning, what is much more important is the spatial distribution of species and their densities in relation to habitat and population dynamics.

"Rough estimates" were made by Tamang (1993) agreeing broadly with Heindrichs (1975) as follows:

	1993		1975
Tiger	362	(Sex ratio 1 male : 2-4 females)	350
Spotted deer	80 000	(Mean herd size 5.4)	80 000
Muntjac	?		?
Wild boar	20 000		20 000
Rhesus macaque	40 000		40 000
Otter	20 000		20 000

Future management will require implementation of the administrative arrangements and fieldwork envisaged in the conservation and wildlife division programme set out in the FRMP and elaborated in the wildlife management section 23.4.2 of this plan.

5.2 Birds

The SRF and surrounding area has a rich avifauna and the most recent list of species by IUCN (1994) indicates that at least 315 species representing 48% of the birds which are known to occur in Bangladesh, have been recorded there. Of these some 84 species are migratory making the SRF a valuable location for passage migrants and seasonal visitors. The inshore island of Tinkonia and offshore islands of Putney, Nilbaria, Kachikali, and Dubla are valuable habitats for waders and resting points for migrating flocks.

The avifauna is of particular interest since birdwatching and more serious ornithology have a large following as environmentally friendly forms of recreation. The SRF is one of the few parts of Bangladesh where natural habitats remain free from forest clearance and agriculture and thus suited to a variety of bird species. Notable among these are birds of prey, of which there are at least 35 species, some rarities such as Grey-headed Fish-Eagle ***Ichthyophaga ichthyaetus***, Pallas's Fishing-Eagle ***Haliaeetus leucorpyhus***, Masked Finfoot ***Heliopais personata*** and migratory waders, gulls and terns. Among endangered species the SRF list includes Spot-billed Pelican ***Pelecanus phillippensis***, and the Greater and Lesser Adjutant Storks ***Leptoptilos dubius*** and ***L. javanicus*** (IUCN 1989; Harvey, 1990).

Visually attractive species such as Red Jungle Fowl ***Gallus gallus***, eight species of Kingfisher, Green Pigeon and Parakeets are common.

The location of the SRF, available habitat for overwintering and migratory species and opportunities for ornithological research, with the prospect of adding new species to the national list (28 new species were added between 1987 and 1990), could make the SRF a desirable venue for birdwatchers.

5.3 Reptiles

At least 35 species of reptiles have been recorded in the Sundarbans. The marsh crocodile ***Crocodylus palustris***, once abundant, is now probably extirpated in the SRF. The saltwater crocodile ***Crocodylus porosus*** still survives in low densities and like the demise of the marsh crocodile its numbers are being reduced through indiscriminate hunting and trapping for skins, quite apart from the immediate conflict with man. This species is only sighted rarely and there is little doubt that its survival is seriously threatened. Although poaching is said to be minimal this is hardly surprising since the population is so diminished that despite an apparent reduction in illegal trade in its skins the population shows little sign of recovery and may even be decreasing (Tamang, 1993; Whitaker, 1982).

Three species of monitor lizards, **Varanidae**, occur in the Sundarbans. These species are also killed for their skins and sometimes for food. Detailed information on densities and the level of the current off-take is not known.

Altogether eighteen species of snakes have been recorded including the king cobra, spectacled cobra, three vipers and six sea-snakes. There appears to have been a general decline in densities or at least in sightings especially over the last 15 years (IUCN, 1994). The Rock Python ***Python molurus*** is listed as vulnerable by IUCN and is another valuable species which is rarely encountered.

Five species of marine turtles: the olive ridley, green, loggerhead, hawksbill and leatherback have been recorded in the Sundarbans and of these green turtles are considered to be the most numerous (Tamang, 1993). Their status is not well established since IUCN (1994) states the reverse, that "green turtles are rare due to excessive fishing" in the estuarine waters and around islands. Turtle eggs are collected and eaten by fishermen and some are marketed and even exported to the Far East but the extent of harvesting is not known. Turtles and turtle eggs are known to be sold in local the markets near the Sundarbans but all marine turtles are protected by law. They are reported to nest on mainland shores and on sandy islands offshore.

The common batagur or estuarine terrapin ***Batagur baska***, listed as an endangered species by IUCN, nests along Katka and Konga rivers. Local fishermen have been harvesting this species for several generations (Salter 1984). The black mud turtle ***Trionyx nigricans*** and roof turtle ***Kachuga tecta***, two fresh water turtles, also occur in the Sundarbans.

The Wildlife (Preservation) Act 1973, lists several species of reptiles as protected including the estuarine crocodile, rock python, three species of monitor lizards and the black mud turtle but statuses are not well known and the herpetofauna should be the subject of careful and systematic study in future. A species checklist is provided in Appendix A26.

5.4 Fish

An aquatic environment which includes freshwater, saline water, fast and slow flowing rivers and streams, man-made canals, areas of high and low turbidity set against a background of marked seasonality in flow rates, tides and ambient temperatures, creates a host of habitats and niches for fish and crustaceans. The inshore and offshore waters of the SRF thus supports many species and these are listed in Appendix A23.

Records so far indicate the occurrence of 8 species (from 2 Orders and 4 Families) of chondrichthyan fish, 168 species (from 14 orders and 59 families) of osteichthyan fish and 31 species (from 1 order and 9 families) of crustacean (Chantarasri, 1994; Smith, Khulna University, 1995). Re-examination of specimens already collected and further collecting can be expected to increase the numbers of species on this list. Seidensticker and Hai (1968) reported that over 120 species of fish are commonly caught in the Sundarbans and IUCN (1994) recorded 53 species of pelagic fish; 124 species of demersal fish; 24 species of shrimps; 7 species of crabs; 2 species of gastropods; 6 species of pelecypods; 8 species of locust lobster.

The formal taxonomy of the fish so far found in the SRF is shown in Appendix A23. Management is discussed further in section 11.3.2.

5.5 Amphibians

The amphibian fauna of the SRF is limited to 2 species of toads and 6 species of frogs and these species populations also appear to be depleted through over harvesting but all are protected and can no longer be exported. A list of amphibians is provided in Appendix A26. In view of high fecundity there is every likelihood that populations will recover and this important group in forest and aquatic food chains will soon regain previous levels of abundance assuming that regulation of illicit harvesting will be achieved (Tamang, 1993 pers. comm.).

The Green Frog ***Rana hexadactyla*** used to be popularly exported as a culinary delicacy and the species is now uncommon, demonstrating exactly how vulnerable even extremely abundant species of wildlife are to uncontrolled harvesting once a commercial value is identified.

The Tree Frog ***Rhacophorus maculatus*** and Common Toad ***Bufo mélanosticus*** are said to be commonly distributed but are both inconspicuous even in suitable habitat (Grepin 1994 pers.comm.)

5.6 Invertebrates - insects and molluscs

The first study of insects ever undertaken in the SRF of Bangladesh was carried out by Professor SH Chowdhury during the course of data collection for this plan in 1994-1995 and the list of insects collected is provided in Appendix A27.

It is a feature of this environment that neither malaria vector Anophelese mosquitoes nor the snail-borne Bilharzia (schistosomiasis) are present in the SRF.

This first study of the invertebrate fauna of the SRF provided a starting point for future studies and the main conclusions of this pioneer work are given below:

- No causal relationship between insects and Top Dying of Sundri was found. The possibility of insects initiating the syndrome is ruled out.
- A large number of insects mostly belonging to coleopteran families **Cerambycidae, Elateridae, Curculionidae, Bostrychidae** and **Anobiidae** were found to attack both healthy and dying or dead trees.
- A curculionid beetle, ***Calandra linearis***, was found to cause almost 100 % destruction of Dhundul seeds in a seed plot at Kalaghachia coupe office.
- Defoliators were not found possibly because the field work had to be stopped early in the summer.
- A number of butterfly species including ***Catopsilia pomona*** were recorded in the first week of April.
- Coccoid sap-suckers were recorded mostly from seedlings and saplings. Plant galls, mostly caused by insects, were also recorded.
- A large variety of entomophagous insects were collected. These act as natural biological control agents against harmful species.
- Seven species of mosquitoes, one species of biting midge ***Culicoides*** sp. and at least 4 morphotypes of gnats of the **Tabanidae** were collected. Mosquito populations were at their highest at Burigoalini, biting midges at Dhangmari and tabanids at Katka. No known vectors of malaria and dengue were found.

In addition to the Insecta other invertebrates were briefly studied:

- **Bactronophorus** thoracites **Teredinidae:** Mollusca were found to attack living Sundri, Gewa, Baen and Passur Trees lining the rivers and creeks.
- Four species of barnacles **Cirripedia** : Mollusca were also collected. These crustaceans may be used as environmental indicators.

Molluscs have been studied recently by Pendred (1995) and previously annotated check lists were produced for marine molluscs by Ahmed and Zaman (1990) and of molluscs of the inter-tidal zone by Jahan, Mannan and Mandal (1990).

A more extensive survey of insects, borer molluscs and crabs, regular monitoring of potentially dangerous insects and maintenance of biodiversity is suggested to follow on from the valuable work undertaken by Professor Chowdhury (1995).

Among invertebrates, shrimps, crabs and bees are immensely valuable as sources of non-wood produce, value added light industries and exports. These are discussed in other sections of the plan. ***Apis dorsata*** is the wild honey bee which is seasonally widespread in the SRF and future yield improvements centre on range management, improved harvesting techniques and post harvest technology.

6 LAND USE AND ACCESSIBILITY

6.1 Land use - the boundaries and the border area

Historically and under the present legal designation, the entire area is classified for management as forest land free from human habitation. This single use category is increasingly questioned and environmental change accompanied by a growing human population and the rise in values of non-wood products has not only led to exceptions to the rules but to daily questions forwarded at all levels of society on the justification for existing management systems. The question to be addressed is whether indeed the land use classification should not be revised in all or part for better production of resources to the meet the nation's macro-economic targets and the more immediate needs of disadvantaged people who reside in the neighbourhood?

The mangroves grow at the limit for conventional non-paddy agriculture and land conversion, even for rice production, ceased by the turn of the century with the last land in the north-western corner Compartment 47 Chunkuri being leased in 1938.

Since many people may pass the greater portion of their lives staying within the boundaries of the SRF, albeit without fixed abodes (their mobility creates its own problems), and with a growing number of exceptions over permanent structures together with the demonstrable difficulty faced by a single department in enforcing the Forest Act's rules of trespass and harvesting, planning proposals are made for options and revisions to systems and the law.

In broad terms the Production Zone land (see Part 2) is used now more as a Managed Resource Area (IUCN MRA - see Appendix A10) than as a Reserved Forest and if this is so then perhaps consideration ought to be given to revisions in order to better maintain prospects for sustainable management of terrestrial and aquatic resources.

There are three main issues:

- Is the SRF being used as a Reserved Forest and is the law of trespass being enforced effectively? Can the Law be enforced effectively?
- How do people access the SRF and how long do they stay there?
- What do people do in the SRF?

It appears that many resource users enter the SRF legally and obtain their permits at Forest Stations but there are many who enter unofficially at night or via access points which are not policed and cannot be readily controlled with existing FD staff and equipment. These stay as long as they like and do what they like, including unofficial harvesting of all resources. They live outside the law. Numbers are unknown but dacoity and unofficial removal of timber, fish and wildlife are widespread despite extensive effort by the FD.

The options are to improve policing and heighten confrontation with trespassers; work with local communities for greater collective responsibility and control by consent or consider redefining the land use classification for parts of the SRF, Dubla island and Compartments 27 and 28 being examples, thereby taking a more realistic and practical pre-emptive view of the likely future position.

The most pragmatic immediate approach appears to be :

- Strengthen the SRF's status by community based education and publicity working with influential NGOs (see Bhuiyan, 1995).
- Upgrade the FD's capacity to enforce the Forest Act with joint strategies agreed and contributed to by other concerned agencies.
- Define and officially acknowledge all forms of ongoing breaches of the Forest Act practised in the SRF and attempt to establish conservation attitudes among user groups, fishermen, Mowallis and Bowallis in particular, through just policing and fairer distribution of benefits (see Part 2 Section 26).
- Devise ways to retain the integrity of the reserved forest but at the same time accommodate new user groups and arrange for realistic spatial and legal adjustments compatible with sustainable management (eg MRA for compartments 27 and 28).

These matters are considered in Part 2 of the plan.

6.2 Access - portals of entry

The central issue in understanding the difficulties faced by the FD in managing the area as a Reserved Forest is the almost insuperable problem of protecting its borders which include a long marine boundary of 158 kilometres with two international aspects:

- Rivers along which small and large commercial traffic is permitted to travel through the SRF under the jurisdiction of other authorities.
- A land boundary along which at least two million people live in very high densities.

There are officially recognised, but ungazetted, points of entry to the SRF but these are of limited value since unofficial access is known to occur at almost every point of the border. Nevertheless the official portals of entry do provide a basis for structural development of the traffic management system and these should continue to be managed and improved for control of entry and exit to the Forest under the jurisdiction of the FD.

Official portals of entry and revenue stations:

From the list in Table 18 and Map 12 it can be seen that the main gap lies to the south-west where entry is in no way regulated and along boundaries which follow the centre line of rivers.

Table 18 Official Portals of Entry to SRF 08/95

[illegible]	[illegible]	[illegible]	[illegible]
Dhangmari	22-260N, 89-350E	FD	-
Bogi	22-120N, 89-500E	FD	-
Supoti	22-020N, 89-490E	FD	-
Katka	21-510N, 89-460E	-	FD Tourism
Dubla	21-460N, 89-360E	FD	-
Nilkamal	21-500N, 89-260E	FD	-
Koikali	22-120N, 89-040E	-	-
Munshiganj	22-160N, 89-110E		FD Tourism
Nalinala	22-270N, 89-260E	FD	-
Kobadak	22-130N, 89-340E	FD	-
Karamjal	22-250N, 89-360E	-	-

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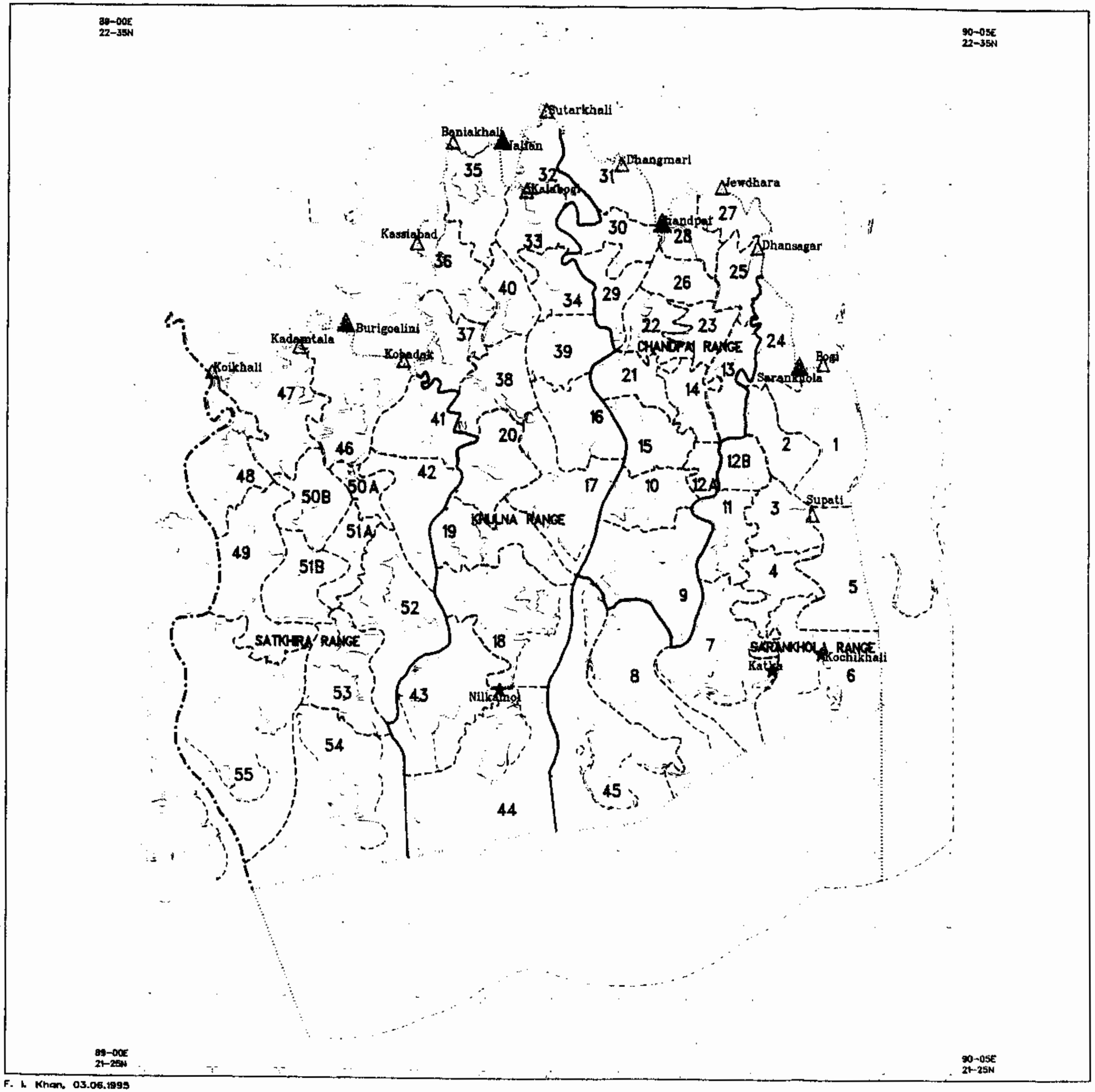
INTEGRATED RESOURCE DEVELOPMENT OF THE
SUNDARBANS RESERVED FOREST

BASE MAP

Scale 1 : 350 000

Km 4 2 0 2 4 6 8 10 Km



F. L. Khan, 03.06.1995

LEGEND

- Land/Water Boundary
- River (width less than 100 m)
- Sand Bar
- International Boundary
- Reserved Forest Boundary (after Curtis, 1928)
- 10 Km Border Line
- Marine Line (12 nautical miles)
- East and West Boundary of Marine Zone
- Range Boundary
- Compartment Boundary
- 45 Compartment No
- ▲ Range Office
- △ Forest Station
- ★ Wildlife Sanctuary Office

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6.3 Navigable and other waterways

A management issue which is fast gaining in significance is the maintenance of up to date records of navigable waterways since increasing siltation and non-existence of any monitoring system leaves such information in the realm of local knowledge and guesswork. Lack of navigable waterway data imposes severe constraints on mobility within the SRF for modern craft and thus limits the options for up-grading FD equipment.

The advent of hydraulic modelling with sophisticated measuring instruments has opened up possibilities for developing a monitoring system.

Map 8 Volume 3 provides information on waterways.

6.4 Protected areas - the Wildlife Sanctuaries

In the face of excessive land pressure and threats to natural environments, it has long been agreed that measures should be taken to protect natural areas from encroachment and destruction.

For the SRF preliminary measures were taken in 1875 when it was first gazetted as a Forest Reserve. By that time the forest area itself had been reduced by about 50%. As part of conservation planning, three sanctuaries were established in 1977 under the Bangladesh Wildlife (Preservation) (Amendment) Act, 1973 setting aside 323.86 km^2, primarily for wildlife conservation. These were sited in areas deemed to have wildlife management potential and as representative portions of natural areas in the three different biotopes which would be free from extraction forestry, other forms of harvesting or capture and killing of wildlife. See text Map 11.

Assuming that the ecological functions described earlier are correct and that the concept of wilderness is a prime asset then these sanctuaries have, and will continue to have, a vital role to play in biodiversity preservation and in sustainable tourism.

Proposals for extension of the sanctuaries and establishment of a national park with appropriate buffer zones in peripheral areas have been made by the FD in the past (Blower, 1985 and Khan, 1986) and further recommendations were made by Tamang (1993) and Grepin (1994) to develop extensions to all three sanctuaries.

Areas of existing Wildlife Sanctuaries and proposals as illustrated in Map ... are as follows ::

1.	Sundarbans West	77 .92 Km^2
2.	Sundarbans South	174.44 Km^2
3.	Sundarbans East	59.98 Km^2

Total area from GIS data 1995: 312.34 Km^2

Various proposals for additions are also illustrated in text Map 11.

1.	by the Forest Department including above areas	479.66 Km^2
2.	by Dr Grepin, Ecologist	360.04 Km^2
3.	by Dr Tamang, Wildlife Specialist	559.79 Km^2

Management of the Wildlife Sanctuaries is discussed in Part 2 Section 20.

A wildlife sanctuary is defined as "an area closed to hunting, shooting or trapping of wild animals and declared as such under Article 23 of the Wildlife Act by the Government as undisturbed breeding ground primarily for the protection of wild life inclusive of all natural resources, such as vegetation, soil and water". Cutting of vegetation, lighting of fires and trespass are commonplace but without conservation staff these are difficult, if not impossible to monitor.

Wild animal is defined as " ...any vertebrate creature, other than human beings and animals of usually domesticated species or fish, and includes the eggs of birds and reptiles". Wild life itself is not defined.

Whilst the Department may in theory issue hunting licenses, in practice none is issued and the whole area is thus officially closed to consumptive utilisation of non-aquatic wildlife. Significantly also fish, shrimps, molluscs and other invertebrates are not in the official definition of 'wildlife' and are subjected to intensive harvesting.

Within the sanctuaries all logging is prohibited and only fishing and the collection of non-wood produce is permitted.

As a Reserved Forest the present management and conservation system places the SRF in the IUCN category of a 'protected area' (PA) or 'Managed Resource Area' and is managed by the Forest Department as such. The sanctuaries add an extra dimension and for tourism their existence helps secure the future.

If the status of Sundarbans West were to be changed to National Park, in accordance with the IUCN definition , this would have the dual effect of standardising its protected area designation and legitimising activities which would benefit tourism without diminishing the level of environmental and wildlife protection. Furthermore recent (1994) revision of IUCN criteria for national parks makes provision for up to 25% of the area being zoned, where appropriate, for sustainable harvesting of resources by traditional subsistence users.

The IUCN (1992) definition (see Appendix A10) for national park is of particular relevance to tourism:

"... to protect natural and scenic areas of national or international significance for scientific, educational and recreational use".

However, the reasons for segregating protected areas from other forms of land use, forestry in the case of the SRF, require definition. The ascription of special status to protected areas nas increasingly to be related to short-term horizons of local communities and also to the GDP growth targets of the Government. They should not be created as merely negative structures designed only to constrain resource use. In the long run this policy is sure to fail but ecotourism on the other hand, could justify their existence.

For the Sundarbans sanctuaries there should be a re-definition of purpose along with management planning and full integration into the conservation and economic objectives of GOB in which the tourist industry has an increasingly important part to play. Re-instatement of Conservator Wildlife should assist this endeavour and will be an asset to many aspects of conservation, biodiversity management and ecotourism.

FAO/UNDP PROJECT BGD/84/056, KHULNA, BANGLADESH

INTEGRATED RESOURCE DEVELOPMENT OF THE SUNDARBANS RESERVED FOREST

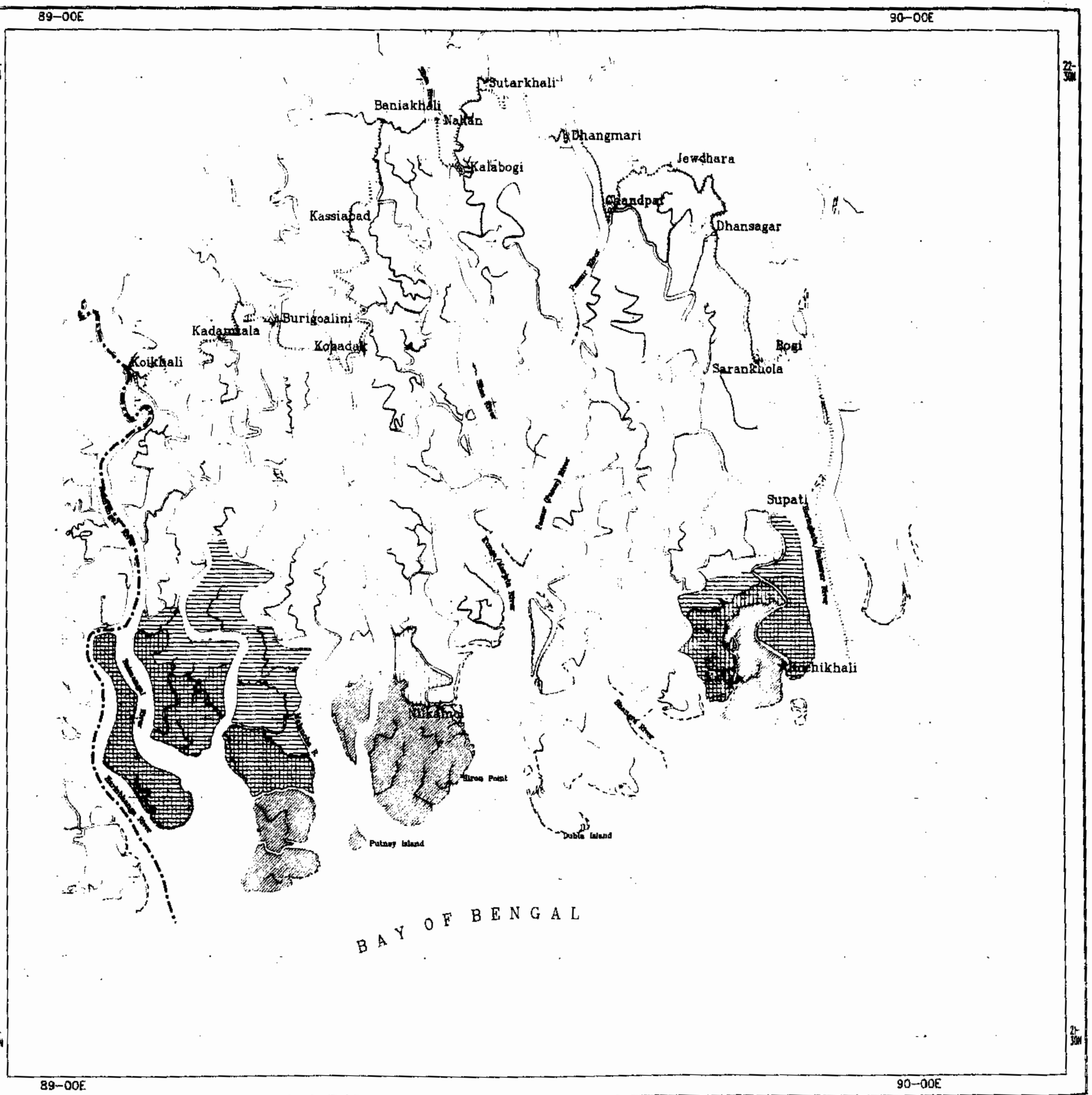
MAP SHOWING THE WILDLIFE SANCTUARY

Scale 1 : 500 000

Km 4 2 0 2 4 6 8 10 Km

LEGEND

- Land/Water Boundary
- Sand Bar
- International Boundary
- Reserved Forest Boundary (after Curtis, 1928)
- Existing Wildlife Sanctuary Area
- Proposed WS Area by Forest Dept.
- Proposed WS Area by Dr. Grepin
- Proposed WS Area by Dr. Tamang
- Range Office
- Forest Station
- Wildlife Sanctuary Office



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F.I. Khan, 26.06.1995

The Cost of Conservation:

If the Sundarbans are of international value and are, to a large extent, managed as a PA, particularly in relation to tiger protection, then international cost standards should be applied. These would provide the Forest Department with a clear benchmark for conservation budgeting.

Leader-Williams (1990) in calculating the amount of recurrent expenditure needed to protect areas where rhinoceros ***Diceros bicornis*** or elephant ***Loxodonta africana*** were threatened, considered that annual expenditure of 400 US$ per square kilometre would be required. Since the tiger is a similarly threatened species, a budgetary estimate for the cost of protection in the SRF would be US$ 2 308 000 or Taka 92 320 000.

At present the Forest Department's recurrent expenditure to manage the entire Sundarbans for all purposes is Tk 34 million or 37% of this internationally recognised standard for species protection alone. Any mechanism for transferring some of the additional revenue, which may accrue through tourism, to the Forest Department's revenue expenditure account to relieve the imbalance and to strengthen the Department in its endeavours, is currently impossible but should be recommended.

Furthermore, if some of this revenue could be applied directly to the welfare of local communities this would start the much-needed process of humanising conservation and would demonstrate tangible benefits derivable from forest management and species protection.

7 INFRASTRUCTURE

7.1 Description and deployment - Forest Department assets

The assets of the Forest Department used in carrying out forest management have barely altered since the time the Forest Department took over the SRF a century ago. Deployment of staff, housing and offices, boats, vehicles and other equipment and the logistical control and back-up for their administration, utilisation, management, maintenance and replacement, are under the authority of the Chief Conservator of Forests, delegated to the Conservator, Khulna Circle.

Most of the infrastructural assets are old, in need of repair or replacement and operated with systems which may have stood the test of time but are often inappropriate or unmanageable for present-day needs.

These assets fall into the following categories:

- Permanent structures, both inside and outside the SRF.
- Semi-permanent buildings in regular use.
- Temporary or mobile offices.

This matter is discussed in more detail in Part 2 in relation to current deployment, future needs and investment.

7.1.1 Permanent structures within the reserved forest

There are 235 units operated and maintained and these are listed in Table 19. The deployment of Forest Department offices and Forest Stations is illustrated in Text map 12.

The Forest Department has total legal responsibility for rights of passage, land tenure and law enforcement with powers of arrest for some criminal offences. Under the Forest Act the Department does not permit any form of permanent human settlement, exceptions being:

- The Forest Department's own administrative buildings, Range Offices, Forest Stations, Patrol Camps and Coupes.
- The Port Harbour Authority Rest House at Nilkamal for which an annual lease for a 3 acre surveyed plot is provided.
- The Bangladesh Navy Camp at Nilkamal, which was previously a well-established and attractive Forest Station.
- Khulna Newsprint Mill Ltd has permission for a semi-permanent timber extraction base camp located in 1993 in Compartment 15 which houses at least 100 staff. These camps have a life of four or five years.
- Various canals and other man-made modifications to the drainage system.
- Cyclone shelters and a hospital on Dubla island.

7.1.2 Semi-permanent structures

It has always been policy to restrict construction inside the Forest to semi-permanent structures since permanent development is contrary to the Forest Act and also because it was deemed that operational locations might change and thus permanent development could not be justified.

Inevitably semi-permanent structures had to be built to withstand extremes of climate and to provide a modicum of security and in this way semi-permanent has led to the construction of many robust buildings within the SRF which in most respects fulfil requirements of more permanent buildings.

These are also listed in Table 19.

FAO/UNDP PROJECT BGD/84/056, KHULNA, BANGLADESH

INTEGRATED RESOURCE DEVELOPMENT OF THE SUNDARBANS RESERVED FOREST

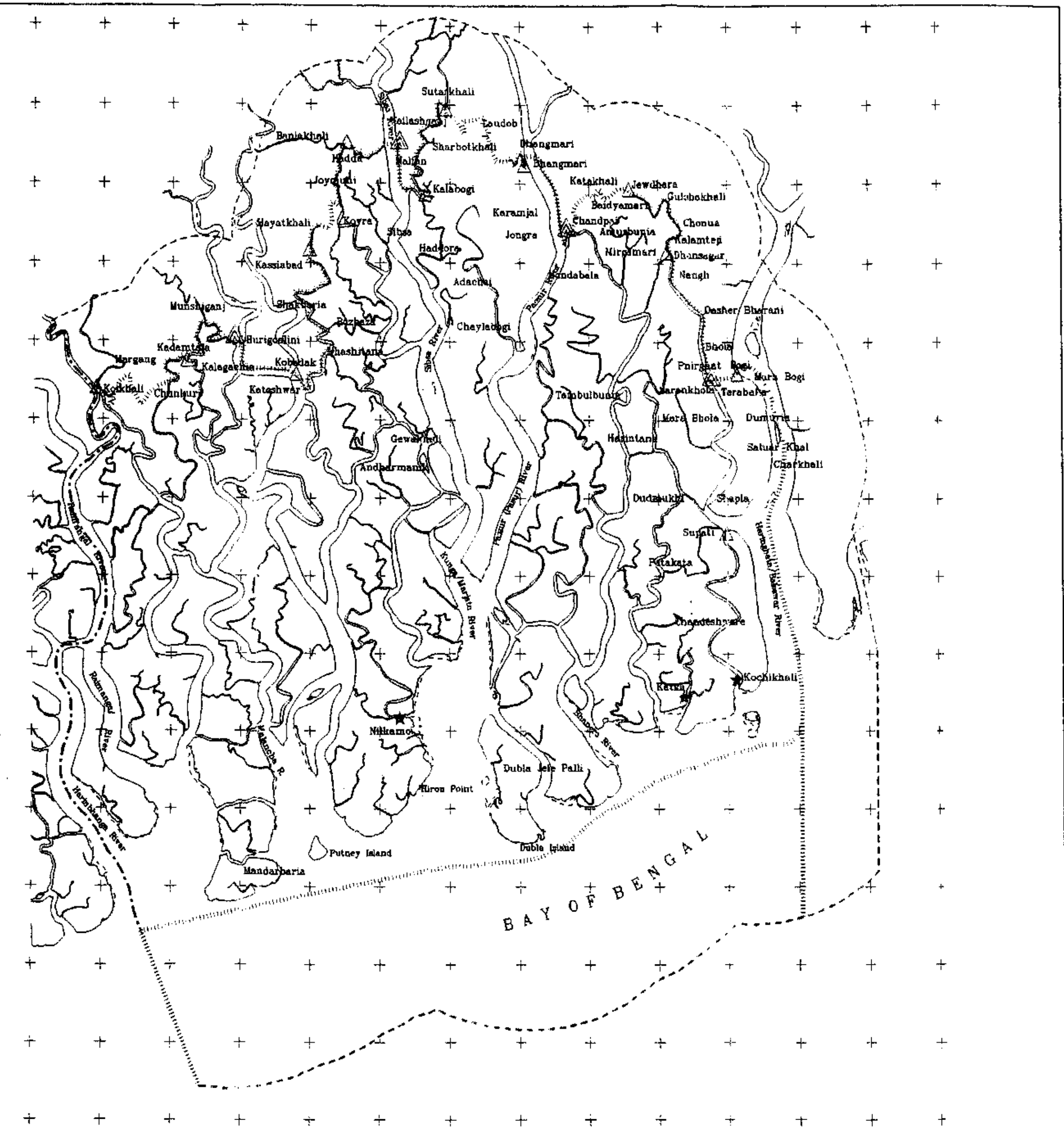
MAP SHOWING THE FOREST DEPARTMENT OFFICES IN THE SUNDARBANS

Scale 1 : 550 000

Km 4 2 0 2 4 6 8 10 Km

LEGEND

- Land/Water Boundary
- Sand Bar
- International Boundary
- Reserved Forest Boundary (after Curtis, 1928)
- 10 Km Border Line
- Marine Line (12 nautical miles)
- East and West Boundary of Marine Zone
- Range Office
- Forest Station
- Wildlife Sanctuary Office
- Coupe Office
- Patrol Post



CREATED BY: FAO/UNDP

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F.I. Khan, 14.09.1995

7.2 Other structures within the SRF

Since people technically are not allowed to reside inside the SRF the requirement for permanent buildings has been minimal except in the cases referred to above which concern Forest Department administration and recently community work by CARITAS on Dubla island.

Over the course of time there has been a steadily growing complexity in administrative and management requirements for the area and this has led to a growing number of exceptions being made to the single sector management policy which evidently can no longer regulate diversification of permanent infrastructural components.

Key user groups are :

- The FD
- Social services
- Law and Order
- Research and monitoring
- Shipping
- Border patrol and defence
- Meteorology
- Tourism
- Aquaculture and long-term fishermen

Deployment of structures which concern these user groups is given in Table 19:

- FD buildings semi-permanent in name only
- Nilkamal Port Harbour Authority Rest House
- Cyclone Shelters
- The hospital near Nilkamal
- KNM field stations
- Seasonal Fishing Camps

Table 19 Location of Permanent Structures within the SRF at 09/1995

STRUCTURE	LOCATION - compartment number	USER GROUP
Nilkamal Port Harbour Authority Rest House	44	MPHA, VIPs, tourists
Cyclone shelters x 4	45	General public
Hospital	45	General public
Kharma Khal	28	General public - aquaculture ?
Fishing camps with freshwater tanks - long term residences	45	General public - aquaculture ?
KNM semi-permanent Gewa harvesting camp	various in Production Zone	KNM industries
FD offices - will be upgraded to permanent status	6, 7, 44, 45, 32 - others needed at 54 and 49	FD int. res. management
Farm and aquaculture	47 outside official SRF boundary but inside natural physical boundary	Private ownership

8 CURRENT ADMINISTRATION

The responsibility for administration of the SRF is vested by law in the Forest Department and to those whom the Department wishes to delegate its authority. The Forest Act and the rules and systems which have been adopted for policy and management have hardly changed since the Act was promulgated in 1927. The Chief Conservator of Forests is the administrative head and is responsible for the Department. He also acts as adviser to the Ministry of Environment and Forest. The administrative structure is illustrated in Table 20 which demonstrates the hierarchical nature of the organisation and the somewhat anomalous lines of command for the CF Khulna Circle and the DFOs Environment and Management Planning.

The Department justifiably takes pride in having been able to maintain the general integrity of the SRF. From the Department's perspective what is needed now is an upgrading of management capabilities, more investment in infrastructure and training for departmental staff, introduction of new skills and improvement to protection systems.

This is a simplified view of a situation which is predicated today by a much more complicated set of administrative, technical and management functions, each requiring its own administrative linkages, chain of authority and command structure and support services. Just as the form of resource utilisation evolves, embracing new products, new harvesting methods and new user groups, so the administrative organisation needs to adapt and be amenable to modern imperatives and challenges.

8.1 Administration of the Reserved Forest

The FD staff employs about 1000 staff of all ranks to manage the Forest and their responsibilities and employment terms fulfil most of the demands of traditional forest management, inherited from previous regimes. The total establishment does not need to be increased at 1 x forester/6Km^2 of forest estate but technical training and resources must be up-graded. There has been little innovation to date for two reasons:

Firstly a chronic lack of funding and secondly a lack of forward planning. The issue now is to endeavour to match needs against resources and to balance these in terms of cost and benefit.

Table 20 shows the command structure of the Sundarbans Division, which is the operational administrative and management unit below the Conservator, Khulna Circle.

8.1.1 Conservator, Khulna Circle

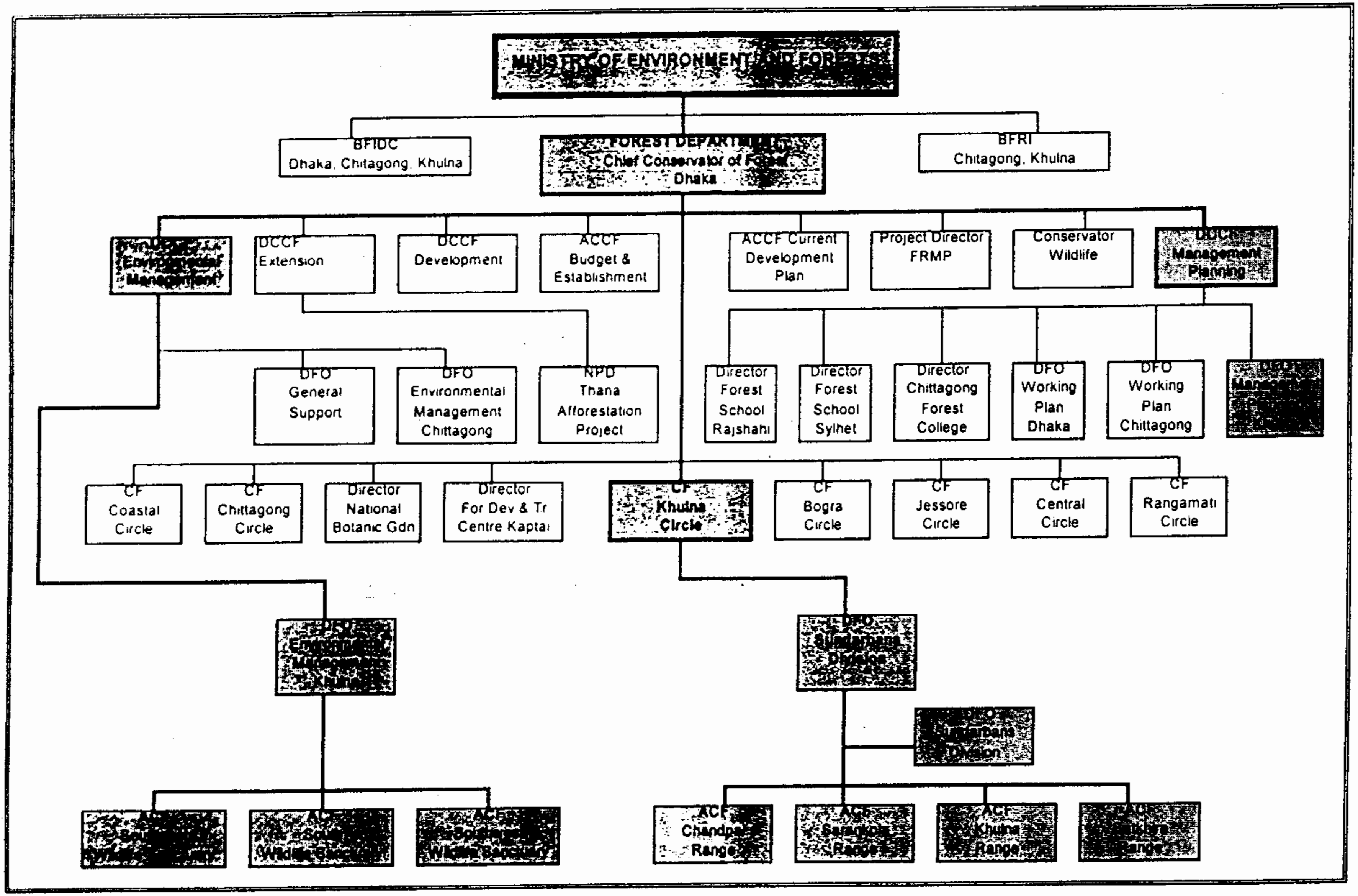
The CF Khulna Circle has his office in Khulna and is responsible for administration of the Circle which includes only the Sundarbans Division. His responsibilities cover budgets, staff appointments and discipline and execution of all functions of the Division as set by Government Acts, Ordinances, Rules Regulations and Agreements. He is also responsible for the execution of work programmes, supervision of DFO'sand for revenue collection and audits.

See Appendix A16 for full lists of duties as provided by the FD HQ, Dhaka.

8.1.2 DFO Sundarbans Division

The DFO Sundarbans Division is responsible for all administration of the SRF including operational plans, staff discipline, revenue collection, budgets, execution of the Forest Act, silvicultural work and sales of forest produce. He is assisted by Range Officers, ACFs at Chandpai, Sarankhola, Burigoalini, and Nalianala.

Table 20 Administrative Structure of the Forest Department, showing field staff of the SRF 08/1995



8.1.3 DFO Environment Management

This post was created in line with the developments proposed in the FRMP and he is stationed at Khulna with responsibilities for conservation and maintenance of the SRF's wildlife sanctuaries, maintenance of biodiversity, planning and implementation of nature conservation activities, research and environmental monitoring. His work is in the SRF but his line of command seems to circumvent the CF and DFO Sundarbans - see Table 20. This matter should be rationalised as soon as possible.

8.1.4 DFO Management Planning

The DFO Forest Management Plan Division is stationed at Khulna and is responsible for the preparation, updating and revision of forest management plans for the SRF and the four coastal afforestation divisions of Chittagong, Noakali, Bhola and Patuakali. It is also proposed that this DFO will be responsible for a pilot study for aerial sowing of mangrove species in coastal areas working in association with the other coastal divisions.

8.2 Law and Order

A primary function of the FD staff has been to enforce the Forest Act. Whilst the policeman's role is obviously essential there is a growing conviction that any hope that forest resources will be conserved through better policing is outmoded and bound to fail. Any conservation strategy that antagonises local people and does not pay sufficient regard to social as well as environmental problems (most of which are generated outside the boundaries of the SRF) is tantamount to blindly ignoring the economic, social and ecological realities which fuel the unstoppable pressure upon resources.

At present the Forest Officer is regarded by the population as policeman and revenue collector and one who restricts access to a common resource. This image hinders co-operation between the officials and the population and obstructs equitable sharing of returns. To plan for stronger policing through provision of better guns and faster boats will only serve to increase tension and confrontation between the FD and local communities (Bhuiyan, 1995; MARC, 1997). The decline in status of nearly all resources underlines the need for a better strategy.

With more resources, information and education in the border area, the Forest Department could readily move away from people's perceptions of a custodial and confrontational stance. This could be done by demonstrating a commitment to the principle defined at the UNCED conference 1992, that there is little future for conservation without social justice. Following the reforms described in this plan the FD could manage the SRF in the certain knowledge that its actions accord with the multifarious needs of society and that its technical base has the backing of other specialist agencies.

The majority of infringements of the law stem from a background of widespread poverty, lack of employment and strident demands from a growing human population for land, livelihood alternatives and justice. **Given the means the FD is well positioned to foster development as well as conservation not only in the Reserved Forest but in the border zoneas well. It will only be successful if the needs of people are fully reflected in the law and in the actions of the law enforcers. This can best be achieved by greater participation of the people themselves in the conservation process for which there must be opportunity and incentive.**

8.2.1 The Forest Act 1927

The purpose of the Forest Act of 1927 was to underpin existing rules relating to forests, transit of forest products and the duty leviable on timber and other forest produce. The Act was up-dated on several occasions by the Government of East Pakistan and latterly by the Government of Bangladesh (Choudhury, 1989).

It has the following provisions:

- To grant the Government the power to reserve forests.
- To grant the Government the power to impose duty on timber and other forest produce.
- To prohibit the acquiring of rights over the land described in the notification except in accordance with such rules as may be made by the Government.
- To prohibit the clearing of forest, or breaking up any land for cultivation or any other purpose.
- To prohibit the removal of timber.
- To prohibit the felling of trees.
- To prohibit hunting, shooting, fishing, poisoning of water or the setting of traps or snares. and,
- To allow any act done by permission in writing of the Forest Officer or under any rule made by the Government.

The Act at the moment is interpreted to prohibit any form of permanent structure or settlement within the SRF with a few exceptions:

- Forest Department buildings.
- The Mongla Port Harbour Authority Rest House at Nilkamal.
- the Bangladesh Navy Camp at Nilkamal.
- A semi permanent camp for the extraction of timber by the Khulna Newsprint Mill.
- Concrete cyclone shelters on Dubla Island built by CARITAS.
- A semi-permanent hospital near Nilkamal.

Rules:

Rules are approved under the Act mostly by notification and publication in the Government Gazette. The most important for the Sundarbans are:

Sundarbans Forest Transit Rules - governing the harvest and transportation of forest produce. First framed in 1885 and with revisions in 1889, 1906 and 1969. These include the following:

- Prohibition of cutting or converting timber without a pass.
- Prohibition of transit of forest produce without a valid transit document. The rule also requires anyone engaged in the harvest or transportation of forest produce to show valid documents for his actions when called upon to do so by a Forest or Police Officer.
- Permits issued for any harvesting will contain specific details on the kind of produce, where it applies and for how long. The permit also specifies the coupe office or revenue station to where the produce must be checked, the permit surrendered and a transit permit obtained.
- Boats used in the harvesting or transportation of produce must have a valid Boat Licence Certificate or BLC.
- Forest produce must pass through one of 16 Revenue Stations located on the SRF boundary at all important portals of entry..For seasonal fishing along the south coast, temporary revenue stations are operated at Kachikali, Nilkamal and Mandabaria (see Map 12).
- Felling and collection rules as set out in the prevailing Working Plan.

Government Orders - Standing Orders:

Under Clause 76 of the Act the Government has the power to make new rules which can affect the management and regulation of the forests which are issued in the form of Government

Orders. These are set by the MOEF and signed by the Secretary. There are at least 125 standing orders which cover:

- Service and discipline of staff
- Forestry working procedures
- Forest offences and the law
- Records and accounts
- Forest Royalties
- Permit rules and fees
- Banning of firing brick kilns with firewood .
- Banning manufacture of charcoal.
- The moratoriums on felling of trees in Reserved Forests.
- Agreements with third parties

Orders have been designed to conserve fuelwood supplies but the order banning the use of firewood in brick kilns has been found impossible to implement in the absence of adequate alternative fuels. Charcoal is also manufactured illegally but this is not on a commercial scale.

The Moratorium Orders: these have a far-reaching impact upon management. Official felling of all trees ceased in 1989, with the exception of Goran, Gewa and Top-dying Sundri. The final Government Order however, was not actually signed until 11 September 1990 (Notification No. sha - 2 / MOEF - 192/90/580). This order imposed a restriction on all tree felling in the natural Reserved Forests until the year 2000. This Order was reconfirmed by another dated 16 October 1993 (Notification No. MOEF (sha - 3) 65/93/696).

For the SRF two exceptions to the moratorium were made: .

- To facilitate the production of newsprint at the Khulna Newsprint Mill an initial annual allowable cut of 2.2 million cft of Gewa (later increased to 4.7 M cft) was agreed 1990. (Hussain et al.,1990).
- **To accommodate harvesting of Sundri with more than 50% of the crown dead due to die back. The DFO must make an application annually to the Secretary of MOEF through the Chief Conservator of Forests (CCF), which if approved receives a separate Government Order in confirmation. The criterion has now been modified to allow the trees showing any symptom of top-dying to be removed.**

Agreements have been made by the Government for supply of wood products to certain industries notably:

Khulna Newsprint Mill Limited

The first Agreement was made in 1959 permitting a quota of Gewa of 464 684 m^3 for 30 years (IUCN, 1994) for wood pulp production. The current Agreement permits an annual quota of 133 000 m^3 and the previous minimum top diameter limit has been reduced from 10 cm to the current 7 cm over bark.

Dada Match Factory:

The present arrangement for supply of material for match production is for KNM to transfer a proportion of its annual quota to Khulna Match Factory. The 1993/94 allocation was 300 000 cft.

Khulna Hardboard Mill:

The brushwood from the tops of Sundri trees sold at auctions is currently used completely by the Khulna Hardboard Mill (KHBM)(Larsen, 1994 and Mitchell, 1995). This wood is purchased on the basis of a royalty payment. As all the Sundri wood is harvested only from top-dying areas much of the KHBM material is rotten. This obviously affects the quality of the end product and the efficiency of processing. The supply to KHBM is augmented by limited amounts of Shingra ***Cynometra ramiflora*** although this causes problems due to its small diameters.

The dimensions used by KHBM are 2 to 4 feet lengths and 2 to 10 inch diameters. Wood with diameters less than 2 inches can only be used if the stems are bundled together.

The large amount of defect in the Sundri wood causes waste which, according to KHBM, can amount to losses of up to 30% when compared to using green Sundri. Additional problems are being encountered with the reduced availability and size of shingra and the other Sundarbans species being used. The diameter of shingra has become so small that it is now often necessary to bundle several stems together to run them through the chipper.

KHBM has tried bagasse and jute in their process and both raw materials have given satisfactory results.

Goran and Gewa cannot be used in the KHBM process. Most of the local woods cannot be used since they contain too much latex.

KHBM has expressed interest in harvesting wood from the wind and water damaged areas in Sundarbans and these issue are considered in more detail in Part 2.

The annual harvest volume and mill consumption goal is 1 000 000 cft stk (stacked). Of this amount, the FD has the objective of providing 700 000 cft stk of Sundri wood. Only KHBM has permission to remove this type of Sundri wood from Sundarbans. In addition FD has been allowing KHBM to harvest about 100 000 cft stk of Shingra wood. The remaining volume of 200 000 cft stk is purchased on the open market and includes jin, jhao, bhaela, amur, keora, kankra and the local wood, babla.

Permits:

The Forest Department issues permits to allow various operations such as timber felling and extraction to occur within the Forest Reserve. These permits include right of way passes or certificates which are issued subject to payment of the appropriate fee or royalty. A full list of Forest Royalties is given as AppendixA12.

8.2.2 The Wild Life (Preservation) (Amendment) Act 1973

The legislation controlling the management, protection and exploitation of wildlife in Bangladesh is provided for in the Bangladesh Wildlife (Preservation) (Amendment) Act 1974. This Act is an amendment of the Wildlife and Preservation Order 1973. (Forest Directorate, 1984).

The Act covers the following:

- Definition of terms;
- Appointment of officers;
- Species defined as 'Game Animals' and 'Protected Animals' are listed;
- Rules regarding the protection and exploitation of wildlife are set out;
- Provision for establishment of wildlife sanctuaries and national parks;
- Description of penalties for offences committed against the Act.

The Act does not define wildlife but 'wild animals' are defined as 'any vertebrate creature, other than human beings and animals of usually domesticated species or fish, and includes the eggs of birds and reptiles'. Wildlife sanctuaries are defined as 'an area closed to hunting, shooting or trapping of wild animals and declared as such under Article 23 by the Government as undisturbed breeding ground primarily for the protection of wild life inclusive of all natural resources, such as vegetation, soil and water'.

The Act specifies Game Animals which can be taken with a hunting license and Protected Animals which are which are totally protected from killing or capture. It also states that the possession, transfer and import of specified animals, meat and trophies requires a certificate of lawful possession.

Various rules are prescribed for hunting and prohibiting the use of certain equipment and methods (such as using automatic weapons or using pit traps).

Whilst the Department may in theory issue hunting licenses, in practice none is issued and the SRF is thus closed to consumptive utilisation of non-aquatic wildlife. Fish, shrimps, molluscs and other invertebrates not included in the definition of 'wildlife' are those subjected to the most intensive harvesting.

A wildlife sanctuary is defined as "an area closed to hunting, shooting or trapping of wild animals and declared as such under Article 23 of the Wildlife Act by the Government as undisturbed breeding ground primarily for the protection of wild life inclusive of all natural resources, such as vegetation, soil and water". Cutting of vegetation, lighting of fires and trespass are commonplace but without conservation staff these are difficult, if not impossible to monitor.

Under the present legislation and definitions, which differ from the IUCN international categories shown in Appendix A10. Wildlife sanctuaries offer greater protection to wildlife than national parks. In the sanctuaries hunting (extended to one mile beyond the boundary), committing any act to disturb wildlife, damaging vegetation, cultivation, and polluting water are banned. Rights of entry and residence and the introduction of exotic or domestic species are also prohibited.

8.2.3 The Fisheries Act

The Protection and Conservation of Fish Act was passed in 1950. The first part of the Act states which officials are empowered to detect breaches of the Act and to make search and investigation. These include the police, officers of the Fisheries Directorate and the officers of the Forest Department in the Sundarbans division (not below the rank of Deputy Ranger).

The Act prescribes punishments for breaches of the law which range from a fine of Rs. 100 to one month's imprisonment for a first offence. Applicable rules which:

- Prohibit or regulate use of fixed engines, regulate structures such as weirs, dams, bunds, embankments.
- Prohibit fish harvesting by use of explosives, guns, bow and arrow.
- Prohibit the killing of fish by poisoning or pollution.
- Prescribe the seasons during which the catching of fish of prescribed species shall be prohibited.
- Prescribe a minimum size below which no fish of prescribed species shall be killed or sold.
- Prohibit all fishing in all waters or in any specified for specific periods.

These rules, regulations and schedules are occasionally up-dated by the Ministry of Fisheries and Livestock (MFL). They are notified in the Bangladesh Gazette but so far no rules have been applied in the SRF where they are most needed.

8.2.4 Contravention of the conservation laws - the situation within the SRF

The penalties in 1995 for breaches of the law range from imprisonment up to 5 years and a fine up to Tk 50 000 plus compensation. The Forest Department also has the right to seize illegal produce together with any tools, vessels, weapons etc.

The Forest Department's code of practice for law enforcement is as follows:

- If the offence is relatively minor, then the DFO may offer the offender a compromise. Under this rule the offender may pay the Forest Charges due plus a fine but is allowed to keep the forest produce. This is recorded by the DFO as a Compounding Offence Report (COR).
- When the offence involves a larger quantity of forest produce then the offender is arrested, the produce and equipment seized and the case sent for trial at the Magistrate's Court. In most cases the offender is bailed but the seized equipment is kept until the trial is over. If the case is proven the offender is fined or imprisoned or both and the forest produce is confiscated. Confiscated produce is customarily sold at auction. These cases are recorded as a Prosecuting Offence Report (POR).
- On occasions when the Forest Department (FD) finds produce that has been obtained without permit but that the 'owner' has absconded the produce is seized, sold at auction and recorded as UDORs or Undetected Offence Reports

8.3 Forestry Working Plans

Traditional forestry working plans detail timebound management operations for a particular area. A plan would normally be based on estimates of growing stocks and their growth and yield which would be used to define the allowable harvest. Plans usually concentrated upon the timber resource, as this was often perceived to be the most valuable commercially and on which most management effort was devoted. The SRF plans differed a little in that they were not limited to timber production alone but included other resources such as Golpatta, honey, and fish. Working plans tended to be extensive documents incorporating site descriptions and factors that affect management of the production but they were not intended to be ecosystem conservation documents.

In Bangladesh, forestry working plans are mandatory instruments, approved by Government on the recommendation of the Chief Conservator of Forests (CCF). If prescriptions cannot be realised or are incorrect then official amendment is required. Wherever there is no working plan forests may be worked on interim felling prescriptions or Government Orders.

For the SRF there have been seven approved working plans or working plan revisions. These are listed below :

1893 to 1903	:	Heinig
1904 to 1908	:	Lloyd
1906 to 1910	:	Farrington
1912 to 1932	:	Trafford
1931 to 1951	:	Curtis
1937 to 1947	:	Choudhury (revision of Curtis's plan)
1947 to 1960	:	During the period the SRF was managed under schemes prepared by DFO's, Sundarbans Division.
1961 to 1980	:	Choudhury . Production continued under this plan until 1985.
1985 to 1988	:	Balmforth Interim Felling Prescriptions
1989 to present	:	no working plan; Gewa production based on ODA inventory and KNM 5 year Felling Plans, Top-dying Sundri, and Goran all in relation to moratoriums.

Khulna Newsprint Mill was constructed during the 1950s to produce newsprint using pulpwood derived from Gewa from the SRF harvested on five year lease agreements. Previously Gewa had few alternative markets. Agreements are made in consultation with the FD and require felling plans and approval by GOB.

Between 1981 and 1985 ODA prepared a detailed forest inventory. Balmforth(1985) used these data to prepare a set of interim felling prescriptions. Subsequently, the SRF was managed under these prescriptions until 1989 when the Government introduced the moratorium. Since that time production from the Forest has been limited to the production of Gewa for KNM and the salvage felling of Top-dying Sundri, both of which are exempted from the moratorium by Government Order. Currently there is no approved working plan in force .

8.4 Other departments and agencies

The Forest Department administers the Forest Act and manages the SRF in a traditional manner. Today there are there are several additional factors, exceptions and new imperatives which will be accommodated under the department's aegis through integrated management and these concern the following:

- Rights of passage
- Security
- Participatory development in the border area
- Harvesting of non-wood forest produce
- Straddled fish stocks
- Shared water resources
- Immigration and emigration of wildlife
- Artificial boundaries
- International marine waters
- Offshore exploration and mining
- International boundaries
- Pollution
- Climate change and SLR
- Tourism
- Socio-economics
- Research, monitoring and Evaluation (M&E)

Most of these either directly or indirectly concern other organisations, agencies and government departments. Some have their own responsibilities in the law and others may be technically highly specialised or who must access the SRF to conduct legitimate business; others relate to matters of global significance or international importance. Integrated management and co-operation in cross-sector activities is therefore discussed and proposals made to effect a realistic way forward to improve forest administration.

There is a need to take these matters into account in a broadened structure which can introduce technical capacity to meet the demands of multi-sectoral management under the administration of the Forest Department. The many widely acknowledged exceptions to reserved forest rules pose sufficient management difficulty that responsibility and effort ought to be harmonised based on new management strategies.

8.4.1 Civil administration

A major consideration in any integrated administrative structure concerns the civil administration in the Border Zone which will become increasingly important in future development. To relieve pressure upon the Reserved Forest investment must increase in the Border Zone to provide alternative sources of fuelwood, timber for construction and industry and new sources of livelihood. A modernised FD would have a full part to play in these endeavours through provision of essential technical support, education and information to local communities.

The Border Zone falls within the jurisdiction of the civil administration thus there will be a growing need to initiate working arrangements between departments to facilitate the development process. Furthermore the SRF includes parts of Khulna, Barisal and Satkhira districts thereby complicating effective administrative links.

Added to this there is universal intensification of drug smuggling, international border disputes, international rights of passage together with technical problems relating to offshore mining, shared waters, straddled fish stocks, agriculture and aquaculture. These will all need to be addressed in any new integrated management structure. .These matters are taken into account in discussions on institutional arrangements in Part 2.

8.4.2 The Bangladesh Navy

The Bangladesh Navy (BN) patrols marine waters and international waterways, both of which have some bearing on affect the administration of the SRF.

There is BN presence at Nilkamal where the navy occupies the old forest station adjacent to the MPHA rest house and present Nilkamal Forest Station.

In view of ongoing dacoity, smuggling, mechanised ingression to national marine waters, collaboration is required on a regular and properly structured basis over these issues. This is certain to be an increasingly important matter since the most vulnerable part of the SRF's boundary is along the marine southern border depicted on Map 13.

8.4.3 The Bangladesh Defence Regiment

Similarly the Bangladesh Defence Regiment (BDR) also has a role inside the SRF in connection with maintaining border security and patrols western borders assisting the FD concurrently with anti-smuggling, dacoity prevention and trespass. The international aspect of these functions are yet another example of the need for collaboration at all levels.

8.4.4 Mongla Port Harbour Authority

The Mongla Port Harbour Authority (MPHA) is based at Mongla and operates in the SRF through provision of pilots for international shipping who change over at the mouth of the Passur river. MPHA has a lease on the land at Nilkamal where it has a large cyclone-proof rest house. This valuable property is seldom used for the purpose intended and 3 acre plot is a prime site for tourism developments. Recommendations are made for better utilisation of this property on a multiple-use basis especially in the development of ecotourism.

MPHA also rents out boats for tourism on an ad hoc basis and whilst these are useful functions they deserve better integration in the mainstream of SRF management and future development. This matter is discussed further in Part 2 of this plan.

Since there are no roads in the SRF obviously administration and control of rights of passage are major functions in forest management. Furthermore substantial oil pollution is said to stem from Mongla Port over which MPHA has formal responsibility and co-operation in research and monitoring of this potentially extremely damaging environmental problem demands early attention in holistic management planning (see Section 3.5).

Recommendations are made for rationalising the current ambiguous sectoral arrangements in Part 2.

9 RESEARCH ORGANISATION

Every subject contained in this plan has involved research and recommendations have been based on the best information available. At times, and in important areas, research has been inadequate and data inappropriate for making informed judgements. This is largely a reflection of past narrow introspective policies and insufficient investment in research programmes, lack of continuity in the Forest Department's field staff deployment and a lack of co-ordination between concerned agencies. This the historical position and intense effort was made during the course of research for this plan to make up for deficiencies using advanced techniques.

Nevertheless considerable research needs to be done to achieve the requisite level of understanding of the ecosystem but this should not be an excuse for postponing action. A constraint which should be overcome is official recognition that research in the SRF has local, regional and international aspects and secondly that clear direction will be received to implement extended research goals.

As was stated in Agenda 21 UNCED 1992 "Sustainable development requires taking longer term perspectives, integrating local and regional effects of global change into the development process and using the best scientific and traditional knowledge available. The development process should be constantly re-evaluated, in light of the findings of scientific research, to ensure that resource utilisation has reduced impacts upon the Earth's system." The SRF forms part of the coastal zone ecosystem physically shared with other countries and its special biophysical characteristics underline its international value, placing a perspective upon research and development beyond narrow sectoral short-term targets of the past.

Integrated management of all resources demands broadly based multi-disciplinary action in a co-ordinated programme of continuous data acquisition, storage and analysis. Such a system does not exist other than in the Operational Unit dealt with in Part 2.

Existing forest research has focused upon inventory data, some work on soils and salinity and plant ecology and uncoordinated studies on silviculture, plantations (conducted by BFRI), wildlife and tourism. There has been little work on non-wood products, previously referred to as minor forest products, other than on the Golpatta and honey harvests.

9.1 Research goals and objectives

Integration of research programmes:

Today research goals encompass all biotic and abiotic components of the SRF viewed holistically as a natural mangrove ecosystem of which the timber resource is but one part. It is now fully realised that the whole ecosystem must be examined. From the point of view of forest management this is greatly complicated by the system's physical dependence upon events outside its borders but the goal should be applied holistic research and analysis.

This section of the plan provides a synopsis of detailed information available in technical reports on production forest research methodology, data bases, growth and yield estimation techniques, stock estimation techniques and guidelines for future inventory studies. These technical reports are based upon current and historical knowledge and the integration of production forestry within the ecosystem inventory.

New research techniques include methods for making accurate and repeatable physical measurements, hitherto impossible, such as hydraulic modelling, elevation mapping, remote sensing for vegetation and landform analysis, GIS data bases and multi-variate computerised analysis of multiple factors. Together these provide managers with hard data on the environment. The biotic resources themselves also must be measured set against knowledge of the physical environment to determine occurrence, relative abundance and growth rates.

From this, carrying capacities, biomass and cyclical production can be calculated to determine the magnitude of sustainable harvests. The ultimate research aim is to understand and conserve the entire ecosystem; to acquire a true picture of how people use resources, how much, where from and when and to enable managers to set measurable yields.

9.1.1 Ecological monitoring stations

Whilst robotics and remote sensing are often essential tools, *in situ* ecosystem research and monitoring can only be carried out through continuous field survey and this is best accomplished using the proposed system of multi-disciplinary field ecology monitoring stations. These will be properly equipped to provide accommodation and facilities for research in ecology and forest management. The following network should be considered:

- Dhangmari - existing site
- Katka - existing site
- Dubla
- Munshiganj
- Central Sundarbans
- Supoti - existing site
- Nilkamal
- Mandabaria
- Burigoalini - existing site

Some of these could be operated seasonally, others throughout the year. These decisions should be made by users and in relation to scheduling of research programmes.

The main goals would be to maintain regular measurement of parameters such as climate, hydrology, sedimentation, erosion and accretion, aquatic and terrestrial animal populations, forest dynamics, harvesting activities, environmental impact assessment and the statuses of traditional user groups.

9.1.2 The Integrated Resources Data Base and RIMS

With the change in emphasis from selected component analysis (working plan data) to holistic ecosystem analysis (ecosystem management plan data) new procedures will be introduced to collect, store, retrieve and analyse data across the resulting broad, arguably infinite range, of subject material.

A computerised integrated data base (IDB Sarker, 1995) which should incorporate the GIS data base and the hydraulics data base provides the fundamental storage system for all data which have been obtained in the past and all data which may be obtained in the future. It will become the repository of information for sustainable management. If it continues to be up-dated it will be invaluable for planning and decision making. All future researchers, especially those involved in the long and arduous task of comparative inventory preparation, will be able to draw upon data quickly and centrally, thereby saving time and cost.

This data base should be linked ultimately with the Forest Department's headquarters data base unit, referred to as the Resource Information Management System or RIMS.

The IDB has a complex dynamic structure illustrated in Appendix A15 effectively integrating all aspects of the SRF ecosystem and management system. The SRF is such a complex system that it may possibly need to be considered as a special case, and only relatively simple linkages established to other projects. Implementation of the IDB and survey and sampling systems from which its data are derived are discussed in Part 2 of this plan.

The IDB structure will evolve over time and implementation should continue to be given a high priority. It is a powerful and important forest management tool, but it will need to be continually maintained and supported. It should be the starting point for developing the sound technical base for the planning of the Sundarbans and coastal areas (Leech, 1995).

9.1.3 The GIS data base

A Geographic Information System (GIS) is a computerised data management system which permits compilation of existing point, linear and polygon data to which can be added any amount of future geographic information. The value of such technology is clear and the system has enabled a whole range of historical and new data to be stored and analysed. The maps included in this text and in Volume 3 were compiled from this source (see Appendix 28). The system has four main attributes:

- It provides up to date and highly accurate mapping coverage for the SRF and the Border Zones.
- It contains data on topography, soils, hydrology, administration etc which are of relevance to ecosystem research, monitoring, management and development.
- It enables flexible compilation, overlaying, additions and up-dating of different data layers and at different resolution levels.
- It facilitates output on historic data, derived secondary data, compiled information or models.

The advent of the GIS data base allows a far wider range of alternative stratifications to be assessed and analysed than ever before. What is needed for the future is the ability to carry out stratification and sample plot measurement completely independently and then, in the analytical phase, to extract the data from a data base for any particular stratification that is required for any aspect of forest management planning. A combination of GIS and IDB will ensure that this can be done at whatever level of resolution is required of the subject which is being studied.

9.1.4 LARST - remote sensing station

Resource management today needs up-to-the-minute environmental information in the field. Whilst centralised processing and co-ordination may be necessary, experience shows that this suffers frequently from priority divergences, losses of continuity, time lags and inevitable lack of individual commitment. The Local Applications of Remote Sensing Techniques (LARST) system, developed by the Natural Resources Institute, Chatham, England, is a low-cost, simple and robust system.

Consideration should be given to acquiring a PC- based Image Processing capacity. A system such as LARST can provide access to local satellite reception from Meteosat and NOAA satellites and then allows data to be interpreted via personal computers. This would complement a system such as MicroBrian which would utilise other commercially available imagery such as Landsat TM and SPOT. A raster-vector analysis system, such as Tydac's Spans could be incorporated. These would become basic equipment for the proposed continuous forest monitoring system.

The range of applications and attributes of LARST includes :

- Information from Meteosat and NOAA satellites free of charge to LARST users;
- Low cost receiver with data storage and interpretation capacity through PCs:
- Purpose-written software
- Mains or 12 volt power
- Receiver hand held or motorised
- Training on site at local field stations available
- Total cost about US$50 000.
- Total biomass measurements;
- Occurrence of fires and distribution of settlements.
- Management of water resources - surface water chlorophyll and suspended sediments.
- Wetlands.
- Forests - condition of vegetation, photosynthetic activity etc.

- Wildlife sanctuaries.
- Estimating rainfall.
- Monitoring growth and condition of vegetation.
- Assessment of natural disasters.
- Surface temperatures.
- Cloud cover and storm warning.
- Tracking radio collared animals.

Unlike *ex situ* methods which take weeks or months to interpret and distribute information, cost-effective direct satellite reception with the combination of PCs and easy-to-use receivers provides information immediately to local forest managers where it is needed most, at divisional level. It increases efficiency, commitment and a sense of responsibility.

9.1.5 Sampling systems for integrated resources management

In any SRF research programme follows from previous comments that there is a fundamental requirement now to broaden the base of enquiry and establish a sampling methodology which takes full account of all components of the ecosystem.

Past surveys in the Sundarbans have been based on stratified random sampling, with the area being mapped and stratified prior to the establishment of plots. The design was based on the known statistical efficiency of stratified random sampling (Leech and Correll 1993). This generally has economic advantages but requires that the stratification be carried out prior to plot measurement, that the stratification be accepted as appropriate, and that it does not change over time. These requirements are not believed to be appropriate for the management of the Sundarbans any longer (Leech, 1995).

Sporadic research ideally should be replaced by co-ordinated continuous monitoring. The issues seem to amount to the following :

- The need to be able to apply any stratification at any time.
- The need to determine changes at intervals of less than the current 10 years or so. preferably every year on a continuous basis.
- The cost of collecting data are so great, that there is a requirement for data collection to be integrated so that measurements are not repeated for different scientific and forest management uses.
- For production forestry purposes, good growth models and other mensurational models can only be developed on very accurately measured data that cover a wide range of silvicultural conditions, far wider than occurs naturally in the forest.

It is well known (Leech, 1995) that accurate remeasurements on 100 permanent plots provides more information for growth and yield modelling than 1000 inventory plots measured to a lesser precision. Sound model development based on accurately measured plots is absolutely essential if the models are to be effectively extrapolated and alternative silvicultural management regimes evaluated.

There is a requirement for two types of plot :

- A PSP system that would provide data for the development of models. The number of plots need not be great, but the plots should be sited so that they are uniform and the range of conditions should cover the complete range of forest conditions. Research trial plots can be measured to similar standards and these can be used to augment the PSP data base and provide data extrapolating stand conditions outside the usual range.
- A Temporary Sample Plot (TSP) system that could provide estimates of the current status of the forest at any point in time. Like the PSP's, these would be stored in the Integrated Data Base. The plot locations would also be stored as a point coverage in ARC/INFO.

For statistical analysis of strata statistics, such as stocking and volumes for any area of interest, it is desirable to prepare the stratification that is desired, determine which TSP's occur within each of the strata, then combine the plots for each strata to determine strata mean statistics. The approach therefore allows the TSP measurement to be completely independent of the stratification.

For storage and management of spatial data the GIS system is entirely suitable and if given continuity this is immediately available to provide rapid and extremely accurate spatial information. An essential precursor to all future inventory work, integrated management and all future plans.

9.1.5.1 PSPs and stratified random sampling

The Permanent Sample Plot (PSP) data base is the existing foundation of research geared for acquisition of data for inventory and working plan preparation. Plots were established prior to the time of the Curtis inventory but lack of maintenance now restricts PSP research to the 120 plots derived from those set up by ODA in 1985 and 12 plots set up by BFRI, Das and Siddiqi (1985).

One factor which is critical to the formulation of PSP methodology is the nature of the PSP's themselves. They were originally established by the ODA survey and then these 120 plots were remeasured in 1986/87. At that stage (1986/87) the 120 PSP's did provide an unbiased estimate of forest status, in essence a very poor inventory. For the analysis used in this plan minimal data only were available from 69/120 plots compared with the 2099 plots for the ODA inventory and approximately 1123 plots of the Forestal inventory.

The PSP's provide estimates of growth, ingrowth and consumption. The moratorium and decree by the Forest Department that no felling should be carried out in any PSP meant that any consumption must be interpreted as unofficial, including mortality. Therefore it is necessary to obtain official felling records, by species, and preferably by relatively small area units, such as at compartment level or at range level, so that the actual net change in status of the forest's timber component may be better assessed.

The limitation encountered in recent studies for modelling stem from the need to use PSP's as both PSP's and TSP's. At present there are barely sufficient plots for simple model development. It is emphasised that the plots sampled are too few to give anything other than a guarded indicative assessment of the current status of the Sundarbans, see Leech (1995).

The PSPs are 0.2 ha in area (100 x 20 m), and the species, diameter and tree category of all trees were recorded at each remeasurement. Trees can generally be located at subsequent remeasurements. At the 1994/95 measurement the height of each tree was recorded, but sample tree heights, or no tree heights, were obtained at some earlier measurements. For the earlier measurements tree height samples were apparently selected haphazardly or at random.

Plots are readily located by paint and a blaze on a tree on the bank, and a series of paint marks leads into the plot. Plots are recorded on a map and in 1994/95 measurements the GPS fixes were made for insertion in the GIS.

Volume estimates are based on tree volume equations, either those developed by the ODA or those developed for this plan. Information is by species and is summarised as:

Stocking:

- standing at 1986/87
- standing at 1994/95
- trees present on both occasions (growing stock)
- trees present only in 1986/87 (unofficial consumption including mortality)
- trees present only in 1994/95 (ingrowth)

Basal Area:

- basal area of trees standing at 1986/87
- basal area of trees standing at 1994/95
- trees present on both occasions (growing stock)
- basal area at 1986/87
- basal area at 1994/95
- basal area of trees present only in 1986/87 (unofficial consumption including mortality)
- basal area of trees present only in 1994/95 (ingrowth)

Volume:

- volume of trees standing at 1986/87
- volume of trees standing at 1994/95
- trees present on both occasions (growing stock)
- volume at 1986/87
- volume at 1994/95
- volume of trees present only in 1986/87 (unofficial consumption including mortality)
- volume of trees present only in 1994/95 (ingrowth)
- and this information can be obtained by diameter class if desired.

Growth:

- growth, based on trees present in 1986/87 and 1994/95
- ingrowth, based on trees not present in 1986/87 but present in 1994/95
- unofficial consumption (the loss from the forest and including mortality) based on trees present in 1986/87 but not present in 1994/95.

These estimates can then be aggregated to produce averages of each of these statistics, by species, across the PSP's that fall within any particular stratum of the forest. The SRF has been taken unavoidably as one stratum for this plan as the official consumption has to be considered before any net change in status can be determined.

The methodology used allows net change in the SRF to be estimated for any stratification but unfortunately this must be extremely limited in scope since:

Part Growth	=	growth on the growing stock component (1994/95 - 1986/87)
	+	ingrowth
	-	unofficial consumption (which includes mortality)

The estimate based on the PSP's was then aggregated by a stratification that matches the level of disaggregation possible for the official consumption. Thus :

Net growth	=	Part growth
	-	official consumption

and the resulting net growth estimate has provided an indication of the changing status of the SRF(Leech, 1995).

Review of the Status of the Wood Resources:

The average information across all PSP's that had been remeasured was summarised. The individual plot summaries are provided in Sarker (1995) to assist users of this document who do not have access to the IDB. Table 21 shows the summarised information for each species (Mitchell, 1995).

From this it can be seen that whilst the total number of stems per hectare has decreased over the period the total standing volume due to growth has increased. These PSPs have not been officially harvested thus the results do not make provision for this component. It is also likely that as the PSPs are clearly marked and each tree painted and tagged it is certain that the amount of unofficial consumption is not as great within the PSPs as in the rest of the forest.

The average net growth across the 69 plots was calculated to be 1.62 m^3/ha/yr. The table also shows that gross growth is 2.91 m^3/ha/yr composed of 2.46 m^3/ha/yr of growth and 0.45 m^3/ha/yr of ingrowth into the lower tree diameter classes. The table also shows that 1.30 m^3/ha/yr was lost each year to unofficial consumption. This includes mortality, missing trees and losses due to illegal harvesting. The unofficial consumption was subdivided into dead and fallen trees and others. Mortality was estimated as 45% implying 0.71 m^3/ha of unrecorded consumption. There were no marked differences in the proportions by species in each of the categories.

The results are approximately consistent with the increment of 1.4 m^3/ha/yr estimated by summing the Sundri and Gewa components of the ODA survey (Chaffey, Miller and Sandom 1985) although this appears to have been defined as gross growth less mortality, but excluding harvesting. The difference could in large part due to the tree volume equations used by ODA for Sundri.

The Sundri growing stock had stayed constant at 53.4% at the 1986/87 remeasurement and 53.0% at the 1994/95 assessment. This result conflicts with previous assessments by ODA and others. The effect of the Moratorium and the fact that consistent tree volume equations were used in this analysis, add some credibility to the general conclusion that overall the proportion of Sundri may be not changing markedly through natural ecological change.

The proportion of Gewa appears to have increased slightly from 38.1% to 39.0% over the same period, but it must be remembered that the PSP's have been excluded from normal harvesting and probably do not reflect the true status of change in the Sundarbans. It could be inferred that in the absence of harvesting, species composition is on average not changing very rapidly. The advantage of these analyses is that they are based on remeasured plots and consistent volume estimation methods. The disadvantage is that the PSP's have been excluded from normal harvesting operations.

However, the net growth information of 1.62 m^3/ha/yr, based on the average across all remeasured PSP's, does not indicate the real changes in the Sundarbans. It is necessary to subtract the official consumption. Mitchell (1995) reports the official consumption at 0.80 m^3/ha/yr in total of which 0.45 m^3/ha/yr was of Gewa, 0.19 m^3/ha/yr was of Sundri. The total volume figures for removals were obtained from the official Forest Department felling records in the Divisional Forest Officer's Annual Reports. The area figure used was the total net land area of the Sundarbans excluding Wildlife Sanctuaries (as there should have been no harvesting in these areas) and also grass lands and sand bars. This was considered the area figure most consistent with the rest of the methodology.

Table 21 Summary of the Results of PSP Analysis - all 69 Plots 1994/95 SRF

(Mitchell, 1995)

SPECIES	STOCKING (No/ha)					BASAL AREA (m2/ha)						VOLUME (m3/ha)					
	1ST	4TH	GST	ING	CON	1ST	4TH	Growing Stock 1ST	Growing Stock 4TH	ING	CON	1ST	4TH	Growing Stock 1ST	Growing Stock 4TH	ING	CON
Amur	21.88	19.49	15.72	3.77	6.16	0.082	0.078	0.054	0.068	0.009	0.028	0.183	0.177	0.115	0.161	0.017	0.067
Baen	4.64	4.20	4.20	0.00	0.43	0.383	0.484	0.343	0.484	0.000	0.039	1.763	1.980	1.575	1.980	0.000	0.188
Bhola	3.12	2.39	1.96	0.43	1.16	0.008	0.009	0.005	0.008	0.002	0.003	0.014	0.020	0.009	0.017	0.003	0.005
Batul/Urmai	0.58	0.00	0.00	0.00	0.58	0.005	0.000	0.000	0.000	0.000	0.005	0.015	0.000	0.000	0.000	0.000	0.015
Dhundal	1.01	0.72	0.65	0.07	0.36	0.018	0.017	0.015	0.017	0.000	0.002	0.098	0.101	0.089	0.100	0.000	0.009
Dagor	1.38	0.58	0.58	0.00	0.80	0.020	0.008	0.008	0.008	0.000	0.012	0.070	0.028	0.029	0.028	0.000	0.041
Gewa	1060.72	1101.30	927.32	173.99	133.41	6.421	7.453	5.439	6.939	0.513	0.983	31.663	37.165	26.732	34.928	2.237	4.930
Goran	2.68	0.14	0.07	0.07	2.61	0.007	0.000	0.000	0.000	0.000	0.006	0.012	0.001	0.000	0.000	0.000	0.011
Jir	0.14	0.00	0.00	0.00	0.14	0.003	0.000	0.000	0.000	0.000	0.003	0.014	0.000	0.000	0.000	0.000	0.014
Keora	0.87	0.65	0.65	0.00	0.22	0.143	0.129	0.110	0.129	0.000	0.033	1.144	0.996	0.893	0.996	0.000	0.251
Kankra	7.68	5.51	4.28	1.23	3.41	0.122	0.130	0.082	0.122	0.008	0.039	0.683	0.771	0.456	0.722	0.049	0.227
Khalshi	0.87	0.94	0.87	0.07	0.00	0.004	0.005	0.004	0.005	0.000	0.000	0.011	0.014	0.011	0.014	0.000	0.000
Karanja	0.14	0.00	0.00	0.00	0.14	0.002	0.000	0.000	0.000	0.000	0.002	0.007	0.000	0.000	0.000	0.000	0.007
Kirpa	0.22	0.00	0.00	0.00	0.22	0.001	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.002
Passur	16.52	16.74	15.94	0.80	0.58	0.503	0.589	0.490	0.582	0.007	0.014	3.014	3.584	2.938	3.554	0.030	0.077
Sundri	830.80	846.81	757.61	63.20	73.19	7.989	8.922	7.293	8.667	0.255	0.696	44.417	50.559	40.529	49.476	1.084	3.888
Shingra	10.51	2.25	1.88	0.36	8.62	0.037	0.009	0.006	0.008	0.001	0.031	0.082	0.019	0.012	0.018	0.002	0.070
Total	1963.77	2001.74	1731.74	270.00	232.03	15.747	17.833	13.850	17.038	0.795	1.896	83.190	95.414	73.388	91.992	3.422	9.802

Legend

1ST = Measurement taken during the period 1985-87

4TH = Measurement taken during the period 1994-95

GST = Growing stock (trees present on both occasions)

ING = Ingrowth (trees growing into the 5-10cm diameter class during the period elapsed between 1st and 4th measurements.

CON = Consumption (trees present at the first but not present at the 4th measurement

A further problem is that there are obviously differences between harvesting practice, the high level of merchantability as practised in the measurement of felled trees for the volume equation calculations, and thus the equivalent removals to 0.8 m^3/ha is probably higher at 1.0 or even 1.2 m^3/ha, but it is really impossible to say with any confidence. Another probability is that the level of unofficial consumption is lower in the PSP's because they are obvious and therefore people are likely to stay away from them.

This would indicate that, as expected, the effect of the Moratorium may have reduced the amount of timber harvested, and that over the 7.5 years, based on the PSP evidence, there has been a slight net increase in the growing stock level of timber in the Sundarbans. In recent years though the volumes harvested from the salvage fellings have increased so that the total is probably back to pre-moratorium over-harvesting levels. Immediate action therefore should be taken by the FD to ensure that the forest does not continue to be depleted.

This should not be taken as a definitive statement of the true status of the Sundarbans as that can only be made when a hidden series of TSP's has been established, measured and then remeasured. The programme to achieve this should be commenced as soon as possible.

Stand, Stock and other tables:

A range of PSP summary tables have been arranged in integrated data base. The programmes for these can provide outputs for a range of aggregations of PSPs and a range of stratifications. A series of these summaries is reported in Sarker (1995) based on individual plots and also the total across all plots. The procedure is not designed to meet all planning needs but enables analysis from the IDB as needs arise.

For example it is common practice to produce tables for 5 cm diameter classes but information may be required at the 1 cm diameter level. This can be simply done by writing a new procedure. The consolidation of data can also be undertaken for any given situation. Table 22 is an example of some of the PSP results across all 69 measured plots.

Official consumption data are not available from the PSP's, only from departmental felling records.. The available records were only available at an aggregate level across the whole of the Sundarbans for the late 1980's. Information from later years can be obtained at the compartment level.

At present it is not possible to determine net growth between the 1986/87 and 1994/95 measurements at any level less than the total forest estate, a matter which will be rectified during the forthcoming inventory.

The IDB should be maintained and should provide summary information to any interested party. Information is only of real value when it is used and so the information should be readily available to the Forest Department and other staff working in the Sundarbans.

Table 22 Summary of PSP Results (all Plots) by 5 cm Diameter Classes

SPECIES	DIAMETER CLASSES								
	DESCRIPTION	>=5-10cm<=	>10-15cm<=	>15-20cm<=	>20-25cm<=	>25-30cm<=	>30-35cm<=	>35cm	TOTAL
Sundri	Stocking/ha	531 45	182 54	77 39	37 32	14 86	1.88	1.38	846.81
	Basal Area/ha	2 25	2 16	1 82	1.46	0.86	0.15	0.21	8.92
	Volume/ha	10 12	11 42	10 81	9.41	5.93	1.11	1.77	50.56
Gewa	Stocking/ha	790 22	267 54	39 35	3 84	0.22	0.07	0.07	1101.30
	Basal Area/ha	3 41	3 00	0.86	0.15	0.01	0.01	0.01	7.45
	Volume/ha	16 14	15 53	4 56	0.77	0.07	0.04	0.05	37.16
Timber	Stocking/ha	5 36	5 00	5 29	4.49	2.90	2.03	2.75	27.83
	Basal Area/ha	0 03	0 06	0 13	0.18	0.16	0.17	0.62	1.35
	Volume/ha	0 11	0 29	0.67	1.01	0.95	1.14	3.25	7.43
FWD	Stocking/ha	24 06	1 38	0 29	0.07	0.00	0.00	0.00	25.80
	Basal Area/ha	0 09	0 01	0 01	0.00	0.00	0.00	0.00	0.11
	Volume/ha	0 18	0 04	0 02	0.01	0.00	0.00	0.00	0.26
Total	Stocking/ha	1351 09	456 45	122 32	45.72	17.97	3.99	4.20	2001.74
	Basal Area/ha	5 78	5.24	2 82	1.79	1.04	0.33	0.84	17.83
	Volume/ha	26 56	27 28	16 07	11 20	6.95	2.29	5.07	95.41

Grouping includes: Sundri
Gewa
Timber Species - Baen, Dhundal, Keora, Kankra and Passur
Fire Wood Species - All other species

It should be noted that:

- Forestal and ODA had many more plots, but they had extremely limited growth information.
- The analysis of the PSP data provides a better estimate of growth and ingrowth and an estimate of unofficial consumption which included mortality, missing trees and also any illegally felled trees.
- This analysis does not provide a good estimate of the growing stock in the forest.
- The PSP data base does provide a good basis for the development of some indicative forest mensurational models but samples were insufficient.
- The PSP's have been maintained for calculation of growth. Unfortunately they can only provide a biased estimate of the forest since they should not have had any consumption.
- The PSP's can be regarded as an unbiased sample of the SRF in 1986/87 but this was not tenable in 1994/95.
- There is a need for a series of plots in areas where official harvesting has taken place accompanied by a full forest inventory.
- At 1994/95 there was no suitable data base to determine net change in the SRF.
- Inferences made in this plan must necessarily be inexact.
- The PSP data base is just one section of the IDB. Within the PSP part of the main data base there are two streams, textural and the formal mensurational data base.

In the face of the serious deficiencies in the existing research system, proposals are made to measure a mixture of PSP's and Temporary Sample Plots (TSP's) with the current 120 PSP's being augmented by a relatively few extra plots and a new TSP system including approximately 1300-1900 plots on a 1 minute systematic grid is defined.

The approach proposes utilisation of two types of plots :

(1) PSP's to provide precise detailed remeasurements of the site and which can include research trials where different silvicultural practices may be tried and evaluated. The information should cover a far wider range of silvicultural and management conditions than is likely to occur in practice. They are therefore not necessarily typical of the current forest estate.

(2) TSPs where information would be collected on a systematic continuous basis over a larger number of plots.

The PSP's can be sited to achieve homogeneity, the TSP's must be measured on the exact location and will be heterogeneous.

Recommendations are made to remeasure all 120 PSP's in the future as they will provide a sound data base for growth model development and when opportunity permits some PSP's should be remeasured to provide control validation and enable a precision estimate to be made.

9.1.5.2 Systematic sampling and TSPs

With increasing demands being made upon managers for up to date and accurate information on the statuses of all resources, decisions must be made upon the most appropriate means for sound and practical sampling.

The alternatives approaches are :

- simple random sampling
- stratified random sampling
- systematic sampling

A simple random sample could be used but this is likely to provide a clumped distribution of plots and is not likely to be satisfactory. The advantage of stratified random sampling is that all strata are sampled and fewer plots need to be measured than with a systematic sample. Theoretically it is economically more efficient. The difficulty is that it is necessary to carry out the stratification before any TSP's are measured. This is not recommended for the management of the Sundarbans where rapid changes occur.

If a systematic sample is used then the whole area is evenly covered and provided that there is a reasonable number of TSP's in each strata, then good strata mean estimates can be obtained. However there is a chance that for a particular stratum there may be no TSP's present, or too few TSP's, which can cause difficulties with an analysis. By strict statistical standards there is a likelihood that some strata will be relatively over sampled, but given the likely range of stratifications to be evaluated this will not cause any serious economic disadvantage.

9.2 BFRI

The Bangladesh Forest Research Institute has its headquarters in Chittagong with a Mangrove Silviculture Division (MSD) based in Khulna since 1972 under the supervision of the Divisional Officer. The MSD endeavours to function as the research arm of the Forest Department for the SRF.

Past research has included :

- Seed production, germination success and seedling growth of major mangrove species
- Regeneration of major mangrove species
- Propagation of upland species
- Propagation, nursery management and planting techniques for Golpatta
- Flora and fauna associations
- Promotion techniques to facilitate natural regeneration of mangrove species

Future multi-disciplinary studies currently in hand :

- Top-dying of Sundri
- Establishment for an arboretum for endangered species as *ex situ* biodiversity conservation
- Broadly based studies on flora of the SRF following up on previous work
- Socio-economic studies

9.2.1 Khulna BFRI mangrove silviculture divisional MSD HQ

The MSD Khulna operates four research stations. There is a research station at Khulna with basic facilities and all are in need of improvement and equipping.

9.2.2 Dhangmari research station and Chittagong

The research station at Dhangmari is within easy reach of Khulna and is situated close to the Forest Station and adjacent to the FD buildings which were used as a research base for this plan. Although management from Chittagong appears to be anomalous, there is a clear opportunity here to introduce research collaboration in shared premises.

9.2.3 Munshiganj field station - MSD

This station operates as a seasonal base for MSD staff and requires development and up-grading. Again consideration should be given to including it in an ecology research field station network.

9.2.4 Bogi research station - MSD

The MSD station at Bogi on the eastern border of the SRF has been used as base for BFRI research for several years and it too would benefit from being properly equipped and fitted out for multi-disciplinary research.

9.3 Khulna University

Khulna University offers opportunities for academic contributions to research and monitoring initiatives providing a bridge between the public and private sectors. There are existing disciplines and programmes which overlap with proposed research for sustainable management which involve forestry, fisheries and socio-economic objectives. The university also has a GIS laboratory which could make a useful contribution to the Forest Department's long-term research. A most important aspect of academic research based at a local university is the opportunity this offers for continuity - an element frequently lacking in field research.

9.3.1 Forestry and Wood Technology Discipline

This discipline in the School of Life Science was established since 1992 and has a full academic programme which includes substantial fieldwork. Emphasis is placed upon environmental science, fuelwood and multipurpose tree species, remote sensing and application of computer technology in forestry. This too could thus make positive contribution to Sundarbans forest and timber resource research.

9.3.2 Marine Biology Discipline

This discipline is actively engaged in fishery research and has already assisted with work on the SRF fish stocks and fisheries management (Smith, 1995) Graduates are expected to contribute towards sustainable development and conservation of inland and marine fisheries resources.

9.3.3 Urban and Rural Planning Discipline

Planned spatial and co-ordinated development is essential to integrated resource management and with a fast growing peripheral population this aspect of rural development is now crucial. There is an obvious interface here for possible investment programmes in the Border Zone where the technical contribution to development by the FD, Department of the Environment, and other agencies could be co-ordinated with the help of the university in participatory approaches for improved production and alternative livelihood projects.

9.4 Bangladesh Water Development Board

The BWDB has an office in Khulna and undertakes hydrological studies and is also involved in project development and implementation for physical infrastructure, polders, embankments etc. The hydrological data collection sub-division provides an invaluable contribution to the South-west Regional Model data base and to knowledge of the characteristics of the catchment immediately upstream of the ecosystem.

9.5 Fisheries Department

Substantial research is carried out by the Fisheries Research Institute under the direction of the Fisheries Department and these activities cover both inland and offshore waters. The department engages in regular meetings and collaborative work with fisheries and aquaculture development projects throughout the country. There would be much to be gained if the FD were to be included in some of those connected with the river systems of the SRF and the Sundarbans offshore fishery, especially in order to establish research links for straddled stock and Marine Zone management.

9.6 Bangladesh Parjatan Corporation

Bangladesh Parjatan Corporation (BPC), also referred to as the National Tourism Organisation (NTO) , took on the official role of creating tourism facilities from the Government of Pakistan Tourism Development Corporation (PTDC) in 1972 and thus there has been a long history to the development of tourism in the country. It is only comparatively recently however, that tourism has been recognised as a potentially rich source of foreign exchange as well as an essential element in the well-being of the Nation.

In the past, development of tourism was thought to be the almost exclusive responsibility of BPC and it is only recently that there has been a growing emphasis on full Private Sector participation. It is now accepted that "tourism is a multi-sectoral industry" and that the private sector must be encouraged to invest in tourism independently or in joint ventures which might be "gradually handed over to the private sector" (GOB/NTO 1992).

A direct result of the historical attitude has been the lack of facilities in the Sundarbans now deemed to be the possible 'taking off point' for tourism in the country as a whole (GOB/NTO 1992).

BPC has its head Office in Dhaka and has no representation in Khulna. Proposals are made for formation of a Tourism Development Advisory Committee in which BPC would be a key member and which would meet regularly in Khulna as the main administrative centre for the development and promotion of SRF tourism. Market research and sharing of information on developments would be helpful in the creation of viable tourism products based upon the assets of the SRF.

9.7 IUCN and National Conservation Strategy

The International Union for the Conservation of Nature (IUCN) or World Conservation Union, works through its regional office in Bangkok and country representation in Dhaka to encourage and assist in the conservation of nature and aims to achieve the use of natural resources in an equitable and sustainable way.

Nature conservation and development of the SRF falls within the scope of the IUCN Wetlands Programme which co-ordinates and reinforces activities concerned with wetland ecosystems. The core of the programme is a series of field projects which develop methodologies for wetland management especially for places, such as the Sundarbans, where wetlands are used intensively by local communities for their livelihood.

IUCN is referred to specifically during the inception of this plan as a key participant in conservation activities. Objectives which were set out included baseline studies on important species, specifically examining their distribution, population and habitat requirements with preparation of a distribution map; linkages with the IUCN were to be maintained to ensure better ways and means of conserving and protecting wildlife and the overall balance in the ecosystem. This was carried out as far as possible and publication in 1994 of the IUCN handbook on the Mangroves of the Sundarbans of India and Bangladesh (Hussain and Acharya ed. IUCN 1994) underlined the absolute need for IUCN to remain an active and leading participant in SRF wildlife conservation strategies.

Proposals are made for IUCN to be a full member of the Integrated Management Committee (IMC) and STDC advisory committees on the integrated management of the SRF and on tourism development. A key function should be independent monitoring and evaluation and ecosystem audit.

National Conservation Strategy:

The rationale for a national conservation strategy (NCS) is set out in the draft NCS document "Towards Sustainable Development", The National Conservation Strategy of Bangladesh, (MOEF, 1991) which states, " The extremely high population density has contributed to the intense exploitation and in many cases over-exploitation of natural resources like forests, fisheries, land and water" and thus " ... resource utilisation must follow a strategy so that it continues to provide for the present as well as the future". The report draws attention to the need to take action to stem the depletion of resources in the SR. and specifically to the problems connected with Top-dying of Sundri and supply of Gewa to KNM and fuelwood to meet growing demand.

9.8 Soil Resources Development Institute

The SW regional office for SRDI is based at Khulna and further collaborative work on deltaic soils, especially in the areas immediately adjoining the SRF should be encouraged to build on existing baseline information.

9.9 Research at KNM

KNM conducts its own research programme on growth and yield of Gewa on which it bases its views on the sustainabilty of the current Gewa quota. This work should be fully integrated in BFRI and continuous surveys which should follow the FRMP inventory studies 1995/96.

9.9.1 Research at Bangladesh Forest Industries Development Corporation - BFIDC

Discussions with BFIDC indicated that better utilisation of timber from the SRF might be expected, especially for REB poles and furniture production, if BFIDC could undertake some practical trials to determine the costs and effects of proper seasoning and treatment on different species. Better utilisation and diversification might be expected. This is another area where more collaboration between the FD and the users of SRF produce could be mutually beneficial as well as of benefit to the economy (Larsen, 1994).

9.9.2 Research at Bangladesh Small and Cottage Industries Corporation

Further contact should be encouraged in future between the FD NWFPs development wing and BSCIC to seek new products and better utilisation of produce (Shiva, 1994). This applies especially to handicrafts and apiculture which offer many opportunities for income generation for women and new avenues of employment through diversification of cottage industries. The FD could play a leading role in this regard by better liaison with BSCIC Khulna office and through active collaboration with NGO's who work with women's groups in the border zone.

9.9.3 Coastal Area Resource Development and Management Association - CARDMA

CARDMA is an association of parliamentarians of coastal constituencies assisted by technical experts which serves as an interest group to the Special Parliamentary Committee for Coastal Development and the Environment. Workshops have been held on resource management issues of the coastal area including an international conference on the greenhouse effect and sea level rise (CARDMA, 1989).

9.9.4 Flood Action Plan - FAP

The Flood Action Plan (FAP) was initiated after the severe floods which occurred in 1987 and 1988 with ensuing bilateral and multilateral studies. It was realised that existing technical, economic and environmental information were inadequate to make decisions on options for long-term comprehensive flood management. (GOB, 1994). A comprehensive range of 26 bi-lateral aid funded research and feasibility studies was initiated, many of which included matters of direct concern to the SRF.

10 THE WOOD RESOURCE

The Wood Resource is defined as the source of products arising from the woody parts of trees. Timber and firewood are included but other products harvested from trees such as leaves, bark, dyes and sap are excluded. The latter are included amongst Non-Wood Resources. Understanding the position of the wood resources in ecosystem management is of prime importance to sustainable management of the forest.

Section 10 summarises extensive studies which were undertaken for the plan especially to provide information on comparison between the past and present situations and to provide guidelines for future inventory studies and reforms in management.

10.1 Production Forest Types, Areas and Site Quality Classes

The production forest is that part of the forest which is set aside for the production of timber and other resources. The production forest is zoned separately from sanctuary and conservation areas and is sub-divided for different administrative and management purposes as follows:

- Working Circles
- Felling Series
- Ranges
- Compartments
- Coupes
- Sub-compartments
- Forest Types

The main Forest Types that occur in the Sundarbans Reserved Forest are described by floristic and ecological characteristics in 4.4. For production and timber volume estimation purposes it is also useful to divide the forest into different areas of similar species mixtures and or quality of the trees. **Table 15 is derived from the GIS data (1995) and is the first step towards moving away from traditional laborious and inflexible methods of stratification to rapid computer based data management. The table provides exact areas and polygon frequency for each "Forest Type" as defined by ODA (1985). These GIS data serve as a baseline for all future inventory research and both strata type and level of resolution can be infinitely altered and up-dated at any time to suit management needs.**

In the early working plans the forest was divided geographically into areas or felling series by Heinig,(1892); Lloyd, (1904); and Farrington, (1906). Trafford, in 1911, divided the whole forest into two working circles : the Sundri or Eastern Working Circle and the Western Working Circle. Curtis in 1933 stratified the forest on his perception of salinity in different areas. The forest was organised as 5 working circles. The three which eventually remained in Bangladesh were : Freshwater, Moderately Saltwater, and Goran working circles. The Freshwater and Moderately Saltwater Working Circles were geographically distinct but the Goran Working Circle overlapped the others.

The Choudhury plan covered the period 1960 to 1980. In this previous Working Circles were abolished and the forest was divided into the Sundri Working Circle, the Gewa Working Circle and the Keora Working Circle. The Sundri and Gewa Working Circles covered the entire forest. The Keora Working Circle covered discrete patches of forest where this species occurs in pure stands.

The Forest is administered and managed on the basis of four ranges each having its own Compartments (see Map 10) :

(1) Chandpai
(2) Khulna
(3) Satkhira (combining Burigoalini and Kadamtala)
(4) Sharankola

The area is further divided into 55 numbered Compartments of sizes physically suited for treatment as single units. Some Compartments have been further divided into sub-compartments. Range and compartment boundaries usually follow natural boundaries. Whilst Compartments do not overlap it is possible for one Compartment to be in more than one Working Circle.

Management is arranged as follows:

- A Working Circle is sub-divided into a series of Compartments for silvicultural operations over a prescribed time period referred to as a Coupe.
- A Felling Series lists Compartments designated for felling over a specified period.
- Other Series may be considered for other silvicultural operations.
- Planting Series
- Cleaning Series
- Thinning Series.
- An Annual Coupe for a Felling Series signifies the sum of the areas to be cut.

To estimate total standing volume of trees it is essential to stratify the forest into areas of similar forest. The Forestal inventory 1957- 1959 divided the SRF into 8 Forest Types derived from aerial photo interpretation of photos taken in 1958 with subsequent ground truthing. This stratification was based on recognition of dominant tree species (Forestal, 1960). The Forest Types were aggregated into 8 Sampling Blocks to facilitate sampling.

During the ODA inventory fieldwork of 1981 -1983, 14 basic forest types based on woody species dominance and 3 categories of non-forest areas were recognised. These were further subdivided by height class and canopy closure. A total of 302 categories of forest were identified and mapped by addition of some minor floristic differences and the presence or absence of scattered overstorey trees. This stratification was based on 1981 aerial photography for the whole of the SRF except the western edge where 1974-75 aerial photographs were used. The Forest Type maps were produced at a scale of 1:50 000 on ten separate sheets. The results were presented by Forest Types and Sampling Block. These were summarised to produce block and total volumes (Chaffey **et al**, 1985). See Appendix A 28.

Table 23 presents a comparison of the major Forest Types and changes detected between Forestal and ODA estimates. It should be noted that when interpreting these figures the Forest Types were not stratified by the same methods and that the definitions for the Forest Types are similar but not identical. Accordingly, percentages and not areas are quoted. The most obvious conclusion is the decrease in pure Sundri forest and increase in Sundri - Gewa forest. **This has major implications with regard to the total value and the level of production from the forest**. There is also a decrease in the amount of land classified as Keora forest. According to ODA this was possibly due to successional change to other forest types and the reduction in areas of accretion for colonisation by Keora.

Table 23 Percentage area of main Forest Types classified by Forestal (1959) and ODA (1984)

Forest Type	Species composition (%)		Area expressed as a percentage of the total Forest Area (%) Forestal	ODA	Difference
Sundri	Sundri	75+	31.6	21	-10.6
Sundri-Gewa	Sundri	50-74	24.4	29.7	5.3
	Gewa	26-50			
Sundri-Passur#	Sundri	50-74	0	0.5	0.5
	Passur	26-50			
Sundri-Passur -Kankra	Sundri	26-50	2.4	1.6	-0.8
	Passur	20-40			
	Kankra	20-40			
Gewa*	Gewa	75+	3.3	4.9	1.6
Gewa-Goran	Gewa	50-74	8.6	9.2	0.6
	Goran	26-50			
Gewa-Sundri	Sundri	26-50	15.6	14.8	-0.8
	Gewa	50-74			
Goran#	Goran	75+	0.7	2.3	1.6
Goran-Gewa#	Goran	50-74	11.3	14.6	3.3
	Gewa	26-50			
Passur-Kankra#	Passur	40-60	0	0.3	0.3
	Kankra	40-60			
Passur-Kankra- Baen#	Passur	20-40	0	0.2	0.2
	Kankra	20-40			
	Baen	20-40			
Baen	Baen	90+	0.2	0.1	-0.1
Keora	Keora	90+	1.9	0.8	-1.1

* includes Gewa mathal, which comprises virtually pure stands of widely spaced Gewa coppice
# Forest type not included in the Forestal assessment (Mitchell, 1995).

The ODA Forest Type data have been added to the GIS data base and have now been digitised and overlaid on updated baseline data taken from 1989 SPOT imagery. These Forest Type maps are provided in hard copy in Volume 3 and the data are stored in the IDB. .Text map 16 shows a summary of the major Forest Types as recognised by the IRMP. Extraction is not permitted in the Wildlife Sanctuaries This reduces the area available for production forestry. Table 24 makes a comparison of these areas.

In addition to recognising Forest Types estimates of site quality can be made to give an indication of size and productivity or growth rates of various species. The first determination of site quality was undertaken by Curtis (1933) who defined site quality classes in terms of the average maximum height of trees at or approaching maturity as follows:

Site Quality Class	Average Maximum Tree Height
1	50' and above
2	35 - 49'
3	20 - 34'
4	less than 20'

The site class classification was used as a management tool to specify the minimum exploitable diameters for each species which were increased for better quality stands.

Forestal and ODA also recognised site classes. Forestal followed Curtis but added an extra sub class in Class 3 to allow for the inclusion of Site Class 3a : for trees of 20' - 24' average maximum height. This accommodated large volumes of trees identified in aerial photo interpretation in the western and south western compartments.

ODA further sub-divided the Sundri and Gewa Forest Types into height classes by inspection of tree height data . The height classes recognised were as follows:

Height Class	Top Height
1	≥15m and above (49' approx)
2	≥10 - <15m (33 - 49' approx)
3	≥5 - <10m (16 - 33' approx)
4	<5m (16' approx)

The top height was defined by ODA as the tallest trees in the vicinity of the plots they measured.

Table 24 Areas of Forest Types : SRF 09/95

(Mitchell, 1995)

Forest Types	Area Km²		
	Production Forest	Wildlife Sanctuary	Total
Sundri	827.17	1.28	828.45
Sundri - Gewa	1139.54	92.93	1232.47
Sundri - Passur	22.14	0	22.14
Sundri - Passur - Kankra	67.99	0	67.99
Gewa	166.88	18.68	185.56
Gewa - Sundri	556.19	43.54	599.73
Gewa - Goran	326.48	49.45	375.93
Gewa - Mathal	8.36	0	8.36
Goran - Gewa	524.36	51.61	575.97
Goran	70.46	16.60	87.06
Passur-Kankra	9.40	0	9.40
Passur - Kankra - Baen	16.14	0	16.14
Baen	3.87	4.41	8.28
Keora	26.27	8.82	35.09
Other	3.51	0	3.51
Sub total	3768.76	287.32	4056.08
Non-forest land	41.05	5.25	46.30
Sand bars	31.42	8.82	40.24
Total Land Area	3841.23	301.29	4142.62

Plantations

Within the Sundarbans Reserved Forest since 1976 various plantations have been established (see section 10.4.4). Table 25 summarises plantation areas. Reference should be made to Karim (1995) for a comprehensive review. It should be stressed that the plantations have not been adequately inventoried and an assessment of their growth rates has not been made.

Table 25 Area of Plantations in SRF by Range as at the end of 1993-94

[illegible]	[illegible]
Satkhira	88.47
Khulna	353.39
Sharankhola	466.63
Chandpai	302.41
Total	1211.40

Source: FD records - plantation journals

10.2 Wood resources inventory

There have been three systematic inventories carried for the SRF :

(1) Curtis with field work during the period 1928 to 1931 for the working plan which covered the entire period 1931 to 1951.
(2) Forestal 1957 3 to 1959
(3) ODA 1981 to 1983

10.2.1 The Curtis inventory 1933

This inventory is discussed at some length since it has been taken to be one of the most accurate and useful sources of data for production forest management ever since it was produced some sixty years ago. The grid maps continue to be used to define, record and monitor annual harvests.

Sampling was based upon a systematic methodology. Line enumerations were made at 1 or 1.5 mile intervals in an East to West direction. The line strips were 11 feet wide and every tree of greater than 3" in diameter within the strips were measured. Sub-plots were used to assess smaller trees and regeneration. All measurements were recorded with the site quality class of the area and the predominant forest type. A total of 2 122 miles (3 397 Km) of line enumeration was undertaken with a high standard of accuracy of 0.11%.

To estimate standing volumes per acre for a given site quality and forest type, volume tables were developed which predicted volume from diameter at a height of 4'6" (slightly higher than breast height which is 1.3m or 4'3" approximately). The volume tables were based on sample fellings of trees which were measured using the quarter girth method developed by Hoppus. In effect the Curtis tables use diameter in inches to predict volume of timber in Hoppus cubic feet over bark. **Care should therefore be taken when comparing Curtis's volumes with other inventories which have tended to use true volumes underbark either in imperial or metric units.**

Curtis differentiated between volume tables based on actual measurements and those which were estimated. Most of the information on Sundri and Gewa are based on actual measurements but for other species, such as Keora and Baen, the figures are assumed. All the figures for all classes of Kankra are assumed.

The Sundri Volume Tables which had been previously derived by Parma Nand Suri (1928) were rejected as the data were taken from areas which did not correspond to Curtis's working circles or site quality classes. Curtis did not make estimates of the total standing volume of timber in the SRF.

Estimates of growth rates for Sundri for site quality classes 1 and 2 were made by analysis of 14 ample plots which had been laid out during the period 1893 to 1911, and 10 more in the year 1916-1917. Unfortunately due to difficulties in measurement caused by buttressing, the earlier plots were abandoned in 1912. An additional plot was set up in 1928 to ensure adequate coverage of the poorer site qualities.

Curtis used growth data from all of these plots to make estimates of Sundri diameter increments. From this he calculated the time it would take average trees for a given site quality to grow through the different size classes. By assuming the time it took for trees to reach the first diameter class it was possible to graphically plot age against diameter. From this he could see how long it took for trees to reach a certain size. By prescribing minimum diameter cutting limits it was possible to calculate a recommended cutting cycle. From this and the stocking and volume assessments he was able to calculate the yield and annual allowable cut.

To assess the growth rates of Gewa the annual rings were analysed. All sample trees came from second quality forest. A similar exercise was carried out for Keora and Baen. These data were used to calculate the felling cycle and yields. Curtis recognised that the growth rings, particularly of Gewa are difficult to see and noted that the average time it took for second quality Gewa to reach 10 inches in diameter was 74 years but because of the doubtful quality of the data assumed that Gewa would take 100 years to attain a diameter of 10 inches. Trees from other site qualities were given assumed periods of growth through the diameter classes.

One of the biggest contributions made by Curtis was production of detailed stock maps which are still in used by forest managers. These maps were based on enlargements of the survey undertaken in 1905 - 1908. As far as possible these maps were updated during the enumeration to show new accretion or erosion either by use of the enumeration lines, triangulation or by eye. The details of the stock were taken from the results of the enumeration and 'personal reconnaissance'.

10.2.2 The Forestal Inventory 1960

The next major assessment of wood resources of the SRF was made by Forestal during the period 1957 to 1960. (Forestal, 1960). This inventory was based on aerial photography (1958) and statistically controlled stratified random field sampling. The main purpose was to provide the data required for the preparation of felling prescriptions and a working plan for the Khulna Newsprint Mill. During the feasibility study the mill's anticipated requirement for Gewa pulpwood was 3.2 m cft per year. This was deemed to be harvestable on a sustained yield basis. The Mill and the inventory were both completed in 1960.

The forest was classified into 8 main different forest types and also by Height Classes which corresponded to the definition, but not the same areas of Curtis's Site Quality Class distribution. The density of the forest types, expressed as canopy closure, was also estimated. The information was recorded on full colour maps at scale 1 : 50 000 - see Appendix A 28.

The SRF was sub-divided into eight sampling blocks which defined on a large scale the main differences between site quality and species composition. The intensity of sampling was designed so that the average coefficient of variation for each strata (depending on the block) would be between 20 and 25%. A total of number of 1 132, one-tenth acre (0.04 ha) plots were selected randomly within the Forest Type strata and measured. In some exceptional instances the plot size was either doubled in sparse stands or halved in dense ones, to contain between 50 - 150 main canopy trees.

At each plot all living trees of 0.5" dbh were measured and recorded in 1 inch diameter classes. Adjacent to each plot four (subsequently reduced to 2)a total of 1 123 sample trees (preferably in the proportions of two Gewa, one Sundri and one of another species) had the dbh recorded and were then felled and measured to give the diameters of four foot billets, the total bole length and the total tree height. Defect in the sample trees was recorded and sample discs were cut from various points up the stem. In some areas which had been cut over at least ten years previously some additional sample trees were felled.

From the field sampling it was possible to calculate the growing stock for the given stratifications. The felled sample tree measurements were used to calculate the volume to four different specifications (i.e. total stem volume including stump, stem volume excluding stump to 2, 3 and 4 inches top diameter under bark) by the Smalian formula (the average cross-sectional area multiplied by the length). Least sum squares regression was then used to develop equations to predict volume for Gewa and Sundri for the different site classes and Keora for all site classes. Equations to predict height from dbh and site class were also produced. Deduction factors for the percentage of defect for a given species and the different volume utilisations were incorporated.

For other timber species the tables developed by Curtis were modified. It would appear that Forestal added the volume of timber and firewood as quoted by Curtis and averaged the volumes over the size classes to fit their different diameter classes. A difficulty in making comparisons is that a tree measured by the Hoppus method used by Curtis measures only 79% of the same tree measured in true cubic feet.

Age and growth rate estimation was done by analysis of growth rings. This was found to be unsatisfactory especially for Gewa, as the rings for this species are indistinct. Additionally analysis was undertaken of some permanent sample plots which were established between 1931 and 1946. The growth figures for Gewa and Sundri were used to determine the yield and AAC through stand projection. For other species the AAC was determined by using Von Mantel's formula.

10.2.3 The ODA inventory 1985

The ODA inventory was also a stratified random sample with the stratification again based on air photo interpretation. The whole area, except for the western edge, was flown in December 1981. For the western edge photography from 1974-75 was used. ODA also based their sampling on the 8 blocks derived by Forestal but further sub-divided block 5 into 5A and 5B to accommodate two clearly visible vegetation types.

ODA measured 2 099 plots with two different plot designs; one circular having an area of 0.03 ha and the other rectangular, 0.2 ha in size. All live trees with a dbh of 5 cm or greater were measured and recorded in one centimetre classes. Sub plots were put into measure regeneration and fuelwood. As well as recording diameter, three stem quality classes were recorded; Transmission Pole quality (for Sundri and Kankra - to give a 7 metre clean stem); Sawlog quality; and, Fuelwood. At each sample location heights were measured on the basis of the tallest in the vicinity. Observations were made on the extent of Sundri top dying and limited soil sampling was undertaken. Herbarium specimens were made for 65 species of woody plants and these were classified from which a key for the trees of the Sundarbans was developed.

It appears that ODA rejected the volume equations developed by Forestal as the sample trees were measured by dividing the stems into 4 foot billets, considered valid for assessing pulpwood but not timber. New volume regressions were therefore calculated from data derived by felling 320 trees of Sundri, Gewa and Keora, selected so that there was a range of trees across the diameter and height classes. Volume equations were developed in metric units, for Sundri, Gewa and Keora for the different site classes. These were used to predict the volume under bark to 10 cm underbark top diameter from dbh overbark. Separate equations were developed for crownwood volumes for sizes down to 5cm underbark. Equations for the other species were developed but these were based on the volume tables in Forestal's report.

Increment studies were undertaken by analysis of rings combined with analysis of twelve small (0.04 ha) permanent sample plots (PSPs) which had been established in 1977.

ODA recommended that a new working plan should be prepared based on their results to establish a sustainable annual allowable cut. Following evidence of over cutting, tentative proposals were made on the level of the AAC based on Von Mantel's formula. Ultimately their recommendations were not followed and the consequences led to the imposition of the moratorium.

10.2.4 Comparison of inventories

Table 26 presents the mean volume per hectare and total standing volume as estimated by Forestal and ODA for Sundri and Gewa. Comparison between the ODA interpretation of the Forestal figures indicates an inexplicable discrepancy. ODA mention that the figures do not include allowances for defect. The table used to compare these figures in Forestal's original report did include allowances for defect and anomalies veer between being higher and lower than the figures presented by ODA (Mitchell, 1995).

Table 26 Volume/ha and Total Standing Volume as Estimated by Forestal (1959) and ODA (1984)

Species	Mean Volume/ha (m^3/ha)		Total standing volume (millions m^3)	
	Forestal 1959*	ODA 1983#	Forestal 1959*	ODA 1983#
Sundri	34.5	19.9	13.04	7.87
Gewa	8.7	4.6	3.30	1.82

* Forestal volumes are for all Sundri over 14.2 cm dbh and all Gewa 11.7 cm dbh

ODA volumes are for all Sundri over 15.0 cm dbh and for all Gewa 12.0 cm dbh
Source: Chaffey **et al**, 1985

Table 27 compares the growth estimates made by Forestal and ODA.

Table 27 Growth rates of Gewa and Sundri as estimated by Forestal and ODA

Species	Annual Volume Increment m^3/ha/yr	
	Forestal	ODA
Sundri	0.71	0.6
Gewa	0.61	0.8
Total	1.32	1.4

The growth figures in Table 27 show that the two estimates to be fairly similar, yet Table 26 clearly shows a large difference in the timber volume estimates. **From these figures it would appear that there had been a vast depletion in the standing volume. Unfortunately the two inventories did not follow the same methodology. Different volume equations were used and different assumptions made. Therefore the two sets of data are not strictly comparable.**

The objectives of the two inventories were different. The Forestal inventory was designed mainly to assess the Gewa stock whilst ODA's aimed to determine total growing stock. The stratifications required to achieve these goals were similar but not the same.

ODA compensated for this source of bias by reassessment of field data for stocking and basal area, using Forestal's Forest Types and also Forestal's Imperial diameter classes. Accordingly the differences between the stocking and basal areas of the two inventories for specific blocks should be valid. The comparison showed that there was a significant drop in the number of stems per hectare and that this was spread more or less evenly throughout the size classes for both Gewa and Sundri. **This unequivocally confirmed the decrease in the growing stocks between the two inventories.**

On the other hand the ODA figures for the 1983 mean and total volume, are based on the results of ODA's own stratification, based on their own volume equations. It is seems likely that some of the difference in the volume figures might be due to the equations and assumptions on merchantability.

ODA used logarithmic transformed volume equations but as Leech (1995) notes there are typing errors, structural difficulties and no certainty that the different regressions for the different height classes are not significantly different and could not have been aggregated into a lesser number of equations. Leech (1995) also notes that the ODA equations use logarithmic transformations of poorly structured equation types that would cause a logarithmic bias for which no correction appears to have been made.

An inspection of the ODA felled tree information (see ODA 1985 figure 10)indicates that the bias caused by this alone could well be 20 to 30%. The ODA conclusion number 1 that the "depletion in merchantable standing volume is of the order of 40% for Sundri", is therefore questioned but it does not detract from the fact that there was undoubtedly serious depletion based in numbers per hectare and basal areas.

For Gewa, ODA concluded that there had been a depletion of 45% of the volume between the two inventories. Observations by KNM suggest that they consistently obtain more volume than the ODA estimates. This can be attributed to growth, between ODA's inventory and felling and to the fact that KNM extract timber to a top diameter of 7cm over bark, whereas ODA estimated the volume to 10cm under bark top diameter. Using equations developed by Leech (1995) for a 15cm diameter tree this difference in top diameter alone would give a bias of 15% to 16%. For the minimum extractable tree diameter this would probably be greater.

Additionally ODA made assumptions about the quality of the stems which were measured. The stems were divided into three stem quality classes but it appears that the volume of crownwood was only included for the timber quality trees but excluded for fuelwood quality trees (Chaffey *et al*, 1985 - Appendix VII). This is unusual as it is common practice in Bangladesh for all firewood trees to be utilised well beyond the minimum diameter limits set by any inventory. It was assumed that stems classed as defective for timber but utilizable for firewood would only have 70% of the volume of the equivalent sound tree. The basis for making this assumption is not stated.

Both ODA and Forestal make allowances for defect (rot and crook) in the stems. Forestal did not differentiate between stems by quality class. Therefore greater allowances were made for defect the figures were not separated from the total figure. It may be more appropriate to compare ODA's figure with the addition of the firewood with Forestal's total figure.

Clearly, whilst the comparison of the two inventories is difficult and the conclusions drawn by ODA probably overstated the case for depletion, there has undoubtedly been a significant reduction since 1960, of the total standing stock (Leech, 1995).

Discussion:

All the past inventories have stratified the forest. The forest had to be stratified before the plots were put in. Once the stratification was decided upon it had to be final. In these inventories stratification could only be at one level; alternative levels of data processing were not possible. This is acceptable procedure for the purpose for which the inventories were intended. Problems arise when a different level of stratification is required. Accordingly whilst the last two inventories met their own particular objectives they were less effective for practical management.

The previous inventories also had limited growth data in terms of the number and extent of the permanent sample plots (PSPs) available and in some cases (notably ODA) the short period over which they had been measured. All three inventories have tried to make growth estimates based on ring counts. All three inventories also state the constraints for tropical species in general and with Gewa in particular.

For this plan the lack of maintenance of PSPs has seriously hampered the production of accurate assessments of growth and yield. Lack of continuous PSP measurement has meant also that in the past it has not been possible to monitor the pattern of forest development. The last two inventories especially have been project based and had the disadvantage of not having well established and maintained representative PSPs of the requisite number and size.

10.3 Annual Allowable Cut

Management of forests on a basis of sustained yield requires that removal of forest produce should occur at a level which would not adversely effect growth potentials. The AAC should be equal to or less than the theoretical annual sustained yield.

Calculation of the AAC was done in the past by dividing a specific area by the number of years in an assumed rotation. This provides a measure of the area that could be cut each year and management was geared to ensure that no more than the set areas were cut. By the time Curtis undertook his inventory it was realised that this method produced irregular harvests as some areas would obviously yield far more than others. A method for calculating estimates of growing stock and growth rates was therefore introduced to help determine a logical cutting rotation for each kind of site to produce the required yield per unit area. Curtis recommended that the control of the AAC should be done not only by area but should include, for the major timber species, control by volume.

Forestal used stand projections for Gewa and Sundri. This is a crude formula which calculates the annual yield by doubling the estimate of the standing stock and dividing that by an assumed rotation. The working plan written by Choudhury that followed the Forestal inventory based the AAC on a modified version of the Hanzlik formula which estimates the AAC by dividing the total standing stock by the rotation and adding the annual increment.

Subsequently control of felling reverted to checks by area alone but with a margin of plus or minus 300 acres allowed per cutting section to help smooth the volume outputs. ODA also used this method to make recommendations on the AAC. Balmforth (1985) used a mixture of the Von Mantel and Hanzlik formulas.

Currently there is no AAC on account of the moratorium. In future, with modern modelling techniques, the advent of GIS and remote sensing technology, the old and crude methods of calculating the AAC will not be appropriate and new techniques using sensitivity analyses will be used to assess the impact, and therefore sustainablity, of different cutting regimes for different areas.

History:

In the first working plan, which covered the years 1893 - 1903, the average annual allowable cut, controlled by area, covered some 75 000 acres. This was estimated to yield between 1 and 2 million cft of timber and around 11 million cft of firewood. In those days the control of harvesting only covered all species in certain areas. In some areas the uncontrolled felling of firewood of some species continued to be permitted (Heinig, 1892).

The plans prepared during the period 1903 to 1931 : Lloyd, 1904; Farrington, 1906; and Trafford 1911 kept production at around the level of the first plan until the Curtis Working Plan for the period 1931 to 1951 was prepared. In this plan the annual cut was still controlled by area and the AAC was set at 68 600 acres. The Sundri, Gewa and Passur cut was additionally controlled by volume. The total annual yield of timber for all species was estimated to be 7.6 million Hp cft. The Curtis Working Plan was found to be too elaborate to follow and several interim management plans based on his proposals were introduced. This practice continued until the plan for the period 1960-61 to 1979-80 was prepared. By Choudhury (1964).

The Khulna Newsprint Mill's original allocation of Gewa was 675 060 acres to which a further 147 530 acres was added to supply the match factories. Subsequently the area was reduced for the establishment of Sundarbans South Wildlife Sanctuary . The current area licensed to KNM is 764 020 acres (309 320 ha).

These areas are harvested by preparing five year felling plans prepared by KNM and approved by the FD and MOEF. In terms of volume, initially the AAC for KNM and the match factories was set at 5 million true cft and 1.2 million cft per annum respectively (Hussain et al, 1990).

In Choudhury's plan, which incorporated the KNM plan, the AAC was also controlled by area and the estimated yield set at 7.2 million cft of Sundri, 6.7 million cft of Gewa and 0.3 million cft of other timber species. This working plan continued until 1980 but in the later years was not fully implemented due to felling restrictions imposed after the war of liberation. The forest was still being managed according to the Choudhury prescriptions at the time of the ODA inventory. Following the findings of the ODA it was recommended that the AAC for Sundri should be reduced by 40% to 78 400 m^3 per annum (2.2 million Hp cft). and 57 000 m^3 (2 million true cft) for Gewa.

Later Interim Felling Prescriptions for the Sundarbans Forest were prepared. (Balmforth, 1985). This plan recommended that the Sundri AAC should be 141 000 m^3 (3.9 million Hp cft) and the Gewa AAC should be set at 91 000 m^3 (3.2 million true cft).

The prescriptions specified that the areas of Top-dying Sundri should be salvaged on a priority basis and that of a minimum diameter of 20 cm dbh should be strictly enforced to conserve the younger growing stock. The Gewa minimum diameter was recommended to be set at 12 cm dbh.

Following the ODA recommendations the FD did not approve the five year felling plan submitted by KNM in 1985 but the mill was allowed to carry on cutting at the previous rates pending further studies. KNM's AAC was subsequently reduced to 4.5 million true cft. (approximately 127 000 m^3) for the years 1987 to 1989.

In 1989, the Government introduced the first moratorium on the cutting of all timber from the natural forest reserves. To keep KNM running an exception was made for Gewa extraction and KNM was allowed to extract 3.2 million cft per annum. This continued until 1990 when a joint KNM and FD sampling was undertaken in some of the Gewa areas. .This revealed that the AAC could safely be set at 5.6 million true cft (approximately 160 000 m^3). An inter-ministerial meeting finally approved that KNM would be allowed to cut 4.7 million true cft per annum (approximately 133 000 m^3). (Hussain et al, 1990). A summary of the history of the AAC is presented in Table 28. .Care should be taken when comparing the figures as they were often not calculated in the same way and covered different areas.

Following the moratorium, the felling of Sundri was restricted to trees that had more than 50% of the crown dead due to top dying, now amended so that any tree exhibiting any sign of Top-dying may be harvested.

Table 28 History of the Annual Allowable Cut for the SRF by Working Plan or Author

(Mitchell, 1995)

Author	Period	Area Covered (Km²)	Species or Grade	AAC Area (Km²)	AAC Volume (m³ x 10³)	Remarks
Heinig	1893-1903	5418	all	304		Uncontrolled areas of firewood cutting was
			timber		42	allowed and not all timber species were
			firewood		156	covered by the plan.
Curtis	1931-1951	6003	all			Sundri, Gewa & Passur were controlled by
			timber	278	214	Volume as well as area.
			firewood	280		Some areas were to be cut twice in the plan period
Choudhury	1960-1980	4071				
			Sundri	224	204	Includes Passur Dhundal Baen & Kankra
			Keora	4	10	
			Gewa	160	165	KNM & match factory allowance
ODA	N/A	4016	Sundri		78	These were recommendations based on
			Gewa		57	the inventory undertaken from 1981-83
Balmforth	1985-90	4016	Sundri		141	Interim felling prescriptions based on the
			Gewa		91	ODA inventory
KNM	1986		Gewa		127	Inter-ministerial meeting adjustment of Gewa
GOB	1989		Sundri		0	Government moratorium introduced
			Gewa		91	- exception for Gewa
GOB	1990		Gewa		133	Inter-ministerial meeting

Note : table compiled in metric units to avoid confusion over Hoppus and true cubic feet.

Table 29 presents the officially recorded removals of timber since 1986-87 for firewood and timber combined. The figures and any apparent trends are discussed in further detail by Mitchell (1995).

Table 29 Timber and Firewood Removals from the SRF by Year (m^3 x 1000)

(Mitchell, 1995)

Species	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94
Sundri	74	116	110	66	21	48	92	36
Sundri B/wd	7	12	15	9	2	0	0	0
Kankra	1	2	3	1	0	1	0	0
Keora	4	1	1	1	0	0	0	0
Goran	27	26	23	23	23	16	20	69
Gewa	173	165	145	171	189	200	182	126
Baen	4	2	4	2	0	0	0	0
Amur	0	0	2	0	0	0	0	0
Singra	2	13	15	6	11	13	8	0
Others	1	0	71	9	14	9	11	12
Total	291	339	388	288	261	286	313	243

Source : FD records

Examination of Table 29 shows that even taking the moratorium into account the production of Sundri has exceeded the AAC as recommended by ODA in all but 3 years out of the eight but In all eight years the Sundri has been less than the level prescribed by Balmforth. Apart from 1993-94 the Gewa cut has exceeded the AACs recommended by all parties. The trends apparent from this table are discussed in greater detail by Mitchell (1995).

10.4 Silvicultural Systems

A silvicultural system is a set of management prescriptions made to achieve specific objectives of management and often results in forests of characteristic form. For example the silvicultural system of a plantation may be one of clear felling and replanting; this should produce blocks of even aged trees of a predetermined species mix. Details for the SRF were analysed by Mitchell (1995) and Karim (1995).

10.4.1 The Selection System

Timber has been cut in the SRF and managed under the Selection System with some exceptions such as the clearing of small areas for plantations and the moratorium. With the Selection System, scattered trees or small groups of trees of all sizes are removed so that the remaining forest comprises trees of all size classes. This creates an uneven aged type of forest in which all size classes should occur at all times and in all areas. After felling, natural regeneration should fill the gaps created and the forest should grow until the next harvest. This system should maintain forests of an uneven age structure with size classes mixed throughout. The process may follow annual cycles with the volume to be removed being fixed by rules of management covering the entire production forest (Matthews, 1989).

The Selection System has been implemented in the SRF by enforcement of the management rules set by the prevailing working plan. Generally, the fellings have been controlled by only allowing the felling of trees above certain diameter limits for each species in each site quality class with the proviso that a certain number of seed bearing trees should be left per unit area. In some areas marked poor quality trees below the set diameter limits are felled improve gradually the quality of the forest. In addition, limited amounts of thinning is undertaken in certain dense stands of a young crop. These adaptations led Curtis to term the SRF silvicultural system "Selection-cum-Improvement". This was not easy to follow and the system eventually reverted to one based solely on diameter limits. By the time the Choudhury plan came into operation it was no longer felt necessary to undertake thinning operations. (ODA, 1985).

Contrary to expectations, with long felling cycles and felling to girth limits the forest was found not to maintain an uneven size class structure and Chaffey *et al* (1985) noted that in most stands in the SRF there is usually a discontinuous set of two or three even aged classes.

Thus to maintain an uneven size structure, immature trees should be thinned at the same time as fellings of trees of exploitable size. This should be done on a fairly frequent cycle but to a light intensity. In large areas of low yielding forest, such as the SRF, it is too costly and impractical to undertake these operations on a frequent but light basis. This leads to more concentrated fellings of an accumulation of mature trees which have had the chance to grow during a longer time interval. Obviously a longer interval between fellings results in a larger volume per hectare available for removal.

Matthews (1989) recognised that, whilst this may have economic benefits the system may favour the regeneration of light demanding species, such as Gewa, through the creation of large gaps and many of the silvicultural benefits of the system are lost. Curtis(1933) noticed that Sundri seedlings will not establish themselves readily except under fairly heavy shade; if exposed, they dry off during the hot weather. The ingress of weed species such as ***Pandanus*** sp and ***Hibiscus*** sp could also be a serious problem. This phenomenon may be a contributing factor to the apparent decrease in the amount of pure Sundri forest as shown in Table 23 and the corresponding increase in the Gewa forest.

Some evidence on this controversial issue from KNM suggests that there is an increase in the proportion of Gewa in the forests that they are now working on the second cycle. Study of the PSPs indicate that when there is no official harvesting the proportion of Sundri remains constant and that the Gewa is only marginally increasing and at the expense of species other than Sundri. Currently the forest is only being worked on the selection system for Gewa by KNM. This unnatural successional problem should be quantified during photo interpretation in the forthcoming FRMP inventory.

Working Circles:

In the past the SRF was divided into Working Circles. The Working Circles were the basic unit of forest to be managed under the Selection System. Each Working Circle was sub divided into annual coupes or for a given felling cycle. It can be seen that for a given felling cycle each Working Circle should have been completely worked over.

Prior to Curtis, the SRF was divided into the Eastern or Sundri Working Circle and the Western Working Circle. Curtis divided the SRF into five Working Circles, three of which continue to be used:

- Freshwater Working Circle
- Moderately Saltwater Working Circle
- Goran Working Circle

The first two Circles were geographically distinct but the Goran Working Circle overlapped the other two. The Choudhury Working Plan redefined the Working Circles, creating the Gewa, Sundri, and Keora Working Circles. The Gewa Working Circle and the Sundri Working Circle each covered the whole forest and were thus superimposed over one another. The Keora Working Circle comprised the patches of Keora forest scattered throughout the SRF. Other forest resources such as other timber species, Goran and Golpatta were dealt with under the heading Miscellaneous Prescriptions. The felling cycles as described by Curtis and Choudhury were 20 years for all Working Circles.

10.4.2 Salvage Felling

An exception to the moratorium is the salvage felling of Top-dying Sundri. Initially, before the salvage could commence the affected areas were marked and trees which were declared to have more than 50% dead crown were selected for removal. This rule has been modified and for the past two years any tree showing the slightest symptom of top-dying may be removed. The argument for this was to utilise timber that has started to decay before it becomes completely rotten. Whilst there is obvious economic merit in the argument it is essential that care should be taken by senior technical staff to ensure proper control.

Top-dying

The top-dying of Sundri has been a much studied condition. Unfortunately the studies to date, apart from ODA (1985) have not been designed to quantify it, or even describe in detail its occurrence and extent. **This would require a systematic inventory and there is a strong case to do this as soon as possible. The extent and nature of the condition is highly variable (Ciesla, 1994). Although the proposed study will be time consuming and expensive it could become part of a continuous survey system thus achieving good economies of scale in the long run.**

It is thought that top-dying can affect all middle to old aged trees within a stand but that it is usually restricted to the larger individuals. The top-dying tends to affect the larger trees more than the smaller ones but it sometimes affects trees which are smaller than the diameter limits set in the Selection System. Generally, the yield from salvage felling tends to be less in terms of total volume and in size of stems than would be expected from the selection felling process.

The amount of Sundri regeneration appears to be variable in top dying areas, ranging from plentiful to zero. For management therefore salvage felling has serious implications. Should the tree cover be removed in areas where the Sundri is not regenerating and so encourage the establishment of other less valuable or weed species? There is some qualitative evidence that other valuable species such as Dhundal and Passur sometimes invade sites which have been lost to Top-dying. Other species such as ***Rhizphora*** sp could be artificially regenerated in these areas.

10.4.3 Goran

Goran ***Ceriops decandra*** is a small tree which covers large areas of the western part of the Forest. It is often found in nearly pure stands or as an understorey. Under the Choudhury Working Plan, Goran was worked in annual coupes within the Sundri Working Circle.

Goran is harvested by cutting in a cycle within a silvicultural system similar to cyclical coppicing. In the coppice system trees are cut at regular intervals and the stumps re-sprout to produce a number of new stems. Coppicing produces many small stems which can be cut on a short cycle. This is an ideal system for producing firewood and long thin poles or rods for artisanal purposes.

The prevailing harvesting rule requires that at least one stem or shoot is left per stool. Curtis (1933) noted that Goran does not readily re-coppice from a totally cut stool. Lack of experience and training among harvesters sometimes results in the worst stems for each stool being left and that many stools are damaged during extraction. Also sometimes the whole stool is dug out of the ground and removed. This in turn leads to the degrading of Goran areas to a state where most of the trees are stunted and twisted.

At present the felling cycle in each range is based upon the area seemingly available for Goran cutting which is surveyed and allocated annually with felling intervals dependent upon arbitrary regrowth.

10.4.4 Plantations

The extensive use of plantations for silviculture within the SRF has not been tested as a practical alternative to the selection system. Plantations have only been established on a pilot basis in a few areas. Currently there are just over 1200 ha of plantations of native and exotic species which have been established since 1976.

Unfortunately the status of these plantations has not been reviewed adequately. It appears that quality ranges from being well stocked to nearly non-existent mainly due to the lack of maintenance. The growth rates from these plantations have also not been properly assessed. Nursery techniques are known for many of the species which are being tried (BFRI, 1992) and the entire matter deserves further attention.

Three important factors point to the need for much more detailed consideration if the plantation system is to be expanded:

- Widespread and possibly increasing, occurrence of Top-dying Sundri accompanied by unrestricted harvesting and inadequate regeneration of commercially attractive species.
- Increasing siltation reported upon by the SWMC (1995). Wahid (1995) and Grepin (1995) causing a detrimental impact upon mangroves and the ecosystem in some places.
- Low growth rates of the natural forest.

There is every indication from existing trials that it would be feasible to increase commercial production of timber by investment in a development programme for plantations in suitable areas, particularly those affected by the conditions listed above. These programmes should only be undertaken if they are found to be financially viable. The whole matter should be the subject of high priority investigation.

10.5 Wood Products

The wood products for the main tree species are summarised here but are discussed in greater detail by Larsen (1994). The properties of some wood species are presented in Appendix A13.

10.5.1 Sundri

Sundri is the species for which the Bangladesh part of the Sundarbans is famous and despite intense selective pressure upon the species for over a century, it remains the most commonly occurring timber species in the SRF. The wood makes strong and durable timber with a reddish colour. It is expensive yet eagerly sought for uses demanding strength and durability. The timber is relatively hard to work and is not often used for decorative purposes but it is sometimes used on a small scale for umbrella sticks and tool handles.

Sundri is harvested in four main forms:

- Transmission poles for the Rural Electrification Board (REB) sold by royalty.
- Logs sold at auctions.
- Brushwood from the tops of the trees sold by royalty to Khulna Hardboard Mill (KHBM).
- Firewood from the tops of the trees sold by permit.

The poles for the REB are generally produced in a special felling operation. REB poles are sold through Bangladesh Forest Industries Development Corporation (BFIDC). The REB poles are harvested to a high specification. Consequently only best trees are selected. The number and volume of REB poles produced since 1990-91 is presented as Table 30. Table 31 shows the estimated revenue derived from sales of the REB poles. The figures quoted were obtained by multiplying the estimated volume figures by the rate of royalty applicable (Appendix A12).

Table 30 The Number of Poles and Estimated Volume Supplied to BFIDC for the REB

(Mitchell, 1995)

Length of Pole (ft)	No. of Poles by Year			
	1990-91	1991-92	1992-93	1993-94*
25	6778	10058	0	5531
30	2120	2237	0	1137
35	120	205	0	75
Total	9018	12500	0	6743
Volume (cft)	59479	81694	0	44998

Source: Forest Department - volume derived from minimum size specification
* Note that the 93 - 94 figures are incomplete.

Table 31 Estimated Revenue from REB Pole Production

Length of Pole (rft)	Net Rate	Revenue (Tk)			
	Tk/cft	1990-91	1991-92	1992-93	1993-94
25	154.25	6152519	9239247	0	5232784
30	162.25	2963962	3165019	0	1656819
35	162.25	214829	371398	0	139943
Total		9331310	12775664	0	7029546

The figures shown here are further discussed in section 13.2.1 on revenue systems.

Currently most of the Sundri timber is sold at auction. The majority of the logs from these sales are taken by the sawmilling industry. Sawn wood is generally used for structural purposes such as house posts, window and door frames, boats, bridges, truck and bus chassis and cold storage shelving. Unsawn Sundri logs are also used for pilings for the foundations for houses, bridges and jetties, and the shoring up of embankments for erosion control Larsen(1994). Limited amounts of Sundri are sold by permits. Table 32 shows the results of the Sundri auctions from 1990-91 to 1993-94.

Table 32 Results of the Sundri Auctions from 1990-91 to 1993-94

Year	Cpt	Quantity Extracted (cft)	Quantity Sold (cft)	Revenue from sale (Tk)	Price (Tk/cft)	Price (Tk/m3)
1990-91	32	11144				
	36	201533	153755	27317300	178	4928
	37	114855	66549	10540900	158	4393
Sub total		327532	220304	37858200	172	4766
1991-92	32	542098	488621	89628355	183	5088
	36	44288	88468	12697100	144	3981
	37	125633	233166	35359100	152	4206
Sub total		712019	810255	137684555	170	4713
1992-93	32		5149	1151100	224	6200
	36	263247	261740	54447100	208	5770
	37	5513				
Sub total		268760	266890	55598200	208	5778
1993-94	39	262301	225431	59719000	265	7348
	20	305493	196858	32663700	166	4602
Sub total		567794	422290	92382700	219	6068
Total		1876104	1719739	323523655	188	5218

Source: Forest Department Records - Khulna Range Office, Nalian
Note : the last two columns are derived from the data in the rest of the table using conversion factors

Brushwood from tops of the trees harvested for auction is used by the Khulna Hardboard Mill for which a royalty is paid. Since all the wood is harvested in Top-dying areas much of the KHBM wood is rotten. This has serious implications for both the quality of the end product and the efficiency of processing.

Prior to the moratorium, after felling and extraction of Sundri timber the tops were left in the field to be sold *in situ* to firewood merchants. Sundri is a desirable fuelwood species as it has a high calorific value and burns with little smoke. Since the moratorium the sale of Sundri firewood in this manner has more or less ceased. Supposedly all the brushwood should be taken up by the hardboard mill but in practice Larsen (1994) points out that Sundri firewood is still available in the local markets and at premium price over other species.

10.5.2 Gewa

Gewa is well represented throughout the SRF and has qualities suited to paper pulp production. The low density white wood is not durable; it has low strength properties and oozes white latex from cuts. Most of the annual harvest of Gewa is sold on a royalty basis to supply pulpwood to KNM. Gewa has few alternative markets.

In the agreement, areas of the SRF are licensed to KNM to harvest Gewa for pulpwood for which five year felling plans are prepared in consultation with the Forest Department. KNM obviously has a vested interest in the resource. Harvesting plans require Government approval and to date seven five year plans have been approved. At present all Gewa harvesting is controlled by KNM under the supervision of the Forest Department. This system must be reviewed.

Other uses have included the supply of matchwood to the match factories and the supply of logs to sawmills producing packaging materials. These were also sold on the basis of royalty payments. The 1994/95 allocation is for 300 000 cft for matchwood which still remains unutilised. In 1993-94 only 6000 cft was taken from KNM's cutting areas which was added to KNM's AAC.

Gewa logs are also used by Bowallis as jhools, dabbas and khorchi. These are logs and poles used to stabilise the loads of the country boats that haul produce out of the Sundarbans. Jools are usually in the form of floating outriggers which are hung from poles or dabbas that traverse the tops of boats. Khorchi are vertical poles used to bind the cargo together. One set of jhools and dabbas is allowed per registered boat per year, without the payment of any royalty and according to Larsen (1994) this practice is a source of significant unofficial harvesting and needs much tighter FD control.

Pulpwood management:

The ADB report (FMP, 1993a) highlighted the increasing demand for all types of paper and board products within the country as a whole and that future demand could not be met by existing capacity. The demand for pulpwood is of direct concern to the SRF and requires better management and more control by the Forest Department. Similar comments apply to Sundri branchwood and Shingra ***Cynometra ramiflora*** which are sold to KHBM.

The areas for felling are not marked prior to the felling operations. All trees greater than 4.6" diameter are harvested except trees left as seed bearers. Gewa is felled and cross cut entirely by axe. Latex excludes the use of cross cut saws for Gewa. Logs are cut into lengths of four foot multiples (i.e. 8, 12 and 16' lengths). Since the trees are soft and small with few buttresses, stumps that remain are small with relatively little wastage. The cut wood is hand carried to the nearest navigable water from where the logs are towed out to collecting stations. Here logs are removed from the water, bundled and sample measured for yield regulation and payment of royalty.

The samples are measured by the Smalian method (see Section 10.6.2). The logs are put back into the water and the bundles fastened in rafts of 220 bundles representing a volume of around 23 000 cft. These are linked in batches of four or five for towing out of the Forest to the KNM.

Although the system appears effective it involves excessive handling and there is scope for improvement :

- Abandon measurement in the field and hence the double handling and add scales to the cranes which lift the logs out of the river at KNM's log yard. This simple innovation would be a more accurate measure as it would not be a sample and would be much less liable to human error (see Mitchell, 1995).
- Arrange for KNM to accept logs other than in four foot lengths. Obviously very few trees have an exploitable bole that is exactly divisible into four foot lengths. The existing system invites wastage and or improper harvesting.

- Losses at the mill of pulpwood, estimated at 5-10% (Larsen, 1994), occur during both machine and hand debarking. Existing procedures should be reviewed and less wasteful methods introduced, bearing in mind that these offcuts are supplied to KNM labour free of charge.

The Gewa royalty is set and revised periodically. Until 1992 the royalty rate for Gewa was set exceptionally low at 0.06 Tk per cft. This in effect meant that the Gewa was supplied to KNM almost free of cost. Since that time price increases have been made and it is now set at Tk 15.00 per cft. This aligns with international standards and is thus thought appropriate for the time being (Mitchell, 1995).

The cutting cycle for Gewa (excluding Blocks 7 & 8) is 20 years. Gewa harvesting has exceeded the AAC in every year from 1986. Furthermore since Gewa is primarily harvested by KNM the FD revenue from Gewa production is dependent on a single main consumer. KNM have recently introduced a second machinery line which utilises green Jute as its raw material. This introduction is intended not to replace a proportional amount of Gewa but to substitute for part of the imported stronger long fibre Kraft pulp used in the production process. The cost of producing one tonne of Gewa pulp is Tk 12 000 to Tk 13 000. This compares with Tk 15 000 per tonne for Jute pulp.

- Until better growth and site data are available, the AAC for Gewa should be maintained at the present level with a minimum dbh of 4.6 in. Harvesting should be from Blocks 7 & 8, on a one-pass-only basis with a 10 cm (4 in.) minimum dbh limit.
- Subject to further refinement, the felling operations of Gewa should be restricted to Blocks 1, 2, 3, 7 & 8.
- FD has allocated 0.3 million cft of Gewa matchwood to DMI for 1994-95. Any further matchwood allocations are to be on an annual basis.
- **Since the FD depends upon KNM for the sale of Gewa, thought should be given to developing other markets to reduce risks inherent in a narrow and controversial market. There could be scope for expansion in the match factories, sawmills for pallet wood, other low grade purposes and fuelwood.**

10.5.3 Goran and other fuelwood

There appears to be an insatiable demand for fuelwood from the Sundarbans which constitutes the single largest source of this produce in the country. The harvest of fuelwood is dominated by goran, shingra and bhola, but includes numerous other species such as amur, chanda, dhalchaka, gewa, gura, hargoza, jhana, jhao, kankra, keora and kirpa. Sundri is also a highly valued fuelwood but its availability in the marketplace is obviously limited. Most of the Sundri fuelwood found in the markets has circumnavigated the official system (Larsen, 1994).

Goran produces good quality fuelwood that has a high calorific value and burns with little smoke. It is therefore much sought after and attracts premium prices. It also produces excellent charcoal but this useful product is banned by Government. The bark from Goran is very high in tannin and has been used by the leather industry and also to preserve fishing nets and sails.

Unlike the use of Gewa by KNM, Khulna Hardboard Mill (KHBM) utilises Sundri branch wood and wood from the leguminous shrub, Shingra ***Cynometra ramiflora*** , as raw material for which very low royalties are paid, 90 Taka/100 mds. This wood is also readily saleable as firewood. Thus the SRF is not dependent on an inflexible single market for this produce.

Earlier restrictions on the use of Goran as a fuel in brick kilns reduced the demand for this species. With current relaxation, Goran and other woods are being used in brick kilns increasing demand on this heavily exploited resource.

Two kinds of Goran are recognised:

- Bachai (selected straight stick) which is used for simple construction as wall supports, roof supports, fencing and as a support for young seedlings.
- Khadi (normal quality) which is most often used for fuelwood.

Goran is harvested during the months of November to April of each year and about 90% of the annual harvest is of the Khadi quality.

- It is recommended that the present level of cut should continue until the results of the impending inventory are known.
- It is also recommended that trials should be conducted to assess the effects of clearfelling which is practised successfully in India but not in Bangladesh. Silvicultural systems for strip felling and group felling should be tested with a view to improving control and yield. Until the results of these trials is known the present system of leaving one stem per stool should continue.
- Fuelwood can be used more effectively if it is burnt in efficient stoves and the means for improved utilisation need to be investigated.
- Fuelwood harvesting requires better control to prevent improper and destructive harvesting activities.

Ineffective supervision appears to be one of the main problems associated with harvesting Goran (Larsen, 1994). Often cutters leave the worst stems on the stool and damage the remaining stems during extraction. Larsen points out that the Goran may be over cut in the areas near navigable water and undercut in the areas further away. This should be quantified and better harvesting prescriptions enforced.

After cutting fuelwood is transported in local boats without engines to various fuelwood yards or depots near the Sundarbans. These sell a little wood to local purchasers and more to other dealers from further afield. The latter usually transport the produce by truck or boat to wholesale urban markets such as Dhaka.

Shingra, bhola and the other fuelwood species are normally harvested during the months of May to October. It was well known that fuelwood collectors often abuse their permits by harvesting other species including Sundri, Baen, gewa, Passur, kankra etc. In addition, they take an excessive amount of gewa johns. All this is evidenced by the large amount of such wood that shows up in the market place (Larsen, 1994). Until recently there were few restrictions on fuelwood harvesting. **However, indiscriminate and illicit cutting, have led to commendable imposition by the FD of additional regulation by permit and area but supervision must be improved.**

Charcoal

In addition to being used as fuelwood, a limited amount of Goran is burnt to produce illicit charcoal. Before being burnt , the bark is normally removed to make tannin. The yield is said to be about 1 unit of charcoal from 3 units of Goran. Other local wood is used to fire up the kilns. **Charcoal has many uses and is often essential to small-scale enterprises such as blacksmiths, jewellers and cafes thus regulations regarding this form of fuel deserve review as soon as possible.**

Keora and other species

There appears to be a decrease in the amount of land classified as Keora forest. This is possibly due to successional change to other forest types and the reduction in accretion of new areas. **Gripe (1995) identified appreciable erosion and readily discernible changes in some Keora stands. Further quantitative studies are needed on this subject which is a direct biotic indicator of the physical relationship between erosion and accretion.**

Site Quality Class descriptions are not applied to Keora and Baen, as these trees could grow much larger than the other Sundarbans species, usually on newly accreted areas. It has been found that it is better to classify the quality of these species by the ecological soil/vegetation characteristics of the areas in which they occur. These species are primary colonisers and as growth and senescence proceed they make space in the catnap for Gewa and Sundri. While the Moratorium is on these species cannot be harvested and as a consequence valuable timber is being lost. This matter should be reviewed.

There are other species such as Kankra, Passur and Dhundal which have many uses and which cannot be harvested for the same reasons. Production is being lost since these species are not being managed, thus at present only those involved in unrecorded offtakes gain, lending weight to arguments in favour of early review of the Moratorium, stepped up control or both.

Taken overall it has been concluded that the demand for all wood products from the SRF will continue to be greater than the sustainable supply and that in many respects the Moratorium compounds the problem. Scarcity of good quality Sundri and other sawlog species has undoubtedly been an incentive for illicit removals. Large quantities of valuable wood of all species are being removed.

There is a clear message here that any hope for sustainablity for the timber resources requires investment in training and better management to improve monitoring, harvesting and post harvest techniques. The Forest Department should be provided with the technical means for exercising better survey, monitoring, management and administrative control which to a large extent is left to the users. This position is confirmed by intensive studies carried out for this plan on management of timber resources by Larsen(1994); Leech (1995) and Mitchell (1995) - see volume 2 Appendices.

10.5.4 Other Miscellaneous Wood Products

There are many other wood products which come from the SRF. The moratorium has limited production to the species described above.. Other trees produce valuable timber and their properties are summarised in Appendix A13. Dhundal and Passur produce fine decorative timber; Kankra has properties similar to Sundri and is strong and durable; Keora and Baen are good light timbers suitable for casking furniture.

Many shrubs such as Shingra are used for making hardboard and Bhola is used as firewood. A vast number of small poles of many species are used by fishermen to support their nets and in the construction of temporary fishing camps which are situated along the southern border during the winter fishing season. These settlements house up to 50 000 people who all consume firewood from the forest.

Furthermore, apart from the low level disturbance factor, paths in the jungle, pollution of various kinds and consumption of forest produce across a broad range of products, nearly all fishing boats carry large anchors made from Sundri. Over 131 000 boats were licensed in 1993-94 (Larsen, 1994) and their forest produce consumption is not recorded, posing a significant management problem which must be addressed.

10.6 Harvesting and Marketing

Harvesting and Marketing has been the subject of a separate study and for more details reports of wood products, harvesting and marketing Larsen (1994) and Mitchell (1995) should be studied.

10.6.1 Sundri

Sawlogs

Currently the felling, cross cutting, extraction and haulage of the salvage felled Sundri Sawlogs is done by contractors engaged by the Forest Department. The finished sawlogs are taken to the Forest Department's depots where the logs are sold at auction.

Felling and extraction is wasteful. It is normal practice that both the felling and cross cutting are done by axe. Added to this trees with buttresses are cut above the buttresses leaving large stumps in the forest which often constitutes the largest and most valuable portion of the log. The timber is then extracted either by carrying or dragging the logs to the nearest creeks for loading onto boats. Further wastage is caused by cutting into short manageable lengths and large logs often have holes cut at the best end to facilitate haulage.

Larsen (1994) estimated that the average waste per tree is as high as 12%. Wastage from axe cuts could be much reduced by the use of cross cut saws. High stumps and unnecessary cross cutting of prime butts could be prevented by a change in the instructions given to contractors, supervision of contractors and a change in the FD's procedures. There is too much man handling of heavy logs. These operations could be made a lot easier and risks of back and other injury reduced by introduction of timber handling hand tools such as cant hooks and tongs.

The sawlogs are transported to the depots by the contractors in unpowered country boats. All the loading and offloading is done by hand. Logs are not sorted and even at auction are sold in mixed lots. Since contractors are paid on out turn measured as the number of cubic feet delivered to the depot, there is a tendency to include undersize or rotten stems which should have been left on site as brushwood for KHBM. This practice reduces the average quality of logs sold at auction.

The current procedure is to auction logs at FD depots where they are stored. Before the moratorium, trees were marked by the FD and sold standing on site. It was the purchaser's responsibility to fell and extract the timber. This is known as a standing sale by auction. The advantages and disadvantages of these two methods of sale are discussed at some length by Mitchell (1995).

Transmission Poles:

For the REB market the forest is selectively marked for transmission poles outside the Salvage Felling operation. Usually the best and biggest trees are selected. This form of preferential removal leaves trees of poorer form and vigour as the source of seeds for the next generation. This practice is poor silviculture and poor ecology. Marked trees are felled by FD contractors who use the same procedure used for sawlog extraction. REB logs are transported by steel-hulled boats which accommodate large logs, straight to the yard of the Bangladesh Forest Industries Development Corporation (BFIDC). Great care is taken to only deliver the best logs to BFIDC as there is no compensation for logs which may be rejected on arrival. The brushwood is left on site, until it can either be sold for firewood or taken to KHBM. The extensive nature of REB pole extraction results in a wide dispersal of brushwood and tops of poles which cannot be harvested effectively and are left to rot in the forest causing wastage of a potentially valuable resource.

Brushwood:

Brushwood from the tops of the felled Sundri trees are left for a separate set of contractors to extract to the side of a creek large enough to accommodate the Khulna Hardboard Mill's barges. The brush wood is then loaded onto the barges for transfer by boat to KHBM's log yard. There are apparently problems sometimes caused due to a lack of co-ordination between the Forest Department and KHBM. Sometimes the mill suffers from an interrupted supply of wood. (Larsen, 1994).

10.6.2 Measurement of Wood Resource Removals

Timber

Timber is traditionally measured by the Hoppus system in Bangladesh. Hoppus feet are calculated by measuring girth in feet, this is then divided by 4, squared and multiplied by the length in feet. However, all timber production since 1985-86 has been officially recorded in the Divisional Forest Officer's office, Khulna in his annual reports in cubic metres. All timber, apart from Gewa, is actually measured in Hoppus feet later converted to cubic metres. In the conversion the factor used transforms $1m^3$ to equal 35.315 cft. This is correct for true cubic feet, used in measuring Gewa but the Hoppus system underestimates the true volume by 21% since $1m^3$ actually equals 27.736 Hp ft. Thus the figures presented in annual reports are under-recorded.

Larsen (1994) recommends that the system of measuring logs should be changed to the Smalian method as used by KNM. Another consultancy report (ADB FMP, 1993a) recommends that the immediate mandatory cessation of the Hoppus system as it "masks inefficiency and cannot be tolerated in a country with such scarce resources".

Whilst it is true that the Hoppus system does under-estimate true volume and this must be corrected, the system itself does not mask inefficiency. That only occurs when the Hoppus feet are recorded as true cubic feet and are then converted using the wrong conversion factors into cubic metres.

In practice the Hoppus system has some advantages. Timber is sold by the Hoppus foot and the purchasers understand the system. The sawmillers themselves can remeasure and calculate the volumes without having to resort to geometry or volume tables. If the system is to be changed then there is the danger that potential purchasers would be alienated. Sawmillers are traditionally very conservative. The Forest Department's own staff are familiar with the existing system and they would require retraining before any new system could be implemented.

Any change should be brought in gradually, possibly working two systems together for a transitional period. When the system is changed it is suggested that rather than change to imperial measures calculated by the Smalian formula, based on the average of the top and bottom diameters and length, that the new measurements are made in metric units using Huber's formula. Consistent comparisons can then be made with inventory data and management plans as well as helping achieve some progress towards international standards.

Firewood

Firewood and Golpatta removals are measured by assessing the capacity of the boats used in hauling the produce out of the forest. The assessment is made annually when the boats are issued with BLC Registration Certificates. The procedure of issuing BLCs is detailed in the Heinig Working Plan of 1892, although the method of assessing the loading capacity is not stated.

BLCs for the country boats which haul produce out of the Forest are issued at the station offices on specific days each year. BLCs for fishing boats are issued at any time. The boat owner must come with his boat and a certificate from the Chairman of the Union Parishad (lowest level of local government) showing proof of identity and ownership. The BLC in maunds is then measured according to the following formula:

$$BLC = 0.356 \times L \times B \times D$$

Where:
- 0.356 = A constant conversion factor.
- L = The length of the boat a long the water line when under full load.
- B = The average breadth measured in 3 places.
- D = The vertical distance between the water line at full load and the bottom of the boat.

Obviously when the boat is measured for its BLC it is empty and the fully loaded water line must be estimated. The estimated line is defined by a level mark painted on the side with its number. All the measurements, the maundage capacity and the BLC number are recorded at the FD station.

Boat owners wishing to collect forest produce must apply for a permit at the station office where their BLC s were issued. The royalty based on the estimated BLC capacity must be paid prior to commencement of harvesting. On departure from the SRF, permit holders must report with loaded boats to issuing station offices for load reassessment. If the water line is found to be higher than the original estimate the capacity is recalculated by adding the difference between the gunwale and the level mark and the gunwale and the actual water line to the D measurement in the formula above. The operator pays the extra royalty before being allowed to depart.

This system was designed many years ago. The shape of boats has changed since then. It is well known that boat shapes have evolved from place to place to maximise carrying capacity whilst at the same time minimising the calculated loading capacity. This has gone so far that boats are badly overloaded and often unbelievably unstable when they arrive for BLC assessment. Following assessment, stability is re-established through the addition of 'mallam' boards on the sides which also increase the load capacity. The FD has endeavoured to make measurements more equitable and consistent by ordering that boats of given lengths must have certain minimum depths but this measure is difficult to enforce.

Recent analysis of loaded boats revealed that the BLC underestimated the amount of Golpatta on one boat by 65% and for a Goran boat the dioscrepancy was 30%.

The method is fundamentally flawed since linear measures are used in the estimation of weight. All firewood and Golpatta leaves will loose a considerable proportion of their weight as they dry. The sample weights for the Golpatta leaves used in the analysis described above for example were taken from freshly cut leaves. This weight would probably reduce to 50% after drying of the leaves. The Goran sample weights were taken one month after it had been cut.

Another deficiency in the method is that inventory data, PSP data and management planning use volumetric measurements and thus recording forest product removals by estimates of weight is illogical. The only circumstance in which measuring by weight might be advantageous would be if bulk purchasers could weigh their produce using cranes or weighbridges(Mitcehell, 1995).

To rationalise the situation, the measurement of Golpatta and firewood in future should be done entirely on the basis of stack measurement or sold standing with sample stack measurement.. Conversion back to either true volume for the firewood and numbers of leaves for Golpatta, could be made consistent by use of control sample measurements, which could be made each year for each coupe.

One improvement could be to measure the entire volume of a boat thus obtaining a measure of the stack which the under present system would not be seen after loading. These figures could then be recorded in exactly the same way as the previous BLC maundages were.

Measurement of firewood and golpatta boats by the BLC method is inaccurate and inappropriate. Produce should be measured and sold on the basis of actual volume as described above or standing before removal or stacked after removal.

The reporting system is old and inappropriate to modern forest management. It needs urgent revision. At present information travels along a long series of compilation points making any audit clumsy and almost impossible to implement along the following trail :

- Primary records obtained at SRF FD station office.
- Second stage consolidation in transfer to range office.
- Third stage from range office to DFO's headquarters office, Khulna.
- Finally the refined data are remitted to the FD head office, in Dhaka.

Attempts at following this line of consolidations by the ADB in the Forestry Master Plan (FMP, 1992) studies and for this plan, revealed that a lot of important management information is lost en route.

With the advent of relatively cheap PC- based modern data processing technology, resource information can be recorded, stored and retrieved cost effectively, even in the environment of the SRF. If the FD is provided the means to adapt to this relatively straightforward technology it could find itself well ahead of most other similarly positioned forest management organisations. The opportunity for development of integrated resource management is in position. Further progress will require a change in priorities, definitive planning and investment in data base systems, staff training and realistic budgeting.

10.7 Wood Products Supply and Demand

A specialist report in the FMP projected the demand for forest products by region and for the whole country until the year 2013 (ADB-FMP, 1992d). The results for the country as a whole have been used in this plan because much of the produce from the Sundarbans is sold in Dhaka. The ADB projected demand and supply for wood products in three different scenarios :

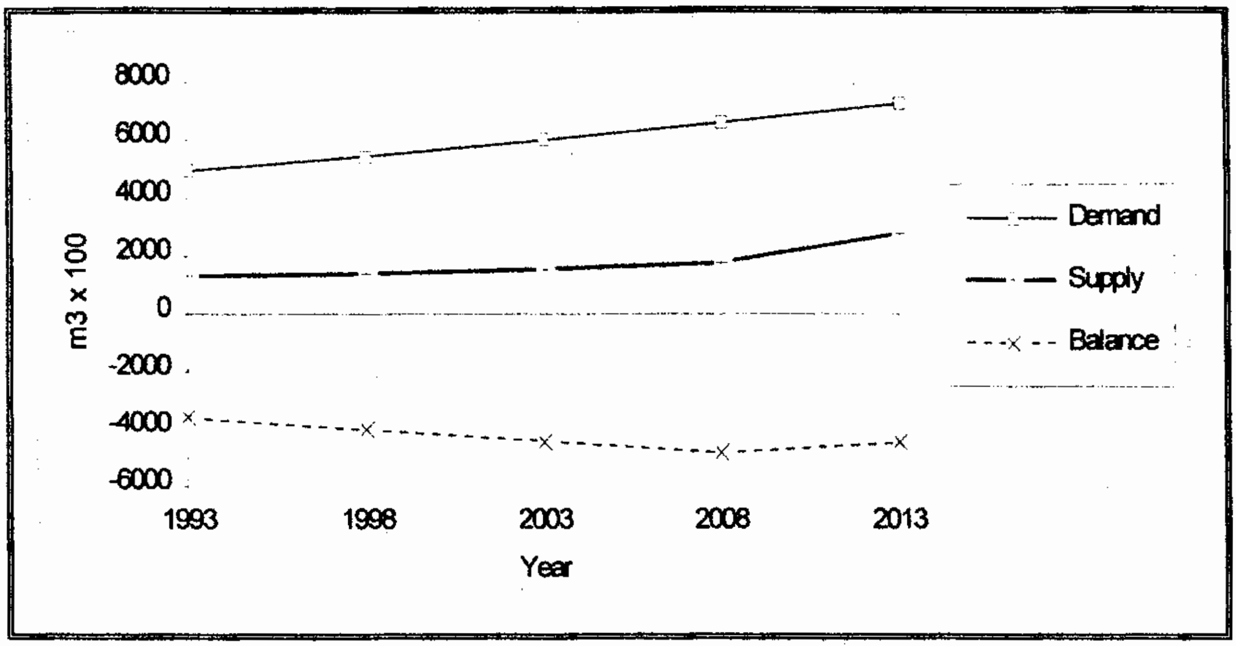
- The Status Quo
- Low Consumption
- High Consumption

Timber:

From the demand and supply projections for timber, all three scenarios show that demand is considerably in excess of supply. In the status quo scenario the difference between supply and demand continues to deteriorate for the whole period. In the other two it is assumed that investment made now in establishing timber plantations will begin to have some impact by the year 2008. The gap remains large in both cases. The intermediate and most likely prognosis is scenario 2. This is presented graphically in Figure 2 below.

Figure 2 National Timber Demand - Supply Projection

(after Mitchell 1995)



Source : ADB FMP (1992)

This clearly shows that the national demand for timber will continue to increase. It may also be inferred from this that the timber demand from the SRF will also rise at least in line with the trends shown above. Sawmillers who have been interviewed have stated that they would prefer to use Sundri and other Sundarbans species over the local village wood which they are currently forced to use.

Fuelwood:

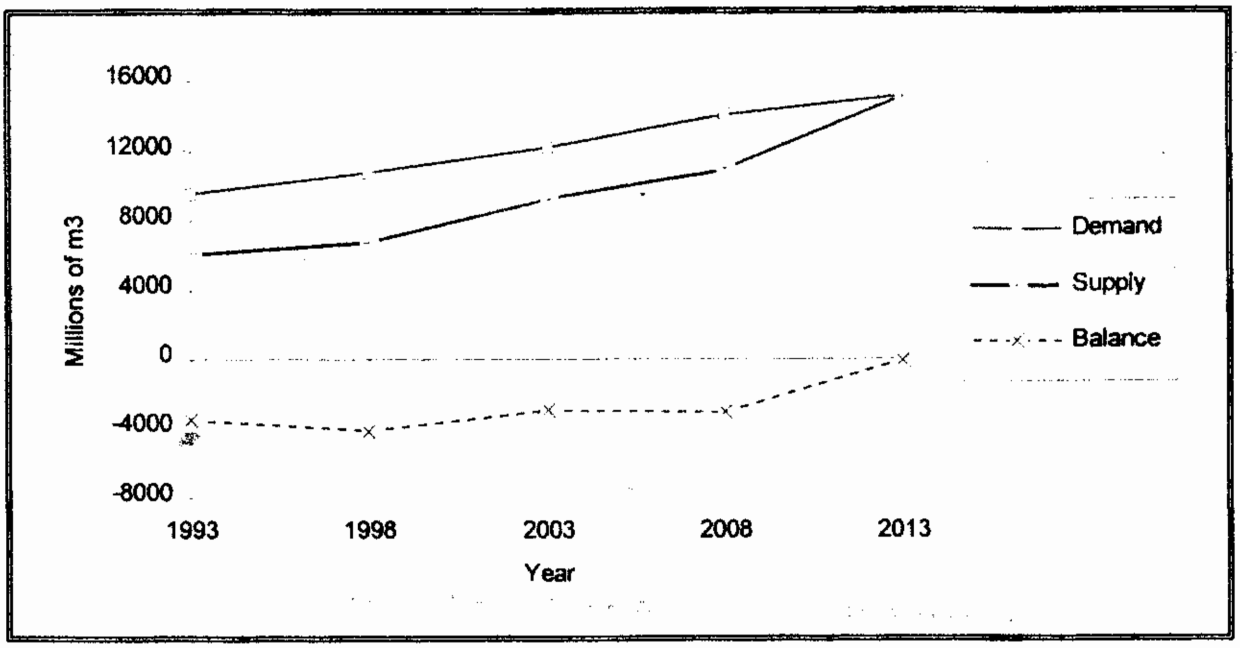
The fuelwood (firewood) position differs in that it is a lower value commodity and that alternatives such as gas, coal, agricultural residues and cow dung, are widely available. Analysis over the past few years has shown that as fuelwood has become scarcer, so people have changed to other fuels, especially the use of cow dung in rural areas. There is of course a negative effect through loss to agriculture in cycling of organic nutrients. The introduction of gas to urban areas also has helped to reduce fuelwood demand. Notwithstanding this, there is a chronic shortage of firewood in the country (ADB-FMP, 1992d).

The ADB Status Quo Scenario assumes that demand will increase in line with population growth and that the substitution of fuelwood with other types of fuel is limited. In this scenario the demand supply deficit continues to deteriorate. In scenario 2, the consumption is the same as for the status quo except that alternatives for industrial purposes, such as coal and gas, become more readily available. This reduction of demand coupled with an assumed moderate investment in fuelwood plantations, sees the supply and demand curves crossing just after the turn of the century.

The third is most likely scenario is illustrated in Figure 3. In this demand continues to rise but that the effect of establishing fuelwood plantations will help meet the supply only by the year 2013.

Figure 3 National Fuelwood Demand - Supply Projection

(Mitchell, 1995)



Source : ADB, FMP (1993)

This graph shows the high demand for all fuelwood. Fuelwood from the SRF is very good quality with a high calorific value and burning with little smoke. If fuelwood were to become more available then it is likely that the rural poor would revert back to using fuelwood. If the market for fuelwood were to drop then other uses that could be made for the fuelwood from the SRF, such as charcoal production, and even for the brick industry. The conclusion must be that fuelwood from the SRF will always be saleable and at a premium.

Whilst the demand for fuelwood from the SRF is high and the total level of production appears to show no signs of decreasing there is a diminished harvest from certain localities. Evidence for this that at certain offices the number of BLCs issued for country boats each year appears to be declining as illustrated by the records at Burigoalini Forest Station where in 1992-93, 516 BLCs were issued; in 1993-94, 391 and in 1994-95, 287. The prescribed Goran cut from this station for 1994-95 was for 1.2 million maunds but permits were only issued for 700 000 maunds.

The explanation for this local drop in demand is due to the inefficiency of working only part of the year with the country boats for Golpatta and Goran harvesting. Prior to the moratorium, timber was sold standing and the Goran was also sold as part of the Sundri Working Circle. The purchaser was left to choose the most appropriate time for harvesting. Goran and Golpatta was cut during the winter season and timber and Goran were extracted during the rest of the year. Under prevailing rules, once Golpatta and Goran have been harvested the boats are taken out of the water until the next season. Not only is there decreased utilisation but also the boats evidently require more maintenance on account of drying out during periods of inactivity.

Pulpwood:

The ADB report (FMP, 1993a) also highlights the increasing demand for all types of paper and board products throughout the country. The future demand will not be met by existing capacity of the country's established mills. The demand of pulpwood is of direct relevance to sustainable production from the SRF of Gewa for KNM and Sundri branchwood and Shingra for KHBM, Comparison of Tables 28 and 29 shows that the present quota of 133 000m^3 / annum was exceeded in every year from 1986-87 to 1992-93.

Whilst at a national level supply of pulpwood does not meet demand and locally there are no plans to install a second Jute line at KNM, there are commercial dangers which must be recognised by forest managers. If the relative price of Jute were to drop or the price of imported pulp reduced then there could be a decline in demand for Gewa. **Other markets should be developed. There could be scope for expansion in the match factories, sawmills for pallet wood, other low grade purposes and fuelwood.**

All recent studies, reviewed by Mitchell (1995) and Larsen (1994) have confirmed that the demand for wood produce from the SRF will continue to be greater than the sustainable supply well into the next century and integrated management will require forward planning based upon reliable information and with better systems and controls which foster respect and participation by the user public.

11 NON-WOOD RESOURCES

The definition of non-wood forest products (NWFP) used in this plan is the FAO definition proposed by Chandrasekeran (1994) which states that non-wood products means "all produce including all goods of biological origin, as well as services, derived from forest or land under similar use, and excluding wood in all its forms".

There has been a marked change in recent years from the concept of minor forest produce to a wholly inclusive position which separates produce derived from woody parts of plants on the one hand as wood products, from all other terrestrial and aquatic products including leases and services on the other. **In many senses this change alone reflects strongly the new trends in forest management. The new position embraces the true economic value of non-wood produce and the need to integrate their management in one composite system.**

In essence all the resources found within a forest are now deemed to be of equal importance in integrated management planning. Nowhere is this more pertinent than in the SRF where by far the largest number of people, probably at least 85% of those who access the forest, are connected with harvesting non-wood produce (see Table 33) which are now more valuable ineconomic terms than wood products. Past and existing management systems have not given adequate attention to this aspect of forestry and future management must keep pace with the trend.

Table 33 Derived Annual Level of Employment and Value of Employment from the SRF by Product

Product	Units	Average Annual Harvest	Number of mandays per unit	Total No of mandays	Value of labour only	Labour plus living costs	Total Value of Labour only	Total labour plus living costs
		Units x 1000	md/unit	md x 1000	Tk/unit	Tk/unit	millions of Tk	
Forestry Dept staff	No.	1038		379				24
Sundri timber	m3	49		1059		872	42	42
brushwood				36				1
Gewa				234				9
Goran	BLC mds	1608	0.39	626	30	39	48	63
Golpatta	BLC mds	1882	0.40	754	57	65	108	122
Fish	tonnes	40	325	12987	4123	6322	165	253
Shrimp fry	thousand	1613	10	16130	400		645	645
Honey	kg	230	0.48	111	76	16	18	21
Others				427				17
Total				32742				1198

This table shows that the total number of mandays worked per year is in the region of 33 million with a value of 1.2 billion Taka. If it is further assumed that there are 293 working days per year (365 less one day per week for Fridays, less 20 days per year for bank holidays, leave, sickness etc.) this represents 112 000 full time jobs derived directly from the SRF. Most of this employment is seasonal and part time. It is likely therefore that the total employment figure is many times greater with ranges estimated between 600 000 and 1 200 000 (Shiva, 1994; MARC, 1997; MARC/DDC, 1997).

The profile of on non-wood forest products has been heightened firstly because of high social and commercial values and secondly because the immediate consequence of the growth in this sector has been the increase in demands placed upon the FD for day to day management. **The Department barely has the means for managing the timber resources and thus a big shortfall in capacity exists in its ability to handle the new, often highly specialised requirements, of modern management of other plant- and animal-based produce. This matter should be given priority attention in follow-on programmes.**

Proliferation in harvesting NWFP's bring with it a host of management problems related to harvesting methods, ecological and environmental factors, distribution of benefits, marketing, transportation, investment and social equity, many of which are directly associated with institutions, people and events outside the SRF.

It is unavoidable therefore that in future NWFP management the FD must work with all the stakeholders especially the traditional resource users whose interests must be safeguarded.

11.1 Existing management of NWFPs

Management of non-wood resources requires substantial improvement to address the imbalances, extend research programmes, research, monitoring, staff training and control mechanisms. The whole range of plant and animal-based non-wood resources and guidelines for their rational development and sustainable utilisation through improved management are provided in this plan which divides NWFPs into plant and animal-based resources.

Until recently the SRF was viewed as a wood-producing unit and the management of other products was given lower priority. NWFPs such as Nypa palm, fish and honey were considered in working plans but managed more from the point of view of revenue earning potential than in terms of improving sustainable production or returns to under-privileged harvesters. For example whilst it had always been intended by the FD that permit prices should be kept low to help Bowallis the reality has been that this has merely exacerbated their manipulation by various middlemen (MARC, 1997).

Today the non-wood forest products (NWFP) can no longer be viewed as minor but on the contrary as having, at least potentially, as great if not greater importance than the wood resource. Recent figures indicate that the Sundarbans' NWFPs provide employment of some sort for about a million people who are engaged permanently or seasonally in harvesting or working with non-wood produce. This could make the SRF the largest single employer in the country. The value of shrimps exported from Bangladesh, for which nearly all fry are obtained from Sundarbans waters, was about US$ 120 000 000 in 1993.

The significance of NWFP is reflected not only in their high market values but also negatively in terms of pressure which is being exerted on the mangrove forest in pursuit of space for the promotion of enterprises such as shrimp and fish culture ponds, extension of seasonal fishing villages and construction of tourism facilities. It is in this regard that great care must be exercised in formulating new policy for better management and more control.

The Forest Department will gain much by collaborating wherever possible with other agencies and by being sensitive to legitimate claims of Mowallis, Bowallis and fishermen for equitable sharing of benefits derivable from NWFPs.

The picture at present appears to be one of growing numbers of people harvesting resources beyond their upper limit who have little say in the setting of fees, licenses, regulations, or markets and who are controlled by a host of middlemen and revenue collectors. Since this large community lives below subsistence their attitude appears to be to harvest to the maximum and have no heed for conservation (MARC, 1995; Bhuiyan, 1995). In the long run it must be concluded that for conservation of the SRF to be successful care for the forest must be accompanied by care for the people who depend upon these resources.

Management systems and the contribution of NWFPs to the productivity of the Sundarbans, to the flow of socioeconomic benefits and to their importance to the national economy rference should be made to Tamang, 1993; Moss, 1993; Chantarasri, 1994; Shiva, 1994; Pena, 1994; Zmarlicki, 1994; Mitchell, 1995; MARC, 1997; Leech, 1995 and Asanullah, 1995.

11.2 Plant-based NWFP resources

The most important plant-based products remain those connected with thatching materials especially Nypa, Hantal and grasses. Of these Golpatta receives most attention. It is widely distributed throughout the SRF and is a major source of thatching material used extensively by the poorer section of the rural population in the south-western part of the country. The inflorescence can be tapped for the production of country wine.

Management of all plant-based NWFPs is linked either to the Golpatta Working Circle or Miscellaneous Working Circle all of which overlap to some extent.

11.2.1 Golpatta *Nypa fruticans*

The SRF is the only commercial source of Golpatta in the country and there is a well-established system of production management geared to maximising the level of harvest and financial returns on a yearly cycle. Seven coupes are administered by ACFs who work as Coupe Officers to oversee the sale of permits and harvesting procedures. Production exceeded 72000 t during (1990-91) and harvesting is allowed in wildlife sanctuaries.

The following rules are applied, some of which require review and all of which should be brought into the mainstream of the GIS Golpatta inventory control :

- Harvesting is confined to the months of November to March inclusive.
- The produce is sold on the basis of individual permits by boat load (BLCs) discussed in section 13.2.1 which are measured by a mixture of volumetric and weight assessments with an estimated underestimate usually of about 30%.
- The central leaf and adjacent leaf must not be cut.
- Dead and dry leaves must be cut at the time of harvest.
- Flowers and fruits must not be damaged.
- Cut leaves must not be left behind on the ground.
- The harvest must be completed in each area before harvesters are permitted to move on.
- Detailed coupe maps are kept by the FD but there is no up to date inventory and the existing data have not been introduced yet into the GIS data base.

Golpatta is a versatile source of basic material for other commercial uses which are not well promoted in Bangladesh and for which, according to Shiva (1994), there could be appreciable development potential:

Sap production for industry

Based on experience in other countries as indicated below the proposal of tapping Nypa for its sap may be economically viable in Bangladesh.

Sap production	--	15 600 litre per ha per year (in Malaysia)
	--	6 480 to 10 224 litres/ha/yr (in Philippines)
	--	18 165 litre (possible by improved method)
Sugar production	--	Av. 20.3 tonnes per hectare per year
	--	22.4 tonnes in Sumatra

Production of sugar from nypa sap is labour intensive compared with sugar cane and nypa sugar yields compare favourably with values for the sugar cane industry in Indonesia (Hamilton and Murphy, 1988).

Vinegar production:

After utilising the fresh sap for making sugar, the stored sap may be utilised for making vinegar containing 2-3% acetic acid by allowing the fermented sap to stand for about two weeks.

Industrial ethanol (fuel alcohol):

There is a good scope for manufacturing industrial ethanol or fuel alcohol from fermented sap. Nipa alcohol can be blended with petrol up to a ratio of 1:4 without the need to redesign or adapt the carburettors of gasoline engines. More details and practical feasibility report may be obtained from Department of Primary Industry in Papua New Guinea.

Medicinal uses:

Young shoots, decayed wood, burnt roots or leaves are useful for treatment of herpes, toothache and headache. Pounded leaves are used as a lotion for ulcers. The ash obtained by burning roots and leaves relieves toothache. The use could be popularised as indigenous medicine.

All aspects of this plant require detailed study and recommendations are made for improving management in Part 2 of the plan.

The Golpatta coupes are worked during the dry season. The rules of harvesting are described in detail by Mitchell (1995); Shiva (1994) and DDC (1995). Table 34 presents the out turn and the revenue collected for Golpatta.

Table 34 Production and Revenue from Golpatta by Year

(Mitchell, 1995)

Item	Unit	Year									
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94
Production	t x 1000	61	62	71	79	68	67	72	72	67	68
Revenue	Tk x 1000	2160	3760	3825	4215	3976	6723	5799	5822	5447	5906
Price	Tk/t	35	61	54	54	58	101	80	80	82	87

Source: Forest Department Records; DFO's Annual Reports

This table shows that there has been little fluctuation in the level of production over the ten year period. Prices follow the changes in royalty rates, as might be expected. It is clear that Golpatta is a valuable resource contributing between 5 and 6 million Taka annually. The price of around Tk 80 to Tk 100 per t is very low considering the effort expended to harvest the produce. Also DDC (1995) state that there are areas inside the forest where Golpatta grows but are not harvested due to fear of being consumed by tigers.

Since growth of Golpatta was not studied in detail the calculation of yield from increment measurement has not been possible. Analysis of existing data suggests that there need be no immediate concern over the sustainability of the current level of harvest. The total stocking area appears to be stable, yielding a more or less constant annual harvest. The status of Golpatta resosurce must be reviewed in detail during the forthcoming inventory.

Conversely it appears that the market for Golpatta is not static. Recently it has been said that there is a decrease in demand and that it is likely that for 1995 not all areas targeted for harvesting will be cut. The drop in demand is thought to be due to competition from cheap corrugated iron sheets which last appreciably longer than Golpatta which needs repair or repalcement every 2 or 3 years.

There are two possible solutions to the problem : the first is to lower the price of the Golpatta and the second is to improve the quality of the product. The first could be achieved by arranging auctions of standing areas thereby reducing the influence of middle-man and windfall profits made along the line. Revenue to the Forest Department would not necessarily fall and indeed might even rise. Improvement in quality of the product could be effected, according to Shiva (1994), by making shingles from the leaves and treating these with preservative to extend their durability. A significant saving could be made also if the method of measuring the removals were to be changed but this would not be necessary if the system of harvesting is changed.

- All jhools, tharias, dabas, masts and mallams etc. which are felled for using in Golpatta carrying boats should be hammer-marked before felling and the outturn should be recorded against the outturn of the compartment from which timber is felled.

- Permits for felling for Jhools, tharias, dabas, and other peripheral requirements of harvesters should be allowed from the annual coupes as far as possible and permits from areas outside the coupes may only be allowed sparingly when the coupe is not within a reasonable distance from the working area for Golpatta. When such permits are allowed, felling should be by way of thinning and should be under close supervision and the choice of species should be with the coupe staff (Rahman, 1992).

11.2.2 Hantal *Phoenix paludosa*

Hantal is also a member of the palm family and is commonly found throughout the SRF. It is usually a slender, straight, small tree which can attain a height of five to six metres. It sometimes forms nearly pure stands of dense impenetrable thicket which are often located along river banks and shorelines flowering during March and June. In other areas it can occur as undergrowth beneath a sparse over storey. Hantal reproduces from dispersal of floating seeds and also vegetatively from root suckers (Karim, 1995)

There is little knowledge about either the standing stock or the growth rates of Hantal. The stems are harvested on permits issued throughout the year. The produce is sold for rafters, purlins and as fence and house posts. The ribs are light, relatively strong and reasonably durable when kept off the ground.

According to Shiva (1994) there is scope for increasing utilisation . The leaves have been found to be suitable for paper pulp (Naskar and Bakshi, 1987). and the fruits are edible.
See table 35 for production and revenue information

Table 35 Production and Revenue from Hantal in SRF

(Mitchell, 1995)

Item	Unit	Year									
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94
Production	tonne	8910	5412	6087	7848	8339	7203	6747	9032	6053	6725
Revenue	Tk x 1000	39	142	170	210	223	339	334	448	391	339
Price	Tk/t	4	26	28	27	27	47	50	50	65	50

Source: Forest Department Records

Production of Hantal ranges from around 6 000 to around 9 000 t/pa. This is a wide variation for a product supposedly produced on a sustainable basis. However, there appears to be no discernable decreasing trend in the production figures. Without more precise inventory data it seems likely that the production at the lower end of this range is sustainable with current harvesting methods. This assumption should be tested during the inventory of 1996-97. The price of Hantal, at around Tk 50 per t, as for Golpatta seems to be remarkably low.

According to MARC/DDC (1995), due to its versatility, Hantal is a popular product among the local poor population creating a constant high demand but, like Golpatta, this too may decline, although Table 35 indicates that there is no obvious trend in the level of production

11.2.3 Bhola *Hibiscus tiliacus*

Bhola is a scrambling woody shrub which is found growing along river banks and in dense impenetrable patches in dry to moderately moist areas around north and central parts of the forest. It is extensively harvested for firewood.

At present only Hantal and Bhola are harvested under the miscellaneous permit system for fuel wood. Felling is not well regulated and encourages illicit removal of other species. Only accessible areas tend to be harvested. In the absence of weeding, removal of Bhola in remoter areas would help growth of larger woody species. **More emphasis upon controlled silviculture combined with Bhola extraction is desirable and should be introduced in future operational planning.**

11.2.4 Ulu Sungrass *Imperata cylindrica*

Two species of grass and one sedge, also known locally as grass, are harvested widely in the SRF and make a valuable contribution to the local economy as fodder and thatching material.

- Ulu grass ***Imperata cylindrica***
- Nal grass ***Eriochloea procera***
- Malia grass(sedge)***Cyperus javanicas***

Ulu or Sungrass grows extensively, especially on well drained sandy soils on the southern seaface and in other sandy areas. A prime commercial use is the shading of betel fields making it a valuable homestead cash crop grown for both export and domestic markets. Ulu from the Sundarbans has a ready market, since it is said to be more durable than that grown outside the mangrove environment (Mitchell, 1995).

Unfortunately data are scarce because harvest records for all three are consolidated under one head. There is also no measurement yet of the total area of grassland within the SRF. The ODA inventory recognised "Grass and bare Ground" in their forest typing definitions. The production and revenue of all these species is presented in Table 36.

Table 36 Grass Production and Revenue by Year: SRF

(Mitchell, 1995)

Item	Unit	Year									
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94
Production	tonnes	9305	11064	11740	13441	13531	11566	7133	4585	5749	5140
Revenue	Tk x 1000	25	33	94	108	119	104	57	37	73	78
Price	Tk/t	3	3	8	8	9	9	8	8	13	15

Source: Forest Department Records

From this table it can be seen that the production of grass from the SRF has decreased substantially during the last ten years. Production for the last 4 years has been less than the annual production for each of the previous years. DDC (1995), make no comment on the production for all the grasses combined, but mention that supply for two out of the three grass products has been increasing. They do not state how this conclusion was derived. The drop in production may in part be due to the apparent increase in price in 92-93. However, there appears to have been no official increase in the royalty rate in that year; the royalty rate for Nal and Malia grass works out at approximately Tk 8 per tonne and all other grasses Tk 16 per tonne. These rates were last revised in 1990.

11.2.5 Nal grass Eriochloa procera

Nal grows along drainage lines and is a pioneer species on newly accreting chars. It can also be found in association with some tree species. The species can reach up to six feet in height and can be sustainably harvested on an annual rotation. According to DDC the occurrence of Nal is increasing with increasing deposition of sediments within the system.

Nal is used in the manufacture of baskets, rice containers (Dola and Shajees) and containers for paddy (dhamas). As for Malia hravesting of Nal is associated with the poorest sector of the local communities.

11.2.6 Hogla *Typha elephantina*

Hogla or Typha is a tall, strong grass which is also known as elephant grass. It is well distributed in the SRF and is widely used in cottage industries in the manufacture of cheap furniture, woven utensils, mats and handicrafts.

Rhizomes are used as a cure for dysentery, gonorrhoea and measles and the spike floss and down are used in protection of wounds (Shiva, 1994).

11.2.7 Malia grass (sedge) *Cyperus javanicus*

This sedge grows along rivers and canals and in low lying hinterland areas with impeded drainage. It attains a height of three to four feet uniform clumps. It is possible to crop Malia sustainably on an annual cycle. Malia is an important NWFP and used as the raw material for the manufacture of mats. Many of the poorest inhabitants of the Border Zone, particularly women, are involved in this cottage industry (DDC, 1995).

The production of Malia is not restricted to the Sundarbans. DDC (1995) estimated that around 75% of the Malia used in the locality comes from outside the SRF, the principal source being polder embankments.

11.2.8 Medicinal and aromatic plants

According to Shiva (1995) there is good potential for harvesting and utilisation of plants for medicinal and aromatic purposes. There is no record of any serious enquiry having been made on this subject although some studies have been made in India and the results of these were discussed by Naskar and Bakshi (1987). The species which occur in the SRF are included in Table 37 as a starting point for future research in this field.

Table 37 Medicinal Plants of the Sundarbans and their Uses

Scientific Name	Known Medicinal Uses
Tamarix dioica	Bark used as a tonic and for skin diseases
T. gallica	Galls and twigs used as astringent and for dysentery
Hibiscus tiliaceous	Roots used in preparation of embrocations
Thespesia lampus	Roots and fruits used to cure venereal diseases
T. populneoides	Bark used to cure dysentery and skin diseases
Xylocarpus moluccensis	Bark used as febrifuge for dysentery and diarrhoea
Derris indica	Powdered seed used for bronchitis and whooping cough
D. trifoliata	Entire plant used as antispasmodic and stimulant
Caesalpinia nuga	Roots have diuretic properties and used in treatment for kidney stones
Ceriops tagal	Root decoction used as substitute for quinine
Lumnitzera racemosa	Stem decoction used for herpes and itching
Barringtonia acutangula	Bark has wide medicinal application in rural areas
B. racemosa	Fruit use in remedies for coughs, asthma, jaundice and ophthalmia
Ammannia baccifera	Entire plant makes strong purgative
Trianthema portulacastrum	Entire plant used for heart disease and anaemia
Launea sermentosa	Entire plant used as saporific, diuretic, and aperient
Cerbera odollam	Bark and nuts used has purgative and narcotic effects
Holarrhena antidystenterica	Antiperiodic, used in treatment of malaria and dysentery
Ipomoea pes-carpea	Leaves used as astringent and laxative and for treatment of rheumatism
Acanthus ilicifolius	Used in treatment of asthma, dyspepsia, and rheumatism
Premna corymbosa	Used for curing piles and tumours
Viscum monoicum	Powerful narcotic
Rhizophera apiculata	Root decoction used to relieve high blood pressure
Causarina equisetifolia	Bark is astringent and used to cure diarrhoea and dysentery

Source : Naskar and Bakshi (1987)

Evidently several species of wild plants have been known for their medicinal uses from ancient times and the Unani and Ayurvedic system of medicine are practised in Bangladesh (Shiva, 1994). **Consideration should be given to organised field and laboratory studies in a field which has a fast growing following amongst professionals and laymen alike. Whether for small-scale industrial purposes, the pharmaceutical industry or ecotourism, there are several factors which should be considered:**

- Selection for the appropriate phenological stage for harvesting and testing.
- Period of optimum percentage yield of the active principles that is perceived to be of value for the desired usage.

- Practical, conservation orientated and non-destructive methodology for harvesting, grading, processing and extraction.
- Involvement wherever possible of existing local and traditional knowledge.
- Appropriate technology for sustainable *in situ* harvesting or *ex situ* propagation bearing in mind biodiversity conservation imperatives.

Aromatic plants appear have also been given little attention in the past in the SRF. Some species, such as Baria ghash ***Blumea sp.***, Sitka or Sitki ***Clerodendrum inerme***, Kucha or Kusha ***Cyperus javanicus***, Chagalkuri ***Ipomea pes-caprae***, Kaka jungha ***Leea aequata*** Kewa kata ***Pandanus foetidus*** and Serpoli ***Premna corymbosa*** are said to contain oils which have pharnmaceutical and medicinal value. There may be some scope for development of cottage industries based on these products.

Cyperus javanicus has commercial uses beyond use of fibre by extraction of essential oil from the tuberous roots which are aromatic and may be useful for perfumes and agarbatties or Joss sticks (Shiva, 1994). Possibilities for increasing its commercial utilisation in cottage industries may be worth considering.

For further details of potentials for this group of plants reference should be made to Shiva (1995).

11.2.9 Mangrove tannin production

Tannins and dyes have been extracted traditionally from many plants found in the SRF. All the work is done by hand but the factory at Khulna has closed down. The bark of goran, gurjan, dhundal, passur and kankra are rich in tannins and with an increasing demand for leather for the domestic and export market in leather goods the possibility of re-opening the tannin extraction factory remains.

Mangroves are known to be a good source of tanning materials and excellent grades of leather are produced from mangrove bark tannins. Few data are available. The economic value for Bangladesh was Taka 77 million in 1992 derived from sources outside the Sundarbans (Shiva, 1994). Table 38 indicates possible sources of tannin resources of the SRF. There is a Leather Technology College at Dhaka and there could be opportunities for scientific collaboration with Leather Institute of India with a view to boosting regional exports and cross-border trade (Shiva, 1994).

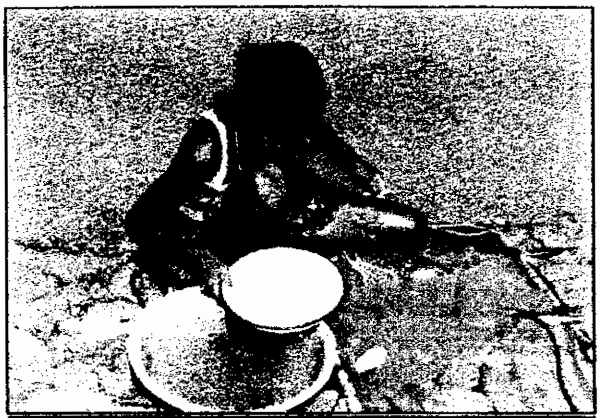
About 10,000 t of mangrove barks are thought to be available annually at the felling coupes in the SRF. According to Shiva (1994) tannins from mangrove barks should be utilised again since Bangladesh uses about 10 million m^2 of raw hides of which only 20% are tanned locally (Razzaque et al., 1987). **There appears to be abundant scope for manufacture of solid tannins for import substitution through utilisation of bark off-cuts from the forest and at KNM.**

Table 38 Tannin Resources of the SRF

(Shiva, 1994)

Scientific Name	TANNIN PERCENTAGE %				Remarks
	Stem bark	Fruits	Twig Bark	Leaves	
Aegialitis rotundifolia	11				Bark & Fruit and/or direct tannin
Aegiceras corniculatum	14 (like avaram)				good
Amoora cuculata *Avicenia alba*	8 5				
A. marina *A. officinalis*	12.5 5-6			Yes	good
Barringtonia racemosa *Bruguiera gymnorhiza*	18 25-72 (fresh) 56-65 (Powdered extract)		7.3	7.3	2.25 very good 2.23 tonnes 3 dry bark yields one ton of solid extract
B. parviflora	9.6 - 25.5	9.6	12.00	12.0	
B. sexangula	7.2 - 36				
Ceriops decandra *C. tagal*	25-40 60-65 (Bark extract) 41.2 67.6 (Extract)				Very good potential
Derris trifoliata *Diospyros peregrina*	9.30	15			
Excoecaria agallocha	10-12 9 (Non-Tannin)				
Heritiera fomes	8-12.4			9.7-11.7	
Kandelia candel	15 - 17 13.5 (Non Tannin)		15.4		
Lumnilzera racemosa	15-19				
Nypa fruticans				10.2% 15.2 Hard tannin	
Rhizophora mucronata	25-35 (Bark) 7-14 (Wood)	12.00 (unripe) 4.2 (ripe)	9.1		very good
Sonneratia apetala	11-16.6	9.6-10.00	14.00	8.00	Bark & Fruit 2:1 good for direct tannin
S. caseolaris *Tamarix indica*	9 - 17 15.3%		11-11.9		Bark & Fruit 2:1 good for direct tannin Galls has 40 - 50
Xylocarpus granatum	25..0				
X. mekongensis	24.0				

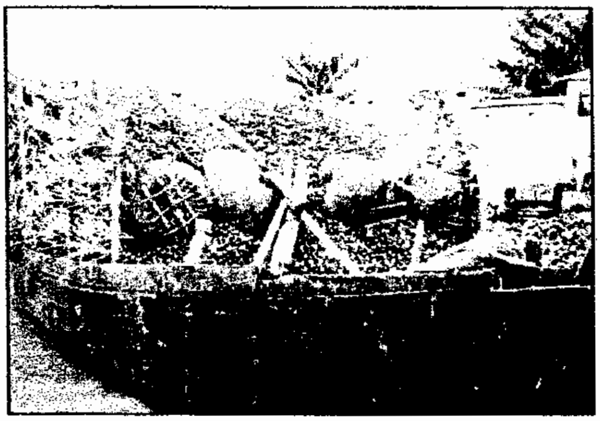
Plate 4



Shrimp Fry Collection

Mud Crabs

Shrimp Harvest



Shell Harvest

Fish Harvest

Ice Blocks for Fish Harvest

11.3 The Fisheries

The Sundarbans fishery is a major resource contributing at least 5% to the total fish harvest of Bangladesh. The fishery was studied for this plan and reported upon in detail by Chantarasri (1994); Pena (1994); Ahsanullah (1995) and Smith, Khulna University (1994) but further work needs to be done if informed decisions on the subject are to be made. These studies have provided some data on stocks of commercially important species of finfish, shrimps and crabs. Two high priorities are how to proceed with institutional strengthening and collaborative research and management.

The case for integration of some aspects of management with the Fisheries Department and with user groups and other specialised technical agencies is irrefutable. How this can be achieved is discussed in this plan.

The SRF annual fish harvest represents the most important non-wood forest product harvested within the ecosystem and proper understanding of the ecology of the fish stocks and all aspects of management of the resource must be a prime consideration for future investment plans. Key ancillary issues, beyond the present technical capability of the FD, include total fish stock assessments, international boundaries, offshore Marine Zone protection, straddled stocks, socio-economic factors, marketing and post-harvest technology.

Future management should proceed by obtaining reliable data on resources utilisation and the social benefits derived therefrom. Nutrition, income and employment accruing to the local population should be quantified and measured. This plan provides background information and guidelines for further investigations and urgent regulatory rules which should be instituted as soon as possible.

A provisional species list is given in Appendix A23 indicating a fish fauna of 8 chondrichthyans, 168 species of osteichthyan and 31 species of crustacean. Further research is very likely to add new species to the inventory. Seidensticker and Hai (1968) reported that over 120 species are commonly caught in the Sundarbans' waters.

There were four reasons why reliable data were difficult obtain for this plan, all of which will hinder future studies if they are not addressed properly in the interim:

- Lack of dedicated survey vessels.
- Lack of definition of areas of responsibility so that there is an unacceptably wide range in interpretation of inshore and offshore areas, not only of their boundaries but also of the fish stocks, especially straddled stocks (Pena, 1994).
- Lack of co-ordination and collaboration between other projects and agencies involved in fisheries research and management offshore and in the Border Zone.
- No data validation system.

An inshore and an estuarine/offshore fishery appear to fall within the sphere of responsibility of the SRF administration and in the absence of any known legally tenable boundary descriptions, proposals are made to define new boundaries which should properly encompass the offshore fishery by including the 5 m contour up to which most fishing occurs and this falls within the 12 nautical mile (22 Km approximately). How this will be managed remains a matter for debate but it is strongly advised that decisions are made soon to assist the FD with practical management of the marine zone. See Map 1.

The SRF fishery has strong ecological, social and economic overtones which relate to the large number of traditional and commercial fishermen who access the SRF throughout the year. **An environmental impact assessment of all fishing activities should be combined with basic research on the status of the fishery in any follow-on study.**

Present indications are that there is almost non-existent management resulting in dangerous over-exploitation of all the the stocks. The situation is summarised below:

- Finfish, shrimps, crabs and oysters are intensively harvested at the "Maximum Social Yield" level (Pena, 1994) which is unsustainable and requires properly directed management of breeding areas, fishstocks, and methods of harvesting.
- There is little doubt that substantial further work will be needed beyond the scope of the IRMP to provide adequate information on fisheries resources and related socio-economic factors since the subject involves many matters connected with the offshore fishery, straddled stocks, seasonal migrations (Dubla and Kachikali) to and from the SRF of fishermen and their followers who are not locally resident. There are many factors connected with harvesting, value added activities and marketing in the Border Zone which require a multisectoral strategy.
- It is essential that the Forest Department is provided training and technical support in order to collaborate with the Fisheries Department in research and management. If there is inadequate technical capability in either or both departments then this is a matter which should be addressed jointly.
- Estimates of optimum yield are provided but it is emphasised that these can only be used as guidelines.

All fish stocks require immediate management attention. Every effort must be made in the near future to improve a perilous situation.

11.3.1 Definitions of inshore and offshore fisheries

Chantarasri (1994) identified an inshore and an estuarine/offshore fishery in the SRF. He did not explicitly delineate the area encompassed by either nor the basis on which the distinction was made. The estuarine/inshore fishery is considered to lie north of latitude $21^0 50'$ (Smith, 1995) which approximates the 2m depth marine contour and the old Curtis (1928) boundary up to which most of the traditional fishing is said to occur (Shahid, 1985). This is an arbitrary distinction but will be reflected by differences in salinity, depth and fish fauna.

This plan summarises fishery data on commercially important fish and crustaceans. The following species were identified by Chantarasri (1994) as being of high commercial value requiring immediate management attention:

• ***Hilsa ilisha***	Clupeidae	hilsha
• ***Pangasius pangasius***	Pangasidae	fatty catfish
• ***Plotossus canius***	Plotosidae	canine eeltail catfish
• ***Lates calcarifer***	Centropomidae	barramundi
• ***Pomadasys hasta***	Haemulidae	white grunt
• ***Johnius argentatus***	Sciaenidae	silver jewfish
• ***Penaeus monodon***	Penaeidae	tiger shrimp
• ***Macrobrachium rosenbergii***	Palaemonidae	giant freshwater prawn
• ***Scylla serrata***	Portundae	mud crab

11.3.2 Finfish

There are 5 major groups of finfish so far identified in the SRF (Khulna University, 1994). These are listed below:

(1) Cartilaginous fishes (sharks and rays). This group is primarily marine though some cartilaginous fishes are adapted to freshwater. Sharks and rays are not uncommon in the lower reaches of the SRF, but are of moderate to low fishery importance.

(2) Herrings, shads and anchovies. A marine group that is able to tolerate low salinities. Some species, notably shads; e.g., ***Hilsha ilisha***, are anadromous, migrating up rivers to spawn. There may also be populations of ***H. ilisha*** that are permanent

residents of the larger rivers (Talwar & Jhingran, 1991). Most fish in this group are of high fishery importance.

(3) Catfishes. Most species are characterised by barbels on each side of the upper jaw. The catfish fauna of the Indian region is large and diverse. Further survey work in the SRF can be expected to result in many more new records and possibly new species. This group is primarily fresh water though many species tolerate brackish water and a small number of marine species also occur in the region. Catfishes are popular food fishes and represent an important element of catches.

(4) "Perch-like" fishes. A large group, represented in the SRF by primarily marine species. Examples include the snooks, groupers, jacks, snappers, grunts, polynemids, jewfish, scats, seabreams, mackerels and mullets. Most of these species spawn in seawater, though the juvenile and sub-adult stages of many spend time in estuaries. These fishes are of moderate to high fishery value. There are many fishes within this group of negligible commercial value but considerable ecological importance through their ubiquity and high abundance, e.g., the gobies.

(5) Flatfishes. A primarily marine group of moderate to low fisheries interest. These are popular foodfishes in India but are not highly esteemed in Bangladesh.

11.3.3 Prawns

Crustaceans belonging to the pelaemon group are here termed prawns such as ***Macrobrachium rosenbergii***.. These are a largely freshwater group and, like shrimps, are of high economic value. Prawns spawn readily in captivity and there is little demand for wild prawn seed.

11.3.4 Shrimps

Crustaceans belonging to the penaeid group are here termed shrimps, such as ***Penaeus monodon***. Shrimps are a marine fishery resource of high economic value, both adult and young stages (termed "seed" or fry) are caught. Shrimps are cultured in south west Bangladesh and a large demand for shrimp seed exists to supply the aquaculture industry throughout the region and elsewhere.

11.3.5 Crabs

A valuable fishery for a small number of species, particularly the edible mud crab ***Scylla serrata***, exists in the SRF.

Until the late nineteen eighties crabs were given scant attention but in recent years edible crabs have become a highly sought-after aquatic resource which has a growing economic value. Unfortunately extensive harvesting is carried out against a background of inadequate data on the ecology and status of the species populations and thus sustainability and management cannot be well predicted or organised.

Crabs constitute a large and ecologically important group of marine and brackish water crustaceans which are now in high demand for export. It is inevitable that with intensive harvesting a decline in harvets can be predicted. Research and controls should be implemented soon.

11.3.6 Oysters, shells and lime production

Shellfish or molluscs such as univalves (gastropods) and bivalves (pelycepods) are generally termed "Ciloen" in Bengali. There are at least 7 species of bivalves in estuarine areas and the mangrove floor of the SRF (Chantarasri, 1994):

• ***Crassostrea gryphoides***	Rock oyster
• ***Anadara* sp.**	Cockles or blood clams
• ***Crassostrea gigas***	Giant oyster
• ***Meretrix meretrix***	Thick - shelled clams
• ***Hiatula* sp.**	
• ***Donax* sp.**	
• ***Pholas* sp.**	

The shells of most larger species are collected for lime production and the Giant Oyster or "Chinuk" is considered to be the most important.

It is believed that dead shells of this species are harvested from June to October. Harvesting takes place at the following sites:

Khulna Range :	Satkhira Range
Adachi coupe	Throughout the coastal area
Gewakhali	
Patkosta	
Nilkamal	
Sarankhola Range	Chandpai Range
	Bhadra
Batmor	
Katkha	
Patakhata	

Shells range in size from 15.2 cm to 38.2 cm with weights between 145 gm and 2 410 gm for a single side (Chantarasri, 1994).

In 1993 there were an estimated 2030 oyster collectors operating in the SRF who worked an average of 12 days per month especially during neap tide periods.. It appears that only dead shells are harvested and that the living animals are not gathered since this is much more difficult.

The production of ***C. gigas*** was estimated at 3650 t in 1993 and the average number of days spent by each collector was 144 days per year. There appears to be no threat to the stocks of this species but the matter requires much further investigation.

Maximum sustainable yields can be determined through use of the Schaefer model since catch and effort data are available. Catch-per-unit effort was computed by Chantarasri as shown in Table 39.

Table 39 Annual production, number of collectors and catch/effort of *Crassostrea gigas* in the SRF

YEAR	CATCH(TONS)	RAISED CATCH(TONS)	EFFORT NUMBER OF DAYS	CATCH/EFFORT KGS/DAY
1989-90	2960	3196	259344	12.3
1990-91	2470	2667	270432	9.8
1991-92	3080	3326	277344	11.9
1992-93	3380	3380	292320	12.4

11.3.7 Estimated current yields - commercially important fish

The current yields from the inshore and estuarine/offshore fishery are still the subject of investigation. The total landed harvest, including the offshore catch, may be as high as 75 000 t. In 1994 131 000 boats of all sorts were licensed to enter the SRF. It is estimated that some 250 000 people enter the Forest each year to fish. Of these over 80% fish for crustacean fry and crabs.

The current yields estimated by Chantarasri (1994) and verified by Smith, Khulna University (1995) are shown in Tables 41 and 42 respectively. The current yield of fish and crustacean larvae is shown in Table 40. Total yields of the commercially important fish and crustaceans in 1993 are shown in Table 40. Estimates of current yield were obtained by summing the total catch of each species for each type of gear. The total catches for each type of gear were estimated by Chantarasri (1994) who multiplied the numbers of gears recorded by the FD by the mean monthly catch. The estimate of mean monthly catch was based on sampling by Chantarasri. **In view of the secondary nature of most of the data on which these figures were based (no independent direct sampling was made) resulting in estimates which cannot be tested for reliability, the figures for present yield should be treated with caution.**

Table 40 Estimated total yield of nine commercially important fish and crustaceans of the SRF

Species	Yield (t) 1993
Hilsa ilisha	761.5
Pangasius pangasius	134.6
Plotossus canius	141.0
Lates calcarifer	150.2
Pomadasys hasta	232.4
Johnius argentatus	504.3
Penaeus monodon	214.8
Macrobrachium rosenbergii	274.4
Scylla serrata	396.2

(Khulna University, 1995).

11.3.8 Estimated future sustainable yields

Estimates of sustainable yield require accurate base data and the figures quoted here are considered unreliable and the methods for calculating optimum yield approximations (Smith, Khulna University 1995). More data of greater reliability will be needed before precise target yields can be set for the SRF. Independent verification of data are a matter which requires properly coordinated research in which the FD, Fisheris Directorate and Khulna University could conveniently participate.

11.3.9 Fish harvesting and marketing

Details of comparative data on the harvesting and marketing of fish in the SRF and adjacent areas are provided in two studies commissioned for this plan (Pena, 1994; Ahsannullah, 1995).

Their findings support the view that stocks are generally harvested beyond sustainable limits and that immediate remedial action should be take. Added to this there is substantial scope for improving post-harvest processes by introduction of better technology and better product preparation, packaging and transport.

High priorities for investment in development of the fishery are:

- Stepped up information and education for user groups.
- Better storage and handling facilities.
- Greater participation of user groups in stock management especially setting of catch restrictions and closed areas.
- Immediate implementation of conservation rules preferably by agreement with defined tradional fishing groups.

11.3.10 Fishermen statuses - groups and their organisation

Few data are available on the organisation of user groups other than geographical and seasonal separation of places of origin and the different areas in which fishing occurs.The majority of fisherfolk are thought to reside in Barisal, Pirojpur, Bagerhat, Khulna, Satkhira, and Jessore with seasonal influxes of great numbers of fishermen and followers from Cox's Bazar and Chittagong.

The most established fishermen in the coastal region are those who come from Chittagong and Cox's Bazar. Fishing is carried out by groups led by an entrepreneur, leading a fleet of fishing boats and known as a Bahardar (owner of a fleet), who does not directly participate in fishing but directs the whole operation. There are about fifty Bahardars who operate from two Chars: Meher Ali and Majher Khal. A Bahardar usually has a fleet of about 2 trawlers (engine boats) and 2 country boats with a group of 40-50 workers. Two-thirds of the workers are fishermen who spend almost the entire 4-5 months at sea catching fish. The Bahardars concentrate on the south western side of Dubla working around Meher Ali, Majher Khal, Office Killa and Moger Tek.

Fishing and sun drying centres around Dubla which is in effect a cluster of about 30 chars. These, for centuries, have been a base for a traditional fishery where fish drying, religious festivities and tourism play major parts during the cool dry months of November to February. During this period over 30,000 people involved in the fish harvesting and drying activities stay on the sea front while another 30 thousand or so visit for religious and touristic purposes.

A group of less established fishing entrepreneurs from Khulna, Barisal regions, known as Savar fishermen, have in recent years concentrated in the north eastern side of the Islands, particularly around the Char known as Alorkole. In Alorkole there are about 6,000 fishermen living in about 800 huts. About 55 % of these fishermen come from Khulna and Satkhira, while the rest are from Barisal, Pirojpur and Bagerhat. Every year new fishermen groups arrive here, so the population steadily increases. About 60 % of the fishermen are traditional Hindu fishermen, while the remaining 40 percent are Muslims consisting mostly of landless labourers.

There are three categories of Savar (Savar fishermen): large, medium and small, depending on the number of boats they own (usually 1-3) and whether any of them is mechanized. In Dubla there are about 1,300 Savars while another 1,600 work from other Chars. Added to these groups there are about 32,000 other fisherfolk who work in this coastal region during the season. (MARC, 1997; MARC/DDC, 1997).

11.3.11 Fishing gear and catch Composition

This matter is described in some detail to assist future managers with basic information on the nature of the fishing system. Fishing usually takes place from partially covered wooden boats 5-7 m in length. The general term for these vessels is "nouka". Catches are stored either inside the shallow hold or are tied alongside so that the catch is retained alive. Some species are stored in cylindrical wicker baskets. Fishermen cook and sleep inside their boats.

There were 14 major types of fishing gear being used in the SRF in 1993 (Chantarasri, 1994; Khulna University, 1995

Data on numbers of fishing gear, numbers of fishermen operating them, class of gear and the fishery they are used in are shown in Table 44. Data for the numbers of fishing gears are based on FD records. The FD does not directly record the numbers of gears operating in the SRF in any one month, but instead the numbers of weekly fishing permits issued. Thus, because one set of gear may have up to 4 permits issued for its use in one month, FD records are likely to over estimate the numbers of gear. Chantarasri (1994) adjusted for this overestimate but gives no expIaNation of how this adjustment was calculated.

On the basis of sites and type of catch, gears fall into 3 classes listed in Table 44. Gears are described below and catch composition is summarised in Table 41.

- Class A : Used in the inshore fishery to catch adult fish and crustaceans. The catch compositions of gears belonging to this class are shown in Table 41. The estimated total catch from these gears in 1993 was 3053.9 t. This class of gear has a relatively high selectivity (mean number of major species caught <10).

- A1 Cast net : A circular net that is thrown. The user retains a foot rope that is used to close the mouth of the net. The diameter of the nets ranges from 3.5 - 10 m. Cast nets are often used by fishermen operating "sit and wait" type gears, such as longlines, during inactive periods. A large proportion of cast net fishermen increase their catches by using a ground bait of clay and fishmeal to attract and aggregate fish in one area. Cast nets are used predominantly in the northern part of the inshore fishery.

- A2 Canal gill net : A single panel of netting set at high tide across relatively narrow side channels of 20-50 m width. Fish are caught when they partially pass through the mesh of the net but are unable to pass completely through. When fish try to reverse from the net they become caught by their backward directed gill covers, hence the name "gill net". Canal gill nets are operated largely in the north and west of the inshore fishery.

- A3 Crab hook and line : A set of between 350-500 wire hooks (0.02 - 0.03 cm diameter) with a shank length of 2 - 2.5 cm, laid along the bottom of side channels. The hooks are baited with fish. The position of the line of hooks is often marked with a polystyrene float or plastic bottle. The line of hooks is deployed from a nouka and hauled in every 3-4 hours. The target species is ***Scylla serrata***.

- A4 Gill net : Details of gill nets and their use in the SRF are not available. This net would work on the same principal as the canal gill net, but is presumably set in the larger river channels.

- A5 Hilsha gill net : Used in both the inshore and offshore fisheries. In the inshore fishery nets are between 300-800m long and deployed from non-mechanised noukas. These nets are used primarily in the eastern part of the SRF from May to October. In the offshore fishery nets are 1000-3000 m long and deployed from mechanised fishing boats from June to March. Hilsa gill nets are set mid-stream and suspended from a set of floats. The target species is ***H. ilisha***.

- A6 Longline : Termed "hooks and lines" by Chantarasri (1994). A set of between 400-800 hooks with a shank length of 2-2.5 cm, baited with fish. The line of hooks is weighted at intervals with a house brick to maintain it close to the riverbed. The line is marked with polystyrene or a plastic bottle. Longlines are used in the inshore and offshore fishery. They are deployed from noukas during high tide for 5-6 hours. Target species are large catfishes and predatory perciform fishes.

- A7 Otter gill net : A 100-300 m long gill net of 3-5 m depth into which fish are driven by trained otters ***Lutra perspicillata***. This gear is operated from 9-12 m boats and requires at least 3 fishermen. The target species are ***Hilsa ilisha*** and ***Lates calcarifer***.

- A8 Pangash gill net : Details of pangash gill nets and their use in the SRF are not available. The target species is probably ***Pangasius pangasius***.

- A9 Rod and line : Termed "stick-hook" by Chantarasri (1994). A wooden stick of approximately 75 cm length to which is tied a length of nylon fishing line of sufficient length to reach the riverbed. A hook with a shank length of 2 - 2.2 cm is attached to the end of the line and baited with juvenile ***Penaeus indicus*** or a flour/fishmeal paste. Up to 6 rods are operated by one fisherman. Rod and line fishing takes place in the northeast of the SRF in both main river and side channels. Fishermen usually operate close to the riverbank, particularly in the major river channels and often at the confluence of small side-streams. The target species is ***M. rosenbergii***.

Class B : Used in the offshore fishery for adult fish and crustaceans. The catch composition of gears belonging to this class is shown in Table 42. The estimated total catch from these gears in 1993-94 was 8648.3t. This class of gear has a relatively low selectivity (mean number major species caught >10).

- B1 Set bag net : A large bag-shaped net suspended between two wooden poles driven into the substrate. The month of the net is held open by 2 vertical wooden poles. The net tapers from the mouth to a cod-end. The cod-end can be raised and lowered by fishermen in a boat positioned above it. The net faces the tidal flow and the direction of the net is reversed depending on the direction of the tide. . Use of the set bagnet is limited to a maximum water depth of approximately 25m.

- B2 Shore seine net : A single panel of netting 150-300 m long and 2-5 m deep. The net may be deployed from the shore or from 2 boats in a half-circle. After deployment, both ends of the net are hauled into the shore where the catch is beached. This gear requires at least 4 fishermen and is used in sandy, estuarine areas. Shore seine nets are fished at high tide, typically from October to March.

Table 41 Summary of the catch composition of Class A fishing gear in the SRF in 1993

Species	Gear[A]										
	CN	CGN	CHL	GN[B]	HGN	LL	OGN	PGN[B]	RL	SN	Total
Hilsa ilisha					743.8		16.2				**760.0**
Setipinna taty					3.5					64.4	**67.9**
Panagasius pangasius	36.0					57.0	8.4	33.2			**134.6**
Arius sp.	20.0	29.2				46.1				2.1	**97.4**
Plotossus canius	68.0			73							**141.0**
Lates calcarifer	100.6						25.2	4.6		19.8	**150.2**
Lutjanus sp.						51.0				3.8	**54.8**
Pomadasys maculatus		5.2									**5.2**
Pomadasys hasta	38.0	66.6								56.8	**161.4**
Johnius argentatus	8.4				18.0	47.8			6.9	43.4	**124.5**
Scatophagus argus										1.1	**1.1**
Liza sp.										6.2	**6.2**
Polynemus sp.		21.6			0.8	16.4				6.6	**45.4**
Gobius sp.										3.6	**3.6**
Penaeus indicus		20.6								36.2	**56.8**
Penaeus monodon										2.4	**2.4**
Metapenaeus monoceros		7.0								5.1	**12.1**
Palaemon sp.										1.1	**1.1**
Macrobrachium rosenbergii	24.6			25.8		15.4			203.7	4.9	**274.4**
Macrobrachium sp[C]									5.8		**5.8**
Scylla serrata	21.4		374.8								**396.2**
Other	21.0	22.3	10.7	433.2	2.8	11.2	2.5	33.8	11.0	3.3	**551.8**
Total	**33.8**	**172.5**	**385.5**	**532.0**	**768.9**	**244.9**	**52.3**	**71.6**	**227.4**	**260.8**	**3053.9**

A - CN = cast net, CGN = canal gill net, CHL = crab hook & line, GN = gill net, HGN = hilsha gill net, LL = longline, OGN = otter gill net, PGN = pangash gill net, RL = rod & line, SN = shore net.
B - Complete catch composition data not available
C - excluding *Macrobrachium rosenbergii.*

Class C : Used in the inshore fishery to catch crustacean larvae. The estimated total catch for these gears in 1993 was 3.52 X 10^9 larvae. This class of gear has a relatively high selectivity (mean number of major species caught <10).

- C1 Shrimp fry hand-net : Termed "tiger prawn fry pull net" by Chantarasri (1994). There are 2 types of shrimp fry hand-net, one having a triangular the other a rectangular wooden frame. Both are mobile nets, the user pushing or pulling the nets through shallow water. The target species, ***Penaeus monodon*** reproduces on a lunar cycle and peak larval abundance is typically 2-5 days following a full moon. Catches are sorted on the shore. After removing ***P. monodon*** larvae, unwanted fish and crustacean larvae are discarded on to the shore to die. Shrimp fry hand-nets are operated throughout the inshore fishery though predominantly in the north of the SRF.

- C2 Shrimp fry set bagnet : This net operates on the same principle as the set bagnet, but with a finer mesh. It is operated in the larger river channels in the northern area of the inshore fishery. Catches are sorted on boats, the cod-end being emptied approximately every 30 minutes. The catch is released from the net into a earthenware pot. A portion of the catch is poured into a white based dish wher ***P.monodon*** larvae are removed using the single valve of a bivalve mollusc, ***Unio* sp**. Small numbers of edible juvenile fish are removed and dried by the fishermen for their own consumption. Unwanted fish and crustacean larvae are returned to the water.

Table 42 Summary of Catch Composition of Class B fishing gear in the SRF 1993-94

Species	Set bagnet	Shore seine net	TOTAL (tonne)
Lamniform sharks	44	-	44
Rajiform rays	68	-	68
Hilsa ilisha	1.5	-	1.5
Sardinella sp.	895	-	895
Coila dussumieri	338	-	338
Setipinna taty	548	7.3	555.3
Harpodon nehereus	1572	-	1572
Arius sp.	16	-	16
Caranx sp.	115	-	115
Megalaspis cordyla	52	-	52
Pampus argenteus	76	-	76
Leiognathus sp.	32	-	32
Pomadasys hasta	71	-	71
Johnius argentatus	411	12.2	423.2
Otolithoides biauratus	161		161
Liza sp.		5.5	5.5
Polynemus sp.		1.6	1.6
Trichiurus haumela	2710		2710
Rastrelliger kanagurta	43		43
Cynoglossus sp.	67		67
Penaeus indicus	210	2.4	410
Penaeus monodon	210	2.4	212.4
Metapenaeus monoceros	164	1.0	165
Parapenaepsis sp.	372	3.0	375
Acetes sp.	41		41
Others	279	3.5	282.5
TOTAL	**8624**	**36.5**	**8648.3**

Table 43 Summary of catalogue composition of class C fishing gear in the SRF in 1993.

SPECIES	Numbers of Fry (X 10^6)
Lates calcarifer	126
Liza sp.	146
Gobius sp.	136
Stolepholus sp.	155
Polynemus sp.	125
Penaeus monodon	1453
Penaeus sp.[B]	140
Metapenaeus sp.	1109
Others	131
Total	**3 521**

(Smith, Khulna University 1995)

A - Separate data for each type of net are not available
B - Excluding *Penaeus monodon*

Table 44 Summary of the types of gear, mesh size, class, number of gears and no of fishermen

TYPE OF GEAR	Mesh size (cm)	Class of gear[A]	Numbers of gears[B]	Numbers of fishermen[B]	Fishery 1993	
					Inshore	Estuarine/offshore
Cast Net	?	A	3256	4232	+	
Canal Gill Net	1.5-2.5	A	240	728	+	
Crab Hook and Line	-	A	2024	3108	+	
Gill Net	?	A	475	1662	+	
Hilsha Gill Net	10.5	A	570	2450	+	+[d]
Longline	-	A	739	1108	+	+[d]
Otter Gill Net	3.0-5.0	A	7	23	+	
Pangash Gill Net	?	A	45	144	+	
Rod and Line	-	A	387	1257	+	
Set Bagnet	1.0[e]	B	3382	21983		+
Shore Net	1.5 - 2.5	A	421	1473	+	
Shore Seine Net	1.2-2.5	B	35	157		+
Shrimp Fry Hand Net	0.2-0.3	C	99920	145884	+	
Shrimp Fry Set Bagnet	0.2-0.3	C	7540	14099	+	
Total			**119041**	**198308**		

(Khulna University, 1995)

A = see Table 41
B = data based on FD
C = for definition of inshore and estuarine/offshore fishery see Table 42
D = catch data do not distinguish between the inshore and estuarine/offshore fishery
E = from Bal and Rao (1990)

11.3.12 Sport fishing

The potential for sport-fishing in the SRF centres around a small number of fish species. In the estuarine/offshore area, the highly prized tenpounder ***Elops machnata*** is said to occur, though its abundance is uncertain. Large marine catfishes,such as ***Arius thalassinus***, are relatively common and are popular with sport-fishermen. In the inshore area barramundi ***Lates calcarifer*** of up to 60 cm TL have been caught. This species is closely related to the Nile perch (***L. niloticus***) a popular sportfish in Africa, and the basis of many sport-fisheries. Other species that might be exploited for sport-fishing include snappers **Lutjanidae**, grunters **Haemulidae** and croakers **Sciaenidae**. Many of these groups are already caught using baited hook and line and whenever turbidity is low artificial lures could be effective for catching many species.

There would be an overlap between the species caught in a sport-fishery and those currently harvested by fishermen in the SRF. Sport fishing would not have a significant detrimental impact on fish yields from the SRF. However, the introduction of a sport fishery could lead to conflicts with local fishermen.

11.4 Wildlife

The SRF is the only remaining environment within the lower Bengal Basin where wildlife is still present in adequate abundance to justify management in its own right and to be considered a National asset. It is an immensely valuable resource which is currently receiving practically no management and suffers from anomalies in legal definition, erratic public perception and ineffective administration. These matters are discussed and guidelines proposed to improve management and for better resource utilisation.

Wildlife, the fauna in particular, has been the subject of a separate technical report Tamang (1993) which should be referred to for detailed information on this aspect of the SRF's biotic resources. Although the forest in many respects has a high degree of uniformity it has an interesting spectrum of faunal species, albeit reduced in numbers in recent times and difficult to observe in many instances.

Some wild animals, such as the mud crab, are excluded from the legal definition of wildlife, yet they are not only a most important species in the dynamics of the mangrove ecosystem but in recent times they have become a valuable export product for which there is no management. Other species, in particular the Royal Bengal Tiger, spotted deer, wild boar, turtles, dolphins and crocodiles are diverse examples of a rich wildlife spectrum requiring urgent attention.

Most writers comment upon the loss of at least five, possibly six, spectacular mammal species, Javan rhinoceros ***Rhinoceros sondaicus,*** one-horned rhinoceros ***Rhinoceros unicornis,*** wild buffalo ***Bubalus bubalis,*** swamp deer ***Cervus duvaucali,*** gaur ***Bos gaurus,*** hog deer ***Axis porcinus,*** in recent times, and few remark on how this decline in biodiversity might be reversed, both as a function of positive wildlife management and as a source of interest for visitors. This matter is dealt with under Section 5.1 of this plan.

At present there are some 42 species of mammals within the SRF and neighbourhood constituting 35% of the total found in Bangladesh. Definitive inventories of mammals, birds, reptiles, and amphibians and some invertebrates are provided in volume 2 Appendices.

11.4.1 The tiger population

Tiger ***Panthera tigris tigris*** occur throughout the Sundarbans ecosystem in Bangladesh and India but their range is now circumscribed by the high density human population and total loss of suitable habitat in the surrounding countryside. Future investment in wood and non-wood resources should make provision for a project to investigate the behavioural ecology and physiology of this population which is of such high National and international importance.

Tidal mangrove forest is a rare habitat for the species but in many ways it is unusually secure nevertheless the species is listed as a CITES Appendix 1 endangered species in the IUCN Red Data book. The Sundarbans population may be the largest discrete population of tigers worldwide and it is a paradoxical source of National pride, fear and misunderstanding. Conservation of this gene pool is a major responsibility for the Nation and the Forest Department in particular. The paradox, which wildlife management must address is that tigers kill human beings and in the SRF compete with man for space yet there is a universal demand for protection of the species.

It is by far the most important tourist attraction on the one hand and is responsible for regular killing of human beings who enter the SRF to harvest forest produce on the other. It appears that the population is not declining (Tamang, 1993) with all population estimates in the last 20 years remaining in the range 350 - 450 animals.

Basic background information on its ecology and behaviour is vital for making the proper management decisions but such data are either scarce or lacking. Tigers are secretive, of low density and essentially solitary hunters, but surviving populations are now isolated, scattered and mostly confined to parks, reserves and adjoining forests. Habitat destruction, encroachment and disturbance by man are the causes of its decline.

The distribution of tiger in the SRF depends upon the dynamics of territorial behaviour and the physical structure of the environment. The home range size of resident males is much larger than of the resident females. The size of female ranges depends upon age and mobility of cubs (Tamang 1982). Females may be restricted most of their lives by raising cubs. The combined ranges of several resident females form the home range of a resident male. There are no overlaps in the occupation of home ranges by individuals of the same sex at the same time. The home range represents the exclusive territory of the resident tiger. The home ranges of resident tigers remains relatively stable. The female to male ratio among adult tigers may be as much as 2:1 to 4:1 depending upon habitat and food situation. A preponderance of females in the adult population may be indicative of a high mortality of males at predispersal and dispersal stages.

The welfare of the tiger population is dependent upon habitat and availability of prey species. Whilst the habitat is probably on the very edge of suitability for the species this population has become uniquely adapated to a hostile environment. However, the principal prey species of deer and wild boar are abundant supporting a well distributed population. Also tigers are opportunist feeders and there are records of predation on macaques, barking deer, otters, monitor lizards, other reptiles, frogs, fish, crabs, small carnivores and occasionally man (Tamang 1993).

For ecological, sociological and commercial reasons, implementation of a professional autecology study as a forerunner to proper conservation of this species deserves high priority attention. Recommendations are made for improving the FD's capability and future integrated management role in this aspect of ecosystem management.

11.4.2 The deer populations

There are two healthy deer species populations in the SRF, spotted deer ***Axis axis*** and barking deer ***Muntiacus muntjak***.

Spotted deer : This species, like the tiger lives on the edge of its natural range in the SRF. They are found throughout the Sundarbans but are most abundant in the south, where extensive grassland and scattered forests of Keora trees occur. Open grassland and Keora appears to be favoured habitat and their appears to be a preference for Keora leaves and fruit. This habitat is available in the three wildlife sanctuaries. Towards the north of the SRF forests becomes denser and deer have lower densities in these habitats (Tamang, 1993).

Herd size of the spotted deer varies considerably with the season and availability of food and water. In the south of the SRF deer were observed congregating in large numbers in areas where the grass had been burned and new forage was abundant during the period March to May. Over 70% of herds studied by Tamang (1993) were found to be in these grassland/forest habitats..

Barking deer : This small and solitary species is a widely distributed in Asia and appears to be confined to the north and northeast in the Sundarbans. They are small, adults weighing between 20 and 23 kg gross. The upper canines of the males are well developed and are distinctly visible from a distance. Although frequently seen around Dhangmari, Karamjal, Jhongra stations in Chandpai Range they are not seen in southern Sundarbans. In contrast with the spotted deer this species appears to avoid grassland and is thus better suited to the denser woodland in habitats to the north. Breeding is at all seasons but the main rut takes place in winter (December/January).

Both species are well represented in their ranges in the SRF but little quantitative data exists on changes in distribution, density fluctuation or optimum mean density. Future research should be integrated with all other inventory studies. Suggestions have been made that sport hunting and sustained yield harvesting should be introduced but it is essential that a better understanding is acquired first of population dynamics.

11.4.3 The wild boar population

Wild boar ***Sus scrofa*** occur throughout the SRF including the offshore islands.

Wild boars are omnivorous and feed on roots, stems, seeds, crustaceans, molluscs, marine turtle eggs, dead fish and other animals. They also feed on the remains of tiger kills. Some damage may be caused to regenerating forest areas through rooting up of seeds and seedlings. They are sometimes seen in big groups of 20 or more.

Wild boar in the Sundarbans breed in December/January. The gestation period is 3.5 months and four to six or more young are born in a litter. Although mortality rates are high, unlike the spotted deer, wild boar are poached since there is little demand for its meat. There could be scope for sustained yield harvesting for export or trophy hunting discussed under Part 2.

11.4.4 Birds

The avifauna discussed in Section 5.2 remains as a relatively visible and successful group of animals in the SRF. Proper management and conservation of breeding sites, feeding areas and specific habitats, together with rehabilitation of derelict bird sanctuaries, will be a positive step in establishing a more responsible attitude to this valuable resource.

The birds listed by IUCN are inventoried in Appendix A22 which should be used as a baseline for developing a management policy and practical strategy for species, some of which are depleted and others under serious but remediable threat. Illegal killing, taking of eggs and disturbance during harvesting of timber and other forest produce all exert a low level, but chronic, pressure upon species populations. A matter which is addressed in part 2 of this plan.

11.4.5 Reptiles

The reptilian fauna is discussed in section 5.3 and as for other groups which are of economic value species populations are under pressure from over-harvesting and habitat disturbance. This pressure is described by IUCN (1994) as a "severe threat" and although quantitative data are lacking there is little doubt that early remedial action must be taken by the DFO Environment to start the long haul of re-introducing control measures. Protection is required for crocodiles, monitor lizards, terrapins, turtles and python.

11.4.6 Amphibians

The amphibia are represented by the genera ***Bufo, Microhyla, Racophorus*** and ***Rana*** as described in Section 5.4 and again a lack of quantitative data makes it difficult to consider management planning other than in terms of encouraging greater control over harvesting and habitat disturbance.

11.4.7 Invertebrates

This group was studied for the first time for this plan by Professor S H Chowdhury (1995) who provided a baseline for future research which could be conducted in collaboration with Chittagong University and other academic institutions. Obviously invertebrates are an important group, some of which are of extremely high economic importance. They occupy almost every habitat and niche in the ecosystem and throughout the complex mangrove food webs (see Section 5.6).

11.4.8 Vulnerable and endangered species

The SRF is noted for the variety of plant genetic resources contained within the ecosystem including timber species, wild relatives of cultivated plants and certain endemics. Changes in environmental conditions combine with natural succession to exert selection pressures upon species and this along with man-made interference caused by intensive harvesting and unregulated commercial exploitation of resources, may cause losses of viability and even extirpation among species.

IUCN (1994) comments upon the loss in recent times of three species of ***Bruguiera*** and notes also that unregulated felling practices today threatens a number of other genera notably ***Cynometra, Amoora*** and ***Rhizophora***.

Elsewhere in this plan it is confirmed that there is a marked reduction in freshwater inflow to the ecosystem from the upstream catchment; that there is a general increase in sedimentation; that water and soil salinity has changed considerably from the patterns recorded by Curtis in 1932 and by ODA in 1985 and that uncontrolled harvesting of all species whether plants or animals must be having an impact upon species and natural succession. Prominent environmental factors such as these may not affect the viability of plant and animal associations in the short term but in the time scale of ecological adaptation and distribution there can be little doubt that some species may decline and in some circumstances disappear.

The more spectacular examples are animals listed in Table 17 and many species amongst animal populations are threatened (see Section 5) but in the SRF among plants the status of Sundri is a source of greatest concern. The occurrence of the Top dying syndrome and change of species dominance from Sundri to Gewa places a responsibility upon foresters to encourage research and to share in conservation actions.

It is not sufficient to remark upon the fragility and vulnerability of the mangroves but to look upon conservation as an integral part of development. Integrated action is to be encouraged to retain as much stability as possible within a dynamic system. This plan in Part 2 urges harmonization of conservation, development and production within an integrated management framework. Protection and monitoring of vulnerable wildlife species is a key component.

11.4.9 Wildlife utilisation

Wildlife utilisation, in the absence of any significant tourism and non-consumptive utilisation, unfortunately only means illegal off-take. It is also unfortunate that the Wildlife Act does not define wildlife *per se* but merely defines "wild animal" excluding invertebrates and fish in the definition (see

Section 8.2.2). This ambiguity needs rectification since not only is a lack of definition confusing, especially in the context of wildlife sanctuaries but also it fosters confusion in people's minds. For example the law does not specify that wildlife means plants as well as animals.

There are few hard hard data on illegal consumption of wild animals and although some species populations appear to be secure, there is every indication that demand for wildlife products will continue to grow as the population of Bangladesh grows.

Apart from the loss of major species such as the marsh crocodile, swamp deer, water buffalo and rhinoceros in recent times, the regular killing of tigers which are said to have attacked man, availability of deer meat in border markets (Kumar Dey pers.comm), lack of visibility of many other species and known export of turtle and dolphin meat from SRF sources, suggest that there is a steady pressure on all edible or marketable wild animals. **This matter will be investigated as soon as possible within the auspices of the FRMP under the direction of the DFO Environment, Khulna.**

11.4.10 Wildlife official and unofficial harvests and their management

From the above it is obvious that if the definition of wildlife were to include all plants and animals wild by nature and if the qualitative information which is to hand can be believed then the unofficial harvesting of wildlife is under the same intense pressure recorded for fish and shrimp fry. There are no official harvests of most species and urgent attention must be given to *in situ* and *ex situ* conservation to preserve genetic biodiversity.

There is no managed utilisation but with the recent restoration of the Environment and Conservation wing of the FD with a DCCF and DFOs in charge, a foundation has been laid for re-establishment of positive ecosystem conservation in the field and that unregulated unofficial harvesting of wildlife will be brought under control.

In 1994 there was some discussion on the prospects for introduction of licensed hunting and this should be given attention since there is a large harvest based upon the natural surplus which is going to waste through unregulated offtakes. This situation simply places benefits in the hands of those who are prepared to take the small risk of being apprehended. A resource is being wasted which could bring substantial new economic benefits to local people and the Nation if properly managed. This matter is discussed further in Part 2 of this plan.

11.5 Apiculture

Honey and beeswax production is a major seasonal activity employing up to 7000 traditional gatherers known as Mowallis (MARC&DDC, 1997). According to FD records they collect about 200 t of honey and about 50 t of beeswax which constitutes approximately 50% of the total production in Bangladesh (Zmarlicki, 1994). In 1995 the socio-economic study (MARC, 1997) revised estimates of the honey and beeswax harvest to 600t and 150 t pa respectively. There is a wide range in figures derived from FD sources and socio-economic studies.

At present there is little capacity to manage the resource other than on a purely seasonal revenue collecting basis. This is effected by the Forest Department by the sale of honey collecting permits. The size of harvest is listed in Table 45 based upon information obtained from FD records which contrast with information obtained during sociological studies which shows that in 1993-94 the total harvest was 16 000 Mds for honey and 4000 Mds for wax.

Table 45 Honey and Wax Production and Revenue by Year as Recorded by the Forest Department

Honey	Unit	Year									
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94
Production	maunds	6853	6015	6130	5956	2652	3909	5634	4265	4890	2841
Revenue	Tk x 1000	103	180	184	179	85	625	563	426	489	284
Price	Tk/md	15	30	30	30	32	160	100	100	100	100
Wax	Unit										
Production	maund	1713	1504	1533	1487	670	975	1407	1159	1223	710
Revenue	Tk x 1000	51	89	92	89	40	195	211	148	183	107
Price	Tk/md	30	59	60	60	59	200	150	127	150	150

Source: Forest Department Records (Mitchell, 1995).

The honey harvest appears to be fairly constant at around 4 000 to 6 000 maunds per annum. There are notable exceptions to this which are 1988-89 which would have followed the severe cyclonic storm which hit the SRF in November 1988, and in 1993-94. There is no apparent reason for the drop in 1995. Wax production follows similar trends.

Honey gatherers are allowed to enter the Forest on the 1st of April every year to collect honey from nests of the migratory wild bee ***Apis dorsata***. Unfortunately, spurred by the need to collect as much honey as quickly as possible since man-eating tigers seem to selectively prey on wandering honey gatherers, all nests whether ripe or unripe are harvested. This wasteful practice destroys newly established colonies and thereby reduces production.

To increase the production of honey in the Sundarbans Reserved Forest, Khulshi ***Aegiceras corniculatum***, Goran ***Ceriops decandra***, Keora ***Sonneratia apetala*** and Passur ***Xylocarpus mekongensis*** should be recommended for inclusion in future silvicultural schemes reforestation and afforestation.

An important management concern is that the inflexible procedure of strict adherence to the 1st of April entry date pays no heed to ecological imperatives bound more by seasonal changes in flowering periods of nectar producing plants than administrative expediency. It is found that frequently the Forest is entered too early in the flowering season thus causing honey collection before it is ripe. Ripeness of honey in the nests should be monitored and permits only being issued on confirmation that honey is ready for collection (Zmarlicki, 1993).

Honey production and processing affords one of the few avenues immediately available to assist disadvantaged social groups, women in particular. Since much of the honey collected in the SRF is badly handled it is often taken to be of inferior quality. Establishment of a pilot plant for processing honey and rendering beeswax established in the Khulna area is recommended so that the FD could work locally with a suitable NGO and thereby make a useful contribution towards poverty alleviation and value added activities based on Sundarbans produce.

A Beekeeping Manual has been prepared as a component of this plan and this should be translated into Bangla for distibution to the user group and those interested in honey culture. The charcateristcs and management of ***Apis dorsata*** and the local domestic honeybee ***Apis cerana*** *are included.*

11.5.1 The Sundarbans honey resource

Honey is gathered in the SRF in widely dispersed tracts. There is a preponderance in the western compartments and most collection occurs between April and June, just before the monsoon.

Plants of particular relevance are listed in Table 46 which provides information on flowering periods is a useful aid in future management of apiculture based upon the Sundarbans resource.

Table 46 Wild plants and forest trees of importance to apiculture : SRF

(Zmarlicki, 1994)

SCIENTIFIC NAME	LOCAL NAMES	ENGLISH NAMES	BLOOMING PERIOD
Acacia arabica	Babla/Babul	Acacia	July-August
A. catechu	Khyer babla/ Khaiya babla	Acacia	March-Mid April
Acanthus ilicifolius	Hargoza	-	May-June
Aegiceras corniculatum	Khulsi/Khalsha	-	March-April
Albizzia lebbeck	Sirish	-	April
A. mollucana	Mallacana	-	Mid April-Mid May
A. procera	Silkoroi	-	April
Anthocephalus cadamba	Kadam	-	May-June
Aphania danura	Amjam	-	March-April
Avicennia officinalis	Baen	-	May-June
Bruguiera gymnorrhiza	Kankra	-	April
Ceriops decandra	Goran	-	April-May
Cosmos bipinnatus	Kachmach	Cosmos	December-February
Dalbergia sisso	Shisho	-	Mid February-March
Eucalyptus	Eucalyptus	Eucalypt	February-Mid March
Eupatorium odoratum	Assamilatala	Boneset	November-December
Excoecaria agallocha	Gewa	-	May-June
Lannea coromondelica	Jiga/Jeal/Jika	-	Mid February-March
Leucaena leucocephala	Ipel ipel	Ipel ipel	October-November
Leucas aspera	Dulfi/Dandakalas	Wild sesame	February-March
Melilotus alba	Sedamethi	Sweet clover	December-March
Melia azedarach	Nim	-	April
Melia sempervirens	Goranim/Bakain	-	End March-April
Mimosa pudica	Lajjabati	-	January-February
Nypa fruticans	Golpata	-	-
Rhizophora mucronata	Jhana/Garjan	-	March-April
Salmalia malabaricun	Simul	Flame of the	February-March
Shorea robusta	Shal/Gajari	forest	March-April
Sonneratia apetala	Keora	Shal	End April-Mid May
Sonneratia caseolaris	Ora/Choila	-	May
Swietenia mahagoni	Mahogini	-	April
Syzygium fruticosum	Putijam	-	Mid March-Mid April
Syzygium grande	Dhakijam	-	Mid March-Mid April
Xylocarpus mekongensis	Passur	-	End March-Mid April

The most important nectar and pollen sources are the following :

- ***Aegiceras corniculatum***
- ***Avicennia officinalis***
- ***Avicennia alba***

- ***Bruguiera gymnorrhiza***
- ***Ceriops decandra***
- ***Excoecaria agallocha***
- ***Rhizophora mucronata***
- ***Sonneratia apetala***
- ***Sonneratia acida***
- ***Xylocarpus mekongensis***
- ***Acanthus ilicifolius***
- ***Cynometra ramiflora***

For the production of honey the most important plant species are Khulshi, Goran and Keora. Khulshi honey has a very good reputation among customers due to its light colour, excellent taste and tendency to remain liquid at room temperature for a long period of time. Khulshi provides a substantial contribution to the production of honey in the Sundarbans.

Blooming of nectar-rich flowers starts in March and April The nectar from the flowers of Khulshi is particularly attractive to bees due to high sugar concentrations ranging from 30% in the morning up to 52% before the noon. Bees tend to visit Khulshi flowers during the whole day, which is rare in tropical countries. The sugar concentration in nectar of Kankra ***Bruguiera gymnorrhiza*** has also been found to range from 15-23% and Hargoza ***Acanthus ilicifolius*** from 34 to 53%. Further research is needed to investigate the statuses of nectar of Goran ***Ceriops decandra*** and Keora ***Sonneratia apetala*** which, together Khulshi ***Aegiceras corniculatum***, are the most important honey plants in the Sundarbans (Zmarlicki, 1994).

11.5.2 Honey and beeswax gathering

Collection of wild honey has been practised for centuries in the Sundarbans. ***Apis dorsata*** builds a single large comb. The honey collectors have to collect the honey during the daylight hours at which time bees are particularly aggressive in defense of the colonies. Honey collectors are also the victims of many attacks from tigers as they wander through the forests in search of honey. The techniques of collecting are still rudimentary. As a general rule all colonies that are encountered are harvested whether the honey is ripe or not and colonies are often destroyed during the collection process.

Due to the high moisture content the honey often ferments soon after collection and honey is frequently contaminated by debris including large quantities of pollen and wax compelling quick sale and consumption locally, thereby limiting opportunity of value added processing.

11.5.3 Honey gatherers representative groups

Honey is traditionally a resource that is exploited by the poorest sector of the local community. The demand for honey is large and with improvements in the quality, the potential for increasing prices in the marketplace is a distinct possibility. The Mowallis represent a relatively small yet ecologically and commercially significant user group which has little say in the conduct of its affairs.

A number of local NGO's, notably Banchte Sheker, PRISM and Uttaran, are engaged in training and development of householder knowledge of honey production and small-scale processing. There is a clear opportunity for the FD to enter into dialogue with these groups in order to encourage better harvesting and post harvest technology to increase household incomes and enhance opportunities for cooperative marketing and employment beyond the short traditional season. **As values will increase it will be important to use participatory methods to establish clear usufruct rights with Mowallis concurrent with introduction of improved processing and marketing.**

11.5.4 Resource utilisation

In order to improve quality and quantity of honey collected from the SRF it will be necessary to change the present procedure of issuing permits on 1st April every year which makes no allowance for the differing flowering periods of honey plants and maturity of honey in the nests. Therefore, before issuing permits a person trained in apiculture should assess the ripeness of honey in the nests and permits should only be issued after confirmation that the appropriate time for harvesting has been reached.

An extension specialist in apiculture, thoroughly familiar with existing conditions in the country, is needed for preparation and distribution of information on beekeeping to the beekeepers. This should be a priority matter for integrated management in which the FD could play a leading role making use of the Beekeepers Manual.

The limitations of seasonality indicate that a good avenue for improving the local apiculture industry would be to integrate production from the SRF with small scale growers in the surrounding area through properly tragetted extension services. Assistance to farmers and rural communities for training of honey gatherers , introduction of apiaries in the Sundarbans and optimization of the use of variations in honey flow shown in Table 45 could be of great benefit to the rural economy. It would also demonstrate the indivisibility of the SRF and the needs and activities of local people, especially Mowallis. This is part of ecosystem management and not simply a source of resource exploitation and resultant revenue.

In future plantation trials and improvement silviculture Khulshi, Goran ***Ceriops decandra***, Keora and Passur should be recommended for reforestation and afforestation, to increase the production of honey in the SRF.

11.5.5 Development of apiculture

There is no regulated apiculture industry based upon SRF produce but recommendations are made in Part 2 for integration of FD operations with local growers and extension services in order to enhance the quality of production and value added small scale enterprises.

11.5.6 Honey processing and other by-products

Since honey collected by the honey collectors in the Sundarbans is of inferior quality, the establishment of a small plant for processing of honey and rendering of beeswax at Khulna would be a most practical way forward. The equipment for a pilot processing plant is available and will be used for training and extension purposes by the FD working with a local NGO with emphasis upon improving returns to Mowallis and increasing employment opportunities for women.

11.6 Tourism and Recreation

A desire to establish tourism in Bangladesh has been demonstrated for many years, featuring a first Masterplan for the period 1965 to 1985 and a second Strategic Masterplan in 1985 (PKF 1985) for the ten year period to 1995. Following the latter, a National Tourism Policy was formulated in 1992. Bangladesh is a founder member of The World Tourism Organisation (WTO) established in 1975. Currently much political emphasis is being given to tourism as a potentially lucrative industry, as seen in achievements of neighbouring countries in Asia.

The National Tourism Policy (NTP, 1992) proposed that, because of its unique and diverse attractions of international renown, the SRF should be developed as the springboard for the tourism industry for the country as a whole.

Location is one of many assets which should be harnessed for the development of tourism. The industry could evolve taking maximum advantage of the country's geographical and historical position of gateway to the hinterland with resultant prospects for several multi-centre tours. To achieve this the SRF must be incorporated in the primary circuits and it could then become the catalyst for ecotourism elswhere.

Integration of sustainable environmentally sensitive and culturally acceptable tourism in the development of the SRF is a much more specialised and professional undertaking than is often supposed and this plan recommends that future developments should define clearly the roles of the FD, the Parjatan Corporation and the private sector in line with the National policy. These should be determined in light of the specific demands of environmental protection on the one hand and a highly competitive market on the other. Table 47 sets out the varied components of the industry which will require constant attention during implementation. This is discussed further in Part 2 of this plan.

Tourism and recreation was reported upon by de Vere Moss (1993). In this study it was concluded that there are no insuperable barriers to the development of high cost low volume ecotourism to generate foreign exchange, together with more price sensitive higher volume domestic tourism. Realistic planning and proper zoning are central issues.

Tourists make demands on the National economic infrastructure of general services and foreigners often disrupt the social fabric of the host country. There is undoubtedly a price to pay for each tourist attracted, which cannot always be easily quantified. **A smaller number of high-yield tourists can be more easily catered for than a flood of mass tourists. Since, in addition, the long air journey from Japan, Europe, America and Australasia - the main potential markets - already ensures a high minimum cost of a holiday in Bangladesh, it is logical to plan to maximise on multi-centre tours and upmarket tourists.**

Since no accommodation, designed specifically for tourists exists in the SRF, an outline model is proposed as part of a phased Ten-Year Development Programme (TYDP) for special interest tourism based upon a concept of 'Jungle Camps and Lodges' and innovative use of the Nation's waterways for transportation and accommodation. This is recommended as the best scenario for sustainable, hard currency-earning tourism.

Socio-economic benefits, economic multipliers, biodiversity conservation and ancillary small-scale industries are reviewed and the proposed developments would allow for interaction between ecotourists, local populations and the environment which are economically beneficial, socially acceptable and avoid environmental degradation, disturbance or exploitation of flora and fauna.

It is generally accepted that tourism in the Sundarbans must be confined to the winter period and only under exceptional circumstances during other times of the year. Some commentaries consider that the 'tourist season' is only four months, November to February (Pannell Kerr Forster, 1988). For the purposes of this plan the 'tourist season' is taken as 20 weeks, October to February inclusive.

Regular inundation, on-going sedimentation, many observable phases of ecological succession and unspoiled natural woodland, interspaced by thousands of kilometres of rivers and their tributaries, inhabited only by wildlife, make the Sundarbans an unusually stimulating environment for first-time and experienced visitors.

Obviously organisation of tourism for both domestic and international visitors is constrained to a large extent by climate, especially seasonality. Design of transport and accommodation is likewise affected by the unavoidable need to provide for extreme environmental conditions, especially during the 'wings' of the 'season'. Climate on the other hand is a most powerful selling factor and for Bangladesh as a whole and the SRF in particular, the excellent winter climate should be sold strongly as a primary attraction.

11.6.1 Tourism and recreation assets in the SRF

The many assets on which tourism could be developed stem from rare wilderness values that abound in the SRF. Natural flora, tranquil surroundings and unusual ecology - each is a valuable asset which forms the content and style of nature-based tourism. The range of recreation opportunities and tourism assets of the forest which may be conveniently linked in circuits to other parts of the country are listed in Tables 47 and 48. Table 48 summarises the SRF's assets by compartment as a starting point for detailed future analysis.

Table 47 Development of tourism in the Sundarbans: part of the tourist industry

(de Vere Moss, 1993)

PROMOTION SERVICES TRAVEL ➡		**BANGLADESH**	**TOURISM**
PUBLICITY	**THE DECISION**	**THE PRODUCT**	**ASSETS**
Films Newspapers Magazines Books Journals		**Transport** Air Road Rail Boat	Location Climate Rivers Lakes * Forests Wildlife Beaches History Culture Cuisine
Public Relations/PR	**Mode ➡** Independent Guided package Group package Cruise Safari	**Accommodation** Hotels Guest houses Motels Camps Cruise ships Floating lodges	
Advertising International Regional National Local **Marketing** **The Travel Agent** Retailer Bookings **The Tour Operator** Wholesaler Retailer Handling agent National	**The Decision To Travel** To the Region To Bangladesh Tothe undarbans	**Recreation Experiences Available In The Product** History Culture Sightseeing Wildlife watching Birdwatching Fishing Botany Art tour Boating Walking trail Scuba diving * Archaeology Participatory ecology Educational study tour	
Services Meet & greet Transfers Regional tours National tours Local tours Excursions			**Development** Finance Public Private Public and private
A MAJOR TOURISM PRODUCT IN BANGLADESH ➡ ➡ THE SUNDARBANS EXPERIENCE			

Assets and Recreational opportunities listed above all apply to the SRF except for the two marked with an asterisk *

Table 48 The Sundarbans Reserved Forest Compartments : Tourism Development Potential

Compartment	FD	Tiger	Deer	Boar	Birds (special	Croc.	Turtles	Grass	Keora	Beach	Hide	History	Extract	Jetty	Accomm.	Rating
01	+	++	++	+	+	+	+	+	+	-	-	-	Go	+	+	
02	+	+	++	+	+	+	+	+	+	-	-	-	Go	+	-	
03	+	++	+	+	+	+	+	-	-	-	-	-	Go	+	-	
04	-	++	+	+	+	+	+	+	+	-	-	-	Go	-	-	High
05	+	++	+	+	++	+	+	+	+	+	-	-	-	+	-	
06	+	++	+	+	+	+	+	+	+	+	+	-	Go,Gor	+	-	High
07	+	++	+	+	++	+	+	+	+	+	-	-	Go,Gor	+	+	High
08	-	++	+	+	++	-	+	+	+	+	-	-	Go,Gor	-	-	
09	-	++	+	+	+	+	-	+	+	-	-	-	Go	-	-	
10	-	+	+	+	+	+	-	-	-	-	-	-	Go,Ge	-	-	
11	-	+	+	+	+	+	+	-	+	-	-	-	Go	-	-	
12	-	+	+	+	+	+	+	-	+	-	-	-	Go	-	-	
13	+	++	++	+	+	+	+	-	+	-	-	-	Go	+	-	
14	-	+	++	+	+	+	+	-	+	-	-	-	Go	-	-	
15	-	+	+	+	+	+	+	-	-	-	-	-	Go	-	-	
16	-	+	+	+	+	+	+	-	-	-	-	-	Go	-	-	
17	-	+	+	+	+	+	-	+	+	-	-	-	S,Go	-	-	
18	+	+	+	+	+	-	-	+	+	-	-	-	S,Go	+	-	
19	+	+	+	+	+	+	+	+	+	-	-	-	Go	+	-	
20	+	++	+	+	+	+	+	-	-	-	-	-	Go	+	-	
21	-	++	++	+	+	+	-		-	-	-	-	Go	-	-	
22	-	+	+	+	+	+	-	-	+	-	-	-	Go	-	-	
23	+	+	+	+	+	+	+	+	-	-	-	-	Go	+	-	
24	+	++	++	+	+	+	-	-	-	-	-	-	Go	+	-	
25	+	++	++	+	+	+	-	+	-	-	-	-	Go	+	-	
26	+	++	++	+	+	+	-	-	+	-	-	-	Go	+	-	Medium
27	+	++	++	+	+	+	-	+	-	-	-	-	Go	+	-	Medium
28	+	++	++	+	++	+	+	-	-	-	+	-	Go	+	+	Medium
29	+	+	+	+	+	+	-	+	-	-	-	-	Go	+	-	
30	+	+	+	+	+	+	-	+	-	-	-	-	Go	+	-	
31	+	+	+	+	+	+	-	-	-	-	-	+	Go	+	+	
32	+	++	+	+	++	+	+	-	-	-	-	-	Go	+	-	
33	+	+	++	+	+	+	+	-	+	-	-	-	Go	+	-	
34	-	+	+	+	+	+	+	+	-	-	-	-	Go	-	-	

Compartment	FD	Tiger	Deer	Boar	Birds (special	Croc.	Turtles	Grass	Keora	Beach	Hide	History	Extract	Jetty	Accomm.	Rating
35	+	+	+	+	++	+	+	+	-	-	-	-	Go	+	+	
36	+	++	++	+	++	+	+	-	+	-	-	-	Go	+	-	
37	+	+	+	+	++	+	+	-	-	-	-	+	S	+	-	
38	+	+	+	+	+	+	+	-	-	-	-	-	Go	+	-	
39	+	++	++	+	+	+	+	-	-	-	-	+	Go,Gor	+	-	High
40	+	+	+	+	+	+	+	-	+	-	-	-	Go,Gor	+	-	
41	+	++	+	+	+	+	+	-	-	-	-	-	Go,Gor	+	-	
42	-	+	+	+	+	+	+	+	-	-	-	-	Go	-	-	
43	-	++	+	+	+	-	+	+	+	-	+	-	Go,Gor	+	-	High
44	+	+	+	+	++	+	+	+	+	+	-	-	Go,Gor	+	+	High
45	+	++	+	+	+	+	+	+	+	+	-	+	Ge,Gor	+	-	
46	+	++	++	+	+	+	-	+	+	-	-	-	Gor	+	+	
47	+	++	+	+	+	+	-	+	-	-	-	-	Go,Ge	+	-	
48	+	++	+	+	+	+	-	+	-	-	-	-	Gor	+	-	
49	-	++	+	+	+	+	-	+	-	-	-	-	Gor	-	-	
50	-	+	+	+	+	+	+	+	-	-	-	-	Gor	-	-	
51	-	++	+	+	+	-	-	+	-	-	-	-	Gor	-	-	
52	-	++	+	+	+	-	-	+	-	-	-	-	Gor	-	-	
53	-	++	+	+	+	-	-	+	-	-	-	-	Gor	-	-	
54	-	++	+	+	++	-	-	+	+	+	-	-	Gor	-	-	High
55	-	++	+	+	+	-	-	+	-	-	-	+	Gor	-	-	High

FD = Existence of Forest Department Office, Station, Coupe or Camp
Jetty = Existence of useable jetty
Accomm = Some form of accommodation set aside for visitors which could be improved and used during transitional phases of development
Tiger + = Confirmed occurrence ++ = Confirmed man killings of more than 6 persons 1985-1990 inc.
Deer + = spotted deer only ++ = spotted deer and barking deer
Boar, Croc, Turtles = confirmed occurrence
Birds = ++Places of special interest, colonial breeding sites, migratory bird resting/feeding places. + = occurrence only.
Keora = Significant stands
Beach = beaches of value to eco-tourism
Hide = existing viewing platform or machan
History = places of historical or archaeological interest
Extract = Commercial Timber Extraction Operation Area : Go = Golpatta, Gor = Goran, Ge = Gewa, S = Sundri
Rating = Potential for tourism development over the period 1995-2004 [Ten Year Plan (TYP)]
H=High/Immediate 1994-1995 Phase : Improvement to existing facilities
M=Medium/1995-2004 Phases : Developments based upon feasibility studies
L=Low/None

Table 49 Attractions of The Sundarbans Reserved Forest

(de Vere Moss, 1993)

DESCRIPTION	COMMENTS
Location	on the Bay of Bengal and largest mangrove formation (USP) in one of world's largest river deltas
Tropical climate	cool and dry during the tourist season
Rivers	large and small giving opportunities for cruising and jungle boating
Forests	unspoiled mangroves; forest ecology
Wildlife	especially the largest single population of Bengal Tiger (USP) and exceptional population of spotted deer and wild boar; adequate bird watching, migratory species and raptures in particular
Beaches	unspoiled, wild, unpolluted and totally undeveloped beaches throughout on the Bay of Bengal and around some islands
History/archaeology	rare sites set in the jungle
Sociology	fishermen in particular; otter fishermen - a strong USP; also other traditional collectors of jungle produce
Cuisine	many different species of edible fish, prawns and crabs
Culture	annual festivals at Dubla and diverse cultures

The potential on which tourism could be developed is shown in Table 50 which summarises the recreational activities which are possible in the SRF and on tourist circuits.

Table 50 Recreational Activities SRF, Southern Circuits and the North-eastern Extension 1993

(de Vere Moss, 1993)

RECREATIONAL ACTIVITY/HOLIDAY	Sylhet	Srimongal	Dhaka	Mainamati	Bagerhat	Rangamati	Chittagong	Cox's Bazar	Kuakata	SUNDARBANS
Sightseeing	X	X	X			X	X	X		
Beach relaxation							X	X	X	X
History interest			X	X	X		X			X
Cultural interest	X	X				X	X	X	X	X
Big game watching		X								X
Birdwatching	X	X	X			X			X	X
Wildlife watching (general)		X				X				X
Fishing	X					X				
Shooting	(X)								(X)	
Golf	X		X				X	X		
Botany		X	X							X
Art touring	X	X	X	X	X	X	X	X		X
Cruising			X			X	X	X		X
Boating	X		X			X	X	X		X
Walking	X	X				X		X		X
Jungle Trails										X
Scuba Diving								X		
Archaeology				X	X					X
Herbal tour										X
Agricultural tour	X	X			X					
Educational study tour	X	X	X	X	X		X			X
Participatory Ecology					X					X

Fauna:

Animals are of great interest to many visitors and wildlife is the principal attraction in many cases. Table 48 demonstrates the comparative importance of the SRF's wildlife.

Fish and Fishing:

There is a rich and diverse fish fauna with over 120 species recorded, representing over 25% of the country's total. Unfortunately high turbidity seems to preclude rod and line angling in most places although this popular pastime has not been investigated to any great extent and deserves of further attention for tourism. There is a sizeable captive audience of dedicated game fishing anglers worldwide who could be attracted to fishing wildlife holidays if the resource is of sufficient quality.

11.6.2 Local Tourist attractions

The concept of a one week module to bring the SRF into the mainstream of National tourism also should emphasise other local tourist attractions since the sources and interests of tourist will be varied and in a situation where seasonality places a strong constraint on economic viability it is important to maximise on all possible attractions and related opportunities for relaxation, recreation and enjoyment.

Despite notions to the contrary and in contrast with much of the competition, it is fortunate that there are many places of local interest and these sites with modes of access, accommodation and respective circuits are described in Table 51.

11.6.3 Domestic tourism

There is a strongly growing demand for facilities for recreation and relaxation for local tourists. People from all corners of society are taking advantage of improved communications and the relatively low cost of travel and are demanding more and better recreation facilities and the development of new destinations such as Kuakata beach and the Sundarbans (BPC 1992).

Apart from the market led demand there is a widely held contention that where there is strong domestic tourism this can provide a sound foundation for investment in international tourism (Matin 1993). Undoubtedly new facilities should be created to meet demand of a potentially huge market; improvements should be made to meet the requirements of a growing middle and upper class domestic tourist and it is true that, for private business, domestic tourism can do much to increase commercial viability. It is relatively impervious to political disturbance or changes in international attitudes but when numbers are potentially enormous environmental protection becomes a key issue.

The main shortcomings are that this usually infers low cost, high volume, high impact and does not lead to direct foreign exchange earnings.

Mass tourism, whether domestic or international often exerts excessive pressure and cost benefits must be assessed to prevent irreversible damage in pursuit of the short term gain. Reports have been received of anything up to 40 people occupying the Katka rest house which has limited facilities for a maximum of eight people.

For the Sundarbans, a fragile environment, difficult to access, difficult to manage and an expensive, rare end-product, the real potential lies in low volume high cost tourism. This is not to say that domestic tourism should be excluded; there must be provision for this, but to maximise returns and make best use of the resources, mass tourism should not and cannot achieve National conservation and economic objectives.

Domestic tourism can thrive and make a real contribution to the industry through developments for which GOB/BPC could be responsible. New low-cost accommodation at Mongla and Munshiganj and seasonal day excursions in custom built, economy, low profile sightseeing boats with fixed zones of operation, might be an effective manner with which to meet the perceived demand. It is understood that BPC has plans in hand to develop a motel at Mongla. A similar facility would be desirable in Phase 2 at Munshiganj. Mongla and Munshiganj could thus become hubs for domestic tourism without detracting from forex-earning ecotourism.

Table 51 Tourism and Recreational Sites near the Sundarbans as at 1993

(de Vere Moss, 1993)

Name	Locality	Circuit	Attractions/Facilities	Access	Accommodation	Development Potential	Priority
Jessore	Jessore District	SC	Airport, Hotel M/L, Craft weaving, picnic site	Air, road, rail	Yes, needs improvement	High	High
Barobazar	Jessore District	SC	Archaeology	Road	No	High	High
Bagerhat	Bagerhat District	SC	Archaeology, Culture	Road	No	High	High
Mongla	Bagerhat District	SC,SBC	Port, Entry Point to SRF, Hotel L, Rest House L	Water, road	Yes, needs improvement	High	High
Dhangmari	Khulna District	SC,SBC	FD Field Station	Water	Yes FD	High	High
Khulna City	Khulna District	SC,SBC	Ferry, Entry Point for SRF, DCs Office,DFO's Office, Civic Centre, Hotel M/L, Zoo, Private Bot. Garden, Jute and Paper Mills	Road, rail and water	Yes, needs improvement	High	High
Kuakata	Bargona District	SC	Undeveloped sandy beach, BPC development plot, Culture	Road + Water	Yes. Unserviced Rest House in need of improvement	High	Low
Mahipur	Bargona District	SC	Bazar ghat en route to Kuakata	Road and water	No.	Medium - important in Kuakata development	Medium
Patuakali	Patuakali District	SC	Jetty town en route to Kuakata	Road and water.	Yes, but not up to international standards	Medium - no special attraction	Medium for development of Kuakata
Barisal	Barisal District	SC	Important Ferry and Terminal Point for Rocket and Sagar accommodation boats. Durgha Sagar tank. STOL airport potential.	Road and water	Yes, but not up to international standard	Medium	GOB
Norail	Norail District	SC	Art/ Painting - Sultan	Road	No. Not Necessary	Medium	Medium
Shagardari	Jessore District	SC	Art/ Poetry - Michael Madhushudan	Road	No. Not necessary	Medium	Medium

There is a high capital cost in specialised tourist vessels and this is an area in which GOB should consider making provision for venture capital and incentives for private operators. A pilot scheme in the SRF could possibly be implemented by BPC in collaboration with the Forest Department which would allocate routes designed to avoid any conflict with international or National ecotourists and would monitor noise pollution and disturbance to the natural environment. A zoning scheme for this purpose is provided in Part 2 of this plan to which environmental monitoring indicators could be added in due course.

11.6.4 International tourism

Figures presented for 'Visitor Arrivals' and 'Foreign exchange earnings from tourism' in the World Tourism Organisation (WTO) Feasibility Assessment of Mongla and Sundarbans 1992 indicated figures of 113 242 "Tourist Arrivals" and earnings of US$ 7.6 million. This information tends to be misleading since there is a confusion in interpretation between 'visitor', who could be any non-National visiting for any purpose and 'tourist' who might also be a 'visitor' coming for purposes which would not necessarily contribute to the tourist industry. The most useful figure, provided by the Police Department, is those visitors and tourists who give their reason for visiting the country as 'holiday' and even these could be visiting friends or relatives.

For the holiday makers, numbers peaked in 1989 with a record high of 32 737 and dropped to a low of 8 586 for the season 1991-1992.

An encouraging trend hopefully is that the figures to the end of September 1993 indicate a rise to 14 107 for those coming on holiday. These figures are a benchmark from which National tourism development strategies should work and are summarised in Table 52 below.

High among the assets on which the international tourism should be developed is the single fact that by its mere geographical location - gateway to the hinterland - Bangladesh would be visited by a significant number of travellers.

Table 52 Foreign Arrivals to Bangladesh and Purpose of Visit

(de Vere Moss, 1993)

Purpose of visit	1988	1989	1990	1991	1992	1993 01/01-30/09
Business	20 011	26 427	28 904	30 612	23 742	22 806
Holiday	35 408	32 737	26 476	20 918	8 586	14 107
Official	8 342	9 554	7 921	6 363	9 411	7 827
Missionary	488	2 503	1 256	486	833	557
Student	_	264	429	249	418	289
Ship crews	17 751	14 935	9 420	_	_	_
Other	38 782	42 086	39 964	54 614	67 485	43 139
TOTAL	120 782	128 506	115 369	113 242	110 475	88 725

Source : BPC 1993

Table 53 Foreign Tourist Arrivals by Region of Origin

Region	1981	1986	1991	1992/1993
South Asia	16 712	84 515	65 876	52 601
Western Europe	13 066	14 908	15 724	21 607
USA/Canada	5 209	7 743	7 266	9 367
SE Asia/Far east	7 148	10 931	13 244	17 137
Australia/New Zealand	1 596	1 594	1 466	1 584
Other	7 519	9 379	9 666	8 069
Total	49 315	129 070	113 242	110 475

Source : BPC, 1993

Table 54 Foreign Tourist Arrivals by Countries of Origin

Country of Origin	1981	1986	1991	1992
India	11 467	60 574	25 842	33 607
Pakistan	4 107	9 231	10 250	14 066
United Kingdom	6 965	7 636	6 484	10 203
United States	4 028	6 028	5 630	7 768
Japan	3 185	4 238	4 950	5 973
Nepal	574	13 306	8 721	1 855

Source : BPC (1992)

Figures presented in Table 53 provide an indication of geographical sources of visitors to Bangladesh and this is valuable in planning marketing strategies for capturing regional markets.

Figures shown in Table 54, indicate that India is by far the largest source of foreign arrivals to Bangladesh. Figures released by BPC for the period 1980-1990 revealed that on average 35 840 visitors from India came to Bangladesh each year. About 1.5 million tourists visit India and in the United Kingdom alone there are 80 tour operators (Government of India Tourist Office 1993) who feature India and other sub-continental destintions in their brochure. It is familiarly said that two-centre tours between Bangladesh and India will be hard to develop, yet one or two local tour operators are already organizing such tours and overseas operators spoken to confirmed an interest in attempting to develop Bangladesh-India special interest itineraries.

It should be possible, with definition of mutual benefits and joint marketing, to make good use of this feature of regional tourism, but above all Bangladesh's geographical location with its pivotal position for regional tourism offers substantial scope for imaginative expansion, especially by carefully designed strategies of Biman airlines to elaborate Zia International Airport as an attractive hub.

One of the most positive characteristics of tourism is its ability to generate international goodwill. Where there are common borders, such as that shared by the Sundarbans with India, common historical and cultural attributes and a common purpose, then the pioneer activities of private sector operators may pay good dividends in the long-run.

There are also about 15 000 temporarily resident foreigners who on the whole take their holidays outside Bangladesh but within the Asia region. This pattern can be, and should be, changed by offering relaxation and interesting alternative holidays within Bangladesh. Innovative strategies with clear marketing messages will need to be directed towards that target. Ingredients of river cruising, wildlife watching, beaches, history and attractive culture are all available in the Sundarbans, especially for the ex-patriate ecotourist.

Whatever reasons in the past brought visitors to Bangladesh and, even if many came on business or to visit relatives, a major concern for the future must be to encourage as many visitors as possible to participate in holidays and recreation activities within the country.

It is important to note that the average duration of visits over the last ten years has been 13 days per person (BPC 1991) which indicates that Bangladesh is significantly more important than simply a stopping over point and this factor must provide scope for exploitation by the tourist industry.

The Regional Market:

There has been an incredible growth in tourism in the Asian regions and although it is often unwise to make comparisons, Bangladesh must compete with its neighbours and comparisons with them are essential in setting standards and to understanding the rigorous demands of the industry. How can Bangladesh's assets be mobilised, developed and managed to be relevant to regional markets?

The Regional market constitutes about 48 % of visitor arrivals and recent developments for joint marketing efforts by SAARC member countries could be of great help to Bangladesh in due course.

What is Bangladesh up against and how can it be successful?

Whilst tourism has grown phenomenally in Asia during the last decade, in some countries growth has been particularly fast. For example the China Travel Service, a privately owned business based in Hong Kong reported recently that it recorded a growth in trade of 375% in 1992, mostly to mainland China, where cultural differences, structural problems, a conservative society, and political uncertainties are prevalent, but still the tourist industry is growing. During the same period tourism in Bangladesh actually declined.

Studies carried out for this plan indicated that there is insurmountable barrier which might prevent tourism from growing again in Bangladesh and the Sundarbans could play a significant role in this. About 8 million tourists visit Southeast Asia's attractions annually. Strategies to take even a modest 2% of the regional market would generate 160 000 tourists (about 440 per day) which would give the tourism trade a powerful base, worth possibly around $US 100 million pa, from which to develop a lucrative industry.

11.6.5 Ecotourism

If the Sundarbans are to be the springboard to the development of foreign exchange earning, tourism then the unusual characteristics of the area must be utilised to attract those who are likely to appreciate them most - the ecotourist. The rare natural features together with other assets of waterways, climate, location and recreation options, give Bangladesh a competitive edge. The way forward should be by controlled development of facilities and services which provide access, accommodation and service to tourists who will be able to enjoy themselves by pursuing their interest in nature and the myriad opportunities an unspoiled natural environment can offer.

Ecotourism has been the foundation to tourist industries in many parts of the world and even in countries like Thailand, where general tourism is often believed to be mass general tourism, ecotourism makes a significant contribution: in 1977 Khao Thai National Park use to receive about 100 000 per year; by 1985 numbers had grown to over 400 000 (Swanson and Barbier 1992).

If these tourists have special interests and these interests can be catered for then the foundation can be laid for product development and marketing which would be targeted at this well-informed and relatively affluent category of ecotourist.

In tis respect wildlife viewing is one of several attractions. The SRF has a healthy tiger population an this must be considered the most important species to introduce properly into the ecotourism product. At present this is not done and since tiger are infrequently seen by visitors there is too much room for disappointment.

Investment in tiger research and management as part of the functions of the Forest Department's conservation, wildlife management and ecotourism responsibility is essential both in terms of present and future values. Single species attractions have been valued and in Kenya it is estimated that the "keystone value" of viewing elephants is at least $US 25 million to the special interest segment of the tourist industry. This part of the industry in Kenya has been growing at the rate of 10-15% per year and at least half the special interest tourists questioned in a survey said that the country would be significantly less attractive to them if it had no elephants (Swanson and Barbier, 1992).

The Sundarbans has much to offer this sector and is thus a prime location for ecotourists. It is proposed that a relatively low cost development for ecotourism in which tiger research and management and conservation are essential elements, should be promoted.

Special Interest Tourism:

Special interest tourism does not necessarily mean ecotourism since special interests could include a number of activities such as speed boat-racing, clay-pigeon shooting, or cross-country motor-bike trailing which cares little for the environment and its enhancement.

Special interest tourism embraces ecotourism which is a major growth area in many countries. Ecotourists wish to visit unspoiled environments, often in out of the way places, and to make positive contributions wherever possible to the improvement of those environments. At the very least they try to ensure that the places they visit are not damaged as a consequence of their visits or as a consequence of the infrastructure needed to facilitate their visits.

The Sundarbans has many of the ingredients which fulfil requirements to develop this segment of the market. Daily rates for jungle boat trips and tailor-made holidays in countries like Papua New Guinea, neighbouring Nepal, or the Galapagos islands, Ecuador, and Brazil commonly range between $US 150 to as high as $US 450 per night with full board, guides, transport and accommodation. Price targets in the $US 100 - $US 200 bracket should be considered attainable but only after service and infrastructure matches the cost. The target discussed in Part 2 of this plan is to organise a marketable ecotourism product based on the assets of the SRF and associated circuits.

11.6.6 Tourism circuits

The SRF has always been difficult to access and although this poses problems for tour operators, for the refined tastes of the ecotourism market this forms part of the attraction for those who seek far away and unusual places on which to spend their money. For practical commercial purposes the difficulties of remoteness and inaccessibility must be overcome in the process of creating the 'product'. In terms of the development of National tourism the SRF should not only be part of a carefully prepared one week Bangladesh tourism package or module, but must be fitted into logistically manageable tourist circuits.

The Concept of Circuits and the Sundarbans:

In order to make optimum use of time, from the point of view of the tourist, and optimum use of facilities from the point of view of the operator, it is important to limit repetitive journeys and incorporate as many attractions as feasible in itineraries. Thus circuits which link together attractions in a one way direction are highly desirable, but the ideal is not always easy to organise.

Geographical location is an all important factor in planning tourist circuits, transport systems, cross-border tours and local excursions. Economic viability frequently hinges upon advantages or disadvantages conferred by location.

Consideration was given to this in the Strategic Masterplan (1985) and, although circuits which linked the Sundarbans with facilities in eastern Bangladesh were rejected, it is now felt that with substantial improvement in communications and perceptible increase in both domestic and international demand for combination holidays, proper consideration should be given to them. The following circuits could be used as a basis for structural plans both for the Sundarbans and adjacent areas:

Circuits

- The Sundarbans Circuit (SBC): Within the Sundarbans
- The Southern Circuit (SC): The Sundarbans linked with Kuakata, Cox's Bazar, Kaptai, Rangamati, Comilla, Mainamati
- The North-eastern Extension (NEE): The Sundarbans linked to attractions at Shrimongal and Sylhet

Combining attractions in circuits (see Appendix A28) maximises the use of assets. For example jungles and beaches; wildlife in one place combined with additions or contrasts in another; or tours which might have a strong bias in one interest which could be combined with another not only within the country but in multi-centre regional tours.

Combinations may emerge such as linking the mountains of Nepal with river cruising, mangrove jungles and beaches of Bangladesh. Locally, river cruising and jungles walks and jungle exploration by country boats in the mangrove forest might be combined with forest walks and the beaches of Teknaf. The history of one part of the sub-continent might be linked with the historical sites of another. The wildlife of the upper Brahmaputra might be linked and contrasted with the environment and wildlife of the mangrove forests.

Once the infrastructure is in position it is then up to the ingenuity of tour operators to work out interesting and competitive packages based on the three circuits described above. Some are already doing this. Development proposals and a ten-year action plan is proposed in part 2 of this plan.

11.7 Other non-wood forest products

Non-wood forest products now include all produce from sources other than wood itself, including services and leases (Chandrashekeran, 1994). The high values placed upon aquatic resources, such as crabs and shrimps, which a few years ago had hardly received any serious consideration, indicates that forward planning should ensure that all possible sources of income and employment are carefully evaluated. As already mentioned wildlife resources are not managed at all and in many respects constitute a wasted asset. Other assets which are of little or no value today may have a considerable value in future.

Among these are the following :

- Sale of rights to conduct tourism - concession permits
- The sale of trophy fees and licenses if sport hunting is to be re-introduced
- The fees for management agreements with lodge or hotel operators
- Licenses to undertake mining or exploration within the boundary of the SRF
- Leases
- Fees for rights of passage

11.7.1 Clay for pots

Whilst removal of mineral resources is not of major concern at the moment there are sites within the forest which indicate the earlier existence of communities which were extensively involved in the production of earthenware pots. Archaeologists and mineralogists could research this subject to ascertain whether there are deposits of clay of commercial significance which could be utilised in cottage industries. Also the ecotourism potential of such sites should not be overlooked.

11.7.2 Leases

Superficially the subject of leases appears unimportant but this could change and be of great significance to future land use and resource management.

At present there are four types of lease which have established precedents which should be brought into account whenever planners consider any deviation from the principal that there should be no permanent developments within the SRF, as follows:

- Rights for the construction of buildings for official purposes, where permanent structures are erected and where exotic plants and animals are introduced even within wildlife sanctuaries.
- The lease or tenure rights given to the farmers in Compartment 47 at the extreme north-west of the SRF where 1 Km^2 of land lying within the natural physical boundary of the SRF has been leased for uses other than forestry.
- The leases given to the Bangladesh Navy and MPHA at Nilkamal for the Forest Station and Port Harbour Authority Guest House respectively.
- Leases for the cyclone shelters and the hospital on Dubla Island, compartments 68 and 118.
- Seasonal use of sites by migrant fisherfolk and associated commercial interests.

These have been mentioned under Section 7.1.1 which considers the exceptions that have already been made to the rule on permanent construction. Leases for some of these have been made and these should be reviewed.

In future, rather than either turning a blind eye or stepping up resistance to demands for purposes which could be of long-term benefit to the SRF, such as ecotourism or field research, legal advice should be sought from the Ministry of Lands for the preparation of leases for which values could be agreed between the respective parties and which could be used to regularise the whole controversial issue of permanent use of land within the boundaries of the SRF.

11.8 Harvesting and marketing non-wood forest products

At present harvesting and marketing of NWFPs is limited to rules applied to specific products with minimum of management and regulation other than to maximise the collection of revenue. There is inadeqaute concern for improvements to wasteful harvesting methods or concern for infrastructure, post harvest improvements, storage, staging points, market organisation or transportation. For example the destructive methods which continue to be employed by honey gatherers, or for the impact upon species populations or the environmental impact of growing numbers of harvesters, illegal off-takes of wildlife or the manipulation of some user groups.

A summary of the current levels of management of harvesting and marketing of NWFPs is provided in Table 55.

Table 55 Harvesting and Marketing of NWFPs : SRF

PRODUCT	FD MANAGEMENT INPUTS	PRIORITY ACTION for Integrated management and conservation
Fish	Almost nil other than revenue collection	Very high with Fisheries Department and user groups. Conservation action urgent
Shrimps and Prawns	Nil other than revenue collection	Urgent conservation action required
Crabs	Nil	Urgent action required
Golpatta	Annual coupes for harvesting and revenue collection	Inventory and continuous survey system needed. High priority for FRMP
Hantal	Almost nil other than revenue collection	Inventory and continuous survey needed. High priority for FRMP
Tourism	Nil other tan some escort duties and revenue collection	High priority for integrate management and development in association with TOAB and BPC
Honey	Almost nil other than revenue collection	Urgent management action and dialogue with NGOs and user groups required
Grasses	Nil	Introduction of harvesting and inventory control urgently required
All wildlife (other)	Nil	Immediate action required for conservation of threatened species
Oysters	Nil other than revenue collection	Urgent action required to assess resource and introduce management

11.9 Non-wood forest products trends in demand and supply and sustainability

Although there is a little evidence that demand for some products such as Golpatta, Hantal and even honey may have declined recently, this will require verification and it is most unlikely that this trend will continue if the open market is allowed to operate. It is much more likely that the overall over-exploitation of resources will increase with human population growth and as some products become more valuable and scarcer.

It is essential that inventories are introduced to a computerised data base and recording system and that integrated management of resources which are generally outside conventional forestry working plans are given attention and support. This is addressed in Part 2 of the plan.

12 SOCIO-ECONOMICS

The socio-economics aspects of SRF ecosystem management is a complex and diverse subject which covers a long history pre-dating the era of the Mughal empire and one which embraces many cultural and economic facets. The central theme is the relationship of people with their environment; their relationship with past and present rulers and the evolution of the communities and their activities which today surround the SRF in a virtually unbroken ring on the landward side.

The interdependence of the Forest and the people who live in its vicinity in the past has been a neutrality; the forest giving of its resources for which people had to pay. Provided laws were obeyed, over which they had little or no influence, the balance of supply and demand managed to survive. It is only in comparatively recent times that the increase in population has led to extreme pressure from encroachment; from illegal felling of trees, killing of animals and environmental degradation. The situation became increasingly unsustainable.

Thus a socio-economic study was included in the research for this plan and readers should refer to the report by MARC (1997) for further information.

Systematic analyses were conducted based on householder interviews and the determinants of the socio-economics of forest resources utilisation were analysed. The main findings are summarised in Table 59.

Detailed information on the extent of community involvement in the SRF and ways in which the different groups, particularly the disadvantaged, might be mobilised and assisted, through provision of credit, training and development of cottage industries were studied. The goal was to make recommendations on how the Forest can be manged to provide maximum sustainable benefits for stakeholders, particularly traditional users, without negatively affecting the flora and fauna of the area.

12.1 The human population in relation to the SRF

The most important social issue stems from the sharp interface between people and the government, brought to a head in the legislation which eventually closed the area to human habitation and classed people, who did not possess official entry permits, as trespassers in their own land. As mentioned in Section 2, the Sundarbans forest was gradually closed to human habitation through a series of notifications during the British colonial administration under the Government of India Act VII of 1878 and the Forest Act of 1927. The forest equally became seen by people as a source of produce to be exploited to its limit and the same people were deemed to be the source of revenue which had to be maximised as far as possible.

Today the sheer social pressure on resources on the one hand and the lack of ability to contain the pressure on the other is the nub of the problem which this plan sets out to solve through relatively new concepts embodied in integrated sustainable resource management set against a background of care for people as well as the environment.

People living in close proximity to the SRF are most likely to depend on its resources to satisfy many of their day to day needs, such as food, fuel, materials for the construction of houses, boats, furniture and fishing implements, medicinal herbs and many other items for trade and commerce. It is difficult to put an exact boundary within which such dependence exits, mainly because the zone of influence is never so sharply defined.

This was confirmed in a survey which was carried out by MARC (1994-95) in 32 selected settlements within a 10 Km zone around the SRF. The households surveyed showed an overall participation rate of 78 % at the innermost (0-2 km) band and 64 % at the outermost (8-10 km) band. The rates were obviously lower for individual household members: 23% and 15%, respectively at the innermost and outermost edges.

It was assumed that, based on a survey of participation rates, the physical proximity zone would consist of a primary influence zone of 0-10 Km band and a secondary influence zone of 10-20 Km band. In estimating the number of persons participating in different harvesting activities, the population in both these areas were drawn upon and the participation rates derived from the survey thus obtained.

Results showed that the total number of persons directly involved in SRF resource exploitation is about 300 000, which accords with other recent estimates (Chantarasri, 1994; Pena, 1994). There is considerable overlap in resource exploitation: some people exploit more than one resource. Furthermore, there would be approximately 2.3 persons more depending on each SRF harvester and if secondary activities are included then the total number of people involved at some time during the year in activities connected with forest produce is considerably higher, perhaps as many as 500 000.

12.2 The history and trends in settlement around the SRF

According to MARC (1997) most of the people who live around the SRF have resided there for a long time: 52% of respondents said they came before their grandfather's generation and 58% did not know when they came. Immigration shows a declining trend from the grandfather's generation, indicating the gradual closure of the frontier character of the Sundarbans. Of those who could tell where they came from, 51% quoted the South-western part of the country and 22% from Khulna Division. The next important source was the south-eastern region, 23 %, possibly from its coastal areas which have similar inter-tidal ecosystems. A small fraction, 2 %, said their origin was in West Bengal, India.

Economic factors were the most quoted reasons for migration; 43%, followed by settlement opportunity, 21%.

12.3 Demography

The sample population in the 0-10 km border studied by MARC(1995) showed a household size of 6.3 which is higher than the National average. The age distribution by gender is shown in Table 56. The proportion in the 0-4 age cohort was considerably smaller than that of 5-9 years, indicating a decline in population growth rate. There were 117 males for every 100 females, which is higher than the National average (106 : 100) and indicates the possibility of temporary male immigrants coming for work. The dependency ratio was 82 %, indicating a relatively higher proportion of people in the working age group (15-49 yrs).

Marriage was found to be virtually universal. Only 0.5 % males and 0.1% females remained unmarried after age 29, and none after age 49. Divorce was virtually non-existent among males and very low among females (0.4 %). Widowhood was higher; 1.2 % among males and 5.9% among females.

Family planning practice was fairly high among couples living in the Border Zone. The estimated contraceptive prevalence rate (CPR) was 58 % which is comparable with the National average.

The illiteracy rate among persons 6 years and older was very high at 36.5%, which is higher than the National average of 29 %. The gender differentials were pronounced : 44.5 for females and 29.8 for males. Madrasa education was not found to be that prevalent, accounting for less than 1 % of the literate population.

About 18% of the people in the order area experienced some kind of disease. The incidence hardly differed among the income categories, but there were sharp differences between the four districts. Of children who were immunisable in the sampled population 62 % were immunised.

Registered doctors were the most favoured, 55 %, method of treatment, followed by quacks 17 %. Registered doctors in conjunction with Kaviraj (herbalists) was also a popular method, 15 %. The results of treatment appeared to be reasonable with around two-thirds of those treated being fully or moderately cured. Kaviraj + registered doctor seemed to be the most successful, 68 %, followed by registered doctors, 64 %. Homeopathy appeared to be the least successful of all methods of treatment.

12.4 Resource utilisation and the community

Agricultural land ownership was low; 51 % of all households owned land, while among the poorest one-third, only 35 % did so. The pattern of ownership of animals and trees was similar to that of land. Boat ownership, as expected, was high, and electronic equipment seemed to have spread even to lower income households; while nearly a quarter of them owned radios, a few among the bottom third reported TV ownership as well.

The materials used in roofs and walls of the main dwelling unit showed a preponderance of Golpatta roofing and mud for walls. Golpatta was the preference of both the rich and the poor and in all the surrounding areas. Regional variation in the use of housing materials were minimal.

The average annual income (see Tables 57 and 58) in the SRF border area was estimated at around Tk 83 000 per household, or Tk 13 000 per capita, which was about 45% higher than the National average. About two-thirds of this income was derived from primary production activities, among which fisheries accounted for half.

The richest third of the households had nearly six times (Tk 165 000) the income of the bottom third Tk 29 000. The poor derived comparatively lower proportions of income from fishing and higher from agriculture, and, as expected, higher proportion in non-agricultural labour.

Table 56 Distribution of Sampled Population around the Sundarbans by Age and Gender

Age Group	Gender					
	Male		Female		Total	
	Number	Percent	Number	Percent	Number	Percent
0 - 4	458	10.6	394	10.8	852	10.7
5 - 9	642	14.9	586	16.1	1228	15.4
10-14	528	12.3	429	11.7	957	12.0
15-29	1228	28.5	1049	28.8	2277	28.6
30-49	906	21.1	746	20.4	1652	20.8
50-59	235	5.5	206	5.6	441	5.6
60+	306	7.1	239	6.6	547	6.9
All ages	4303	54.1	3649	45.9	7952	100

Note: Includes households living within a 10-km band around the Sundarbans Reserved Forest + those whose members were in sampled boats collecting SRF resources. The sample comprised 1,266 households and 7,952 members thereof. Hereafter population will refer to this sample unless otherwise stated.

Table 57 Average Annual Income of Households Located Around the Sundarbans

Sectors; Sub-sectors	Districts									
	Satkhira		Khuln		Bagerhat		Patuakhali		Total	
	Takas	%	Takas	%	Takas	%	Takas	%	Takas	%
A. Primary:										
1. Agriculture	17133	14.0	9905	13.1	10767	18.4	34733	36.5	15622	18.9
2. Fishery	61893	50.6	24972	33.0	9887	16.9	24630	25.9	27578	33.3
3. Animals/birds	5299	4.3	1586	2.1	2687	4.6	7309	7.7	3765	4.6
4. Forestry & Horticulture	5043	4.1	11135	14.7	8937	15.3	2798	2.9	7554	9.1
B. Secondary:										
5. Non-agricultural labour	4092	3.3	6627	8.7	5090	8.7	1678	1.8	4664	5.6
6. Cottage Industries	301	0.2	2521	3.3	149	0.3	320	0.3	693	0.8
7. Business	13900	11.4	4967	6.6	6587	11.2	4440	4.7	7698	9.3
8. Services	5192	4.2	4423	5.8	4242	7.2	429	0.5	3949	4.8
9. Rent/lease/mortgage	2437	2.0	1036	1.4	536	0.9	4903	5.2	1730	2.1
10. Remittances	5767	4.7	6414	8.5	8944	15.3	10232	10.7	7856	9.5
11. Other receipts	1166	1.0	2170	2.9	729	1.2	3721	3.9	1565	1.9
Grand Total	**122247**	**100**	**75775**	**100**	**58580**	**100**	**95201**	**100**	**82694**	**100**
(N)	(164)		(139)		(281)		(100)		(684)	
Income from the SRF	72558		38137		21145		25426		37614	
% of Total Income	59.4		50.3		36.1		26.7		45.5	

Table 58 Average Annual Income of Households Located Around the Sundarbans

Sectors, Sub-sectors	(Income Category)							
	Bottom		Middle		Top		[illegible]	
	Takas	%	Takas	%	Takas	%	Takas	%
A. Primary:								
	7658	26.6	8931	16.3	30280	18.4	15622	18.9
	7559	26.2	19559	35.7	55621	33.8	27578	33.3
3. Animals/birds	1327	4.6	2303	4.2	7674	4.7	3765	4.6
4. Forestry & Horticulture	3111	10.8	5477	10.0	14083	8.6	7554	9.1
.								
B. Secondary:								
1. Agriculture	2999	10.4	4311	7.9	6683	4.1	4664	5.6
2. Fishery	139	0.5	722	1.3	1218	0.7	693	0.8
7. Business	1635	5.7	3945	7.2	17515	10.6	7698	9.3
8. Services	1468	5.1	3553	6.5	6833	4.2	3949	4.8
9. Rent/lease/mortgage	269	0.9	747	1.4	4187	2.5	1730	2.1
10. Remittances	2383	8.3	4587	8.4	16492	10.0	7856	9.5
11. Other receipts	277	1.0	625	1.1	3797	2.3	1565	1.9
Grand Total	**28825**	**100**	**54765**	**100**	**16449 1**	**100**	**82694**	**100**
(N)	(228)		(228)		(228)		(684)	
Income from the SRF	11639		25483		75729		37614	
% of Total Income	40.4		46.5		46.0		45.5	

Table 58a Shows the production of non-wood products as estimated by the results of the socio-econon : survey. It also shows the value of this products. These figures are then broken down to show how much of the total each section of the production process received.

Table 59 Production and value of Non-Wood forest products estimated by the socio-economic survey

SRF Resources	Annual Yield			Received by officials			Pirates	Operating expenses	Entrepreneur	Primary harvester
	Qty	Unit	Value	Govt Revenue	Extra Charges	Total				
			(million takas)							
A. Animal Origin:										
1. Shrimp fry OFP	1.7	bln	3438.0 228.6	80.3	109.4	189.7	12.8	507.1	1231.5	1725.3
2. Dubla: Dry fish Shrimp Raw fish OFP	 11500 1200 500	 mt mt mt	 1150.0 120.0 25.0 79.5	13.8	34.9	48.7	n	200.1	878.7	240.7
3. Hilsa	13000	mt	520.0	19.7	14.6	34.3	5.5	68.8	237.4	174.0
4. Crabs OFP	2500	mt	250.0 28.0	0.1	2.2	2.3	2.9	30.8	77.3	146.6
5. Shell	3400	mt	3.4	0.1	0.2	0.3	-	1.4	0.9	0.9
6. Honey and Beeswax OFP	600 150	mt mt	60.0 30.0 4.8	0.6	9.8	10.4	1.6	8.1	23.4	51.4
Subtotal (%)			5937.3 (100.0)	114.6 (1.9)	171.1 (2.9)	285.7 (4.8)	22.8 (0.4)	816.3 (13.7)	2449.2 (41.3)	2356.9 (39.7)
B. Plant Origin:										
7. Golpatta OFP	112000	kaon	140.3 12.9	8.7	60.8	69.5	0.7	17.6	18.7	46.7
8. Hantal	7000	mt	4.6	0.3	0.8	1.1	n	0.5	0.8	2.2
9. Mele	40000	mt	132.0	3.3	3.6	6.9	0.5	20.1	19.2	85.3
Subtotal (%)			289.8 (100.0)	12.3 (4.2)	65.2 (21.5)	77.5 (26.7)	1.2 (0.4)	38.2 (13.2)	38.7 (13.4)	134.2 (46.3)

Note : bln = billion, OFP = other Forest Produce, n = negligible, kaon = (16 pon x 80) = 1280 pieces

12.5 Dependence upon the SRF ecosystem

The dependence of people in the SRF border on the mangrove ecosystem was obvious everywhere (MARC, 1995). In depth studies revealed about 46 % of income being derived directly from SRF resources. The extent of dependence seemed to vary more from area to area than between the rich and the poor. The two districts lying in the eastern side, Bagerhat 36% and Patuakhali, 26 %, showed substantially lesser dependence than did Satkhira, 59 % and Khulna, 50 %. The level of dependence was similar among the rich and the poor, all ranging between 40 % and 46 %.

About two-thirds of the households reported some degree of dependence on the SRF resources for subsistence; for 38 % it was seven months or more and for 21 % the dependence was virtually for the whole year.

Among the income categories, the poorer households stated a comparatively lower level of subsistence dependence, namely 45% of the bottom third not depending at all compared to 24% and 36% of the middle and upper thirds, respectively. This, too, corroborates the income related dependence on the SRF.

The message that comes through clearly is that any constraining act in respect of access to the SRF resources hurts substantial numbers of households in the border area, but the middle and upper income households are hurt comparatively more. Hence a vigorous lobby should be expected against any future additional constraints which may be imposed by the government (MARC, 1995). More optimistically, it may be easier to make these comparatively better off people understand where their long term interests lie and realise the difference between short term, narrow self interest and long term, enlightened self interest.

12.6 People's Perceptions on SRF status and how to save It

The people in the SRF border were asked by MARC (1997) about their own perception as to the extent to which their basic needs were being met.

Most people, 94-95 %, felt that their food and clothing needs were by and large being met. The situation was also reasonable in respect of housing due to the plentiful availability of Golpatta and Goran. Education and transportation needs were not met for nearly a third of the households. It is interesting to note that unmet recreational needs were being articulated by two-thirds of the households. It is possibly indicative of a heightened consciousness about basic needs extending to more items than food and clothing, a situation which usually arises only after basic food and clothing no longer poses a serious challenge. In short, people seemed not be in dire straits.

There seemed to be some controversy about the status of tigers, deer and monkeys; substantial proportions of respondents having conflicting opinions.

One way to explain the confusion about tigers is that there may have been an increase in tiger attacks in recent periods. Some interpret it as an indication of an increase in their number, while others consider it as a sign of habitat deterioration. Regarding other wildlifespecies there was unanimity about their decrease in numbers. Turtles, in particular, were thought to be on the verge of extinction, shells, crabs and crocodiles were seriously threatened and in decline, while trees, fishes, lizards and shrimps were said to have substantially decreased in recent times.

Overall, it is clear that the people in the SRF border are aware of the degraded status of the forest and its wildlife, both terrestrial and aquatic. It is likely therefore, that a well thought-out management proposal designed to save the SRF would not be morally rejected by them.

The survey asked respondents what they thought were the most urgent management requirements to save the Sundarbans. The most common opinion was to have a complete ban or firm regulation on the extraction of resources, particularly on the use of fine mesh nets for capturing shrimp fry. Unaunthorised levies also featured prominently in responses.

12.7 Problems facing people in Border Zone

The problems which featured highly in the lives of people was their concern for personal security, difficulty in dealing with unscrupulous entrepreneurs and income inadequacy.

When asked how their occupational problems could be solved, the answers were mostly related to improving security followed by Government assistance and financial assistance from donors. Stopping unfair competition also featured, but not as prominently as might have been expected. Whether this can be interpreted as fear or a resigned acceptance of a situation about which nothing much can be done, was not clarified.

Other concerns related to the incidence of disease, lack of drinking water and inadequate facilities for children's education. The same respondents made recommendations urging government assistance in providing more tubewells, medical facilities and schools. Strong statements were also made about the community's own role and desire to solve their own social problems, particularly those related to marriage, divorce and banditry.

13 FINANCE AND BUDGETS

Historically, the forces which led to the establishment of the SRF were a combination of factors mostly connected with conservation of the wood resource, provision of timber and fuelwood to the local community and collection of revenue for the state, as discussed in Section 2. Working plans measured the resource and the Forest Department gauged the necessary staffing levels.

The deployment of staff, their emoluments, terms and conditions of service, accommodation, transportation and administrative support to carry out their functions were all tied to estimates of revenue expenditure, maintenance, depreciation, and capital expenditure, as was deemed necessary to be efficient servants of the state. Relative expenditure on these accounts has hardly changed over the last 100 years.

Given the manifold increase in management requirements coupled with the huge increase in the numbers of people dependent upon forest produce with incumbent problems, it seems wholly unrealistic that still only 25% of revenue is afforded to the Sundarbans Division's annual revenue expenditure. This state of affairs is the direct cause of the following :

- A large fall in real living standards for all FD staff leading to reduction in morale and perceived social status.
- An inability to maintain buildings and equipment in relation to normal depreciation.
- An inability to carry out capital improvements in proportion to rising demands.
- These conditions provide a strong justification at all levels to abuse the system.
- As the gap between reasonable personal needs and the means for carrying out official responsibilities continues to grow society can only expect more time to be devoted by otherwise loyal civil servants to finding ways of filling the gap rather than to devoting time to carrying out official duties.

This is the unfortunate condition in which the Sundarbans Division in 1995 finds itself (Abdur Rob pers. comm 1995) and which this plan seeks to address. The Division's equipment is run down and wholly inadequate to carry out its demanding functions in a rapidly changing economic and technical world.

Details of income and expenditure for the Forest Department, Sundarbans Division are provided by Mitchell (1995). The Sundarbans Division accounts for only 5% of government expenditure on forests yet it contributes between 35% and 49% of total national forest annual revenues.

13.1 Valuation of the SRF

In order to make rational decisions on recurrent expenditure it is essential to know the economic value of the resource which is to be managed. Without this yardstick it is impossible to calculate costs and benefits of alternative management or to make priorities for work plans.

The issue is complicated since many of the benefits to society which are attributable to the ecosystem itself, as opposed to products and services *per se*, cannot be given a direct cost or benefit value. In pure economic terms the value of coastal protection is undoubtedly worth much more than the value of other more easily valued benefits.

Usually a direct land use benefit value of a new treatment or management system can be compared with existing use values. Thus for a mangrove system the benefit of producing wood might be compared with the value of producing shrimps for export. The calculation does not rest at that point since the central issue is not whether shrimp production brings higher economic returns in the short-term but which form of land use is more sustainable, more capable of bringing lasting benefits. Experience gained with the Chakoria Sundarbans near Cox's Bazar has demonstrated that shrimp production brings higher economic benefits than mangrove timber production in the short run but that this is not sustainable and leads ultimately to virtually irreversible ecosystem degradation. In effect the protective value of the forest that initially sustained the shrimp farming was lost over a few years following the destruction of the forest.

Values for the SRF were estimated and reported upon by Mitchell (1995) and are summarised as follows :

- Direct use value : the benefits accruing from the ecosystem that can be both defined in terms of quantity and price.
- Indirect use value :those that are usually derived from the protective and existence functions of the forest. These are obviously less tangible and are hence more controversial.
- Total net value : a summation of all the values of the ecosystem less the cost of managing the resource.

It has been difficult to calculate net values for all the main components since it is impossible to abstract specific management costs from the records. All figures quoted must therefore be treated with caution bearing in mind the assumptions made during calculation (Mitchell, 1995). Assumptions :

- Future revenue is restricted to what is currently possible within the existing infrastructure. Potential value is ignored. Valuations are for the value of the SRF under the current management regime.
- Wildlife is valued under indirect benefits because at the moment there is really only an existence value. Changes should be measured in the context of new management practices or infrastructure developments. For example sustainable consumptive utilisation and perhaps the introduction of trophy hunting the potential direct benefits are enormous. Wildlife viewing is valued under tourism and recreation to avoid double counting.
- Total value is the price of the product on the open market at a specific time.
- prices are applied and that inflation will be constant in terms of both prices and costs.
- The value placed on the timber in the Sundarbans may be artificially high by intentional standards. Sale prices attained at auction of the Sundri timber are exceptionally high. Prices compare with timber from superior species of better quality and size on the international market. Also importation of timber is discouraged and local timber prices

protected from competition through import duties which range from 7.5% to 60% *ad valorem*. (ADB FMP, 1993a).

- With the exceptions of Sundri sold at auction and the Gewa to KNM, the current prices paid for many products are undervalued.
- Where the data are available new estimates of economic values have been derived. The calculations and all assumptions used are presented in the Appendices volume 2.
- For other products it is assumed that the current royalty rates are correct.

13.1.1 Direct use

Wood Resources:

Two methods for estimating values are used :

(1) Total Standing Value = total value of the total standing crop including that in wildlife sanctuaries at current market prices using notional sale prices less the cost of harvesting and haulage.

(2) Net Present Value = present value in terms of potential sale value. The future value can be ascribed as net present value (NPV) through discounting. This assumes that inflation will affect costs and benefits equally and that capital is cost in correctly. Also it can be assumed that if the resource is managed on a sustained yield basis, giving an annual economic return in perpetuity, this can be valued as an investment at a given rate of interest that would yield the same return in perpetuity.

Total Standing Value:

Table 60 presents the average standing volume per hectare as estimated by the PSP fourth measurement. This is probably a slight over estimate as during the period since PSP first measurement the plots have not been officially harvested.

Table 60 Average Standing Volume/ha by Diameter Class

SPECIES	Volume/ha by 5 cm diameter class (m^3/ha)								
	5-10	10-15	15-20	20-25	25-30	30-35	35+	5+	10+
Sundri	9.65	11.40	10.81	9.41	5.91	1.11	1.77	50.04	40.39
Gewa	14.98	15.50	4.56	0.76	0.07	0.04	0.05	35.95	20.97
Timber (other)	0.22	0.29	0.66	1.01	0.95	1.14	3.25	7.53	7.31
Firewood (other)	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.08	0.04
All	24.90	27.20	16.04	11.19	6.92	2.29	5.07	93.60	68.70

Volumes were estimated using new volume equations for Sundri and Gewa developed by Leech (1995) and for the remainder, equations developed by ODA (1985) were used. All estimate the merchantable volume of the main trunk or bole. The volumes for firewood derived from offcuts are generally over and above the volumes estimated by these volume equations. The volume equations will probably over estimate the merchantability of the sawlogs since some firewood will be obtained from defective stems included as sound in the equations. It is assumed that :

- Half of the firewood volume will be from defective timber stems and half from the crowns.
- That 50% of the firewood volume would be of a quality as utilisable for KHBM.
- That Sundri firewood would have the same economic value as goran and that the prices of other firewood would increase in the same proportion as the goran

Over the past four years, on average the amount of Sundri firewood is equivalent to 28% of the sawlog production. The prices per unit of volume were calculated on the past four years auction results and current royalty rates for Gewa and brushwood to KHBM. An economic value for Goran firewood was derived from sale prices less production costs.

For other timber species it has been assumed that they would fetch half the Sundri value. It is not possible to find out what they are actually worth as there are no official sales due to the moratorium. It is considered that some species, such as Dhundal and Passur may be worth more than Sundri and others such as Baen and Keora would be worth less.

For Gewa and firewood the current official royalty rates listed in Appendix A12, were used. For firewood this probably underestimates the true value. Table 61 presents the average value per hectare for the different species by diameter class.

Table 61 Value per hectare of Wood Products by Species Group and Diameter Class

(Mitchell, 1995)

SPECIES	Quality	Value/ha by 5 cm diameter class (Tk/ha)							
		>5 - ≤10	>10 - ≤15	>15 - ≤20	>20 - ≤25	>25 - ≤30	>30 - ≤35	35+	Total
Sundri									
	firewood	1388	1639	1553	1353	849	159	254	7195
	KHBM				275	173	32	52	532
	timber				42316	26559	4971	7939	81786
sub-total		1388	1639	1553	43944	27581	5162	8245	89513
Gewa			8213	2413	401	35	19	25	11106
Others timber									
	firewood	32	41	95	145	137	164	468	1082
	timber				2274	2136	2573	7315	14298
sub-total		32	41	95	2420	2272	2737	7783	15380
Other firewood		6.28	1.97	1.80	1.43	0.00	0.00	0.00	11
All		1426	9895	4064	46766	29888	7918	16052	116010

On average the standing crop is worth around Tk 116 000 per hectare using upper and lower values the range 107 000 and Tk /ha to 132 000 Tk/ha.

If this average value per hectare is multiplied by the total area under forest cover, then the total value of the standing timber inside the Sundarbans Reserved Forest is obtained. Table 62 defines present area for different area types in the SRF used in these calculations.

Table 62 Areas of The Sundarbans Reserved Forest :1995

Area Type	Km^2	Source
Total area inside SRF boundary	6017	GIS
Total forest land area	4101	GIS
Unproductive area	32	ODA
Productive forest land area	4069	GIS
Sand bars	42	GIS
Water	1874	GIS
Existing wildlife sanctuaries	301	GIS
Net productive land	3767	Derived

The standing value of the timber is Tk 47 billion (or Tk 4 720 Crore) or US$ 1.2 billion with a lower value of Tk 43 billion (or Tk 4 342 Crore) or US $ 1.1 billion or a higher value of 54 billion Taka (Tk Crore 5 357) or US $ 1.34 billion, using minimum and maximum annual sale prices achieved at Sundri timber auctions.

Value of sustainable annual production:

Another method of valuing the wood resources is to place a value on the production both now and in the future. If the forest is managed sustainably there should be the same level of annual production in perpetuity, normally equivalent to the AAC. For the SRF the value of trees and their production inside the wildlife sanctuaries is excluded.

To estimate the value of the annual production it has been assumed that the production of Gewa at the current AAC (133 000 m^3/ha/yr) is sustainable and that the production of Sundri and other timber species would be sustainable at the last AAC as recommended by Balmforth (1985), (141 000 m^3/ha/yr). The assumptions made regarding merchantability for the standing valuation have also been made here, except that the value of Sundri brushwood to KHBM has been set to cover their requirements of 1 000 000 cft stk/yr (Larsen, 1994),

As there are no data regarding the standing stock or growth rates of Goran and Shingra, it has to be assumed that the level of cut currently achieved is sustainable. It is not known if the resource is being depleted or if illegal harvesting is a significant factor. The under-valuing of firewood removals is known to be significant. The true economic value or correct royalty value was calculated in Appendix A12 and used to estimate the value of annual production. Assumed out turns are presented in Table 63.

Table 63 Assumed Annual Sustainable Wood Production from the Sundarbans Reserved Forest

SPECIES /GROUP	Assumed Sustainable annual out turn (m^3/yr)				
	AAC	Timber	Pulpwood	KHBM	Firewood
Sundri + other timber	141000	121532		14407	24530
Gewa	133000		133000		
Goran					28197
Shingra					9942
Others					15239

(Mitchell,1995)

Table 64 Projected Annual Revenue based on Annual Sustainable Wood Production : SRF

		Assumed Sustainable Annual Revenue (Tk x 1000)				
		Timber	Pulpwood	KHBM	Firewood	Total
Sundri + other timber		634128		3053	3527	640708
Gewa			70453			70453
Goran					2861	2861
Shingra					257	257
Others					1380	1380
Total		634128	70453	3053	8026	715659

(Mitchell, 1995)

Using average auction prices and prevailing royalty rates the annual revenue for wood products of Tk 716 million (Tk 72 Core) shown in Table 60 should be attainable. Applying the average annual minimum auction price the revenue would drop to Tk 654 million (Tk 65 Crore) and with the average annual maximum price a return of Tk 819 million (Tk 82 Core) per year could be possible.

Comparing annual income with a capital investment that would return the same amount annually. Estimates were made using bank interest rate to investors of 13% based upon a range of 12% -14% defined by the Bangladesh Bank, Economic Trends (1994) as the lending rate for agriculture.

At 13% the principal required to achieve an annual return annually of Tk 716 million is Tk 5.5 billion (Tk 551 Crore) or US$ 138 million. This is about 8 times less than the valuation derived by assessing the standing stock. This is a function of the difference in the growth of the forest, expressed as the AAC and the interest rate chosen. The return on capital would be much greater than the percentage growth rate of the forest as might be expected from an over capitalised industry. To give the equivalent value as derived by the standing stock method an interest rate of 1.6% would be required.

By using the lower and higher average annual prices for Sundri timber at a 13% interest rate the value of the forest ranges from Tk 5 billion to Tk 6.3 billion (Tk 503 Crore to Tk 630 Crore) or US $ 126 million to US $ 157 million(Mitchell, 1995).

Non Wood Resources:

Economic valuation of the non-wood resources has been seriously hampered by the lack of good data. There have been no definitive stock assessments or inventories, even in the past and there is considerable debate over some of the data which have been collected (Mitchell, 1995).

Fisheries:

The Sundarbans fisheries have been valued in terms of the annual catch rather than the size of the stocks. The annual revenue from the fishery should be the value of the receipts collected by the Forest Department each year assuming that all the fish harvested are recorded and the level of fees is set at the correct economic level. Unfortunately the evidence suggests that this never occurs and it has been necessary to use the alternative method of estimating annual production and then calculating the economic value.

Estimates of the annual SRF fishery landed harvest vary considerably and a summary of current information is provided in Table 65. Given, the huge numbers of people that fish in the reserved forest (200 000 - 400 000) it is likely that the most realistic estimate is at the upper end of these figures (Mitchell, 1995; MARC, 1997).

Table 65 Estimates of the Annual Fish Harvest by Source

Source	Fishery harvest (tonnes/annum)			Shrimp fry No. x 10000
	Offshore	Inshore	Total	
Forest Department#			5699	8014
Khulna University 1995~	8733	3054	11787	
Ahsanullah 1995*	33485	11765	45250	
MARC 1995^	59200	15500	74700	180000

Average figures from DFOs annual reports from 86-87 to 93-94 collected from issue of permits

~ Based on field data collected by Chantarasri 93-94 and reworked by Khulna University

* Based on comparisons with Fisheries Directorate statistics collected from neighbouring areas

^ Based on Socio-economic survey of fishermen and entrepreneurs during the 1994-95 fishing season

Similarly the fishery can be valued keeping in mind that the data used for fish prices and costs are based on very limited field work. The calculations used to derive the figures presented here are shown in Appendix A32.

The average price (all species over one year) obtained for fish at the first point of sale was taken to be Tk 40 / kg. The average costs including the costs of traders, middlemen and finance came to Tk 28 / kg. If a further allowance is made to let the fishermen make a profit of say 30% on costs (equivalent to a further Tk 8 / Kg) then the true economic value of the fish harvest should be Tk 3.94/kg (Tk 147/md). This nearly three times the current level of royalty. If this figure is then multiplied by the estimated production (76 700 t) then the annual economic value of the fishery is Tk 134 million per year. This is the equivalent of 2 325 million Taka invested at 13%.

Shrimp Fry Production:

The FD records an estimate of the numbers of fry caught within the SRF. This method probably underestimates total production. A large proportion of the fry are caught in areas immediately adjoining the forest, especially in areas in the north, where the boundary has been modified from river bank to centre stream. The economic value of total shrimp fry production should include these.

According to the Fisheries Department (1994), part of the life cycle of the black tiger shrimp ***Peneaus monodon*** or Bagda, is dependent on the SRF for both passage and feeding. Therefore the value of the Bagda fry collected for shrimp farms in Khulna, Bagerhat, Satkhira and Jessore districts probably comes from waters of the Sundarbans. The area of bagda shrimp farms in these districts covers some 107 000 ha and represents nearly 80% of the Nation's total bagda shrimp farm area.

The Department of Fisheries further estimates that the production of wild Bagda fry for all Bangladesh is some 2 033 million/year. Assuming a proportionate distribution of fry then production of 1 613 million bagda shrimp fry must be attributable to the SRF which does not accord with the Forest Department's annual total of 231 million fry produced in 1993-94 which includes fry caught outside the forest and represents only about 14% of the likely total.

Although a large proportion of the estimated fry production comes from outside the SRF, the economic value to society is still the same. Ideally the full value of fry caught in the SRF should be received as Government revenue and the production outside the SRF as profits to fry collectors. This would lead encourage more people to collect fry outside the reserve, thereby increasing competition and probably reducing the number of people wanting to enter the Forest.

Measures aimed at reducing pressure on fry inside the SRF could increase densities and thus improve the likelihood of capture. Some form of biological equilibrium might be achieved and the greater productivity inside the SRF would justify the cost of the collection permit. By issuing permits the Forest Department would be able to control the level of harvest and thereby ensure that the stocks are not over-exploited.

The value of total annual shrimp fry production is estimated by multiplying the number caught by the economic value (Tk 335/1000, about seven times the existing permit level). This gives a total value of shrimp fry production of Tk 541 million per year. An investment of Tk 4.2 billion at 13% would yield the same amount annually.

Tourism and Recreation:

It is difficult to value tourism and recreation in the absence of reliable data on numbers, the fees paid and associated costs. There is no capital infrastructure dedicated to tourism thus all the revenue from tourism can be ascribed to the intrinsic values. The current level of fees varies considerably, but has shown a marked but arbitrary increase since 1986. The increase is unlikely to continue in the same fashion as there is no economic justification. Tourism is valued solely on the basis of the FD fees collected in 1993-94 which were officially recorded as Tk 85 000 per year.

The level of investment required at 13% to achieve this revenue is Tk 634 000. If existing tourism were costed in detail it would almost certainly create a net loss for the Forest Department. The cost of FD staff administering tourism and recreation was estimated at Tk 189 000 per year, equivalent to over twice the sum collected in fees.

Apiculture:

There are no estimates of the resource base for this component. There is also no information on the cost of production. It seems likely that this resource is undervalued in line with the fish, shrimp fry, Goran and Golpatta production.

Table 45 indicates that the average annual production from FD records is 4 915 maunds for honey and 1 238 maunds for wax. However MARC 1995 estimated the annual production at 16 000 Mds of honey and 4 000 Mds of wax. This level is probably more accurate and would give an annual value of 2.2 million Tk/year based on current royalty rates. An investment of Tk 17.0 million yielding 13% would be required to sustain this level of production.

Golpatta:

Table 34 indicates the average annual production of Golpatta as 68 500 t. The derived economic value (Mitchell, 1995) is assumed to be just over Tk 12/md. This equates to 322 Tk/t with a total annual value of Tk 22.6 million.

The amount required, invested at 13 %, to have the same annual yield would be TK Other

Other NWFPs:

Annual production and values derived by Mitchell (1995) using the same procedures as described for other non-wood products are summarised in Table 66 for Hantal, Grasses, Oyster shells and miscellaneous.

Table 66 Average Annual Production, Revenue and Estimated Value of Hantal, Grasses, Oyster and Miscellaneous Products : SRF

(Mitchell, 1995)

Product	Average Annual Prod (tonnes)	Present Royalty (Tk/t)	Average Annual Revenue (Tk x 1000)	Investment required to yield similar annual return at 13% millions of Taka
Hantal	7235.6	49.6	358.64	2.8
Grasses	9325.42	16.1	149.91	1.2
Oysters	3193.70	26.8	85.57	0.7
Miscellaneous			2420.3	18.6

The values of annual production and the standing capital value derived in the preceding sections are summarised in Table 67. The management of the SRF concentrates on production of direct use components and to estimate values it has been necessary to deduct the cost of management bearing in mind that it is not possible to disaggregate the Forest Department's expenditure under different management headings. The total net value of the Sundarbans Reserved Forest direct uses is thus estimated at 54 billion Takas or 1.3 billion US dollars. Table 67 summarises direct use values and costs of management.

Table 67 Summary of The Direct Use Values and Costs of Management

(Mitchell, 1995)

[illegible]	Annual Revenue	Capital Equivalent	Standing Value	Estimated Total	
	Tk x 1000	millions of Taka	millions of Taka	millions of Taka	millions of $
PRODUCT					
Wood	715659	5505	47202	47202	1180
Fish	302436	2326		2326	58.16
Shrimp Fry	541185	4163		4163	104
Apiculture	2200	17		17	0.42
Golpatta	22591	174		174	4.34
Hantal, Grasses and Oysters	594	5		5	0.11
Miscellaneous	2420	19		19	0.47
Gross Total					
	1587086	12208		53905	1348
Estimated Cost of Managing the Resources					
Forest Department Costs	34169	263		263	6.57
Net total	1552917	11946	47202	53642	1341.05

13.1.2 Indirect use

Mangrove ecosystems fulfil a variety of environmental roles which are of considerable importance to coastal regions and of inestimable value to society. Most of these constitute indirect values which stem from the intricate interface of water, land and human activity. These include non-marketable uses such as coastal defences, pollution abatement, nutrient cycling and energy conversion. These are difficult to measure and even more difficult to ascribe a dollar value.

Whilst such benefits are obviously tangible, unlike goods and services, which extend direct benefits, they cannot be traded and therefore elude direct evaluation. In the face of intense external pressure to bring the natural mangrove ecosystem under alternative forms of land use, human settlement, agriculture, shrimp culture or simply plantation forestry, it is essential that values are estimated for the principal indirect uses of the system. There are a few ways this can be achieved :

- By drawing a comparison with other more easily costed methods for obtaining a similar benefit.
- By calculating a price using the opportunity cost or the forgone revenue value.
- By pricing the particular benefit by calculating the cost of an alternative investment that would yield a benefit of a similar value.

Examples of Indirect use values are listed below :

Storm Damage and Flood Alleviation:

About 10% of the world's tropical cyclones occur in the Bay of Bengal and of those 17% hit Bangladesh.

Unfortunately it has never been possible to usefully value the cost of storm and tidal surge damage by region or district , therefore the protective function of the mangrove forests are probably best evaluated by calculating the cost of protective infrastructure that would be needed if the forest were not there.

The Southwest Area Water Resources Management Project (1993) estimated that the coastal defences that would be required in the absence of the Sundarbans would be 2 200 Km of storm and flood protecting embankments. This would require a capital investment of Tk 160 billion with an annual maintenance budget of about Tk 320 million. An investment of Tk 2.46 billion would be needed at 13% to give the annual return of Tk 320 million (Mitchell, 1995).

Marine Production:

The ebb and flow of tides which mingle throughout the mangroves with the inflow of freshwater from proximate and distant upstream catchments, ceaselessly transfers organic and inorganic nutrients to enrich the waters of the Bay of Bengal. Photosynthetic activity and energy conversion throughout the ecosystem has a direct use value but the benefits to the offshore fishery cannot be directly cost.

Values for this important ecological function have been derived by making some very broad assumptions. Apart from the crucial role of primary producer, the Forest encompasses breeding habitats for freshwater shrimps and prawns and extensive nursery areas for some species of fish which spend part of their life cycles in the mangroves and partly at sea. Much of the material consumed in the food chains of the rich offshore fishery originates in the mangroves. Some studies have concluded that 60% of the total marine shrimp industry and 20% of the white fish industry is dependent to some extent upon this source.

There is substantial scope for development of marine and inshore aquatic resources but this will require a stable environment with minimum of human disturbance. Crabs are only just beginning to be exploited and oysters are only harvested for their shells for the production of lime. Squid and octopus are only sun-dried and used for fish meal production. The prevailing system overlooks the export potential for these products. There are many species that are not utilised at all. This represents a high unrealised value, the magnitude of which cannot be estimated without further research.

As it is not possible to disaggregate the contribution that the SRF makes to these industries they have been included as dependent industries in Section 13.1.4.

13.1.3 Existence values

Existence value is a value placed on an environmental good which appears to have no direct or indirect use but is able to attract vicarious attention or secondary benefits (Mitchell, 1995) and is therefore difficult to assess. For example a value may be given to contributions by third parties for preservation of species or habitats. In some instances the contributions may be wholly altruistic.

A specific existence value might be obtained for the cost of preserving the tiger or conserving biodiversity. If it can be assumed that tigers are readily saleable on the black market, by preserving it a loss in that potential revenue cost is incurred. Equally, it is possible to estimate the costs involved in managing the tiger population. Obviously, under existing arrangements the costs of managing the tiger would be far less than the value the tigers on the black market.

The endangered status of the tiger is frequently mentioned in the media. This underlines a high existence value which should not be overlooked in future management since this value could be harnessed for its development potential. Mitchell (1995) cited the following examples:

Time International, March 1994 :

"A beautiful tiger skin may fetch US$ 15 000 and bones and other parts generate even more money".
"Parts such as the forelimb, valued in traditional medicine can fetch more than US$ 1000/kg".
"Affluent Taiwanese with flagging libido pay as much US$ 320 a bowl for tiger penis soup".

BBC Wildlife, January 1994 :

"A minimum of £ 4000 (US$ 6400) per tiger, more if all the bones reached China ; this meant big money".

Evidently there is a high market value for the parts of a tiger. Conservative estimates of the value each tiger are as high as US $ 50 000. The current population census (Tamang 1993 and Dey, 1995) records the SRF population at about 400 in the Bangladesh part of the Sundarbans. The total opportunity value of the tiger population would thus be US $ 2 million or Tk 80 million.

On the other hand for the existence value of the tiger this figure may be too low. It is conceivable that funds might be available from international organisations or in the form of debt for nature swaps that would give a higher return for the preservation of the tiger, the valuable habitat and other species. de Vere Moss (1994) estimates that it would be possible, with the necessary infrastructure developments, to develop an ecotourism industry based on the Sundarbans low volume high cost product that could well initiate an industry with a total income of US$ 100 million per year. It could be argued that the development of this industry would to a large extent depend on the presence of the tiger.

There is also widespread poaching of the spotted deer, for skins, antlers and meat. It is estimated that around 1500 to 2000 animals are poached in any one year. At an approximate market value of around Tk 5000 per animal, depending on size and sex, the an annual offtake could be valued at about Tk 8.75 million.

Biodiversity values:

Biodiversity may be defined as the diversity of all forms of life that inhabit the planet. Unfortunately this diversity is diminishing at an unprecedented rate; the extinction of species is an irreversible process. Destruction of tropical forests is a major cause of species extinction because diverse habitats are being lost. One of the tragic ironies is that these extinctions are occurring at precisely at the time in history when the most advantage could be made of them. Biodiversity represents a gene pool and source of new chemical compounds. These genes and chemicals can be used to improve agricultural crops, be a source of new medicines or be of value in the pharmaceutical industry. Nearly a quarter of all prescription drugs have been derived from chemicals found in tropical plants. (Tientenberg, 1994).

The unique physio-chemical characteristics of the organisms which have adapted to the mangrove ecosystem offer rare opportunities to study halophytic specialisations for the conservation of biodiversity *in situ* and *ex situ* and which might lead to new discoveries of value to commerce and science. Such finds could be very valuable, possibly of greater value than all the other uses of the forest put together. This matter is so conjectural that it is impossible to place a practical value on it yet the subject should not be overlooked and recommendations are made in Part 2 for applied research in this field. Table 68 summarises related economic direct and indirect benefits and their values.

Table 68 Summary of total direct and indirect benefits : SRF

(Mitchell, 1995)

Net Benefits	Annual Benefit	Capital Equivalent	Standing Value	Estimated Total	
	Tk x 1000	millions of Taka	millions of Taka	millions of Taka	millions of $
Direct use values	1552917	11946	47202	53642	1341
Indirect Use Values					
Flood and Storm Protection	320000	2462	16000	18462	462
Marine and shrimp production					
Existence values					
Tiger			80	80	2
Spotted deer	20 000	154		154	4
Biodiversity					
Total	1892917	14561	63282	72338	1808

13.1.4 Dependent industries

Some major industries are either partly or totally dependent upon the SRF for their raw materials. If alternative forms of land use were to be considered then the loss of these dependent industries, the employment generated and other multiplier effects must be added to the values described above. Table 69 illustrates the position, shows their relative values, their estimated total annual turnover and makes an estimate of ultimate dependency.

Table 69 Annual Turnover of Industries Dependent on SRF Production

(Mitchell, 1995)

Industry		Annual Value millions of Tk	Proportion dependent on SRF %	Value of dependent production millions of Tk	Source
Extraction of Resources		1198	100%	1198	derived
KNM		838	100%	838	BBS
KHBM		85	100%	85	BBS
Sawmills#		315	100%	315	derived
Marine	fish~	49	20%	10	DOF+derived
	shrimp*	1542	60%	925	DOF+derived
Total				3371	

Based on the average timber production per year multiplied by the average sawmill selling price, with an assumed recovery of 70%

~ average annual production of 2458 t per year based on recorded harvests from 88-89 to 94-95 multiplied by assumed sales price of 20 Tk/kg

* average annual production of 4820 t per year based on recorded harvests from 88-89 to 94-95 multiplied by assumed sales price of US$ 8/kg = 320 Tk/kg

From Table 69 it can be seen that there is a annual derived production of Tk 3.4 billion with a net present value at 13% of a further Tk 26 billion (US$ 0.65 billion) dependent on the SRF. Any alternative land use scheme must be weighed against these values in the cost benefit analysis.

13.2 Government revenue (SRF Forest Department)

The total revenue and expenditure for the Forest Department as a whole and for the Sundarbans Division are presented in Table 70.

Table 70 Forest Department Total and Sundarbans Division Expenditure and Revenue Figures

EXPENDITURE	Year						
Millions of Taka	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	Average
Forest Department							
Development Budget		414	437	371	569	753	
Revenue Budget	148	181	198	236	293	306	
Total		595	635	607	862	1059	
Sundarbans Division		30	29	31	34		
SD as % of revenue budget		17	14	13	12		14
SD as % of total		5	4	5	4		5
REVENUE							
Forest Department Total		260	194	322	356	382	
Sundarbans Division Revenue	284	128	68	138	115	172	
SD as % of total revenue		49	35	43	32	45	41

Source: Forest Department Records

This table clearly shows that the Sundarbans Division contributes on average 41% of the Forest Department's revenue but that it only receives 5% of the total expenditure and 14% of the Revenue Budget expenditure.

13.2.1 Revenue systems

Revenue systems were reviewed in detail by Mitchell (1995) and reference should be made to the report on natural resources economics for further information. Historically and to the present day forest charges have been levied by a wide range of licenses, royalty payments, permit fees and at auction sales. There are more than 96 different charges which can be levied.

A key issue is not the level of fees but how these are set. For example when fees are set by Government Order they are not up-dated to keep pace with general price increases. Prices are invariably set too low. Consumers will always complain if the rates are too high.

A good example of the effects of inappropriate rates concerns the exceptionally low rate set for Gewa in the past which in effect was an indirect means for applying a national subsidy to state run industry. Under-pricing has the following effects:

- It discourages efficient utilisation and hence increases the amount of wood waste.
- The state enterprise rely too heavily on subsidised raw material instead of searching for alternatives.
- The standing Gewa forests are under-valued thus reducing competition and the incentive for improving management which encourages the mis-allocation of investment funds.

13.2.2 Permits and Royalties

Forest charges for many different products are collected by charging either a royalty per unit of production in arrears (usually for timber to the large scale industries) or for a permit for a specific quantity of a product prior to harvest. Generally, permits are issued for the lower value products and most of the non-wood forest products. Rates are periodically revised by modest amounts. When the rates are revised there is generally a survey of prevailing market prices. **The permit fees are set at approximately 10% of the market price.**

Fees are also charged using many different units such as cft, mds, 100 mds, pieces, pon etc and in some instances by different size classes. The entire system is cumbersome and inaccurate and the lack of financial precision is made worse by the contradictory custom of collecting under numerous headings followed by aggregation under a single miscellaneous head.

Permits for many products are sold in proportion to the quantity harvested. For example Tk 5.00 per 100 fry caught yet it is clearly impractical for anyone to count numbers of fry harvested. In practice an assumption is made that one net will catch 1400 fry in a week. The system in effect records the number of nets and not the true number of fry.

Appendix A12 lists royalties and permit charges and official fees announced by Government Order. These omit other fees from the approved schedule such as 'miscellaneous fish', 'under size fish' and arbitrary fines imposed when an offender is caught red handed (Chandpai Range Annual Administrative Report 1993- 94).

Revenue is collected for permits for a specific quantity of relevant produce. The schedule of rates has only been revised 6 times in the past 19 years so that the value of permits in relation to market prices tends to be low. **For most non-wood products the volumes and value of the products are so low that the current system of permits should continue unchanged but with three notable exceptions for which quantity and value are key factors namely Goran, Golpatta and fish.**

REB Transmission Poles:

The FD produces Sundri poles for the Rural Electrification Board in 25', 30' and 35' lengths. The REB pays a fixed royalty of Tk 156 / cft for the 25' poles and Tk 164/ cft for 30' and 35' poles. The FD however have a marking cost of Tk 1.75 / cft which is not reimbursed by REB. The net benefit is Tk 154.25/cft and Tk 162.25/cft respectively. Whilst the royalty paid by REB is high in comparison to the listed royalty fees, it is extremely low when compared to the prices paid for Sundri at auctions. The REB poles are of a selected quality so it would not be possible for them to buy their requirements in the present auction system where lots are made up of mixed quality timber. Currently REB poles are produced by the FD as a separate operation and are not included in other felling operations.

Sundri Brushwood to KHBM:

Khulna Hardboard Mill prefers to use green Sundri branchwood or Shingra. Since the moratorium KHBM have been restricted to using branchwood from Sundri harvested because of top dying. Inevitably much of the Sundri supplied is rotten and dry. This results in a lower quality product with poor conversion rates. Currently KHBM pay Tk 3/cft for Sundri and Tk 1.73/cft for Shingra.

Gewa Pulpwood to KNM:

The Khulna Newsprint Mill pays a royalty rate of Tk 15.00 per cft (true cft) for Gewa. It also arranges cutting and extraction at its own expense. The royalty rate was revised in 1992 from Tk 0.06 per cft to Tk 6.03 per cft. The pulpwood was supplied virtually free of charge in the past. The cost of importing substitute pulpwood is estimated by ADB at Tk 6000 per air dry tonne (ADT) in 1993 delivered to the mill. (ADB - FMP, 1992). This equates to Tk 206/cft (assuming $1m^3$=1 tonne). KNM's total costs to fell, extract and haul the Gewa to their yard is Tk 45/cft including royalty payments.

During 1993-94 KNM started to use jute as a substitute supply of long fibre. Initially, the jute consumption was set at 5000 tonnes. This, according to KNM, provides the same amount of fibre as 500 000 cft (approximately 14 000 m^3) of Gewa. The jute costs KNM between Tk 15 000 and Tk 18 000 per ADT of pulp. This equates to Tk 150 - Tk 180/cft of Gewa, assuming that processing costs are the same.

The price paid for rough pulpwood bought standing in the UK is comparable to the royalty that KNM are pay suggesting that the current royalty is probably correctly set.

The demand for Gewa is by no means limited to the pulpmill. Match companies like to use Gewa for splints, it can be used by sawmills for pallet wood, for lining furniture and it can also be used for firewood.

Goran Firewood:

As has been shown in Section 10.6.2, measuring Goran by means of the BLC, produces an underestimate of the true volume by around 40%. Consequently, even before the level of permit is set, there is a serious undervaluing of the product. During studies of the revenue system and harvesting and marketing of Goran and Golpatta (MARC, 1997) (MARC & DDC, 1995; Mitchell, 1995) major problems within the existing revenue system were encountered. The background data are summarised in Appendix A32

It was found that the amount estimated on the BLC was equivalent to 61% of the amount measured at the time of sale Analysis of costs were as follows:

- Actual cost of harvesting and transport: 42% of the total costs.
- Legitimate forest charges: 7% of the costs.
- The cost of finance, middleman and marketing charges: 16% of the costs.
- The remaining 35% of the cost production were attributed to other forms of levy.

To cover these losses the contractors (bawallis) are forced to take more than the permit allows by way of compensation. The consequence is that the real loser is the Nation which does not receive the true value of revenue from the resource.

By reforming the system the level of permit could be raised by nearly five times. Also the bawallis would be able to earn a modest profit for their labour which does not happen at the moment.

Golpatta;

Prior to 1972 Golpatta was sold standing by area at auction. This led to a small group of traders monopolising the business. In an effort to make the market fairer, the MOEF introduced a permit with a ceiling of 500 mds per person; later reduced to 300 mds. Unfortunately the very low cost of the permit had the opposite of the desired effect in that it merely served to allow in various vested interests thereby distorting what would otherwise have been an equitable system.

The level of permit fee, low as it is, still remains beyond the reach of the local poor population. The product is under-valued, unfair profits are made and benefits do not reach the targeted disadvantaged section of society and this too is a matter which must be addressed.

Two Golpatta harvesting surveys were undertaken by MARC and DDC (1995) who followed four Golpatta boats through the entire harvesting, marketing and costs procedure. Some of the raw data are recorded in Appendix A32. This analysis revealed the following :

- The official permit charge represented 5% of total costs.
- The cost of production amounted to 58%.
- The cost of finance and trading was 10%.
- The cost of various unrecorded levies was estimated at 27% of the total costs.

The management issues are much the same as those described for Goran, that the real loser is the Nation and that the Bawallis make up for their losses by taking more than the record shows.

If the unrecorded levies are removed it would appear that the level of permit fee could increased fourfold. This would allow the contractor to make a modest profit of 30%, still allow the existing methods of finance and trade and increase the annual revenue considerably.

13.2.3 Auction sales

The level of Forest Charge varies considerably with the value of the product. When Sundri is sold at the official auctions, the maximum value the market can bear should be achieved thereby maximising the value of Sundri timber for the Nation.

Detailed analysis of two types of timber auction sale are presented in Appendix A33 and summarised below.:

- Standing Auction
- Depot Auction

The average price obtained for Sundri at the depot auctions in 1993-94 was Tk 219 per cft. Under the previous standing crop method the average price obtained during 1985 - 86 was Tk 87 per cft. This is equivalent to Tk 131 per cft for 1993-94 prices (prices were estimated using price indices published by Bangladesh Bank, 1994). (These figures should not be used to compare the efficiency of the two auction methods as the volume sold in 1985-86 was over seven times that sold in 1993 - 94).

Whichever method of auction is used the returns are high when compared with official rates for extraction of Sundri by permit of Tk 18 per cft, approved in 1986.

Standing Auction Sales:

From November 1975 until 1988 the system of selling marked standing Sundri by auction was used. The system functions as follows: an area of harvestable trees is selected and individual trees are marked and their diameters measured. The heights of some sample trees are also estimated. Details are summarised and published in the Government Gazette along with the time and place of the auction. After inspection by potential buyers the timber is sold by the FD to the highest bidder at the auction. The successful purchaser pays a deposit immediately and it becomes his responsibility to harvest the timber. The terms of the sale stipulate the dates and proportions of staged payments.

The main constraints for selling timber standing relate to control and supervision. Purchasers, if not properly supervised, tend to take more good stems than are marked and leave uneconomic marked trees. This has the effect of decreasing the quality of the forest over time. Also there is a tendency to leave high stumps and generally cut corners in order to reduce harvesting costs.

Depot Auction Sales:

Standing timber was sold at auction until the moratorium when the current system was introduced. Timber is now sold by auction after it is cut and brought to a FD depot. The timber is marked by the Forest Department and trees are felled and extracted by approved contractors.

When there is sufficient timber in the depot an auction is held. At time of arrival logs are not graded but are stored and sold in lots as they are received. On top of the sale price the purchaser is expected to for felling, extraction and haulage. Selling pre-felled timber at depot by auction is a better system in that it eliminates some of the difficulties described in the standing timber method.

Disadvantages of the system are :

- It requires a high market led demand for the timber. If demand is low, buyers may attempt to reduce the price by bid rigging.
- Contractors tend to cross cut the logs at lengths convenient for their own extraction often cutting the larger valuable butts into shorter less desirable lengths.
- The reserve price is set on a basis of previous auctions. This does not take into account any changes in supply and demand. There is alleged rigging of sales by unscrupulous traders; these parcels are resold, sometimes on the same day.
- The FD requires working capital to pay the contractors in advance which the Ministry of Finance often does not forward on time. In the absence of alternatives the necessary funding is provided by KHBM who in return for advance payment receive the branch wood which they require. When funds are insufficient contractors are not paid until the timber is sold at the auction leading to other pressures upon FD management.
- The amount of timber worked in this system remains low and is not enough to remove all the Top-dying Sundri resulting in large areas of Sundri going to waste.
- The amount of space in depots is limited and any increase in delivered timber would be certain to create logistical difficulties.

Notwithstanding these disadvantages the system enables better control of felling and it is therefore the preferred method.

13.3 Government expenditure (SRF Forest Department)

The Sundarbans Division has an annual expenditure of around 35 million Taka. Table 71 presents a summary of expenditure since 1986-87. Further information is provided in Tables of Expenditure in Appendix A34 together with details of the salary structure of the Forest Department.

Table 71 Summary of Forest Department Sundarbans Division Expenditure by Year (Taka x 1000)

Budget Head	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93
Conservancy and Public Works	6146	7137	5799	7676	6160	6152	5925
Administration Costs	15209	17507	16999	22623	22376	24606	28244
Total	21354	24644	22798	30299	28536	30758	34169

Source: Forest Department Records

Activities such as felling, extraction, plantation establishment, building maintenance and jetty construction are included in the budget line Conservancy and Public Works. In 1992-93 over 85% of the expenditure on this line was spent on felling and extraction of Top-dying Sundri. Administration Costs include salaries, staff allowances and office running costs. In the same year the cost of salaries and allowances amounted to 80% of total expenditure. Analysis of expenditure over the period 1986-87 to 1991-92 shows that increases kept pace with the general wage rate increase. (Bangladesh Bureau of Statistics, Statistical Year book 1993).

Since the bulk of expenditure is on staff emoluments it is clear that there is not much latitude for either capital projects or for increasing the operational capacity of the Department.

These figures however, only include the costs of the Sundarbans Division and exclude any central over-heads. In the past, management planning was done centrally and these costs were paid from central or head office budgets.

The Forest Resource Management Project (FRMP) - Forest Department Component - commenced in 1992-93 and is due to continue until 1998-99. This is a Ministry of Environment and Forest project and is funded through a World Bank (IDA) loan and MOEF local expenditure. In this project there are two components that affect the SRF :

- The creation of a Wildlife and Conservation Division to manage the Sundarbans wildlife sanctuaries.
- The establishment of a new Forest Management Plan Division at Khulna which will undertake forest inventories and prepare management plans for the Sundarbans Reserved Forest as well as four other coastal afforestation areas.

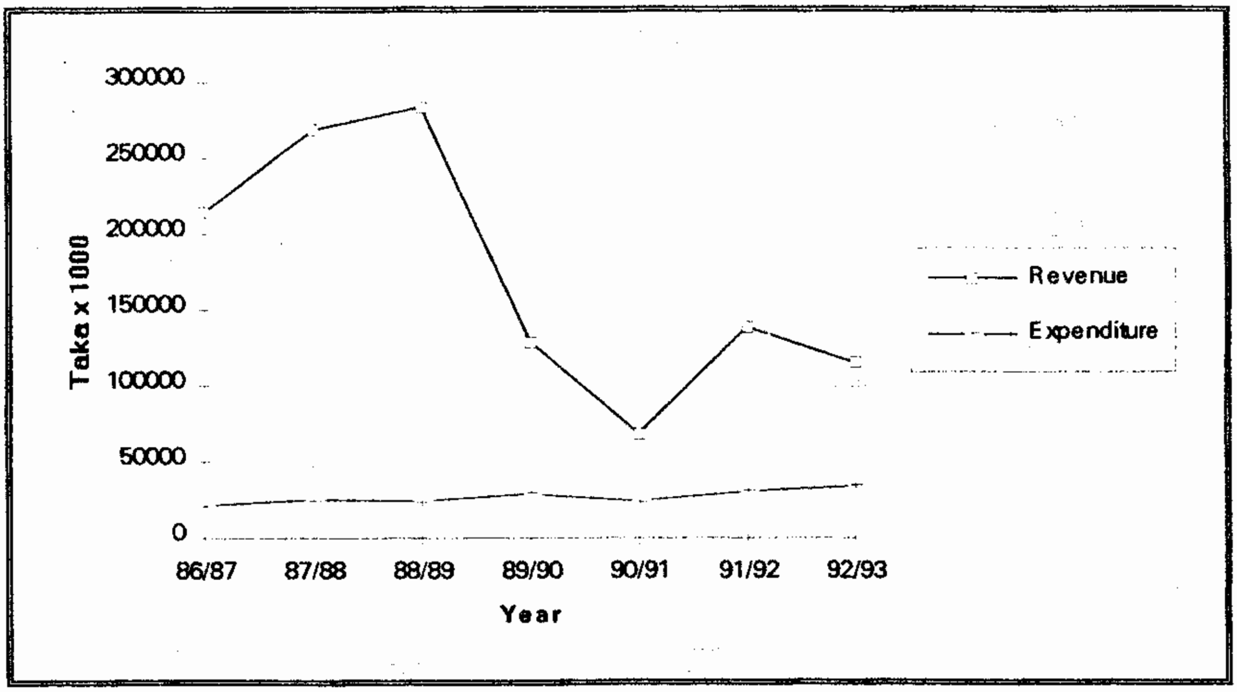
Although the project started in 1992, expenditure to August 1995 has been limited to staff salaries and the construction of two new DFO's residences, a new office block and the purchase of boats and vehicles.

The Sundarbans Division's expenditure accounts are presented in such a way that it is difficult to analyse expenditure without making some large assumptions. For example, it is not possible to ascertain how much was debited for protection activities (Mitchell, 1995).

Figure 4 shows the Sundarbans Division's level of expenditure in comparison to the amount of revenue collected. It underlines the fact that revenue markedly exceeds expenditure. The graph also shows that for the past 8 years at least, expenditure has been reasonably constant but that the levels of total revenue vary considerably.

Figure 4 Forest Department Revenue and Expenditure

(after Mitchell, 1995)



A significant comparison may be made with Leader-Williams (1990) who estimated the cost of protecting areas for the conservation of large endangered mammals at US $ 400/km^2. Measured against this cost standard, an annual budget of nearly Tk 100 million, or three times the current total expenditure, would be needed by the FD for the SRF for conserving the tiger population, without conducting any other forestry activities.

13.4 Sources of income from wood produce

Despite the moratorium, the main source of revenue for the FD is derived from the wood resource as described in Section 13.1.1 under the following broad categories:

- Top-dying Sundri - public sales
- Gewa - KNM
- Sundri for REB poles
- Goran firewood

13.5 Sources of income from non-wood produce

NWFP constitutes a fast growing and far from fully realised, source of sustainable income and the background to this is provided in Sections 13.1.1 and 13.1.2 for the following resources:

- Finfish
- Golpatta
- Grasses and sedges
- Other wildlife
- Honey and beeswax
- Shrimps and prawns
- Hantal
- Crabs
- Tourism and recreation

14 EXISTING MANAGEMENT SYSTEMS

Reports often mention that the FD has successfully managed the SRF for over 100 years with limited resources. Forestry operations have used a sequence of working plans based upon various inventories, mostly of the standing stock of timber with some marginal reference to what, until recently were called minor forest products. This integrated resource plan is the first to consider all aspects of the ecosystem and to makes the first set of preliminary guidelines for integrated resource management. This new approach merely keeps pace with global changes in emphasis in forest management. This trend was well anticipated by GOB and UNDP at the time of formulation of the project of which this plan forms a part.

Whilst developing strategies to effect reform it is borne in mind that proposals for integrated management are all set against the background of the history and socio-economic situation which face planners and legislators.

Nevertheless, the reality of existing management systems is that they are out of date, do not work successfully and should be modernised. The SRF may retain a high proportion of forest cover but the quality of the forest has declined in the last 60 years and the rate of decline is accelerating.

There is practically no silvicultural management practised, revenue collection is the dominant activity and systems for this are unreliable and inequitable; the management makes no attempt to share responsibilities with other concerned departments and agencies and has alienated itself from the goodwill of people. Staff conditions of service have hardly changed in a century and performance is admitted by the FD itself to be deficient in almost every respect (Rahman, 1995). Buildings, accommodation and equipment are old and badly maintained yet revenue figures suggest that the whole system could be transformed from within the resources generated by the Forestry sector in its own right if the will to do so could be kindled and the official fiscal policy adapted to do so.

14.1 Administration

The existing FD administrative structure which handles management in the SRF is discussed in Section 8.1. All administrative responsibilities are vested in the office of the Conservator, Khulna Circle, who delegates his powers to the DFO Sundarbans Division. There is no institutional arrangement for integration of activities of other concerned departments or agencies.

Essentially the DFO Sundarbans Division has absolute authority over all technical, economic and sociological matters within the Reserve. Forestry, fisheries, wildlife, tourism, meteorology, hydrology, law and order, issuance of licenses, orders and agreements, revenue collection, public relations, harvesting and marketing and official record keeping are all his sole responsibility.

The staffing position is that the DFO has provision for 1038 staff of all ranks and of these some 961 posts are filled and many are for unskilled positions.

14.1.1 Field organisation of resource management

All resources are managed as far as possible through Range offices at Chandpai, Sarankhola, Nalianala and Burigoalini which in turn maintain field stations, coupes and some mobile stations. These are illustrated in Map 12.

Deployment of staff is to the north and east of the SRF leaving much of the centre and west with almost no FD presence for most of the year.

14.1.2 Yield regulation and Yield Control

The DFO, Sundarbans Division manages yield regulation and control except for the special Agreement with KNM, the Goran harvest and the Golpatta coupes. There is no yield regulation for anything else beyond issuing of permits at prescribed times for specified harvests.

Normally under the existing system the control of yield for timber is made in annual returns which compare areas worked with areas prescribed in the working plan. If these do not match the disparity is remedied as far as possible, in the following year. Yields of Golpatta and Goran are regulated by setting targets at the beginning of the year through sample enumeration of the stock and comparing the out-turn at the end. With this method it is not possible to mitigate against over cutting.

Yield control improvements are discussed further in Part 2 Section 21.4

14.1.3 Management of wood resources

Good management decisions obviously require sound data and this is mostly either out of date or lacking. Guidelines for future research have been prepared and presented in Part 2. In the first instance it is essential that the impending FRMP inventory conducts broad-based systematic surveys of all resources beyond standing stocks of commercial timber. This will go a long way towards making up for the gaps in the data.

In all past inventories the resultant Working Plans were based upon Working Groups and Working Circles with only one level of stratification. The level selected was the level considered appropriate for the timber component of the inventory. Discussions elsewhere in this plan suggest that various levels of stratification are necessary and that use of one level of resolution for all activities is no longer valid.

A similar single level approach has been used in forest management in the Sundarbans with operations being primarily at the compartment and in part at the sub-compartment level.

Also a land based management unit is obviously not appropriate for physical management of the aquatic environment which might more reasonably be based on the major rivers. The management of a complex ecosystem requires consideration of all biotic and abiotic resources which may require varying levels of resolution in planning. **A multi-level, multi-disciplinary approach to planning is needed to accommodate new demands on management and new technologies.**

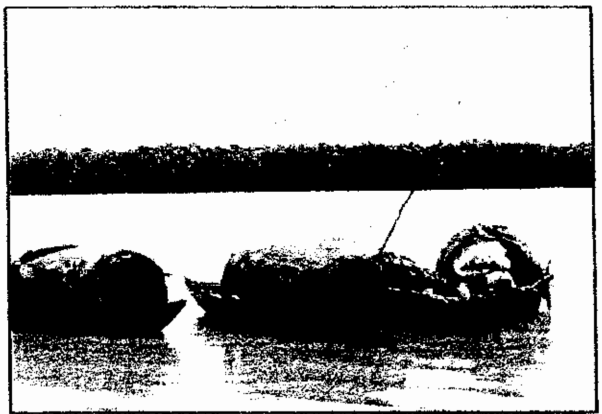
14.1.4 Management of non-wood resources

A recurring theme is the change in emphasis that has taken place in recent years, moving timber resource management towards full integration of non-wood components all within the framework of ecosystem planning, implementation, monitoring and multi-sectoral management. In the SRF the need for this adjustment is underlined by the fact that the value of NWFPs is greater today than ever before and has greater economic potential than the wood resource (Mitchell, 1995).

Unfortunately existing management plans offer no avenue to attain this ideal. Full incorporation of non-wood resources in inventory data collection or inter-sectoral conservation and development of NWFPs in an integrated resource management operational plan may become feasible after the FRMP inventory and after the proposed investment in staff and training.

There is little institutional capacity, no clear policy directive and insufficient trained manpower (Rahman, 1995) to expect more than simply tacit acknowledgement that reform is needed at every level of administration. The wide spectrum of NWFP management could be merged subsequently into regular management activities. The lack of attention to the importance of NWFPs, especially fish, wildlife and ecotourism in policy statements on forest resource planning is indicative of the degree of re-orientation that will be necessary for a more balanced and therefore more sustainable development of land under the Department's jurisdiction.

New Survey Vessel - ex UNDP

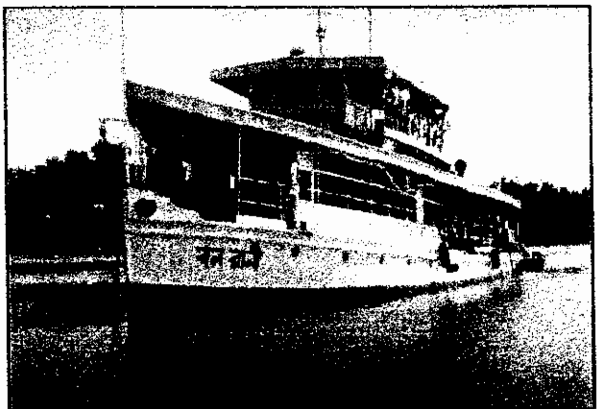


Traditional Fishing Boat

Fish Traps

Fish Nets Drying

Katka Rest House



Forest Department Vessel - Bano Rani

15 MANAGEMENT POLICY FOR ALL MANGROVE RESOURCES

The current *de facto* management arrangement is to endeavour to keep harvests of all resources to existing levels and at the same time maximise on revenue earning. Trained staff are ill-equipped, motivation to improve performance on non-revenue earning duties is weak and there is no apparent inclination to share responsibilities with other concerned departments or agencies. From all accounts the daily pressure to allow alternative forms of land use and the covert over-exploitation of all resources appear to weaken any internal efforts by divisional staff to improve performance or up-grade forest operations. Considering the lack of resources, already analysed and the conservative structural arrangements, this is not surprising.

Much store has been placed upon the guidelines which this IRMP will provide and also upon the innovations agreed in the IDA financed FRMP. The latter focus on better conservation and operational planning for which two new DFO posts have been created. To date (08/95) neither has been able to carry out any specific management functions in the mangrove forests over the last 18 months and evidently it will be some time before institutional arrangements and practical division of responsibilities will be possible.

This scenario seems to offer only slight hope for early acceptance of integrated resource planning and less for integration of shared management, research and monitoring which this must entail. For a system that has survived so long there is a perfectly understandable reluctance to change. On the other hand, this plan offers alternative practical approaches to moving with the times without detracting from the basic principal that the Reserved Forest should be managed by foresters.

It is the FD's approved policy (1995) that the following matters should receive full consideration in development programmes :

- Ensure sustainable forest management.
- Improve environment management capability.
- Rationalise boundaries and management plans for existing protected areas.
- Create and empower an effective body responsible and accountable for protecting wildlife, preserving biodiversity and managing protected areas.
- Alter existing silviculture systems and practices to eliminate destructive impacts of current harvesting and planting practices.
- Rewrite and update forest management plans to include effective measures to protect watersheds, soil and wildlife.
- Increase productivity by planting open and sparsely covered areas with multipurpose and non-wood forest product species.
- Keep coastal areas and char lands with mangroves, creating plantations on accreted areas, rather allowing conversion to agriculture.
- Prohibit low technology shrimp farming from further expansion on forest lands.
- Implement the conventions on biodiversity.

The proposed management guidelines, together with the proposed investment and implementation programme take full cognisance of the FD's long term goals which are set out in Part 2.

16 MANAGEMENT PRIORITIES FOR SUSTAINABLE DEVELOPMENT

The trends which face the FD in its management planning for the SRF fall into the following categories which are quantified and analysed in relevant sections of the plan. Further information is provided in Volume 2 Appendices.

Trends which affect long-term management planning:

- The resident population living around the Sundarbans numbers about 2 million people and this number will double by the year 2025.
- The last two forest inventories have recorded a decline in growing stock of Sundri and Gewa which is a direct reflection of the human pressure upon these resources which is stimulated by the low economic status of the Nation and much of the population. It is likely that the overall stock of harvestable timber will be found to have further declined at the next inventory despite the moratorium.
- The ecosystem itself, together with the soil and plant associations it contains, face gross changes in six factors :

- There has been a considerable and continuing reduction in freshwater inflow from the upstream catchments especially from the Ganges-Gorai drainage.
- There is a widespread increase in sedimentation and resultant silting of waterways and parts of the mangrove forest.
- Global warming and sea level rise will affect a large proportion of the mangrove forest by 2050 which is less time than it takes for a Sundri tree to reach maturity.
- Water salinity no longer conforms with the three (NaCl) rigid salinity zones miohaline, mesohaline and polyhaline, previously identified, rather a dynamic hydrological regime within which there are daily and seasonal variations in salinity levels throughout the ecosystem which are infinitely variable but with a discernible trend of increasing salinity for longer duration in some places..
- Pollution from shipping, industrial wastes from the Hoogly and Pussur/Baleswar rivers and agricultural chemicals and pesticides may have a hitherto unmeasured impact upon the system's biota.
- Harvesting intensity and silvicultural methods forest management or lack of it compound the changes which appear to be occurring in plant succession and woody species dominance, in particular the trend from Sundri dominance to Gewa-Sundri.
- Non-wood forest products, especially fish, shrimps, ecotourism and other wildlife are now more valuable than the timber resource and this alone will necessitate a revision in management policy.
- Shared responsibilities for water resources, international obligations and environmental agreements for biodiversity conservation, international shipping, mining and exploration and human activities across the 10 Km Border Zone will also require co-ordination of management with other departments and agencies.

Priority issues:

Frequent reports in the media and the results of the socio-economic study all confirm the general concern that is felt for the perceived decline in the condition of the Sundarbans. Priority management issues frequently brought up in public debate involve an array of matters covering the following:

- Over-harvesting of fish and shrimp fry.
- Hydrological change, salinity, siltation.
- Effects of badly managed silviculture.
- Blank areas in the forest.
- The moratorium and harvesting of fallen trees.
- Ecological changes.
- Tiger attacks upon human beings.
- Top-dying of Sundri.
- Unofficial off-takes of all plant and animal resources.
- The plight of disadvantaged social groups.
- The need for more consultation with user groups.
- Dacoity and piracy.
- Lack of equipment and funding for the FD staff.
- Pressure for land.

All provide pointers for integrated management and a perspective for a new approach to mangrove conservation and development without destruction set out in relevant sections in Part 2.

PART 2 : FUTURE MANAGEMENT

17 GOAL, OBJECTIVES AND SCOPE OF INTEGRATED RESOURCE MANAGEMENT

The justification for planning for the future management of the SRF was set out clearly in the agreement between the Government and UNDP in the technical assistance project on which this plan is based. This states " ... in order that the contribution of the forest sector may be enhanced to provide for a wider range of socio-economic benefits on an environmentally sustainable basis, a suitable strategy and integrated plan to manage the Sundarbans forest is urgently required". This part of the plan therefore provides practical guidelines to bring together all the diverse facets of the SRF, described in Part 1, in order to achieve integrated sustainable management.

The plan addresses the questions of what is needed, how can it be organised, what will it cost and how can the necessary developments be paid for in the longer-term.

Although the desire for integrated management is the underlying theme it has taken many years and extensive inter-disciplinary research to be able to formulate a realistic strategy with policies which will introduce a multi-sectoral management system.

The necessity for this approach was echoed by FAO in a commentary on the State of the World's Forests (1995), that we must recognise that "... impacts on the economy, society and environment depend not so much on the effect of the policies on one forest but their net effect across these diverse settings. The resulting forest conditions reflect the consequences of policies that created and modified the motives for cutting and growing trees in different places and at different times".

Within the SRF whatever strategies are pursued, a rational view must be taken of the balance between one part of the ecosystem and the other and that no single resource should be exploited to the detriment of another. Above all the Forest is a national asset and its future has international implications.

Whilst it is true that management should not favour one resource over another there will be an unavoidable trade-off between different resources. For example by creating wildlife sanctuaries where harvesting of timber is not permitted, the annual harvest of timber will be proportionately reduced

Preliminary proposals are made for zoning for different purposes. In the absence of adequate data these are based to a large extent upon accumulated experience of the FD and intuition. It will only be possible to measure the effects of these once there are better methods for monitoring and assessing changes in the ecosystem. Development of growth and yield models, discussed in this plan, will become one part of the strategy which will include verifiable biological, social and economic indicators.

In many instances determining the criteria for assessing and monitoring impacts of management are difficult even to conceptualise. For example the values gained from wildlife habitat conservation are often not readily measurable compared with measuring the growth in a stand of trees. It may be that the benefits gained from conservation through increased tourism, research, education and natural protective functions of mangroves far outweigh the loss in production of timber. The creation of marine reserves with appropriate restrictions can actually increase the fish catch and also improve returns per unit effort. The problem of the trade-off between different resources is complex and requires far more detailed research before management decisions can be made which will ensure sustainability.

These constraints point to improving data gathering systems and to better analysis and model development. Once models have been established they can be used as a powerful modern management tool in conjunction with more traditional field monitoring methods. This plan discusses how this may be achieved in a multi-sectoral setting. **However, the legal and institutional environment must first be prepared.**

Alternatives for institutional development are offered. Each makes provision for co-ordinated technical direction and a multi-disciplinary approach to management and to preparation of operational plans. Data acquisition for a new operational plan was not an objective and these are to be obtained in the forthcoming FRMP inventory studies.

For full realisation of the potentials of the Forest the goal must be to introduce management structures and functions which have the means for harmonising future decisions on production forestry, the environment itself and economic and social goals.

Integrated management demands comprehensive analysis of all the integral parts of the system, biotic and abiotic, accompanied by careful arrangement of all the multi-sectoral management issues which must be addressed. At the centre of the management strategy several questions were asked in Part 1 which must be kept in mind and around which policy decisions can be made. These are summarised below:

- What are the biophysical characteristics of the mangrove ecosystem?
- What is the status of each of the components separately and together?
- What is the history of management and what is the present position?
- Who is responsible for administration and management and how are all the concerned institutions organised now and how should they be organised in future?
- Who benefits from the resources and products of the SRF?
- How can there be more co-operation with user groups and the local communities?
- What can be done to improve management and ensure sustainable production and optimum utilisation of all the produce from the SRF for the benefit of the Nation and local people?

17.1 Goal - integrated management of the Reserved Forest and National objectives

Table 2 in Part 1 of this plan illustrates the exceptionally wide range of considerations and inter-related agencies connected with one aspect or another of the Sundarbans. Appreciating the existing and future roles of the large number of stakeholders is the foundation to integrated resource management.

Historically the SRF was reserved primarily to be managed for sustained production of timber and other minor produce. There were minimum economic or social concessions to resource users. The goal today has moved forward in the face of relentlessly growing human pressure for land and for a wide variety of increasingly valuable resources ranging now from crabs to offshore oil wells. Furthermore there is a new set of comparative values and responsibilities which go far beyond the borders of the SRF.

On the technical side there are new technologies, computerised systems, remote sensing, growth and yield modelling, hydraulic modelling and envigorated traditional skills all of which can be immediately harnessed to help the process. From the point of view of sustainable management it is universally accepted that there is no hope of achieving resource protection without social equity. Thus means should be found to introduce community participatory processes, consultation and genuine involvement in decision making, wherever this is feasible.

The target is to formulate a plan for the Forest Department which will be in charge, to work with other concerned parties, to continuously up-date the ecosystem inventory, measure accurately the size of the resources and the level of harvest which can be sustained and at the same time be sensitive to the needs of people, to have more transparency in administration and more equitable distribution of benefits.

17.2 Objectives - conservation, sustainable production, economic improvement

To achieve scientifically sound sustainable conservation the theme common to all sections of this plan is that all the resources must be given equal attention. The impact of management must be measured continuously and accurately; the information must be stored in such a way that it can be synthesised and retrieved easily by resource managers and the methods of harvesting and control must be technically reliable and socially equitable. If there is concurrent tangible livelihood enhancement in the Border Zone it is likely that sustainable utilisation of resources and the permanent integrity of the environment will become attainable, building on the foundation laid by the FD over many years with minimum resources. The objectives therefore are to :

- Develop methods for sustainable ecosystem management using an integrated systems approach.
- To provided strategies for improving resource harvesting and utilisation.
- To reconcile the needs of production and conservation within a zoning plan.
- To ensure that all community stakeholders are enabled to participate in consultative processes and to have a role in decision making and management as appropriate.
- To develop an integrated research, monitoring and evaluation system.
- To make recommendations on administrative, management, financial and legal requirements to achieve the stated goal.
- To develop a ten-year implementation schedule for development and investment.

17.3 Scope - the way ahead

The way ahead depends upon ascertaining the extent of the will at all levels to reform the management system. Political will, in partnership with technical implementation by all the concerned specialist departments could find the generous support of donor agencies and above all the people of Bangladesh. The timeframe has three clearcut phases :

- Short term: What immediate action can be taken to remedy deficiencies in the management system as it is now?
- Medium term: What can be done to build up capacity in the next 10 years or thereabouts?
- Long term: What are the macro-economic and environmental factors which must dictate policy to the middle of the next century and beyond, taking into account such matters as sea level rise and population increase?

The strategy is to develop a framework for action which defines functional links between multi-disciplinary technical activities as the precursor for a future Operational Plan which should emerge from the FRMP programme. Guidelines for integration of responsibilities and functions in relation to protection, production, conservation and institutional and policy elements are provided. This new strategy offers an unprecedented opportunity for those concerned with the SRF to work for a common cause.

18 INTEGRATED MANAGEMENT STRATEGY

The change in values of forest products, new technologies and inescapable demands for improvement in management, formed the background to the review of systems presented in Part 1. The entire programme of proposed action is orientated towards attainable objectives with policy guidelines for addressing key issues. The assessment criteria should be to guage quantifiable targets that serve to focus on management effort, measure performance and measure the impact upon resource conservation (FAO,1994).

Structural linkages

At present the SRF is managed without any form of multi-sectoral arrangements and thus the first step is a definition of viable links at all levels. As mentioned in the foregoing section, there already exists an extraordinarily large number of concerned parties and stakeholders who have immediate connections and there are many others which would also have some bearing upon integrated management. This is illustrated in the report on tourism and recreation which identifies no less than 23 ministries, departments and agencies concerned only with the tourism component and the list excludes NGOs and people's organisations.

A core group of concerned departments and agencies which could work together at the local level might include the following :

- Ministry of Environment and Forest
- Ministry of Defence
- The Civil Administration
- The Fisheries Department
- The Bangladesh Water Development Board
- Bangladesh Parjatan Corporation
- Bangladesh Forest Research Institute
- Khulna University
- User groups
- People's organisations

Steps should be taken to determine areas of mutual concern to define exactly what "concerned agencies" means in relation to management of the SRF.

The challenge is how to bring multiple disciplines together in a single inter-sectoral management system with forestry, hydrology, fisheries, wildlife, apiculture, tourism, socio-economics, and security under the administration of the Forest Department, at the same time avoiding conflicts of interest. This is the nub of integrated management.

18.2 Definition of the areas of authority for integrated management

Integrated management requires clear re-definition of areas of responsibility. The existing system must be up-dated to realistically accommodate the needs of management of the entire ecosystem under the authority of the Forest Department. Proposed reforms in the production management system, introduction of commercial tourism and extended wildlife sanctuaries plus development in the Border Zone will require substantial structural re-organisation since these involve matters which affect management both within the SRF and outside.

From the outset it will be essential to realise that holistic management of the SRF is no longer restricted to production forestry but to all those areas, local national and international that today affect the integrity of the ecosystem. There are thus three elements which require differing legal and technical consideration which have significant bearing upon the development programme discussed in Section 27 :

1. Development which concentrates on management within the Reserved Forest.
2. Development which affects both the SRF and the Border Zone.
3. Developments which have national, regional or broader international dimensions.

The main considerations relate to the following:

- The human population particularly those resident in the Border Zone which in part could be deemed a Buffer Zone.
- The hydrological characteristics of the ecosystem which are affected mostly by upstream catchments and oceanic tides, the sources of which lie beyond the physical boundary of the SRF.
- The Reserved Forest boundary has no tenable legal definition and this must be a prime objective for early action at the national level since international borders are involved.
- Forestry operations within the SRF will require early adjustment for new production and conservation zones which will also require demarcation.

Understanding the spatial relationships and particular characteristics of these issues will greatly assist determination of the nature and composition of any new management organisation. At the field operational level there will be a need to define and survey the boundaries. **Initially the two key boundaries affecting the Reserved Forest's main area of jurisdiction should be agreed after full consultation and at local and national levels:**

- **The boundary of the SRF, the Marine Area and the border area.**
- **Specific areas for production and protection.**

The GIS data provide up to date information on areas of land and water together with proposed boundary lines for the SRF, protected areas and production forest, the 10 Km Border Zone and the marine boundary. These are illustrated in the Text map 13.

19 ZONING THE SUNDARBANS RESERVED FOREST

In all previous plans the area was divided into ranges, compartments and blocks to facilitate management of timber stocks and their harvesting. Attempts also were made to define the perceived spatial separation of high, medium and low salinity zones which has now been superseded by recent multi-dimensional data on salinity and hydrology (SWMC, 1995).

Whilst these management units, especially the compartment level, are still valid and usable, the broader strategy of ecosystem management requires a broader form of definition at different levels of resolution. Zoning is therefore proposed which will enable better direction, with controls and monitoring appropriate to the nature of each zone and to specific management objectives. This new approach permits allocation of management time and resources geared to the needs of each management function. Strategies for interaction between them will provide the foundation for more effective administration, management and monitoring

Since it is fundamental to ecosystem management that in the first place biodiversity is secured, introduction of controls, quantitative assessment and sustainable management must be early objectives. Furthermore, because many aspects of production involve interference with natural succession and other natural processes (plantation forestry and human settlement being extreme examples) it is essential to delineate and demarcate the boundaries of each zone as soon as possible.

For the Protection Zone baseline surveys should be undertaken to set benchmarks for monitoring and evaluation (M&E) especially to quantify the extent to which different ecotypes are represented in each area.

Apart from the historical desire to maintain the integrity of the Forest, it is only since the introduction of the wildlife sanctuaries in 1977 that recognition has been given to *in situ* conservation of biological diversity *per se.*

Initially management planning should consider zones which may be adjusted as need arises and which are discussed in due course in regard to biodiversity conservation, production forestry, wildlife, fisheries, tourism and rural development. Operational plans will also consider activities which address problems of pollution and the negative effects of marine shipping, oil exploration and mining.

19.1 The Protection Zone

The purpose of the Protection Zone is to protect the bio-physical components of the ecosystem and to safeguard them from degradation, physical erosion or losses of genetic diversity. The first action therefore is to delimit core areas where strict protection may be afforded to conserve the main plant and animal communities. This principle was established with the development of the wildlife sanctuaries which are illustrated in Text map 11.

Here provision is made for conservation of representative examples of the flora and fauna of the Sundarbans and if these are actively managed they should form the basis for not only safeguarding genetic resources but also as the source of baseline indicators to measure environmental changes, especially the impact of new management practices (ITTO, 1995).

The disposition of further zones to accommodate *in situ* biodiversity management should be considered especially the following:

- A southern coastal zone for protection of marine resources along the Bay of Bengal boundary.
- A protection core zone composed of wildlife sanctuaries and the proposed marine PA (SCMPA)(Grepin, 1995).

To the north of these, an inner production area should be delineated where harvesting of terrestrial and aquatic resources will occur. To the landward side, outside the SRF a Buffer Zone should be developed with its own specific set of conservation rules and regulations. These would be given legal authority only after comprehensive consultation and agreement with the local communities and People's Organisations. Initially this area is referred to and mapped as the 10 Km Border Area (see Map 36 Volume 3).

19.1.1 Strict protection - core areas

The strict protection core areas are confined to the discontinuous wildlife sanctuaries which constitute about 7% of the whole SRF. Management systems for these are discussed in Section 20.1.1. It is clear that much more research is needed to analyse the flora and fauna of the sanctuaries and to establish monitoring stations and monitoring systems.

The core areas require a rigorous patrolling and reporting programme which should form the basis of annual workplans under the direction of the DFO Environment and Wildlife. Precise details of patrol routes, check points and reporting methodology should be determined after the division is fully staffed and personnel and equipment deployed. Routine patrolling and wildlife data gathering should become primary activities of staff appointed to these PAs.

19.1.2 Managed buffer zones

To manage and monitor harvesting activities, particularly fish and other NWFPs, it is essential to give further detailed consideration to conservation management in all the buffer zones. Along the Bay of Bengal seaface and extending into the sea to the 12 nautical mile boundary depicted in Map 10 there is scope for a managed marine and estuary buffer zone where seasonal fishing and other harvesting activities may be permitted. Grepin (1995) proposed a Sundarbans Coastal and Marine Protected Area (SCMPA) for coastal conservation and integrated biodiversity management. The area would include the main marine fishery which requires new policies and management strategies.

Technical and financial support will be needed to develop the Buffer Zones and the existing GIS data can be used as a starting point for preparation of purpose specific maps. Once consensus is reached, the boundaries should be mapped at 1:50,000 scale and presented for demarcation and enactment along with the SRF boundary itself.

A land use and marine resource use plan for the buffer zones should be drawn up in collaboration with other concerned agencies as part of future plans and these should be presented for public hearings prior to adoption by the Forest Department.

At present the marine boundary has practically no protection and if it is to be managed as a buffer zone there is a strong case for concerted action by research, monitoring and policing agencies as soon as possible. This whole area is exposed to trespass in all its forms, piracy, smuggling and in recent years a marked increase in the number of mechanised trawlers fishing in the offshore sea but using resources of the SRF for shelter, fuel and food.

Effective management of this buffer zone is outside the capability and in many ways brief of the FD alone and thus presents a good case for integration of the management and administrative capacities of the FD working jointly with the Defence Ministry, Coast Guard and Fisheries Department. The zone will also require delineation and demarcation using a combination of land markers and marine marker buoys. The provisional boundary is shown on Map 36.

19.1.3 Domestic tourism zones

Among the most important priorities is the need to allocate zones for non-consumptive yet potentially damaging activities which might occur in strict protection and buffer zones such as high volume low cost tourism and recreation. **It is recommended that these activities are not permitted in the core areas at all and that they should be developed in the high volume tourism zones sketched in Map 13. Again further research is needed to establish the real suitability of the zones currently identified near Mongla and Munshiganj. Monitoring implementation of tourism zones should be part of the functions of staff working in the Wildlife and Conservation Division.**

19.1.4 Ecotourism zones

Ecoturism in contrast to high volume tourism is based upon total retention of wilderness values and whilst in the strictest sense, these in the long term would only be found in the wildlife sanctuaries, there is an immediate need to set aside specific areas within the core protection zones to allow for seasonal low volume high cost ecotourism under strict management rules and regulation. These areas are illustrated in Map 13 and will require formal definition during the preparation of feasibility studies for the implementation of the ecotourism model TYDP discussed in Section 23.4.4.

19.2 Production and multiple use zones

The whole of the Sundarbans Wildlife Division outside sanctuaries and fishery protection areas could overlap with other activities and would be in the production zone managed for sustainable production. This will be administered and managed by the Sundarbans Forest Division. The wildlife resources in the production zone will be under the management of the Wildlife Division working in close collaboration with the DFO Sundarbans. These areas could be developed within operational planning as multiple use zones where a variety of sustainable production activities would be permitted within the scope of annual workplans within the framework of the operational plan.

FAO/UNDP PROJECT BGD/84/056, KHULNA, BANGLADESH

INTEGRATED RESOURCE DEVELOPMENT OF THE
SUNDARBANS RESERVED FOREST

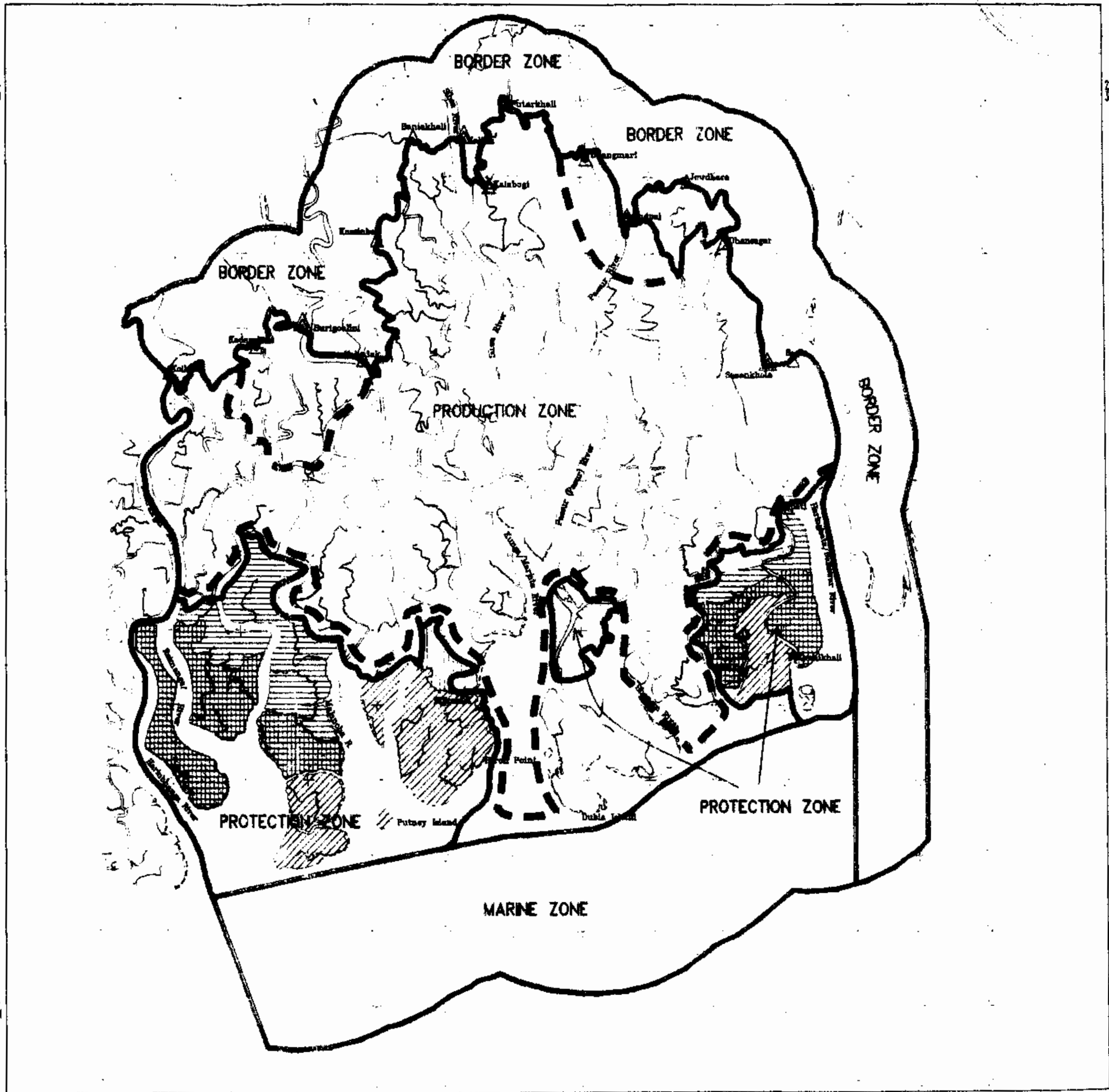
MAP SHOWING ZONES

Scale 1 : 550 000

Km 4 2 0 2 4 6 8 10 Km

LEGEND

Land/Water Boundary
Sand Bar
Production & Protection Zones
Tourism Zones
Existing Wildlife Sanctuary Area
Proposed WS Area by Forest Dept.
Proposed WS Area by Dr. Grepin
Proposed WS Area by Dr. Tamang
Range Office
Forest Station
Wildlife Sanctuary Office



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F.L. Khan, 24.09.1995

19.2.1 Integrated management : resource utilisation areas

North of the wildlife sanctuaries and south of the SRF boundary most production and harvesting activities occur in operations connected with specific products, their spatial distribution and the interactions of Working Circles discussed further in Section 21.6 and which will ultimately be catered for with specific management prescriptions in the operational plan.

19.2.2 Intensive Use Zones

Several smaller areas in sanctuaries and elsewhere which are essential for buildings and gardens to meet the needs of the management staff such as Forest Stations should be included in this category.

Rules regarding introduction of exotic plants and domestic stock require clarification and enforcement. Generally these should not be permitted within wildlife sanctuaries.

19.2.3 Production forestry rotation areas

As soon as the FRMP inventory data are available in 1996 the new aerial photographs and GIS data base should be used to prepare and store data on the specific production areas which may be considered in future harvesting programmes. Rotation maps could follow at whatever scale is required by the production forest management team.

19.2.4 Plantations

Proposals are made for a new silviculture plantation trials programme and details for this are included in Section 27.1.4 as a development project. Any programme of this sort should be preceded by detailed analysis of existing plantations.

20 MANAGEMENT OF THE PROTECTION AND BORDER ZONES

Whilst it is evident that the boundary of the Forest has been well protected against encroachment comparisons made with the historical record indicate that almost every resource shows a decline in status. This strongly re-inforces the need for effective measures to combat the decline and wherever possible reverse the trend which requires action both within and outside the SRF.

There must be several concurrent actions in the early stages of implementation which are set out in the Implementation Schedule and these have been ranked to follow the general needs of policy formulation, institutional strengthening, protection, production, training and investment. Monitoring and evaluation are concerned with the ecosystem as a whole and with particular regard to the results of particular management prescriptions and future revision of the IRMP.

20.1 Protected Areas - specific provisions

- Ratification, delineation and demarcation of the boundaries and management of the Protected Areas throughout the SRF should be addressed as soon as possible. The DFO Environment now has some staff and equipment but it appears that definition of his role in integrated management has yet to be finalised.

Other priority matters are as follows:

- Arrange for the full integration of the PAs in overall SRF management with a line of administrative command which includes the CF, Khulna Circle and the DFO Sundarbans Division.
- Set up research programmes with the DFO Environment to study the validity of the existing and proposed boundary adjustments.
- Follow up on the preliminary information on special management of fish breeding areas, bird sanctuaries, crocodile breeding areas and turtle habitats. These require detailed analysis and introduction to the GIS data base and it may be expected that the data will be derived in the systematic census of the FRMP.

20.1.1 Wildlife Sanctuaries

The main purpose of the wildlife sanctuaries is to provide protection to representative samples of each of the biota in the Sundarbans and to help maintain biological diversity. These areas should be actively managed under the Wildlife Act and agreement on the development and expansions be integrated in overall SRF operational plan. It will be counter-productive if the wildlife sanctuary operational plan does not from part of a composite plan for the Forest as a whole.

Exceptions to the terms of the Act should be defined and formal orders made by the MOEF on advice from the CCF. Nature conservation in the Sundarbans is of highest priority in Bangladesh and must be provided with adequate resources. From the point of view of biodiversity conservation the whole of Sundarbans should be treated as a single unit and managed as such (Tamang, 1993). The three existing wildlife sanctuaries need staffing, protection and management and serious consideration should be given to extensions and additional PAs discussed below.

The three wildlife sanctuaries are bounded to the south by the Bay of Bengal and additional PAs could incorporate other parts of the Forest and the marine area to good effect.

1. A Marine Sanctuary area proposed by Grepin (1994) to protect coastal habitats and wildlife;
2. Parts of compartments 27 and 28 to the north-east to include habitats in a part of the SRF where siltation and changes in flooding regime seem be creating conditions not entirely favourable to mangrove species and where land pressure could become difficult to resist.

Map 11 shows the existing wildlife sanctuaries with proposed extensions.

20.1.2 Sundarbans West Wildlife Sanctuary

The Sundarbans West WS in Satkhira Range should be extended towards the west to include compartment 55 to link up with the Sundarbans National Park in India for the establishment of a trans-border protected area. The existing sanctuary covers an area of 9069 ha, in compartment 54. Addition of compartment 55 and the remaining portion of 54 will provide a total area of 37,195 ha, for this sanctuary. The proposed expansion to the west is of vital importance for the long-term welfare of the tiger population and its management in the Sundarbans. There are no forests or tiger habitat surrounding the Sundarbans to allow immigration of tiger from outside. The space provided by the

Sundarbans (both in Bangladesh and India combined) is considered essential for the conservation of tigers in the wild and in maintaining a viable population and necessary genetic diversity.

Sundarbans West Wildlife Sanctuary needs expansion to include the area adjoining the Indian border to achieve some uniformity of management with the contiguous Indian Sundarbans National Park. This could make a small start in relieving the physical stifling of "island" SRF.

Furthermore it is recommended that to standardise the classification of protected areas and the manner in which they will be managed in the future, early consideration should be given to changing the status of Sundarbans West Wildlife Sanctuary to National Park or World Heritage Site. The feasibility of establishing a Jungle Camp or the Conservation Centre/Eco Village at Mandabaria might be undertaken at the same time and it is recommended that these matters should be high priority in Phase 1 of the TYDP for tourism.

20.1.3 Sundarbans South Wildlife Sanctuary

The Sundarbans South WS (17,878 ha) lies between the Malancha and Kunga rivers and includes Putney Island. Presently the sanctuary headquarters is located at Hiron Point. Fairly extensive grasslands occur close to the shore lines and coastal areas south of Hiron Point that provide good habitat for spotted deer, wildboar and tigers. The area for this sanctuary is considered adequate for the present.

20.1.4 Sundarbans East Wildlife Sanctuary

The Sundarbans East Sanctuary has an area of 5439 ha derived from compartment 6. It has been recognised for sometime that the sanctuary is not large enough to support viable populations of large ungulates and tigers. Chowdhury (1968) in his Working Plan for the Sundarbans Forest Division had proposed establishment of a "game sanctuary" to include compartments 3,4,5,6 and 7. Proposals were also made for expansion by Salter (1984) and Blower (1985).

Sundarbans East Wildlife Sanctuary is too small and needs expansion as originally intended in 1977 when it was established. It is recommended that Sundarbans East WS should be extended to include compartment 5 and 6, 4 south of Dora Khal, and 7 east of Betmar Gang that covers an area of 18 538 ha, for this sanctuary.

20.1.5 Sundarbans Coastal and Marine Protection Area (SCMPA)

Protection of the coastal zone, which is covered W ➡ E by Compartments 55, 54, 44, 45, 7 and 6 has been identified as a matter of great importance for long-term conservation of the ecosystem and biodiversity. It has already been mentioned that this is a long and almost totally unprotected and unmanaged zone which is therefore wide open to every kind of abuse. Its ecology and biophysical characteristics are inextricably linked to the welfare of the mangroves, energy flows, immigration and emigration of macro- and micro-aquatic fauna and as an integral part of the whole ecosystem.

Grepin (1995) defined guidelines for establishment of a Sundarbans Coastal and Marine Protected Area (SCMPA) and this proposal should be considered at the same time as the proposals for other Protected Areas will be reviewed.. A network of marine and coastal protected areas would be designed primarily to protect breeding areas of endangered species along the sea facing coast. There is little doubt that in areas adjacent to the SRF the coastal and marine environment and its biota are under threat and without special protection are vulnerable to increasing degradation by growing numbers of fisherfolk and tourists.

Endangered species of sea turtles,such as the olive Ridleys turtle ***Lepidochelys olivacea***, the coastal shell turtle ***Pelochelys bironi*** and the green turtle ***Chelonia midas***, are known to nest along the coast of the Sundarbans. All species of marine and estuarine turtles are also seriously threatened due to excessive fishing and disturbance to nesting sites.

Estuarine and fresh water soft shelled ***Tryonix spp*** turtles are commonly sold in markets around the SRF and harvesting is not controlled.

All species of the marine environment animals which breed, nest or live on the beaches, or in shallow water along the coast or inside the estuarine part of the RSF need special protection since it appears that they are all subject to chronic human disturbance or are harvested on an unsustainable basis.

Three species of molluscs ***Crassostrea sp., Telescopium sp*** *and* ***Arca sp***, are intensively harvested for lime, for shrimp and poultry food and in most cases as human food as well. Limulus or King crab ***Carcinoscorpius rotundicauda*** must also be protected since there appears to be uncontrolled widespread exploitation of this species.

The main goal of the SCMPA.s is to protect, restore and assure sustainable use of the coastal and marine parts of the ecosystem. The PA would include the protected areas in the international network of marine and coastal protected areas. The following matters should be considered in making planning decisions:

- The SCMPA should encompass inter-tidal and sub-tidal seabeds, mud flats, sandy areas and beaches. The water covering these areas and the totality of associated flora and fauna should be protected.
- Management should provide effective standing orders to protect partly or totally these areas during breeding or nesting periods of wildlife or over all the year, if necessary.
- Since the coastal area is intensively harvested during the winter months any new policy should make suitable provision for customary users to avoid conflicts and indeed their active participation should be sought in any future management operations.
- At the international level, links should be established through MOEF with the following:

• Man and Biosphere Programme	UNESCO
• Marine Science Programme	UNESCO
• International Marine Organisation	IMO
• Regional Seas Programme	UNEP
• CITES	IUCN

Implementation will require rules and action to cover:

- Sustainable use of coastal and estuarine sea-facing ecosystems.
- Measures to protect habitats essential to the survival of threatened or rare species.
- Protection of important habitats for the completion of life cycles of commercially important species.
- Prevention of activities detrimental to the ecosystem.
- Protection of breeding and nesting grounds for resources needed by customary users.
- The protected areas will be an extension of proposed wildlife sanctuaries it will therefore be necessary to improve existing legislation starting with legally tenable boundary descriptions.

Preliminary action:

- Determine the level of use of areas by customary users and its consequences
- Identify the breeding and nesting sites to be protected
- select priority areas and sites
- Determine for each area the type of protection needed; the period of time of the year when control will be most effective;
- Determine the necessary systems to enforce protection, preferably without heightening confrontation;

- Obtain the support of traditional users on a preferential basis and make provision to protect their rights.
- establish links with NGOs, universities and other organisations interested in wildlife conservation in order to involve interested scientists in conservation studies.
- new legislation must consider scientific research, education, conservation and recreational objectives and international obligations concerning pollution or misuse of marine interconnected environments. By doing this the FD and could play a leading role in conservation and sustainable use of coastal areas and strengthen its position as a leader in holistic conservation of mangrove ecosystems.

The proposed SCMPA is not included in an existing management regime and it is a logical extension to cover the vulnerable southern boundary and marine zone. The area has the potentiality to be declared as a Biosphere Reserve and could be included on the World Heritage list. Its scientific value and its economic importance for aquatic resources are obvious.

20.1.6 The proposed north-eastern protected area

Since all the sanctuaries are located in the southern coastal areas and do not represent the more diverse environments to the north and north-east in areas where freshwater flow is usually greater and where there appears to be increasing sedimentation.

Additional protected areas should be considered in this zone and immediate technical analysis should be made for inclusion of Compartments 27 and 28 as a new sanctuary, see Map 10, or preferably as a Managed Resource Area (MRA) since wildlife re-introductions and plantation silviculture may be the most beneficial forms of land use for this part of the SRF where siltation and habitat change appear most pronounced (Grepin, 1995).

20.2 Bird sanctuaries

The SRF has a rich avifauna but at present there are no provision in operational plans for management of the bird species populations, habitats, feeding and nesting sites or indeed any conservation activity whatsoever. It should be a high priority for the DFO Environment to research in detail over a period of at least two years the distribution of areas where birds are relatively abundant and also places which appear to be utilised by migratory species.

There is little information available on the two known bird sanctuary sites other than that they have both been harvested for timber and are neglected as sanctuaries. Rehabilitation of these, if feasible, would be another function to include in operational plans for the DFO Environment.

20.2.1 Chunkuri Khal bird sanctuary

This sanctuary was recorded by Curtis (1933) in Compartment 47 at Kadamtala and probably owes its recognition for birds on account of the diversity of vegetation in the vicinity of the Chunkuri khal. The site was also mentioned by Khan (1947) and Choudhury (1968) and deserves re-examination. Re-instatement of the bird sanctuary should be considered if conditions appear conducive to setting it aside for protection of birds. Obviously further harvesting of timber should not be permitted in the area.

20.2.2 Jewdhara Sanctuary

Jewdhara Bird Sanctuary in Compartment 27, features in the Choudhury (1961) Working Plan in which he states that "thousands of birds", especially vulnerable species such as the Greater and Lesser Adjutants were common at this site. There is no up to date information and this old sanctuary should also be investigated with a view to including it in new measures for conservation of the SRF's avifauna.

20.3 Seasonally closed areas

Lack of any protection to breeding animals is a major deficiency in management of all animals whether they are harvested or not. It is clearly essential that part of the work of the DFO Environment should be establish a research programme to study the distribution of wildlife breeding sites for terrestrial and aquatic species alike, for the whole of the SRF. This rewarding research could receive considerable day to day help from foresters working in the field and from the wildlife and zoology departments of academic institutions.

Positive efforts should be made in this regard as soon as possible since the work can be part of continuous surveys and is both low tech and low cost. Thus the only burdens for the DFO would be planning, management and co-ordination of targeted field research. The data could be introduced into the IDB on an ongoing but easily accommodated *ad hoc* basis .

20.3.1 Fish breeding areas

All reports concerned with aquatic fauna comment on the dangerous over-exploitation of fish stocks. Harvesting seems to take place everywhere at all seasons without any real regard for breeding stocks, breeding seasons or breeding areas. Fish are therefore not only given no relief from intensive harvesting with all kinds of gear and at all seasons which must eventually have a devastating impact upon populations but also the ecological equilibrium of the natural mangrove fish fauna has been disturbed through the loss of ***Crocdylus palustris*** from the food chain and ***Crocodylus porosus*** is also much depleted.

It is essential that a positive effort is made in the near future to research the breeding cycles of commercially important species and introduce some seasonal controls over specific breeding areas. Again this is work in which the Fisheries Department and Khulna University could collaborate over to good effect in association with the DFO Environment.

Fishery management rules and regulations should be prepared by the DFO for approval and field implementation as an early priority.

20.3.2 Wildlife breeding sites - crocodiles and turtles

One of the main purposes of the SCMPA is to offer some respite and protection for the turtles and crocodiles which use the more sandy levees and river banks for their breeding sites. It is unfortunate that these areas happen to coincide with the places utilised intensively by fishermen, many of whom are seasonal visitors from Chittagong and elsewhere who take whatever wildlife resources they need from their immediate environment, including turtles, monitor lizards and crocodiles at random.

These sandy areas are preferred for nest sites and thus the populations are under relentless low level pressure which takes its toll to the extent that probably all reptile are now vulnerable and in some instances may have reached such low densities that their survival is at risk.

Again an early responsibility for the DFO Environment should be to investigate all potential breeding sites and undertake systematic censuses to ascertain the statuses of these species populations.

20.4 Management of the Protection Zones

Management of the Protection Zone, which is illustrated in text Map 13, is a key function of integrated resource management and to be successful it will require considerable further analysis of the ecosystem. The goals are to stabilise the loss of species and decline in the overall biological status and to implement controls and developments which will ultimately lead to attainment of tranquillity so that species populations may increase and biodiversity be secured in the long-term.

Most of the actions proposed come under the general jurisdiction of the CF, Khulna Circle and the DFO Environment with administrative authority remaining in the hands of the CF. The five administrative wings set out in the FRMP are:

1. Planning and monitoring.
2. Forest management and operations.
3. Extension.
4. Environmental management.
5. Administration and finance.

It is increasingly clear that for any hope of improvement in management of the Protection Zone and the sanctuaries and of special conservation areas contained therein, the DFO Environment will need considerable support and input from other concerned departments and agencies and in particular from those communities nearest to the boundary living in the Border Zone. Here is a prime example of the urgent need for integrated management planning and action. The Staff Organigram illustrated in Figure 5 demonstrates the lines of authority and linkages within the FD and Figures 8-11 offer schemes for future consideration.

To avoid misunderstandings it is advisable to keep in mind the separate roles and responsibilities of those involved in natural resource protection (nature conservation) compared with the work of those involved in commercial production.

Whatever future management structure is agreed the administration of the laws which regulate the overall administration of the reserve under the Forest Act must remain in the hands of the administration of the SRF which is headed by the CF, Khulna Circle and the DFO Sundarbans Division.

The DFO Environment should recognise this line of authority for total SRF administration but from that point the management and protection of flora and fauna and total biodiversity it is the prime responsibility of the DFO Environment throughout the Reserve and especially in the protected areas. This arrangement is clarified in Figure 7.

In addition at the local level the DFO Environment will need to work with other departments and agencies especially:

- IUCN
- Fisheries Department
- The Coast Guard
- BFRI
- Khulna University
- User groups and other People's Organisations
- Department of the Environment
- Ministry of Defence
- Civil administrations
- SWMC/RRI
- NGOs

Information, education and consultation should be high priority activities for the DFO Environment and his annual workplan should specify a detailed strategy to bring conservation issues to the multi-sectoral community.

20.5 Management proposals, recommendations and implementation

Responsibility for management within the Protection Zone should be an integrated function organised by the DFO Environment but including active participation of all other foresters and with involvement of the Fisheries Department for management of aquatic areas and associated fauna where these concern straddled fish stocks, cross border habitats and fisherfolk.

The FRMP nature conservation programme aims to improve infrastructure, provide new equipment and strengthen the management and protection capabilities of the FD's nature conservation staff. Integration of their functions both on the ground in the Border Zone and with members of their own department and other agencies will greatly enhance prospects for practical achievement of management targets.

Priorities for the DFO should include:

- Development of an annual workplan for staff at all levels.
- Boundary delineation and demarcation.
- Assessment of wildlife population statuses, especially vulnerable and endangered species.
- Development of rules and regulations for visitors.
- Negotiation of harvesting rights where these are permitted for NWFPS.
- Development of an extension education, information and communication programme (IEC) for the Border Zone.
- Development of terms of reference for a multi-sectoral advisory committee for tourism.

The following is a summary of proposals, recommendations and implementation schemes for management of the Protection and Border Zones:

- Arrange for a commission to make new legal definitions of the SRF boundaries, the Border Zone and the protected areas using the existing GIS data base.
- Finalise the extensions to the wildlife sanctuaries and agree the statuses of additional conservation and protected areas, the Marine Zone and the Border Zone.
- Agree the lines of administrative authority and management functions of the CF, DFO Sundarbans and the DFO's Environment and Management Planning;
- Set up joint research and monitoring stations with contributions from the FD, BFRI, SWMC, and IUCN.
- Determine the roles of the Integrated Management Committee and operational unit under the direction of the CCF and Conservator, Khulna Circle.

It is important that there is an early agreement between all parties on the main objectives of and realistic strategy for environmental protection not only within the Protection Zone but within the entire ecosystem. Somehow, an administrative understanding should be made on collaboration and not mutual exclusivity.

Hydrological Survey

Bee Keeper - Apiculture Experiment

Wild Life Viewing Tower - Katka

Siltation - Kharma Khal Boundary (NE SRF)

21 MANAGEMENT OF THE PRODUCTION ZONE

The Production Zone is illustrated in Text map 13 and encompasses all that part of the SRF which is not the Protection Zone and core areas. Production is defined as the management of resources for yields of various wood and non-wood produce or commodities which have a direct use or can be sold. Thus everything that is harvested or otherwise utilised commercially is included but indirect benefits such as the protective function of the forest are excluded. Production management has been reported on in detail by Shiva(1994); Larsen(1994); Ahsanullah (1995); MARC (1995) and Mitchell (1995) - see Volume 2 Appendices. These reports should be studied for further information.

For planning and practical management each resource needs to be considered independently yet as integral part of an ecosystem. The number of interactions that are possible is enormous and the task of integrated management planning complex.

To achieve this complicated task it is therefore essential that the database of information on all the components is as complete as possible. Only once the extent of the resources are known and assessments are made on sustainable yield is it possible for production to be planned.

The first step is to introduce all existing spatial and status data into the GIS and IDB data bases and to add these to the data which will be acquired in the impending FRMP inventory studies.

Organisation of accurate multi-dimensional data for each resource separately and as integral parts of the whole is fundamental to production management planning. This must be set against short and long-term timeframes and backed by adequate administration, management, research and monitoring. Environmental audit should be compatible with financial audit and systems must be introduced to integrate these two essential functions. Project based one off inventories and periodic management planning, such as a 20 year working plans, must be replaced by continuous assessment and continually up dated management plans. New systems for this should be a primary objective in improving production management.

21.1 Improvement to the Management System

The traditional method of management in the SRF has reached a crisis point (Mitchell, 1995). Some of the plant and animal resources are in a precarious position. Past inventories have demonstrated the decline in standing stock of harvestable timber; important mammals and reptiles have been extirpated; fish stocks may be on the verge of a biological crash; there are new permanent buildings inthe Forest and much of the production forest appears to be subject to over harvesting.

This is a repeated theme in this plan and it is no longer a viable option to control access to the resources of the SRF through exclusion. The way forward for sustainable management of production is through less confrontation and more co-operation especially with disadvantaged user groups; by sharing of information; by establishing the means for equitable access to the resources and equitable sharing of benefits and with independent audit and multi-sectoral accountability.

From the existing base several fundamental changes could be made without affecting the benefits of the existing stability of the long-established management system:

- Administrative capacity should be up-graded for more effective management of the production zone.
- By use of continuous field surveys, data collection, modern technology and new methodologies information can be up-dated on the status of all the resources on a much more frequent and regular basis.

- By improving infrastructure, equipment, and facilities for staff in the field and by further training performance and will be improved so that exact statistics can be gathered, collated and analysed more efficiently in the field.
- By integration of research and monitoring functions as a clear part of implementation of workplans it will be possible to up-date production operations and make appropriate management responses rapidly and effectively.
- Support for better production, harvesting and conservation practices will require the support of user groups who should be consulted with the help of NGOs and community leaders.

A phased programme of systems replacement, new revenue procedures, more control and better harvesting techniques, especially in regard to silviculture and fishing, and sharing of responsibilities are proposed. Continuing with the Operational Unit (OPSUNIT), see Section 26.2 at Khulna and based on the GIS, hydraulic and integrated databases already set up, could offer a practical step forward. This will require substantial donor support and careful consideration of long-term financial security via innovative funding mechanisms. Reference should be made to Appendix 17 for financing details.

21.2 Administration and the Integrated Management Committee

The details of the proposed structures for the administration are presented in Section 27 and as for the Protection Zone the overall administrative authority is the Forest Department. However, moving forward from pure forest management to multiple resource management, links could be forged the with other departments, agencies and local communities. This could be achieved through formation of an integrated management advisory committees(IMC).

It is important that at the level of the specialist manager and policy decision maker formalised hierarchies should be replaced by a matrix structure in more than the one dimension. A hierarchy infers that the interactions flow up and down the system. For multiple resource management it is essential that the interaction flows between all the constituent managers, specialists and advisory committees and outside governmental frameworks. Future integrated management structures and local communities could be incorporated in the matrix which through the IMC could provide advice to the FD and receive high level direction from an inter-ministerial steering committee (see Section 26.2).

With the increase in demands upon field staff and infrastructure the need for investment in both personnel and equipment, already partly identified in FRMP was echoed recently by the CCF (Rahman, 1995). This is discussed in detail in Section 27.1 Investment Proposals.

21.3 Yield Regulation Rules and Planning Methods

Production from one resource may have far reaching consequences for another. In some instances these effects are unpredictable but must be anticipated if possible through sufficiently sensitive control and monitoring. Also overall optimum yield may not be the sum of the optimum yield for all the individual resources. For many resources there may be conflicts in objectives of management, therefore within the parameters of the current resource data base a start can be made for the regulation of the yield of all the resources with systems for monitoring the effects on all other resources and the ecosystem as a whole.

The rules for regulation cannot be properly defined at this stage. More research is needed in certain key areas such as fisheries harvesting and plantation silviculture. Some guidelines are proposed :

- Despite the requirement for integration of activities with other agencies responsibility for production must rest with the Forest Department.
- Yield regulation rules must be flexible enough to allow management to respond to changing circumstances so that planning should be pro-active rather than retro-active.
- Yield data for all resources must analysed concurrently in order to maintain the requisite balance between resources.

21.4 Yield Control

Clearly with many of the resources being over exploited it is necessary to set levels of sustainable yield and then ensure that these levels are not exceeded. This will require that for most resources new methodologies must be developed to determine the sustainable level of production and appropriate controls.

Using the proposed data management systems it should be possible to control the yield within a much shorter timeframe than at present which operates on a yearly basis with a time lag of approximately six months before yield data are collected and processed.

The exploitation of the wood resource at least is governed by statute and mandatory working plans must be adhered to by the FD. Future production and yield regulation plans must be structured as an integrated resource working plan which should have an overall strategy for all resources taking into account the following:

- Proposed yields
- Control and monitoring
- Continuous survey
- Sustainable production targets

All produce harvested from the SRF should have the same mandatory control. The existing "control forms" for timber felling form part of the mandatory control system required by law. The limitation to these is that they only give spatial information and do not give management information such as volumes by species removed. This is a matter requiring priority attention in order to control yields and gauge these against sustainable potentials.

Any new system should not only control the yield for all resources but should also provide up to date methodology for monitoring the ecosystem and continually updating the database. The inter-relationship between ecological factors and resource harvesting could thus be established as the foundation for sound and sustainable management.

21.5 Information Requirements

New demands necessitate that all the information from production is adequately known at a level of resolution not previously possible to collect or collate. It is no longer right that information is recorded in manual ledgers and left at the station or range office.

Production data in all its forms must be passed up the line to the management planning offices as soon as possible. The information thus collected will provide managers and planners a basis for decisions. With computer technology it will be a simple matter to enter this information into a database and for any level of report information can then be extracted or selected and analysed under any topic.

This will require up dating the present system of information flow and the reporting procedures throughout the SRF. This new system will require considerable forethought and systems planning before it can be implemented.

Another area where a regular information collection procedure is required is the collection of market data. For example it would be inappropriate to auction sawlogs at a time when the local market was already saturated.

For each resource an inventory or stock assessment is needed with growth and yield models, for without this there can be no management or development planning. This is discussed in detail for each of the resources in the relevant sections. From this starting point various models can be designed and run to evaluate various scenarios, which in turn can show the effect of the different management decisions can have on the resource as a whole. This should prevent management of one particular resource to the detriment of others.

21.6 Working groups - Working Circles

Using the Forest Department's current terminology, commonly used by forestry authorities and planners throughout the world, consideration should be given to managing a number of overlapping Working Circles. By extending the concept beyond timber resources, for ecosystem management it may become desirable to consider an alternative name such as Integrated Management Unit or IMU. For clear recognition of the practical and logical requirement to create a composite framework for integrated management of multiple resources in overlapping areas of interest, the following should be considered :

- Sundri Working Circle
- Top-dying Sundri Working Circle
- Gewa Working Circle
- Other Timber Species Working Circle
- Goran and Other Firewood Working Circle
- Plantation Working Circle

- Golpatta Working Circle
- Offshore Fisheries Working Circle
- Inshore Fisheries Working Circle
- Shrimp fry Working Circle
- Wildlife Working Circle
- Apiculture Working Circle
- Tourism Working Circle
- Other Products Working Circle
- Border Zone Working Circle

Recognition of the structural form should be agreed at an early stage before preparation of Annual Operational Workplans. There is a natural division of functions between wood resources and non-wood resources, terrestrial and aquatic resources and product specific technical management.

Spatial deployment of each circle and its specific functions would be introduced to the integrated resource data base. This approach will facilitate better data analysis for management planning and operational programmes. Co-ordination and implementation would occur under the direction of the CCF and Conservator, Khulna.

In all past inventories and associated Working Plans there was only one level of stratification possible and the level selected was the level considered appropriate for the timber component of the inventory. Discussions elsewhere in this IRMP suggest that various levels of stratification are necessary, and that use of one level of resolution for all activities is inappropriate.

A similar single level approach has been used in forest management in the Sundarbans with operations being primarily at the compartment, and in part at the sub-compartment level.

A land based management unit is obviously not appropriate for management of the aquatic environment which might more reasonably be based on the major streams and associated khals and in any case should incorporate social and economic factors associated with the communities of the Border Zone.

The future management of any complex ecosystem requires consideration of all the resources, and that will require varying levels of spatial resolution in planning. A multi-level, multi-disciplinary approach to planning will be necessary.

22 MANAGEMENT OF WOOD RESOURCES

Although the value of wood production from the SRF is less now than the total revenue value of non-wood products, timber and fuelwood production remain the cornerstone of production forest management and economic utilisation (see Table 66). Management of wood resources must now become fully integrated in the balanced management of all products of the ecosystem but at the same time the policy must be to improve harvesting and silvicultural methods to attain higher and sustainable yields.

22.1 Silvicultural Systems

Silviculture is considered to be integral to forest ecology as a science for the management of forests for specific reasons. A key principle is that whatever interventions are practised the result should be gradual improvement of production from the forest. Two levels of recommendation are made :

1. Where it is considered that the benefits of a given treatment are already widely accepted and that the proposed treatments will pay for themselves from the sale of produce.
2. Proposals based on silvicultural improvements where the benefits need to be quantified and it is not known if the treatments will be cost effective.

For the second level of proposals a programme of trials is recommended to build on existing research and to attempt new approaches in emerging environmental situations such as increased sedimentation and increased salinity.

22.1.1 Natural forest

Traditionally the SRF has been managed with versions of the Selection System. Currently only Gewa is managed in this way. Sundri is salvage felled in the areas subject to top-dying.

Regeneration of Sundri in salvage felled areas seems to range from poor to plentiful but it has been shown that the species mix in the worked forest appears to be changing with proportions of the high value Sundri decreasing and the low value Gewa increasing (Mitchell, 1995).

The level of silvicultural information is insufficient to make site specific management decisions. The effects of changing the method of silviculture is therefore difficult to predict yet action should be taken to halt the apparent decline in the value of the forest.

The current level of silviculture in the forest is rudimentary; simply felling to diameter limits. Without maintenance or selection this does not represent good silviculture. Curtis in 1933 tried to introduce better silvicultural practices but the rules were found to be too complicated to implement and were subsequently abandoned. It is recommended that skilled

silvicultural officers should be kept in their posts for longer periods than at present in order to build up experience and local knowledge of the forest which is frequently lacking at present.

New compartment and sub-compartment maps should be made using GPS co-ordinates, systematic sampling and the IDB. Details of areas for silvicultural treatment could also be recorded and correlated in a perpetual calendar system. Areas treated at regular intervals could be monitored and any remedial or other action taken could be taken and systematically recorded in the same data base. This information system would be gradually developed to provide detailed sub compartment records. All treatments should be recorded in the sub compartment records together with the results. By recording information in this fashion the problems that normally arise when key members of staff are transferred or records lost would be overcome. Other recommendations are:

Timber Moratorium:

Until the FRMP inventory has been completed it is recommended that the moratorium should continue. Once the results of the inventory and the growth figures from all the PSPs have been analysed then new recommendations regarding sustainable levels of cut can be made.

Selection System:

For the time being, the present system of cutting Gewa to the diameter limits, on a felling cycle of 20 years, should continue. This needs to be reviewed as soon as the results of the inventory are known and revised in the light of the results.

Research:

Research into different or modified silvicultural systems in different areas should be tried. Research plots should be set up within some of the Gewa cutting areas to measure regeneration and growth rates for different treatments.

Diameter limits and felling cycles:

These should be raised but at the same time allow improvement fellings in sizes below the diameter limits reducing the length of the felling cycle. Trees for improvement fellings below the diameter limit would be marked by the FD. In this way it might be possible to see whether leaving larger trees would increase the proportion of Sundri regeneration. The resultant increase in the cost of the harvest might be expected to be recovered through the eventual increase in value of production by the improvement.

Salvage Felling:

Due to the incidence of top-dying it is recommended that the salvage felling should continue so that valuable timber is harvested before it becomes rotten. As with selection felling it is suggested that this entire procedure be reviewed once the results of the inventory are known. From the current procedure, it is apparent that the definitions of top-dying need to be tightened up and measures taken to ensure that only top-dying trees are harvested.

Within top-dying areas the level of regeneration has been shown to be variable. Karim (1995) undertook a regeneration survey in top-dying areas and he found that the stocking of regeneration of all species ranged from under 40% to over 90% of what he termed adequate (1000 stems/ha). This definition of 'adequate' is considered for, practical management purposes, to be exceedingly low. A plantation at 2 x 2m spacing would have a stocking of 2500 stems per hectare. When working with natural regeneration it would be expected to have many times this number of stems; around 10 000 stems per hectare would be considered low but adequate.

The salvage felling should not be restricted to the top-dying of Sundri alone. Where and when there are areas of cyclone damaged or wind blown trees these should be harvested as a priority even over the current operations in top-dying areas or Gewa cutting areas. Once the areas have been harvested the volumes for the AAC for the Gewa (and other species where applicable) should be reduced by the amount harvested and they should be should be monitored for regeneration and erosion.

Enrichment Planting in Top-dying Areas:

Prior to the marking phase of salvage felling, a brief survey of regeneration should be undertaken. In areas where there is limited enrichment planting should be tried with a mixture of species. The choice should take into account the following:

- Value.
- There should be evidence that the species is growing in similar conditions in the locality.
- It should be a species for which nursery and establishment techniques are known.
- Preference should be given to viviparous species which do not require an expensive nursery stage.

Other considerations:

- If deer browsing is a problem consider re-introducing deer stalking. Fencing and spraying are not practical options.
- Enrichment plantings, if carried out for single species at a close spacing of say 2m x 2m, could be beneficial but the areas must be tended and failed trees replaced.
- If a mixture of species is planted and one species performs well this should be selected for replacing failed trees.
- Plantings should be kept weed free for as many years as the weed species are competing with the planted trees. It should be stressed that within the planted groups, the presence of other tree species such as Gewa or even Sundri through natural regeneration after planting is undesirable and if the planted trees are surviving the natural regeneration of other species should be removed.

Thinning and Improvement Fellings:

Thinning in areas of dense pole stage crops should be undertaken as routine practice. These areas can be quickly marked following general silvicultural principles such as removing the worst stems and favouring the more valuable species such as Sundri, Passur, Dhundal and Kankra.

Thinning should help remaining trees in their competition for canopy space. In a stand that has grown up from prolific regeneration it is likely that in the first thinning operation as many as 50% of the stems could be removed. In the past this practice was abandoned because the contractors tended to remove the unmarked better stems. This can be remedied by adequate supervision and management. Selective thinning of young stands is the essence of good silviculture and the practice should be actively followed.

In subsequent years the thinned stand should be inspected. This will be facilitated with the help of the database and the perpetual calendar. Periodically the stand should be subject to further thinnings. In a slow growing forest a thinning cycle of probably once in ten years will be sufficient. Again this needs to be monitored by the forest rangers on the ground and they should take the ultimate decision of when to thin the stands. In second or third thinnings the intensity of the thinning would be reduced to about 25%.

In more mature stands the equivalent of third or fourth thinnings can be undertaken to release the better trees and to improve the overall form of the growing stock. The use of improvement thinnings should also help encourage the establishment of Sundri under the shade of the final crop prior to felling.

Tending:

In areas of younger regeneration the crop often becomes infested with undesirable species such as Bhola and ***Pandanus sp.*** These will compete for both canopy and root space and will thus reduce the increment of the crop. Bhola tends to be a climber and will often climb up the crop and eventually bend over or even flatten the trees either killing them entirely or spoiling the form of the tree. These areas should be cleaned and the young crop freed from competing weed growth. Some weed species are sold as firewood suggesting that freeing of young crops can be done at relatively low cost. All tending operations should therefore be encouraged.

- Goran

Harvesting Goran on a cyclical basis leaving one stem per stool should continue until data are available to calculate sustainable yield levels. Evidence from India has shown that other silvicultural systems also work well including 200 m strip clear felling. This system has the benefit that the resulting regrowth is straight and is not spoilt by the extraction of the crop.

It is recommended that some trial clearfelling of Goran might be attempted. This should include other silvicultural systems and designs such as group felling as well as the strip system.

22.1.2 Plantation Forest

Analysis of the PSPs by Leech (1995) has indicated that the growth rate of the natural forest is very low. This is due to a variety of reasons and rates differ between species. A major contributing factor is the utilisation of the effective canopy space.

Plantations aim to maximise the utilisation of the canopy by desirable species and to minimise the amount of gaps. Plantations therefore, even using slow growing indigenous species have the potential to increase the growth and yield. Since 1976, just over 1200 ha of plantations have been established. Unfortunately these plantations have not been reviewed in sufficient detail for growth rates to be assessed against site quality and variations in environmental factors.

It is recommended that the cost effectiveness of existing trial plantations be evaluated as soon as possible and new trial plantations established using the results as well trying other species. These trials should be rigorously designed so that site and species interactions can be monitored growth rates measured.

Factors to be considered:

- Species selection for given sites.
- Growth rates by species and site.
- Establishment and maintenance techniques.
- Protection against damage by wildlife.
- Should exotic species be introduced? Karim (1995) recommends that only native species should be planted. Grepin (1995, pers. comm.) has stated though, that in certain areas of higher lying land exotic species may be more suitable, and that these should not adversely affect the gross ecology.

It is also suggested that the establishment of a plantation extension unit should be considered. The concept behind such a scheme would be to encourage local land owners, villages and user groups to plant trees on and around their farms, shrimp ponds and polder embankments within the 10 km border area.

Benefits which will accrue are :

- Pressure on wood resources of the SRF from the local population would decrease.
- Protective functions of trees against cyclones and flooding would be enhanced.
- Financial rewards from the sale of timber could accrue to the local poor.
- It would be an indirect tool for environmental education.

Nurseries:

The technology exists within the FD to raise seedlings of most of the mangrove species. The manual for nursery development produced as part of the preparatory work for the IRMP (Karim, 1995) should be published for dissemination during future extension work by the DFO. The size and scope of nurseries cannot be defined until the level of planting stock requirements are known. Development of small nurseries close to the proposed planting sites is a preferred strategy. It is therefore suggested that the nursery development programme is defined once the plant requirements have been assessed. By offering work to local communities near proposed planting areas it would be possible to grow seedlings under contract.

22.2 Management Prescriptions for the wood resource

Prescription proposals for management of the wood resource are summarised below :

Selection System:

- Trials of different silvicultural systems should be initiated.
- Abolition of sample measuring gewa.
- Install weighing cranes at the KNM yard.

Salvage felling:

- Define top-dying and improve supervision of marking so that only trees which are definitely top-dying are selected for removal.
- Consider environmental and regeneration impact of harvesting of wind blown areas.

New felling rules:

- Needed to improve timber utilisation.
- Mandatory use of cross cut saws for cross cutting and making the back cut during felling of Sundri by contractors.
- Mandatory low cutting of stumps - all stumps must be under 50 cm, preferably about 30 cm.
- Train contractors in the use of handtools such as cant hooks and tongs.
- Sawlogs should be cross cut in lengths which maximise the yield and not minimise the effort required to carry the log out of the forest.

Log measurement and Grading:

- A new system of log measuring needs to be gradually introduced to convert the present Hoppus system to metric.
- Once the logs reach the depot they should be sorted into graded parcels so that graded lots can be sold at the auction.

REB poles:

The practice of selling specially selected Sundri to BFIDC for REB poles should cease. With the introduction of a new grading system they will be able to purchase logs of selected quality at the auctions at the market price.

Enrichment plantations:

- In areas where there is limited regeneration of desirable species, enrichment planting trials should be undertaken.

Thinning, Improvement Felling and Tending:

- Selective thinning should be undertaken in areas of dense pole stage crops.
- Improvement fellings should be undertaken in stands where there are sufficient stems of large enough diameters.
- Young crops which are infested with weed species such as bhola should be cleaned.

Goran:

- Trials of new silvicultural systems for working Goran should be undertaken.
- The BLC method of measurement for removal of Goran should be discontinued. This should be replaced by stack measurement or sales by area of standing crop.

Plantations:

- A programme of trial plantations should be initiated.

22.3 Inventory and Growing Stock

A standard forest inventory is carried out to determine what the status of the forest timber resource. Generally this provides an estimate of the growing stock of timber in the forest at a particular time. It is the base for planning but on its alone it is not sufficient for fully integrated resource management planning.

22.3.1 Recommended Procedure for the Future

The problem of holistic management of the mangrove ecosystem resolves itself into two issues:

- The need to be able to apply any stratification to the inventory data base at any time.
- The capacity to determine changes in the status of the SRF at any desired interval.

Past surveys have been based on stratified random sampling as described in Part 1. The advent of the Geographic Information System technology allows any spatial information that can be collected about the Sundarbans to be stored readily offering a multiplicity of stratifications at varying levels of resolution. The polygon coverages might come from past inventories or from aerial photography. Unfortunately the speed of field inventory has not kept pace and it takes a considerable length of time, especially in the Mangrove forest, for even an experienced field crew to establish, measure and record the information for a field plot.

It is essential to separate field plot measurement from the stratification to be used as a prerequisite for consistent up-dating of estimates of resource statuses. The proposal is to use a Temporary Sample Plot (TSP) system based on systematic sampling to continually monitor the forest.

These will complement, but not replace, the existing Permanent Sample Plots which are vital for determining growth rates and for model development.

Systematic Sampling separates field plot measurement from the stratification and the most logical approach is to establish plots as a systematic sample (Leech, 1995).

A more complete description of the reasoning for recommending the change from stratified random sampling to systematic sampling is included in Leech (1995).

Temporary Sample Plot Layout:

If plots are established such that an equal proportion is established each year, say 400 per year over a five year measurement cycle, then by careful location of the grid cells to be measured each year, a very good estimate can be obtained each year into the future. Because only 20% of the plots are replaced each year any changes may take some time to appear but annual trends do become evident, even though plots are only remeasured every five years.

There are many ways sampling could be arranged. One method is as follows:

- Ensure that the complete area is covered.
- Lay out plots for each of the five years of the measurement programme with 1-5 representing the grid cells to be measured in each of the first 5 years of the inventory. In the sixth year the plots measured in the first year would be remeasured.
- Sampling is carried out annually and should be planned as an ongoing regular ecosystem research activity geared to forest management targets.
- Establish a forest mensuration and environmental measurement team with requisite staff, facilities, equipment and budget . and would be a continuing activity rather than a project by project operation.

It is believed that if this type of design is implemented that it will be possible to better monitor the ecological evolution of the Sundarbans and it will also provide a basis for forest management that can effectively utilise all the latest available information.

- Primary locations should be set at intervals of 1 minute. This has the advantage of being directly transferable to SPOT imagery for field use to assist plot location.
- Approximately 1900 primary locations could be anticipated of which approximately 1250 would be on land and 600 on water with some indeterminate. Approximately 2000 sites would need to be surveyed to ensure that all TSP sites are measured.
- Each Primary Site could be the centre of a 3x3 or 4x4 grid cluster of sub-plots, or a cross shaped line of 7 or 9 plots, each sub-plot separated from each other by 50-100 m.
- Sub-plots could be 10x10 m (0.01 ha) up to 25x25 m (0.0625 ha) in area. They should be square to provide the greatest homogeneity.
- Alternatives to consider are either to measure only one plot, probably at least 30x30 m in size or to have a central larger plot with small satellite cluster plots for some attributes. These designs might be simpler and more appropriate for measurement of non-wood variables.
- Any final decision should include inputs from other concerned agencies such as Khulna University and BFRI.

TSP Measurements:

Because each TSP would be established at a particular location and should not be shifted to make it uniform, unlike the PSP's which have been established as uniform plots, it will be necessary to subdivide the TSP into mappable sub-plots of different gross habitat types and forest types which together form the ecosystem as follows:

Mangrove Forest:

Vegetation:

- Baen
- Passur-Kankra-Baen
- Gewa-Goran
- Gewa-Mathal
- Gewa-Sundri
- Goran
- Goran-Gewa
- Korea
- Passur-Kankra
- Gewa
- Sundri
- Sundri-Gewa
- Sundri-Passur
- Sundri-Passur-Kankra
- Golpatta
- Golpatta-tree mixtures

Habitats:

- Open grassland
- Backswamp
- Silt and sand flats
- Water
- Marine zone

Each sub-plot could be mapped in 2 x 2 m or 3 x 3 m units and the data recorded for each of these. Each would be considered uniform. This would enable estimates to be made of the proportions of each TSP that occur in each forest type category.

Measurements should include the following:

- Plot Information
- Plot key
- Nominal location
- Exact GPS location
- Habitat and forest Type
- Map of habitat and forest type in each subplot
- Soil type
- Distance to navigable water

For each sub-plot and for each recording unit:

- Habitat
- Forest type

For each tree :

- Species
- Dbhob
- Tree condition
- Crown type
- Number of saplings less than 2.5 cm dbhob
- Number of seedlings less than 1.3 m high

Under-storey species :

- Species
- Abundance

Golpatta :

- Clump diameter
- Number of seedlings
- Number of one year old stems
- Number of mature stems
- Number of over mature stems
- Number of cut stumps
- Flowering or not
- Fruiting or not
- For a sample of clumps
- Tallest stem
- Height
- Number of leaflets
- Average Stem
- Height
- Number of leaflets

Water :

- Depth
- Turbidity
- Salinity
- Temperature
- Tide

Other ecological parameters:

- Soil details
- Climate
- Entomological observations
- Wildlife observations
- Other environmental factors: slope, accretion, erosion, and sedimentation characteristics.
- Site description : part of a forest station, fishing camp, jetty, other.

The TSP would provide a focal point for any data collection designed to provide estimates of the current status of any particular parameter or characteristic in the Sundarbans. The distance to navigable water is highly desirable as this parameter is likely to be very useful in the prediction of unofficial consumption, especially firewood collection.

One further advantage of this systematic TSP programme is that the programme would be an annual programme with its own budget line. This would enable the formation of a section of highly trained measurement crews, which in turn would result in the data obtained being of higher quality than can be obtained with one-off inventories.

Well trained and motivated staff, to carry out the mensuration in such a difficult environment is an essential prerequisite. Provision for training and leadership must be made at the outset of future research. The problems with the data quality of the current PSP remeasurements are in large measure due to the insufficient training, knowledge and skills. If a permanent crew is created, they would become an experienced elite measurement crew and would be able to assist all other research objectives.

The overriding advantage of the proposed PSP and TSP system is that it could ensure that all monitoring work is carried out on the one site, and that researchers do not duplicate measurement effort. For example if sedimentation traps are to be installed and measured then it makes sense to do it in TSP's, even if not in all TSP's, as then the soil, forest ecology, and forest type have already been recorded and more measurements do not need to be made.

A broad based, multi-disciplinary TSP system would facilitate the carrying out of multi-variate statistical analyses. One such analysis might assist in resolving the issues relating to Top-dying Sundri and could lead to a better appreciation of forest management options (Leech, 1995).

TSP Data Storage:

Data would be stored by plot, sub-plot and recording unit key, and retrieved as necessary to provide estimates for any stratification. Point coverages of both PSP and TSP plot locations would be stored in the GIS.

The TSP data base stores point estimates and but does not store strata areas. Area information is external to the TSP system. Strata statistical means would be able to provide proportions by habitats and forest types and thus estimates can be made of the area of any forest type, Golpatta or the area of Mangrove forest in any stratum as a proportion of the area for any particular stratification. Analysis can also provide proportions by major species if so desired.

As the TSP's should be located accurately with a GPS, they can provide very useful ground truthing plots for GIS, Image Processing, and other spatial analytical activities. This is an extension of the IDB.

Logistics, Procedures and Standards:

There are a number of measurement challenges including how to measure and record coppicing from stumps, how to the separate stems and trees, recording of buttress height and diameter at a specific point above the buttress, the recording of change in buttress height, recording pneumatophore size and status, and the need to make records of information of use to a wide range of disciplines.

The use of the GPSs to locate TSPs will need to be the subject of considerable training. In most of the SRF it is relatively easy to gain suitable fixes on satellites, but in the denser forest it is difficult. It may be necessary to use an aerial on a telescopic pole.

The selection of measurement equipment will also need to be carefully considered. Staff will require considerable training in the use and maintenance of this equipment. Although many Forest Department staff know how to use mensuration equipment the level of experience observed is generally poorer than desired.

Aerial photography of the Sundarbans, at scales of 1:15000 but preferable 1:7500 or 1:10000 would enable the most appropriate access method to be determined. It would also provide a method of assisting plot location. Speed boat size will also be important as it must be sufficient to carry a complete measurement crew plus measuring equipment and also a spare outboard motor.

The definition of the full TSP inventory will take considerable effort in defining complete sets of standards and procedures (in both Bangla and English), in training and in building up specialist expertise so that precise and useful measurements are obtained. This methodology will need to be defined interactively so that all problems and difficulties are effectively resolved. This IRMP makes the recommendation that such an inventory be established but does not provide a comprehensive field plan.

Summary of systematic sampling proposals:

- The main advantage is that it breaks the nexus between stratification and plot measurement and would facilitate comparison between stratifications.
- The system facilitates inter-disciplinary analyses and multi-variate statistical analyses.
- The sampling programme would be annual with its own budget line. This would enable the formation of a cadre of experienced, highly trained measurement crews, which in turn would result in the data obtained being of far higher quality than can be obtained with one-off inventories.

23.3.2 Best Available Estimates

Part of data gathering for this plan was organised to review information from the Permanent Sample Plots. These have a number of weaknesses when used as though they are Temporary Sample Plots. They are not a random coverage of the forest and of the 120 PSP's originally remeasured in 1986/87, only 69 were remeasured. Even these 69 may not be considered a truly random sub-sample of the 120 PSP's as the remeasurement was initially concentrated in the Sundri and Sundri-Gewa forest types. Further, this remeasurement must be compared with 2099 plots measured for the ODA inventory. Some limited control enumeration was carried out to ensure that the enumeration itself was unbiased (Leech 1995).

Growing Stock estimates cannot be obtained from just this information but have to be obtained as follows:

Part Growth	=	Growth on the Growing Stock component (1994/95 - 1986/87)
+ Ingrowth	-	Unofficial Consumption (including mortality and illegal removals)
Net Growth	=	Part Growth - Official Consumption

Net growth estimate provides an indication of the changing status of the Sundarbans Reserved Forest discussed in Part 1 Section 9.1.5.

22.4 Biometric and Prescriptive Models

Future planning systems will require a mixture of biometric and prescriptive models. These models may be integrated in a system to provide predictions for the future based on the best available inventory. There are essential components in the planning system and detailed examples are provided by Leech, (1995).

Biometric models are predictive and are generally based on statistical analysis. They predict what will happen if you do this or if something occurs, or what the growth on a particular stand will be given certain management practices, or given a particular set of circumstances then the models are able to predict what the future yields will be. These are complemented by prescriptive models that define actions that will be carried out.

Objectives must be carefully defined which will enable systems analysis of the entire area and not an isolated part.

23.4.1 Future Needs

The first task for future managers is to determine practical resource management requirements which may be helped during decision making by a suitable range of models. The steps to follow would be :

- Determine what models are necessary.
- Develop models.
- Develop strategy.
- Implement the agreed planning system.
- Try the system.
- improve the system and data in areas where weaknesses are shown to exist.

Biometric Models:

There are a number of biometric models that will need to be developed for inclusion in the planning system. There is no one, single, simple set of equations, nor is it possible to define a methodology for model development. There should be a balance between the objectives of the modelling exercise, the availability of data, the ability to collect new data, and the experience of the analysts.

Some planning considerations useful to future management of the forest based on Leech (1995) and Vanclay (1994) are summarised below :

- The first requirement is for suitable growth models. The models should be able to predict growth by species and by size class over a range of forest types and site productivity strata and should also provide predictions of the variables required.
- For short term predictions the most appropriate methodology is to take the actual diameter distribution from the inventory and develop models that predict the future status. This can be on a tree by tree basis, or by diameter classes, or by groups of trees (cohorts) obtained by dividing the population into cells of equal frequency and then modelling the growth of these cells over time.
- The longer the prediction period the poorer these models are and it becomes more appropriate to develop either stand volume growth models or basal area and height growth models and then use distribution models to apportion increment to various size classes.
- Growth models predict gross growth and it is necessary to predict mortality. In the SRF the changing species composition results in differential mortality by species, exacerbated by the Top-dying Sundri problem. A matrix approach that predicts the probability of mortality by species, by diameter class, for a given standing basal area and species composition is likely to be the most appropriate method.
- Models to predict ingrowth, or recruitment into the lowest recorded diameter class, also need to be developed. These models can be developed from PSP information.
- Apart from these ecological models it will be necessary to predict unofficial consumption, to predict the probability of illegal removals from the forest. The information from this is not simply obtained but can come from remeasured TSP's. The PSP's have provided a simple but biased estimate, a TSP system would reduce the bias and may allow a spatial component to the models.
- It is also necessary to develop models to predict tree volume from tree diameter and optionally tree height, merchantable or total.

Equations are needed to predict volumes :

- Over bark and under bark.
- By size assortments, to various top diameter limits.
- To different merchantability levels, including stump height and bole length.
- To include crown wood, branch wood and foliage, to enable firewood and above ground biomass models to be developed.

Prescriptive Models:

Prescriptive models are intended to direct the system to perform practical resource management operations. They are rarely the result of specific statistical analyses. They are often just a formal mathematical restatement of current practice. Examples of prescriptive models are as follows:

Merchantability models:

- Sundri stump height
- Gewa stump height
- Gewa top diameter limit (5, 7 or 10 cm)

Felling prescription in natural stands:

- Minimum tree diameter to be cut, for each species and site class. For example for Sundri:
- Height Class 1, dbhob 22 cm
- Height Class 2, dbhob 20 cm
- Height Class 3, dbhob 15 cm

Felling cycle, which might be 30 years, or perhaps it could be defined as a felling prescription, for example harvest when there is 50 m^3/ha of Sundri > 25 cm dbhob and cut 90% of trees > 25 cm dbhob.

For plantations:

- Area of plantations expected to be planted in the future, by species.
- Stocking at establishment
- Survival in first year
- Thinning regime, for example:
- T1 at age 5 to 1500 trees/ha
- T2 at age 10 to 1000 trees/ha
- T3 at age 15 to 700 trees/ha
- CF at age 35

Provided that the planning system can effectively integrate all the necessary component models then it is possible by modifying these prescriptive models between runs of the planning model to predict the likely change in the forest and in forest outturn for a range of alternative management strategies (Leech, 1995).

23.4.2 Model Development

In the absence of an up to date inventory and because it was not possible to disaggregate the official consumption figures, the available PSP data were used to develop tree volume equations to facilitate volume predictions more precisely than in the past (Leech, 1995).

Tree Volume Equations for Sundri and Gewa:

Tree volume equations are required so that the diameter measurements recorded on the PSP's can be used to predict tree, and hence stand, volume for each species.

Leech (1995) reviewed the tree volume equations in the ODA report (Chaffey, Miller and Sandom 1985) as these seemed to be a distillation of all available equations for trees in the SRF. He concluded that the equations could not be used because of typing errors, because the structure was unsatisfactory and because the equations had not been corrected for logarithmic bias.

New data were collected from felled trees in 1995 to improve on the analyses. Data for Sundri and Gewa were collected from 6 sites at which 159 Sundri and 59 Gewa trees were measured. Equations were developed using WLS (Weighted Least Squares) in order to stabilise the error variance.

The equation development for both species is reported in Leech (1995) and the equations for Sundri are also reported in Leech, Karim and Sarker (in press). For Sundri the following equations were the best predictors of over bark volumes:

$$V = 0.00017809 * (D ** 2.3358) \qquad \text{if } D>=10.0$$
$$V = 0.0 \qquad D< 10.0$$
$$V = 0.000006083 * (D ** 1.9631) * (H ** 0.8270) \qquad \text{if } D>=10.0$$
$$V = 0.0 \qquad D< 10.0$$

For Gewa measurements were taken to both 5 and a 10 cm top diameter limit (V05 and V10). The best predictors of over bark volumes were as follows.

$$V05 = 0.0004218 * (D ** 2) - 0.001502 - 0.008738 / D \qquad \text{if } D>= 5.0$$
$$V05 = 0.0 \qquad D< 5.0$$

$$V10 = 0.0004218 * (D ** 2) - 0.002032 - 0.2506 / D \qquad \text{if } D>=10.0$$
$$V10 = 0.0 \qquad D< 10.0$$

If it is necessary to predict volume to some other top diameter merchantable limit less than 10.0 cm then the simple assumption can be made that the difference between the 5 and 10 cm top diameter limit can be approximated by a frustum of a cone. For the 7 cm top diameter limit currently used by KNM (V07) this results in the following equation.

$$V07 = 0.75 * (V05 - V10) + V10 \qquad \text{if } D>= 7.0$$

This is obviously biased for trees between 7.0 and 10.0 cm dbhob but still provides a useful predictor.

The equations used in all the analyses reported in this IRMP are detailed in Appendix A31 along with the estimated volume for various diameter classes for each species.

Growth of Top-dying Sundri and PSPs:

The problem of Top-dying Sundri has been major concern for many years. Reports such as that of Christensen (1984), and the failure of any recent analysis to provide a definitive description of the cause, suggests that the problem is extremely complex and that a true multi-disciplinary study, carried out by a diverse team of workers is likely to be necessary to determine the cause of this problem. All recent statements on the subject agree that even if a cause is determined the remedy may be impossible (Christensen 1984). What is needed is a management strategy for the management of Top-dying Sundri.

The Permanent Sample Plots provide a sound base for determining ecological changes over time and have the further advantage that they are not affected by harvesting operations.

The 69 PSPs remeasured as at April 1995 were summarised recording the proportion of Sundri that was affected by top-dying symptoms. These were then arbitrarily divided into two approximately equal groups depending on whether this proportion, based on the 1994/95 assessment was greater or less than 10%. These were then plotted on a GIS Arc/Info map of the Sundarbans showing the PSP locations and it was found that three general strata could be defined. Some plots without Sundri trees, or where tree classifications had apparently not been recorded, were ignored. Analysis by Leech (1995) revealed :

- The western zone where all but one of the 16 PSPs showed greater than 10% top-dying symptoms.
- The eastern zone where all 26 PSP's showed less than 10% trees with symptoms.
- The intermediate zone of 20 PSP's where approximately half had more than 10% of trees with symptoms, half less.

The results of this work are presented graphically in Map 11 as an overlay of the ODA incidence of Top-dying map. The stratification showed little coincidence with the ODA top-dying map but showed a greater correlation with the Curtis height class map. There were only 69 PSPs to analyse and so it is difficult to make firm conclusions about the appropriateness of alternative stratifications for mapping Sundri top-dying.

The analysis of these results also support the observation that the Sundri proportion is changing in the area most affected by top-dying. It also shows that where there is relatively little top-dying the natural changes in Sundri-Gewa proportions is quite limited.

The PSP system also provides a sound basis for determining the changes, if any, in the biodiversity of tree species in the Sundarbans. Simpson's index or other statistics can be readily calculated for the 1986/87, for 1994/95 and for future measurements. These statistics can be augmented by TSP information.

The 12 BFRI Permanent Sample Plots have been used (Latif *et al* 1992) to determine diameter increment for six mangrove tree species and their work indicated higher growth rates on areas of higher site quality. They found an increase in the proportion of Gewa and a reduction in the proportion of Sundri.

It therefore seems quite possible that the changes in the proportions of Sundri and Gewa observed in areas not affected by top-dying may have been caused predominantly by harvesting and only to a lesser degree by ecological succession.

22.5 Planning Systems

In the past, planning in the SRF was relatively simple and this was generally appropriate and adequate for the purposes required at that time. Today the various pressures on the ecosystem have increased considerably and a new approach is required. At the same time technology has advanced considerably. Emphasis on management of all resources now demands an improved planning methodology that effectively integrates modern modelling technology, considers the complete ecosystem and looks forward to stability throughout the ecosystem and sustainable utilisation of its produce.

22.5.1 Philosophy

Recent studies underlined the need and value of using modern technology in an integrated system combining GIS, remote sensing, hydraulic modelling robots, computers, and field inventory. These have become essential tools for resource managers but to abandon the past and continue with this new approach will require a commitment to new management structures, determination to improve management capabilities, opportunities for training and improved terms and conditions of service. The commitment must be at all levels otherwise the impetus may be lost or become unbalanced.

It takes a great deal of time to build up the considerable expertise that is necessary to design and then implement a modern planning system that can assist the management of such a fragile and complex ecosystem. The task should be carried out by a highly specialised and dedicated team.

Aspects of the planning system will undoubtedly be addressed by the FRMP as part of the redevelopment of RIMS. The integration of the GIS with TSP field data and with remote sensing imagery is quite feasible, but requires care and expertise. It is essential that the planning system be flexible enough to cope with future change, it must be dynamic; it is an antithesis of the past and cannot be satisfactorily carried out by a project based or narrow sectoral strategy. New dimensions include factors related to the communities resident in the Border Zone and the Marine Zone where management must take account of international issues.

22.5.2 Example Analyses

For future implementation purposes some analyses are described to show the types of calculations which can be undertaken when more data become available. It is stressed that these analyses are only to be taken as examples and are not representative of the forest as a whole (Mitchell, 1995).

Initially, some six PSPs were selected on the basis that for Sundri at least they appeared to have volumes in the higher diameter classes which would infer that in the normal course of events they would now be ready for felling. The PSPs were simply chosen as an example and were chosen because they appeared to have suitable data and were not selected because they were representative of any particular stratification in the forest.

Table 72 presents the average stocking and volume figures for the main species for these selected plots. For the purposes of these calculations it was assumed that for Sundri the minimum diameter limit would be 20 cm and for Gewa 10 cm resulting in nearly 50 m^3/ha and for Gewa nearly 10 m^3/ha. The management issue is to be able to calculate the rate of replacement after harvesting.

Also from the PSP data, it is possible to calculate for this stratum the average annual diameter increment by diameter class. Initially the data were looked at in 1 cm diameter classes. This data showed that diameter increment showed a reverse J distribution as would be expected. Further investigation showed that there was a correlation between diameter class and diameter increment for the Sundri at least. This meant that it was possible by regression analysis to prepare an equation that predicted diameter increment from diameter. For the Gewa data it was found that the correlation was not significant, so therefore the average diameter increments by diameter class were used.

Table 72 Volume and Stocking per Hectare for Six Selected PSPs

Volume (m^3/ha) by 5cm diameter classes									
Species	5-10	10-15	15-20	20-25	25-30	30-35	35+	5+	10+
Sundri	9.88	22.02	31.61	28.53	16.16	3.48	1.48	113.17	103.28
Gewa	4.42	4.98	2.75	1.44	0.22			13.81	9.39
Other timber	0.01	0.21	0.43	0.68		1.40	3.33	6.05	6.04
Other firewood	0.40	0.14	0.12					0.66	0.26
Total	14.70	27.35	34.92	30.65	16.39	4.87	4.80	133.68	118.98
Average No/ha by 5cm diameter classes									
Species	5-10	10-15	15-20	20-25	25-30	30-35	35+	5+	10+
Sundri	476.67	336.67	219.17	112.50	40.83	5.83	1.67	1193.33	716.67
Gewa	200.00	84.17	22.50	6.67	0.83			314.17	114.17
Other timber	0.83	3.33	3.33	2.50		2.50	4.17	16.67	15.83
Other firewood	51.67	5.00	1.67					58.33	6.67
Total	729.17	429.17	246.67	121.67	41.67	8.33	5.83	1582.50	853.33

For the other timber and firewood species there were not enough data for this analysis to be completed. The diameter increments used by 5 cm diameter classes are presented in Table 73.

Table 73 Average Annual Diameter Increment Six PSPs by Diameter Class (cm/year)

Species	Average Annual Increment by 5 cm Diameter Class (cm/year)						
	5-10	10-15	15-20	20-25	25-30	30-35	35+
Sundri	0.14	0.19	0.22	0.23	0.22	0.20	0.16
Gewa	0.20	0.19	0.34	0.15			

From this it is possible to calculate how long it would take a tree to grow through the diameter classes. This is shown in Table 74.

Table 74 Average Time taken for passage through the Diameter Classes (years)

Species	Average time take for passage through the diameter classes (years)						
	5-10	10-15	15-20	20-25	25-30	30-35	35+
Sundri	37	27	23	22	22	25	32
Gewa	25	26	15	32			

By assuming that the distribution of stems through the diameter classes is even then it is possible to calculate the number of stems passing out of one diameter class to the next each year. This is shown as Table 75.

Table 75 Number of Stems Passing Out from One Diameter Class to the Next each Year (No/ha/yr)

Species	Average Number of Stems passing into next diameter class by Year (No/ha/yr)						
	5-10	10-15	15-20	20-25	25-30	30-35	35+
Sundri	12.99	12.56	9.56	5.19	1.84	0.23	0.05
Gewa	8.07	3.22	1.53	0.21			

By assuming that all the Sundri above 20 cm and Gewa above 10 cm have been removed it is now possible to calculate how long it would take for the volume to be replaced. For Sundri, from the above table, it can be seen that in the first year after cutting 9.56 stems/ha will grow into the 20 to 25 cm diameter class.

The volume that grows into the 20 to 25 cm diameter class can then be calculated by multiplying this number of stems by the volume of a 20 cm diameter tree (from the volume equations derived by Leech, 1995).

In the second year the trees that grew in the first year will have grown more and will now have a the volume of trees with a diameter of 20 cm plus the annual diameter increment. Additionally, there will be another 9.56 stems of 20 cm diameter recruited into the bottom end of the diameter class. This then continues in a similar fashion with each year there being new recruitment and the trees in the diameter class growing by the annual diameter increment. By adding the volumes by each year it is possible to calculate the number years it would take to replace the volume removed by cutting to the 20 and 10 cm diameter limits.

In this specific example it took 21 years for the both Sundri to replace the over 20 cm volume removed and the Gewa to replace the over 10 cm volume. For these particular plots, this would indicate that the present cutting cycle of 20 years is marginally too short.

From this it can also be shown, that if these plots were to be cut each year on a cyclic system, the average annual allowable cut (AAC) for these plots only would be 2.36 m^3/ha/year for Sundri and 0.45 m^3/ha/year for Gewa. Again it is stressed that these figures are only applicable for this selection of plots. The Gewa AAC shown above is low simply because the plots chosen were not typical and they had a well below average standing volume of Gewa above the arbitrarily chosen theoretical cutting limit.

These figures also do not take into account the losses due to unofficial consumption, natural mortality, cyclone damage or erosion. The volume equations would also over estimate the actual amount that would be harvested due to the way the sample trees would have been measured assuming a high degree of merchantability. Therefore these figures would have to revised down accordingly. From the overall PSP results (Table 21) it can be seen that the average mortality (consumption) represents 8% of the growing stock for Sundri, and 14% of the Gewa growing stock.

If it is estimated that the unofficial consumption is say 10% (loosely based on the illicit removals as estimated by Larsen 1994), that around 5% of the production is lost to erosion and cyclones, and that there is a general contingency of 10%. Thus the ACC figures presented above would have to be reduced by 28% for Sundri and 34% for Gewa. This would give AACs for these plots of 1.70 m^3/ha/year for Sundri and for Gewa of 0.30 m^3/ha/year.

The Gewa figure quite clearly shows the limit in the usefulness of these calculations for the whole of the SRF. This because the heterogeneity of the forest is too great. Calculations based on all the PSPs therefore were not possible. Calculations were not possible for other strata such as forest type or block as the distribution of the stems through the diameter classes did not follow the necessary pattern. These problems will be solved with the collection of more data as described in the proposed

TSP system. It will then be possible to calculate the AAC for given stratifications and also to calculate the total AAC by aggregation.

22.5.3 Uses of the Planning System

The new planning system will have two different uses :

1. To determine the current level of stocking and to predict the future yields.
2. To evaluate different scenarios. This could be to predict the effect of taking different management decisions such as increasing or decreasing the length of the felling cycle or increasing the utilisation of the trees harvested. Other evaluations could include the effect of wildlife sanctuary expansion.

The evaluation of different scenarios should also include other resources so that the interactions can be assessed for given management decisions. For example effects of changes in the salinity and erosion and accretion may have major impact on forest growth. Cutting of the forest in certain areas may be unacceptable from the tourism perspective.

22.6 Annual Allowable Cut

The history of the Annual Allowable Cut and the method of calculating the AAC in the past are included in Part 1 Section 10.3.1. The determination of the AAC really depends firstly on the objectives of management and secondly on other factors such as the growth rates. For example if it is decided to convert an area to plantations this could be preceded by a considerably larger AAC than if the area was to be sustainably managed on the selection system. The setting of the AAC therefore depends upon policy decisions set against the status of the resource. The overriding objective for timber stock at the moment is defined by the Moratorium which aims to conserve stocks of wood in the natural forest thereby obviating any need for an AAC for any species other than Gewa and Goran.

For this plan no AAC is calculated for two reasons:

1. No inventory data were available.
2. The impossibility of disaggregating felling records on account of the existing system.

On the other hand the methodology to calculate the ACC has been defined and the changes in the status of the forest have been discussed in Part 1 Section 10.2.5.

22.7 Harvesting recommendations

It is recommended the present system of managing production forestry should continue through the use of existing overlapping Working Circles:

- Sundri WC
- Gewa WC
- Keora WC

The results of the FRMP inventory may indicate the need for modification and in particular for Goran and Golpatta, which should be treated as separate resources and have separate management prescriptions and separate Working Circles. This should be considered as soon as the extent of the resource base is known.

On completion of the inventory comparisons must be made with the past and from these results a new production working plan for the timber resource should be prepared bearing in mind the requirement to relate production to the conservation and management of other resources wood and non-wood , especially wildlife, biodiversity and wilderness values. The Working Plan is only a part of the overall SRF management plan and whilst it must consider all Working Circles concurrently it must also be sensitive to the need of conservation and protection.

22.7.1 Sundri

It is recommended that the harvesting operations are kept as at present and are restricted to the salvage felling of Top-dying areas. The control system must be improved so that only affected trees are harvested.

There is a significant risk already that the forest is being over harvested if healthy trees are taken thus it may be that areas may need to be salvage felled more than once which although inefficient it is vastly preferable to over harvesting. At present it appears that some areas are left to regenerate with less valuable species or are even left blank with no regeneration at all.

Over harvesting now will result in a forest without a normal age class distribution and hence the yield will not be sustainable in say 20 years time when there will be a very high proportion of the production forest in the younger pole size diameter classes.

Interpretation of the FRMP aerial photography should provide an accurate assessment of the spatial distribution and status of top-dying which should be compared statistically with the ODA 1985 inventory. From these data it will be possible to calculate the period, scale and deployment of future salvage operations felling.

Analysis from the PSPs has shown that in the PSPs at least the stocking has increased from 831 stems per hectare to 847 and that the average standing volume of Sundri has increased from 44 m^3/ha to 51 m^3/ha. These figures include natural mortality and will include only a limited amount of unofficial removals. These figures make no allowance for the fact that there has been no official consumption inside the plots and probably very little unofficial consumption. Without this additional data it is not possible to determine the real status of the growing stock. After taking into account the total growth and the official removals it is possible that the net growth is greater than the unofficial consumption. It is therefore possible that over the 7 year PSP measurement period the standing volume of Sundri under the circumstances described may have increased slightly.

Unfortunately these data are not representative of the forest and from analysis of harvesting records it is clear that the level of Sundri harvest over the last two or three years has reverted to the pre-moratorium level. The inescapable result therefore will be depletion of the forest if care is not taken to ensure that selection of affected trees for salvage felling is not only policy but also practice.

22.7.2 Gewa

As with the Sundri harvesting, the harvesting of the Gewa should continue using the existing system discussed in Part 1 Section 10.4.1, until the FRMP inventory is completed.

For sustainablity it is obvious that continual cutting above the AAC though should cease. Whilst the level of cut is dictated to a certain extent by KNM's requirements, in future this must be weighed against the findings of the FRMP inventory. If the present level of cut cannot be sustained then the AAC should be reduced accordingly.

The PSP analysis revealed that the Gewa inside the PSPs increased in stocking from 1061 stems/ha to 1101 and that the volume increased from 32 m^3/ha to 37 m^3/ha. Again the same comments that were made for the Sundri hold for the Gewa, in that these figures include natural mortality and the limited amount of unofficial consumption that occurs inside the PSPs. They exclude official consumption and unrecorded consumption. Bearing in mind that the PSPs are not truly representative of the forest as a whole and that the total consumption figures are not known, it is considered by Leech (1995) that the Gewa volume may have remained constant or could have increased slightly to the detriment of Sundri.

22.7.3 Other Working Circles

Currently apart from the Sundri and Gewa, Keora is the only Working Circle but harvesting is banned under the Moratorium. It is recommended that this should continue until the inventory is complete and that then the situation be reviewed. Comparison of the FRMP data should be made with the ODA inventory which indicated that the stock of Keora may be declining. This is an issue which should be studied from the ecological and forest production points of view since Keora is a pioneer indicator species and a valuable timber asset.

22.8 Allocation of wood resources

As there is no information available on standing volume by compartment and by diameter classes it is not possible to suggest how the wood resources should be allocated. Management decisions will be possible for all the wood resources management of the Production Zone when the results of the FRMP inventory are to hand. The current information merely provides a measure of the extent of the areas which may be harvested in juxtaposition to the needs of conservation and protection.

22.9 Research on the wood resource

Lack of trained staff, shortage of equipment and out of date logistics are all issues which must be addressed and to some extent this has been included in the FRMP Environment Management programme with the introduction of information and planning and environmental management branches at departmental level.

Fundamental Research:

Whilst applied research is the ultimate goal fundamental research cannot be excluded and this is carried out by BFRI as described in Part 1 Section 9.2.

BFRI has a number of Permanent Sample Plots in the Sundarbans. Some 12 plots were established in 1977 after the recommendation by the International Engineering Company (1977, ODA 1985) and these have been remeasured at intervals, including by ODA, and by Latif *et al* in 1990/92. At that stage a further 12 were established, and a further 3 in 1993. These plots are circular plots and are 37' in diameter, an area of approximately 0.04 ha. The plots are very small, especially for such diverse forest.

These plots could be used in a number of ways. It would be possible to use the PSP's from the IDB to develop biometrical models that are necessary for the planning system and then use the BFRI PSP data as independent test data.

Participation of other organisation should be encouraged so that by sharing the use of ecological monitoring stations there could be considerable economies of scale and the FD would not only save in expense but would benefit from increased access to information from multi-disciplinary research. The principle should be that all data sets are available to all workers as this will facilitate model integration and a better understanding of the ecosystem.

Applied Research:

The problem that the Forest Department faces, like forest managers throughout the world, is how to integrate the various fundamental research studies into practical resource management..

There is a primary need for an essential subset of models to be developed and incorporated into the planning system. The best data base at present is that derived from the PSPs and for the immediate future it is recommended that FD should continue to remeasure and develop this data base.

The decree that no official harvesting should take place in these plots should be maintained and stressed. The plots should be remeasured at least every 5 years, and preferably every 3.

A useful adjunct would be to establish satellite PSP's adjacent to a few of the existing PSP's in the more uniform ecological forest types, but separated by appropriate sized buffers. These plots could be silviculturally treated in different ways to provide data from a wide range of forest conditions. For example, in a series of satellite plots in a basic Sundri-Gewa area conduct treatments as follows:

- Harvest all Sundri > 20 cm dbhob
- Harvest all Gewa > 5 cm dbhob
- Take out small Sundri in order to see if the growth of the larger Sundri is accelerated
- Remove all small Sundri and Gewa from the under storey to see if the under storey is affecting stand growth and how.

It will also be necessary to establish research trials in the plantation areas so that firm recommendations about the future of plantation management in the Sundarbans can be made.

Obviously in such a difficult working environment it is highly desirable that all available research effort be concentrated on topics considered by all concerned departments and agencies involved in integrated management to satisfy primary management and planning objectives. Obviously a fundamental goal is to avoid duplication of effort, share information and integrate data in a unified IDB system.

23 MANAGEMENT OF NON - WOOD RESOURCES

Management of non-wood resources, as underlined throughout this plan, is integral to the sustainable management of the entire mangrove ecosystem. Although component parts must be understood and are analysed separately they are linked in every respect not only together but in management planning of production and protection zones under the direction of the CCF, Conservator Khulna and the DFOs..

23.1 Improvement to the management structure, organisation and systems

It is unfortunate that despite the fact that non-wood resources and their products (NWFPs) are now more valuable in economic and social terms than wood resources, the existing management arrangements are virtually non-existent. This plan offers strategies to rectify this and sets out guidelines to facilitate integration of non-wood resource management in systems and organisational reforms. These should be considered within the institutional framework options described in Section 26.2.1. At the departmental level the following matters should be considered:

- Staff and systems management : what staff and what new methods are needed for each product to be measured, harvested and monitored? This plan considers options for each main resource and in regard to integration of staff functions to avoid duplication and streamline operations.
- What inter-sectoral structure and co-ordination mechanisms can be arranged between resources?
- Initially it is essential to have accurate inventory data, a clear indication of existing and likely levels of demand and ways for predicting levels at which harvests may be sustained in perpetuity.

Some of these data are already available, some will be derived from the FRMP inventory and much more will be obtained in future surveys. Fundamental to management planning is having up to date information to answer the following key questions for the resource base :

- What are the resources?
- What is their distribution?
- Who is harvesting them, when and where?
- How abundant are they?
- What is their rate of growth or mean density levels?
- How are they being utilised? What level is the harvest?
- Can they continue to be harvested at the present levels?

Without answers to these questions it will be difficult to formulate plans for sustainable management and all future research should be geared towards supplying requisite information.

23.2 Non-wood resources

The current statuses of non-wood resources and NWFPs were described in Part 1 Section 11. Whilst they include all products, services and leases not derived from the wood resource they are conveniently classified in the broad categories of plant-based resources and animal resources with a further division, which assists organisational planning, into resources of the terrestrial and aquatic environments.

23.3 Plant-based resources

23.3.1 Golpatta

The most important plant resource is Golpatta currently managed under the Golpatta Working Circle. There is a general lack of reliable inventory data on distribution, area, stocking and growth rates. It is therefore essential that assessments of the Golpatta resource are made during the FRMP inventory.

Simple growth plots could be put into make estimates of growth and yield.

In other parts of the world, notably India and the Philippines, Golpatta is cut completely and no leaves are left on the stem. Trials should be set up to see which treatments are the most productive.

It is also clear that the current practice of trimming the leaves down to size is very wasteful. This might cease if golpatta is sold on a standing crop basis or alternatively new rules could be enforced requiring removal of the entire leaf.

23.3.2 Other plant-based resources

Other plant based resources receive scant management under existing systems and it is recommended that new responsibilities should be arranged at Range level to ensure that each resource receives more than simply revenue control. Detailed distribution mapping, seasonal changes in phenology and inter-resource planning should be prepared. The principal plant resources are described in Part 1 and listed below:

- Hantal ***Phoenix paludosa***
- Bhola ***Hibiscus tiliacus***
- Ulu Sungrass ***Imperata cylindrica***

- Nal grass ***Eriochloa procera***
- Hogla ***Typha elephantina***
- Malia sedge ***Cyperus javanicus***
- Cane
- Medicinal and aromatic plants

Each must be inventoried and harvesting regulations introduced to mainstream ecosystem management.

23.4 Animal resources

Animal resources from both the terrestrial and aquatic parts of the ecosystem now constitute the most valuable sources of commercial produce and have by far the greatest development potential (Mitchell, 1995). All are wild by nature and receive no management of any sort at the moment other than as a source of revenue. The main resources are described in Part 1 Section 11 and are listed below:

- Fish
- Dolphins
- Snakes
- Deer, wild boar, tiger
- Shrimps
- Molluscs
- Turtles
- Monitor lizards
- Honey and wax
- Crabs
- other wildlife

23.4.1 The Fishery

Management of the Sundarbans fishery involves issues which affect the wildlife sanctuaries, forest resource conservation, socio-economics, international boundaries and border area agriculture. **This matter involves many agencies and areas well beyond the SRF. It is not a case of giving foresters more training in another specialised field or of developing a new division with a multitude of skills overlapping with other institutions but a matter of integrating existing complementary functions, skills and responsibilities to mutual benefit.**

The fishery resource includes commercially important finfish as well as shrimps, oysters and crabs, values for which have escalated enormously in recent years. Obviously several administrative, management and research issues must be resolved and it is recommended that early attention be paid to setting up a sub-committee to establish a course of co-ordinated management involving all agencies concerned with:

- Straddled fish stocks especially ***Hilsha ilisha***, ***Lates calcarifer*** and shrimps which have part of their life cycle outside the mangrove forest.
- International trespass in marine waters.
- Migratory seasonal fishermen in particular winter visitors to SRF from Chittagong and elsewhere.
- Management of shrimps, crabs and oysters
- Conservation biology, harvesting and post-harvest treatment.
- Practical measures to increase the minimum sizes of fish and shrimps caught.
- Further assessment of closed seasons and their enforcement.
- Integration of research and monitoring data collection and sharing of information between the Forest Department, Fisheries Department, Fisheries Research Institute, universities and regional fisheries projects.

It is recommended that since little reliance should be placed on indirect estimates of current yield (Smith, Khulna University, 1995) independent validation of fishermen's catches should be made in follow-on fishery research.

Added to this it is recommended that an improved system of record keeping at Forest offices should be introduced which would help future assessment of numbers of fishermen, gears and catches.

Future yield:

Estimates of optimum yield made by Chantarasri (1994) can only be treated as provisional. Ideally, catches of all species should be held at current levels until more data are available. Efforts should be made to reduce the size of the catch of those species identified as being overexploited. For species in which gross overfishing is occurring the imposition of minimum size limits would eventually lead to increased yields without an increase in fishing effort. Better estimates of future optimum yields for the fish and crustaceans in the SRF can only be made when more reliable data have been collected and for a greater number of species. It is recommended that this matter should be included in one of the priority follow-on research projects.

A prominent feature of the SRF fishery is that, for as long as records have been kept, the size of the fishery has been expanding. The expansion of the fishery will need to be controlled if fish and crustacean stocks are to be conserved for the future. Without control, recruitment overfishing will occur and stocks of the currently most heavily exploited species will begin to crash. Fishermen will then begin to target other, currently less desirable, species and under increased fishing pressure these populations too will crash.

Ideally the fishery should be managed by increasing the size of fish and crustaceans at first capture and restricting the numbers of gears in the fishery. Size at first capture can be increased by setting minimum size limits for each exploited species and/or increasing the mesh size of nets. Regulation of size at first capture and mesh size should enforced by random inspection. A subsidised net replacement programme may be more acceptable to fishermen. The size of the fishery could be controlled by limiting the number of weekly gear licenses issued by the Forest Office.

It is recommended that measures to regulate the SRF fishery by the introduction of closed seasons and protected zones should be considered. The migration of fish and crustaceans from sanctuary areas into the surrounding overfished waters would enable the fishery to be sustained. Identification of stocks "belonging" to the SRF could readily be done using electrophoresis and this should be investigated by working with the Fisheries Department and the University of Khulna.

A summary of recommendations is provided below to assist integrated fishery management:

- Collect monthly length-frequency data for commercially important species.
- Age fishes using hard structures, otoliths and scales to provide an alternative to length-frequency data.
- Collect length-weight data for commercially important species and use the constant b, defined in the IRMP, in the length-weight relationship to monitor the body condition of fish stocks over time.
- Obtain data on size and age at maturity for commercially important finfish and crustaceans.
- Record the distribution of fish species including seasonal changes in the SRF along with details of their age/size.
- Calculate a correcting factor to adjust for bias inherent to indirect data.
- Make an independent assessment of the numbers of fishermen, fishing gears and catch composition.
- Collect data on the catch size and composition of the offshore set bag-net fishery.
- Determine where and when ***Hilsa ilisha*** that pass through the SRF spawn.
- Identify different fish stocks and their movements in and outside the SRF using electrophoresis.
- Collect figures for mesh size of pangash gill nets and other gill nets.
- Research the effects of capture by rod and line on the survival of ***Macrobrachium rosenbergii.***

- Introduce a minimum catch size for ***Lates calcarifer*** of 30 cm TL and 10 cm TL for ***Johnius argentatus***.
- Restrict the numbers of hilsa gill nets, pangash gill nets and gill nets operating in the SRF or endeavour to keep to current levels.
- Endeavour to hold exploitation of commercially important species (except ***Penaeus monodon*** fry) constant at present levels.

It is recommended that for straddled stocks and species which spawn outside the SRF, either in the open ocean such as ***Lates calcarifer*** or upstream ***Hilsha ilisha***, stock management control over the entire life-cycle of the stocks should be introduced. Without this control, decisions made for the rational management of stocks while in the SRF are at risk of being violated when fish are outside the SRF. Regulatory powers should be established by co-ordination of responsibilities between the Forest Department and Departments of Fisheries and Agriculture.

23.4.2 Wildlife

Wildlife, in its inclusive meaning applied to all plants and animals normally wild by nature and not domesticated. It constitutes the largest single component of the ecosystem yet it is little understood and wholly undervalued. The resource was studied by Tamang (1993) this report and the wildlife management plan contained therein should be referred to for further information. The resource base is described in Part 1 Section 11.4.

Until recently there was no staff or budget dedicated to wildlife management and the position remains ambiguous. With the establishment in 1994 the Environment Management and Nature Conservation Division (DCCF in Dhaka) and appointment in Khulna of a DFO Environment and Nature Conservation with three ACF's who are responsible for the SRF Wildlife Sanctuaries a new approach was introduced. It is now recommended that early implementation of wildlife management, conservation and research programmes should be instituted in consultation with the IMC and with particular regard to:

- Definition by the CCF and DDCF Environment Management and the Conservator, Khulna Circle, of areas of responsibility and integration of activities of all the DFO's working in the SRF especially overlapping functions which stem from the Forest, Wildlife and Fisheries Acts.
- Finalisation of wildlife sanctuary extensions.
- Training of staff connected with wildlife management.
- Implementation of the outline wildlife management plan.
- Follow up on research especially the ecology of the tiger, spotted deer, wild boar, muntjac and crocodile populations.
- Ensure integration of management, protection, research and monitoring activities with other forestry and fisheries staff and link data collection, storage and analysis with the continuous survey teams, GIS and IDB data bases.
- Establish biodiversity conservation priorities in collaboration with IUCN and with due regard to NEMAP and the NCS.

Wildlife management should place particular emphasis upon man-eating behaviour of tigers, tiger management and tiger research. All vulnerable and endangered species must be properly studied and practical measures taken to stop the ongoing decline in their statuses.

Furthermore it is recommended that to standardise the classification of protected areas and the manner in which they will be managed in the future, early consideration be given to changing the status of Sundarbans West Wildlife Sanctuary to National Park. The feasibility of establishing a Jungle Camp or the Conservation Centre/Eco Village at Mandabaria might be undertaken at the same time and it is recommended that these matters should be high priority by the FD in Phase 1 of the TYDP for tourism.

Protection:

Wildlife is ostensibly protected by a total ban on all killing or capture of animals other than fish, crabs, shrimps and oysters under the Wildlife Act 1973 by GOB Notice Sha - 2/MOEF- 61/90/91 dated 08 August 1990. Despite these measures there is said to be a pattern of declining biodiversity, loss of species, notably at least six mammals this century and that the "ecological quality of the original mangrove forest is declining" (IUCN, 1989). Since it is well known that spotted deer, monitor lizards, dolphins, python and turtles are killed and sold in local markets (MARC, 1995; Grepin, 1995) it is strongly recommended that specific research should be undertaken to quantify the level of illegal off-take as a first step in reversing this wasteful situation.

Field Research Programme and Monitoring:

Additional research should be directed by the DFO Environment working towards the following objectives:

- Improving knowledge of all major species populations and habitats.
- Sustained yield harvesting.
- Biodiversity management.
- Re-introductions.
- Deer ranching and captive breeding of crocodiles.
- The illicit trade in wildlife products.

It is recommended that the wildlife research should be conducted in close co-ordination with the forest mensuration team and in consultation with IUCN. Logistics should be shared as far as possible especially costly transport and radio communications equipment and all data should be stored and analysed in the IDB.

Much work needs to be done and it is a well known fact that research activities provide a benign form of control over illegal activities such as poaching and unofficial timber removals. The following topics should be given priority attention in follow-on activities:

Flora and Fauna inventories:

Presence and absence studies should be undertaken using continuous survey techniques. Inventories and distribution of flora and fauna should be added to the IDB and GIS data bases. Data on distribution, immigration and emigration, relative density, habitat preferences, predator-prey relationships, life tables of harvestable species and seasonal changes, are still virtually unknown and should be worked upon by the DFO Environment in close collaboration with Khulna University and DFO Sundarbans.

Ecology of Tigers:

The tiger is included in the IUCN Red Data Book of seriously endangered species and the survival of the species is threatened throughout its range. The Sundarbans population (in Bangladesh and India combined) is probably the largest surviving population of Bengal tiger. This population is a source of fear and pride and is of enormous national and international significance. It is now completely isolated and not well understood by laymen or scientist alike. It is by far the most important large mammal species in the country and with its high profile deserves decisive action to determine its status and to introduce positive management and conservation measures.

Whilst it appears that the population is not declining (Tamang, 1993) with all population estimates in the last 20 years remaining in the range 350 - 450 animals, future investments in wood and non-wood resource harvesting, research and monitoring and tourism will require a much better understanding of the behavioural ecology and physiology of this population.

It is strongly recommended that the proposed FD tiger autecology study be implemented by an in-depth study of this unusual population using remote sensing and other advanced research techniques, starting in the Katka/Kachikali area, as soon as possible with particular regard to :

- Ethology
- Physiology
- Population structure

The SRF tiger population is part of what is probably the largest single gene pool of the species and warrants international co-operation in Project Tiger or the Global Tiger Forum which aims to secure the future through international action and co-operation.

Ecology of other priority species:

It is recommended that further priority studies be conducted on spotted deer, barking deer, wild boar, otters, fishing cat and rhesus macaque as part of on-going surveys to properly understand the ecology of some terrestrial species populations. This work should be selectively extended to predator-prey relationships, smaller mammals, aquatic mammals and large reptiles, monitor lizard, python, turtles and crocodiles.

Vegetation Studies:

Vegetation studies at the association level have not been carried out and it is recommended that a full botanical survey be made out leading to the analysis of the plant community types and re-confirmation of floristic composition of vegetation types. Permanent sample plots, enclosures and fixed-line transects should be studied over a long period to determine the stability or otherwise of associations and successional changes in relation to major environmental factors outside and inside protected areas. This could be an area for collaborative work between the Forest Department, IUCN, BFRI and Khulna University.

Saltwater (Estuarine) Crocodile:

The saltwater crocodile ***Crocodylus porosus*** population has depleted to a critical point. Every effort should be made to conserve and manage the SRF population and to do this the FD should take a lead role in collaboration with IUCN. It is recommended that:

- Sapla khal and Bhadra Gang should be closed to fishing and other traffic to stop disturbance and protect nesting sites.
- A crocodile expert should be recruited for six months to study the prospects for raising crocodiles in captivity to help increase the wild population and to establish a commercial crocodile farm. This could be a private sector venture and a feasibility study should be made for crocodile farming outside but near the SRF.

Consumptive Utilisation : Future Possibilities for Sustained Yield Harvests:

Most wildlife-based tourism is a non-consumptive means for using wild resources to benefit human populations but consumptive utilisation on a sustained yield basis might also be considered in order to make better use of the natural surplus of animals previously referred to by the FD as 'game' animals. This would accord with the primary objective of integrated resource management, to achieve optimal exploitation of the forest resources without disturbing ecological balances and that multiple use management of the Sundarbans could provide increased opportunities for people's participation in wood and non-wood cottage industries.

Consumptive utilisation of the wildlife resource in the SRF on a sustainable yield basis, other than in terms of commercial farming of deer has seldom been discussed yet there is an on-going harvest not only of almost all wildlife of which crabs and shrimps are regarded as revenue earning produce but other even more valuable species such as crocodiles, turtles, monitor lizards, snakes, deer, wild boar and probably tiger are harvested entirely outside the law. The hunting of wildlife is supposed to be regulated under the Bangladesh Wild Life (Preservation) (Amendment) Act, 1974 and under Section 26 (1)(A)(g) of the Forest Act XVI 1927, it is an offence to remove any forest produce without permission, including evidently all wild animals.

Tiger's claws and python and monitor lizard skins have been found for sale in Dhaka. Within the SRF and vicinity there are recent records of illicit harvesting of deer, dolphins and turtles. Enquiries at Munshiganj revealed that it would be easy to obtain spotted deer meat at the market.

Tamang (1993) reports on the apparent viable statuses of the tiger, deer and wild boar populations and the precarious state of the crocodile population. Since there is a significant natural surplus of deer and wild boar and each year tigers continue to kill human beings, there could be a case for exploring the potential for controlled consumptive utilisation of these species as part of a sustainable yield harvest from a healthy natural resource, which is currently neglected.

Whilst licensed hunting of wild game animals, is often an emotive subject and tiger is deemed to be an endangered species listed in CITES Appendix 1, it is nevertheless incumbent upon those who have responsibility for optimising returns from areas where viable populations of game animals exist, to consider objectively all options for their utilisation. This is especially important for areas like the Sundarbans where incomes are low and opportunities for regular employment are scarce.

Options:

- Keep the status quo : turn a blind eye to illicit off-takes and hope that in due course improvement in capacity for management and control will help achieve better protection of species and further limit benefits which at present are obtained by people through illicit harvesting.

- In essence the resource is illegally exploited by a narrow group of people, up to the limit achievable under existing policing, but the return is not quantified. Ultimately more and more resources are committed annually to law enforcement, often working against the best interests of the rural poor who derive some benefit from the illicit harvest which carries on unmanaged and covertly. In the case of crocodiles this has had a serious deleterious effect upon the population, almost wiping out one species and bringing another to the verge of local extinction to join the other five or six large animal species already eliminated.

- Confine utilisation to non-consumptive photographic tourism. Usually a pastime enjoyed by the relatively well off and the foundation for the proposed model.

- Include the economic value of game animals as a natural resource with a potential for proper management and harvesting on a sustainable yield basis. Introduce controlled harvesting techniques, which would provide the optimum spread of benefits, and potentially significant economic returns. Where tourism is involved, the financial return per tourist is up to ten times the yield per photo-tourist. Big game hunting commands a 'daily' rate in some countries up to 1500 $US per day and this discounts the value added yield in the by products part of the industry.

Promotion of sustainable consumptive utilisation:

- Issue hunting permits under Section 47 (2)(d) of the Wild Life Act, in harmony with a pre-determined land use zoning scheme. Arrange for properly trained Forest Department guides, ensure local employment of shikaris, skinners and other staff and monitor taxidermy and by-product usage. Develop a small but valuable export industry round the by-products, skins, horns, teeth, bones, hooves etc.

- Establish 'game farms' and obtain a harvest by scientifically organised culling which could include trophy hunting. Deer farming outside the SRF was rejected by Tamang as theoretically possible but not practical.

- Establish a small-scale 'trophy hunting' industry based upon controlled harvesting of spotted deer and wild boar initially on offshore islands such as Putney or plantation chars near Kuakata. There is a well-established international market constantly seeking new destinations for trophy hunting even when the number of species is strictly limited. It might also be feasible to introduce limited bird shooting on some of the Haors near Sylhet where it is understood that sustained yield harvests might be possible.

Crocodile farming:

Establishment of crocodile farms outside but near the Sundarbans should be given further consideration and a feasibility study is probably justified. Crocodile farming could have multiple benefits of:

- Introduction of a small-scale industry which could supply raw materials to the growing export-orientated Bangladesh leather industry.
- Make a practical contribution to the conservation of one, perhaps two species, of critically endangered crocodiles through easing pressures on wild populations and providing a source for re-introductions.
- Provide employment.
- Help achieve multiple use of land and water resources by integrating crocodile farming with fish or poultry production.
- Provide a potentially highly lucrative long-season tourist attraction.

FAO has executed successful crocodile framing projects in a number of countries including India, Indonesia and Papua New Guinea (Whitaker 1988; Bolton, 1989). Experience from these projects would be invaluable in helping create a new industry which would benefit the wildlife of the SRF and tourism.

Deer Farming:

Deer farming is another possible source of employment diversification and income generation and could make significant contributions to other industries in the private sector such as tourism, crafts and the leather goods. Farming ***Axis axis*** could be combined effectively with sustained yield harvesting from wild populations. It is recommended that these matters should be studied for feasibility in the follow-on phase by a captive animal breeding expert.

Captive deer, kept under cramped conditions at Karamjal Forest station opposite Mongla Port already attract over 50 000 visitors a year and it is recommended that this site be developed as a pilot wildlife breeding centre. Karamjal Animal Breeding Centre could provide opportunities for tourism, captive animal breeding studies, training and on a full commercial basis, be the source of stock for deer farms. All this will relieve pressure on wild animals and make a positive contribution to the economy.

This recommendation has been included in the Ten-year Implementation Schedule as part of the SRF development plan. There has been successful reintroduction of spotted deer in Nijhun Dweep plantations and there has been a successful deer breeding programme at Dhaka Zoo. This indicates that there is every possibility for successful and commercial management of deer. Any future project should utilise the experience gained at the Zoo and other deer management projects implemented in the country. Apart from Karamjal othe nearby sites could be found at Bagherat, Khulna University and Jessore.

FAO's position on wildlife as food is discussed in Sustainable Development and the Environment, 1992 p 53 "... major efforts should be made to assess, manage and utilize these resources with a view to their inclusion in national economic development plans ... management systems and technologies should be developed...and the additional income from sport hunting and recreation is an added benefit...conservation for its own sake does not work".

The idea that such activities are not feasible because of a lack of control is contradicted by the fact that by the same token it is argued that a total ban on hunting game animals is enforceable. If this is true then it must be equally true that controlled off-takes are also manageable.

"There can be no long-term future for wildlife or protected area management where local people are antagonised. Instead, they should benefit from the management of these resources and have a vested interest in their conservation as sources of food and income". (FAO, 1994)

Wildlife Management Plan

A plan aimed at protecting important species and improving their habitats should be implemented as far as possible under the auspices of the DFO Environment and additional investment and technical assistance are proposed in Section 27.1(5).

Early consideration should be given to the following management issues:

- The Sundarbans Wildlife Division

  The area of responsibility of the Sundarbans Wildlife Division following the FRMP should be the same as that of the Sundarbans Reserved Forest. Wildlife by definition is free by nature and has no boundaries and its management should reflect this as far as practical. From the point of view of integrated management any fragmentation must be avoided.

- A Wildlife Working Circle

This was established within the Forest Department in 1977 with responsibility for wildlife and nature conservation and was headed by a Senior Conservator of Forests responsible directly to the Chief Conservator of Forests . This initial development was setback when the Wildlife Development Scheme (1977) was abandoned "in the interests of the economy" in 1982. It is recommended that the staffing, housing and equipment provisions for the Environment DFO, Khulna in the FRMP, should be organised and put into operation as intended under the FRMP without further delay and dual management systems should be avoided as far as possible. For example the radio network should be shared and jointly organised.

Proposals by Tamang (1995) for deployment of staff, their responsibilities, Conservation Stations, a Nature Conservation Centre, field research and captive breeding of deer and crocodiles should be given immediate consideration by a Wildlife Sub-Committee.

Ten year management programme:

Tamang's (1993) detailed proposals for a Ten-year Management Plan for the Sundarbans Wildlife Division should be studied by in conjunction with the FRMP and new recommendations on zoning, sanctuary extensions and protected areas should be acted upon as soon as possible.

The plan includes :

- Staff
- Operations
- Training
- Capital building works
- Equipment
- Operational budgets

Organisation and implementation should be carefully co-ordinated by the Conservator, Khulna Circle and capital and expenditure budgets to permit the DFO Environment to eliminate current ambiguities and carry out his responsibilities for conservation and wildlife.

The DFO Environment would be responsible for day-today administration and would handle the following tasks:

- Staff
  Staff recruitment, deployment and terms and conditions of work, leave, salaries, discipline
- Transport (boats and vehicles) and equipment
  Procurement, drivers, maintenance, insurance, fuel, records, office equipment and furniture
- Financial control and budgets
  Estimates, budgetary control, petty cash account, bank account, financial statements, audit
- Records
  Administrative correspondence, confidential files, legal matters, disputes, non-expendable equipment inventory
- Reports
  Monthly activity report, annual reports, financial returns, visitor statistics
- Meetings etc
  IMC etc
- Attendance, minutes, follow up, action
- Liaison with technical departments, NGOs and POs
- Task forces, integrated plans and action, public relations

The main management functions of the FD wildlife staff should be elaborated in the Annual Operational Plans and should include the following:

- Conservation:
  Patrolling and field records
  Ranger meetings
- Extension:
  IEC work in the community
- Protection:
  Law enforcement
  Routine checks on activities
  Routine surveillance
- Visitor management:
  Control of entry
  The Visitors' Centre and Interpretative Programme
  Guiding
- Range Management:
  Surveys of statuses of vegetation types
  Control of harvesting
  Habitat statuses
  Species protection
- Estate management:
  Maintenance of buildings, jetties, tracks, paths, bridges, drains, camping sites, sign boards, boundary markers
  Surveys of boundaries for demarcation and maintenance
- Development programme:
  New buildings, sign boards, trails and boundary demarcation
- Wildlife Management:
  Observation and protection of breeding sites of endemics and threatened species
- Research:
  Follow through with co-ordination of applied research programme
- Monitoring:
- Evaluation and up-dating of operational plans:
- Annual up-date of the Workplan

Zoning is crucial to wildlife management, species protection and habitat management. These should be key objectives for the DFO Environment within, but not exclusively, the area which should be designated as the SRF Protection Zone. The spatial and conservation needs of production forestry, wildlife management, tourism and genetic resources management should each be kept under constant review and zoning requirements adjusted as necessary.

The Sundarbans Wildlife Division should divide its activities within five management zones under the overall administration of the Conservator, Khulna Circle and DFO, Sundarbans Division and be managed by the DFO Environment. The extent and operational plans for wildlife management will depend upon and be modified in relation to agreed prescriptions for zones described in Section 23.4.2 as follows:

(1) Strict Protection Zone

(2) Production Zone

The whole of the Sundarbans Wildlife Division outside sanctuaries and fishery protection areas could overlap with other activities and would be in the production zone managed for sustainable production purposes by the Sundarbans Forest Division. The wildlife resources in the production zone will be under the management of the Wildlife Division working in close collaboration with the DFO Sundarbans..

(3) Tourism Zones

Designated areas within the wildlife sanctuaries and in parts of the Production zone should be managed for research, wildlife viewing and low volume ecotourism and high volume domestic tourism. These should include sites of special scientific or historical interest which should be managed accordingly, such as the ruins of Shekertek in Compartment 39.

(4) Intensive Use Zones

Several smaller areas in sanctuaries and elsewhere which are essential for buildings and gardens to meet the needs of the management staff such as forest stations should be included in this category.

(5) Marine zone

This will include the offshore fishery and the proposed Sundarbans Coastal and Marine Protected Area (SCMPA) for coastal conservation and integrated biodiversity management, discussed in detail by Grepin (1995).

Legislation and Regulations:

- Legislation

The Bangladesh Wildlife Preservation Act 1973 provides for establishment and management of wildlife sanctuaries and other protected areas. The Divisional Forest Officers under the direction of DCCF's and the Conservator, Khulna Circle should define suitable regulations for management of zones, sanctuaries and other Protected Areas. The definition of "Wild Life " itself should be reviewed. Under existing legislation invertebrates and fish are excluded. It is recommended that a more inclusive definition be considered.

Wildlife means : All plants and animals, which are normally wild by nature and not domesticated; some feral organisms could be included in special circumstances.

Although the 1973 Act provides for the issue of hunting licenses the current prohibition on taking wildlife precludes issuing of licenses. There is potential for revenue earning through sustained yield harvesting. This and the ongoing illegal offtake suggest that wildlife utilisation should be researched and reviewed as a matter of urgency. The restriction on hunting should continue until the law and its enforcement and the gains to be achieved by relaxation of the ban, can be technically reviewed.

Sanctuary Regulations:

The following regulations should be considered for sanctuaries as an early consideration by the Wildlife Division for enforcement by the DFO Sundarbans and DFO Environment :

- Visitor use and scientific research are permitted only under permit granted by the DFO, Khulna.
- All visitors must report to the sanctuary staff on first arrival at the sanctuary.
- No hunting.
- No cutting of any vegetation.
- No burning of natural vegetation, except as part of a prescribed management measure.
- The bringing of firearms, nets, traps, poisons or explosives into the sanctuary is prohibited except for official security reasons;
- The bringing of dogs, cats or free ranging domestic animals and the introduction of any exotic wild animals or plants is prohibited;
- Special permission is required for the collection of scientific specimens from protected areas or the undertaking of commercial photography anywhere in the SRF. This administrative function should remain with the DFO, Sundarbans who may share this administrative function with the DFO Environment, Fees for commercial photography in the SRF should be ordered by MOEF on the recommendation of the CCF.

Boundaries:

All boundaries of the SRF and zones should be delineated and demarcated including the Marine and Border Zones. With the advent of fast moving vessels and high values placed upon so many of the products of the SRF, the scale of abuse of the restriction on entry and the law of trespass on which the FD relies, should be studied together with rationalisation of controversial parts of the SRF boundary, during the follow-on phase.

These matters, vital to the good organisation of forest management are not the concern of the FD alone. They are very much part of integrated resource management and some parts of the boundary, notably the western and south-western sections would need referral to a commission at inter-ministerial level for legal interpretation and ratification. There are five matters of immediate concern :

1. The National boundary along the western edge.
2. Shared marine waters boundary - 12 nautical miles.
3. The SRF boundary rivers - landward shoreline, middle line or forest inner shoreline. The Curtis line or the ODA line or something else.
4. The Wildlife Sanctuaries - how much water to be included.
5. The Border Zone.

FAO/UNDP PROJECT BGD/84/056, KHULNA, BANGLADESH

INTEGRATED RESOURCE DEVELOPMENT OF THE SUNDARBANS RESERVED FOREST

MAP SHOWING THE TOP-DYING AREAS

Scale 1 : 500 000

Km 4 2 0 2 4 6 8 10 Km

LEGEND

- Land/Water Boundary
- Sand Bar
- International Boundary
- Reserved Forest Boundary (after Curtis, 1928)
- Severly Affected Top-Dying Areas (ODA main report, 1985)
- Range Office
- Forest Station
- Wildlife Sanctuary Office
- PSP location (approximate)

CREATED BY: FAO/UNDP

F.I. Khan, 25.09.1995

The wildlife sanctuaries were established in 1977 under Article 23 of the Wildlife Act. Provisions of the Act prohibit trespass, cultivation of land, damage to vegetation, hunting, introduction of domestic or exotic species of animals and the setting of fires. Rights of residence are not mentioned *per se* but residence is prohibited through application of the rule on trespass.

Integrated wildlife management implementation programme:

Integrated management of the wildlife resource will require phased development as follows:

Implementation of the FRMP nature conservation programme ➧ introduction of co-ordinated research and monitoring in a new SRF management structure within one of the three proposed options ➧ research and monitoring ➧ further investment in training, development of institutional capability, Project Tiger, captive breeding programmes, consumptive utilisation and re-introductions ➧ integration of multi-sectoral management and research.

23.4.3 Apiculture

Honey collection from the SRF is a major seasonal activity and was reported on by Zmarlicki (1994) who made recommendations for improvement to harvesting and post-harvest activities. His report should be studied for information on specific production techniques. The status of the resource is summarised in Part 1 Section 11.5.

Honey and beeswax production is a major seasonal activity employing some 2000 gatherers known as Mowallis and producing about 200 t of honey and about 50 t of beeswax according to FD records which constitutes approximately 50% of the total production in Bangladesh (Zmarlicki, 1994).

The socio-economics of this small but valuable industry was studied by MARC (1995) resulting in new estimates of annual production of honey in 1994-95 was 600 tonnes and that the wax produced in the same year was 150 tonnes. This equates to over 16 000 maunds of honey and 4 000 maunds of wax indicating a substantial under recording of honey removal and substantial under-realisation of revenue.

At present there is little capacity to manage the resource other than on a purely seasonal revenue collecting basis through control by the FD of the sale of individual honey collecting permits accompanied by the manipulative activities of money lenders and middlemen.

Honey collectors are permitted to enter the Forest on the 1st of April every year to collect honey from nests of the migratory wild bee ***Apis dorsata***. Unfortunately, spurred by the need to collect as much honey as quickly as possible since man-eating tigers seem to selectively prey on wandering honey gatherers, all nests whether ripe or unripe are harvested. This wasteful practice destroys newly established colonies and thereby reduces honey production.

To increase the production of honey in the Sundarbans Reserved Forest, Khulshi ***Aegiceras corniculatum***, Goran ***Ceriops decandra***, Keora ***Sonneratia apetala*** and Passur ***Xylocarpus mekongensis*** should be recommended for reforestation and afforestation assuming that silvicultural direction can be obtained on suitability of sites and cost effective methods for propagation, tending and management.

Future management should concentrate efforts on the following :

- The inflexible procedure of strict adherence to the 1st of April entry date pays no heed to ecological imperatives bound more by seasonal changes in flowering periods of nectar producing plants than administrative expediency. It is found that frequently the Forest is entered too early in the flowering season thus causing honey collection before it is ripe. This procedure should be replaced to one which is linked to the flowering period of plants important to honey production. See table 46.
- The Beekeeping Manual produced as part of this plan should be translated into Bangla and distributed amongst Mowallis and their families living in the 10 Km border zone and

amongst those living in the same area who are small-scale honey producers and wish to improve techniques and production;

- Honey production and processing affords one of the few avenues immediately available to assist disadvantaged social groups, women in particular. Since much of the honey collected in the SRF is badly handled and it is often taken to be of inferior quality, the establishment of a pilot plant for processing honey and rendering beeswax established in the Khulna area could make a useful contribution towards poverty alleviation and value added activities based on Sundarbans produce. The equipment obtained by UNDP through BGD/84/056 should be immediately set up and operated jointly with suitable NGO's and user groups for this purpose.

Improvement to management controls:

The disparity in data on production and harvesting indicates a lack of control since routine monitoring is unable to take account in any way of recent trends of multiple resource harvesting by individuals. It seems unlikely that this trend will change and that new more participatory approaches will be needed to help regulate production and harvesting, especially in the links between honey collectors, fishermen and shrimp fry catchers.

23.4.4 Tourism and recreation

Prospects for the development of the SRF for tourism and recreation were reported upon by de Vere Moss (1993) and this report should be studied for further details and be referred to with this plan. The assets on which the industry could be based using SRF resources and the various approaches to the subject are summarised in Part 1 Section 11.6.

The ecological, historical, administrative and economics aspects of tourism and the SRF were reviewed. The past situation, the present and a plan for the future, based upon a model "Sundarbans Camps and Lodges" operation have been described. Recommendations are made for the FD, as sole administrative authority for the SRF at the moment, to be the executing and controlling agency and for operations to be either joint ventures or by Private Sector concession holders.

The results of the study indicated that profitable tourism could be established in the SRF and that this would be a source of revenue for the FD and, with ancillary small-scale industries such as crocodile farming, would generate substantial economic activity as well as employment opportunities for men and women and disadvantaged social groups.

Tourism development scenarios should be considered during the policy making phase:

- Carry on with the present *ad hoc* arrangement and hope that tourism will evolve in the normal course of events.
- Permit expensive 'tourist complex' mass market developments.
- Aim for environmentally friendly semi-permanent construction of camps and lodges linked to high quality water-borne transportation and accommodation.

This plan recommends scenario (3) as the best option which provides the best all-round prospects for sustainable tourism and integrated resource development.

A desire to establish tourism in Bangladesh has been demonstrated for many years, featuring a first Tourism Masterplan for the period 1965 to 1985 and a second Strategic Masterplan in 1985 (PKF 1985) for the ten year period to 1995. Following the latter, a National Tourism Policy was formulated in 1992. Bangladesh is a founder member of The World Tourism Organisation (WTO) established in 1975. Currently much political emphasis is being given to tourism as a potentially lucrative industry, in line with achievements in neighbouring countries in Asia.

The National Policy:

In any making any management planning decisions the process should be guided by national policies where the subject is of national importance. For the SRF this is clearly the case and the

National Tourism Policy guidelines states in its aims and objectives that the prime objective is to use tourism as a means for changing the socio-economic condition of the country and that tourism "should be considered as an industry". Also that, "in order to create interest among travellers to visit Bangladesh by marketing tourist attractions", (GOB/NTO National Tourism Policy, 1992 [2.2]) the following facilities will have to be developed within the country:

- Appropriate accommodation.
- Arrangements for safe transport within the country through road, river and airways.
- Eating and drinking arrangements.
- Arrangements for recreation.
- Arrangements for sightseeing tours.
- Arrangements for selling souvenirs and handicrafts.
- Arrangements for the safety of travellers and keeping regulations for movement within the country at a minimum level.
- Development of 'safari' tours and 'treetops' style lodges.

Any tourism development in the SRF should plan to fulfil the nation's stated aims for raising national income in foreign currency" (GOB/NTO 1992) and prepare an appropriate ground for employment through the tourism industry along the lines listed above and also by:

- Increasing foreign currency (forex) earnings by attracting foreign tourists.
- Increasing interest for tourism among the people and creating tourist facilities for them at a low cost [BPC].
- Taking steps for the alleviation of poverty by creating employment opportunities for greater number of citizens.
- Creating a favourable image of Bangladesh abroad.
- Opening an accepted field of investment for private capital.
- Creating recreational facilities for foreign tourists and local people.
- Developing handicrafts and cottage industries, consolidation of national solidarity and consensus through fostering and development of culture and tradition of the country.

In the past development of tourism was thought to be the almost exclusive responsibility of Bangladesh Parjatan Corporation (BPC) [the National Tourism Organisation (NTO)] and it is only recently that there has been a growing emphasis on full Private Sector participation.

Circuits:

Combining attractions in circuits discussed in Part 1 Section 11.6.6 maximises the use of assets. For example jungles and beaches; wildlife in one place combined with additions or contrasts in another; or tours which might have a strong bias in one interest which could be combined with another not only within the country but in multi-centre regional tours.

Combinations may emerge such as linking the mountains of Nepal with river cruising, mangrove jungles and beaches of Bangladesh. Locally, river cruising and jungles walks and jungle exploration by country boats in the mangrove forest might be combined with forest walks and the beaches of Teknaf. The history of one part of the sub-continent might be linked with the historical sites of another. The wildlife of the upper Brahmaputra might be linked and contrasted with the environment and wildlife of the mangrove forests.

Ecotourism:

For tourism designed to meet the needs of the ecotourist who is concerned with the integrity of the environment the following matters need to be addressed:

- What are the interesting environmental assets, flora and fauna in particular?
- How accessible are they? What is their distribution and status?
- What facilities exist for enjoying and learning about the environment?
- What is the future for the environment where attractions are situated? Is there any conflict with other users or in other plans such as timber extraction, the fishing industry, shrimp production, agriculture and pollution, illegal harvesting of forest and non-forest products,

uncontrolled settlement, flood control engineering works, or mining, which might damage the area's integrity?

These interests should be assessed during feasibility studies and incorporated in any development plan and which must include administrative, monitoring and control guidelines for resource allocation and end users.

Control systems and the Tourism Advisory Board:

Although the Forest Department controls tourism; control over rights of entry and commercial utilisation of resources, future control of new portals of entry eg. seaplanes, Munshiganj or from the south via the Baleswar river and development of more sophisticated tourism, will need help from some form of local co-ordinating and advisory body. Khulna would be a suitable administrative hub.

The composition of this body might be :

Chairman: To be appointed by the NMC
Secretary and Member: the Divisional Forest Officer, Khulna
Members:Senior Officer of Bangladesh Parjatan Corporation
Representative from the Mongla Port Harbour Authority
Representative from Archaeology Department
Representative from Department of Cultural Affairs
Representative from Tour Operators Association
Representative from IUCN by invitation
Representative from the Police Department by invitation

The terms of reference of the Committee might include:

- Advice on new legislation which will be needed to control tourism.
- Advice on policy as it might affect local communities.
- Advice on matters such as security, flood action control, and public health which might have ramifications outside the SRF.
- Advice on licensing, setting of fees and control of operators.
- Advice on tourism developments both inside and adjacent to the SRF which could have application beyond the SRF.
- Advice on co-ordination of actions of all parties connected with tourism in and around the SRF in any way in order to work towards a "common goal".

Potential for the Future - Development Criteria and Constraints :

Development of tourist attractions and recreational opportunities will depend upon the following which must be considered during the feasibility study phase of implementation :

- Does the site fall within the scope of the National Tourism Policy and Masterplan?
- Can the environment be enhanced in the interests of future tourists - all developments by definition involve some for of enhancement or physical modification.
- Will the development create a potential vested interest in environmental preservation - preservation and control are essential to sustainability and how much better if the developer recognises the need to protect the asset upon which he depends?
- What will be the environmental impact and will this be at an acceptable level-damage to natural systems, pressure on fuel supplies, socio-cultural effects, waste disposal problems?
- What will be the costs?
- What will be the returns? Who is going to benefit?
- Who will pay the development costs?

A ten Year Development Plan for tourism:

The destinations linked with the various circuits which apply fall within the long-term National Development Plan and potentials have fortunately not been obscured by past efforts and thus any developments will not be clouded by preconceptions.

The notion that the wilderness asset could be utilised as part of an integrated resource development scheme were borne out during studies for this plan and proposals are made for a phased strategy for the ten year period 1995-2004 which will gradually, but effectively, phase in environmentally and commercially viable tourism which can be built upon. A Model ten Year development Plan (TYDP) is proposed as part of this plan for implementation in the follow-on phase and this could be replicated elsewhere as need or occasion arises.

TYDP three phases :

- Phase 1 1994-1995 : A transitional period of two years during which time existing facilities at Katka and Nilkamal are extended and improved to international tourism quality and cost standards and high quality Jungle Camps constructed. During the same period a range of development sites and plans for them are considered and feasibility studies undertaken. Some of these will be accepted some will not.

- Phase 2 1996-1998 : A three year implementation period during which time the proposals made and accepted in Phase 1 will be implemented, construction undertaken and operations started. This is not a period of profit-making period but one for investment, development of the product and promotion.

- Phase 3 : A five year period for profitable operating, product enhancement and diversification. During this time the Sundarbans will become an internationally renowned prime destination taking a sizeable share of the special interest and ecotourism regional market. It will be acting as the catalyst for further developments of this nature at other locations in Bangladesh. This scheme is illustrated in Table 76.

Criteria:

The development criteria set are to optimise use of the wilderness asset with minimum disturbance to the environment - development without destruction - and these correspond with GOB policy on creation of forex enterprises, based on natural attractions, in which the Public Sector might invest in the short term with a view to "handing them over to the Private Sector" (Section 25.2 National Tourism Policy 1992) or in joint ventures or by the Private Sector alone.

Table 76 Sundarbans Tourism Proposed Development Schedule:

Ten Year Development Plan (TYDP)

(de Vere Moss, 1993)

OPERATION DESCRIPTION	1995-1996 Phase 1 2 Years	1997-1999 Phase 2 3 Years	2000-2004 Phase 3 5 Years
Improve existing facilities & operations for domestic & international tourists (FD,BPC,TOAB); build 2x Jungle Camps; extend Katka Jungle Lodge. Develop the 'model'.	==========➡ ————————	============	===============
Feasibility studies - site studies - accommodation - transportation - communications - tours	=========➡		
Marketing studies	===========		
Investment Plans	===========		
Contracts		=======➡	
Construction		=======➡	
Implementation and operations		=======➡	=======➡
SUSTAINABLE ECOTOURISM THE SUNDARBANS EXPERIENCE ➡	➡	➡	➡
Conservation Programme (FD) - forest management - wildlife management - fishery management - training guides - training escort guards - tourism regulation - tourism monitoring - extension education - interpretative services	========== ========== ———————— ———————— ———————— ———————— ———————— ———————— ———————— ————————	========== ========== ========== ========== ========== ========== ========== ========== ========== ==========	========= ========= ========= ========= ========= ========= ========= ========= ========= =========
Conservation Centre Development (FD)	——————— ➡	========= ➡	=========== ➡ ➡

————————	start up
=======	implementation
➡ ➡ ➡ ➡	direction of progress

Constraints:

A model is proposed for establishing a tour operating enterprise, bearing in mind specific constraints which apply to the SRF:

- Seasonality and climatic factors;
- Shortage of drinking water.
- Lack of power and telecommunications.
- Lack of hospital facilities.
- Distance to airports.

- Lack of a tourism "ethic" and trained personnel.
- Lack of infrastructure and staff for wildlife management and conservation of wilderness values.
- A fragile environment and difficult terrain.
- Unpredictable "hartals" or strikes which locally or nationally, bring business to a halt;
- Lack of a "common purpose" and institutional framework for the development of tourism in the SRF.

Within the design and implementation criteria of the model, every effort should be made to maximise employment opportunities, ensure participation by disadvantaged social groups and to identify opportunities for the participation of women. These are key objectives leading to socio-economic improvement envisaged by GOB in the Fourth Five Year Development Plan 1990-1995 which also aims to ensure improvement to the "technical capability of the national institutions operating in the SRF area".

Re-introductions, sport/trophy hunting and wildlife farming are all areas where research and pilot projects should be considered with the goal of improving utilisation of the wildlife asset. Each has its position in the totality of conservation tourism.

Sustainable Tourism:

Integrated planning must consider development criteria and constraints and keep these in view during the feasibility studies of TYDP Phase 1. The integrated resource development plan should help the tourist industry establish itself in the secure knowledge that the assets on which it is based will be protected in perpetuity.

Wildlife sanctuaries, their possible extensions; possible new sanctuaries and a national park; commitment to low volume high cost tourism; agreement to keep permanent property development outside the SRF wherever possible, and commitment to professionalising the industry, are all aspects which could foster the ideal set at the UNCED meeting in Rio de Janeiro in 1992 when the world endorsed the recommendation of the Brundtland Report that development should be sustainable : "meeting the needs of the present without compromising the ability of future generations to meet their own needs".

Conservation Centre for Sustainability:

For tourism to be sustainable, the resources on which it is based must be secure against degradation and wherever possible measures should be taken to improve their statuses. To achieve this, properly directed research, monitoring and management will be needed. Development of a Conservation Centre, Eco Village is thus proposed as one of the physical developments which could be managed as a private sector joint venture possibly by a conservation NGO working with the Forest Department.

The Conservation Centre, EcoVillage Development:

Those to whom this concept would appeal are :

- scientific workers researching on topics of value to the area and its inhabitants;
- science students helping with research;
- local and foreign visitors especially those seeking new 'Earthwatch' participatory field research destinations;
- local people seeking specific information;
- local employees working at the SRF and EcoVillage

Facilities would incorporate:

- accommodation
- conference and lecture room
- interpretation centre for visitors
- library
- environmental monitoring centre with LARST[1] or similar remote sensing capability
- research laboratory and meterological centre
- herbarium
- arboretum

Design:

- simple local design for exteriors echoing the 'Jungle Camp' style
- good quality facilities to international standards would apply to fixtures, fittings, management and service

Action to be taken:

- identify and agree site
- feasibility study in Phase 2 for commercial viability
- finance, probably joint venture with international organisation
- make early advertising to find suitable management
- conduct proper marketing study

Cost : the feasibility study should be done by a professional organisation and there are precedents for international donor funding up to (ECU 60 000) US$ 75 000 for this purpose.

A Visitor's Guide to the Sundarbans Reserved Forest:

A most important contribution to tourism would be the production of a handbook covering ecology and visitor facilities of the SRF. This should be a professional publication and would provide an excellent opportunity for collaboration between the FD, the tourism industry and the Private Sector. The handbook preparation could become an assignment for a future Warden of the National Park and publication costs might be borne by a large multi-national company or perhaps as part of Biman's or BPC's contribution to conservation.

The handbook would be a source of interest for all visitors and would provide a small source of revenue and publicity.

The Visitor's Guide should cover:

- Description of the SRF and protected areas and history.
- Flora and Fauna, giving brief descriptions of important species and habitats.
- Items of special cultural interest such as festivals, otter fishermen, traditional fishing techniques etc.

- Description of facilities and their locations.
- Description of SRF circuits and loops.
- Maps.
- Check lists and animal spotting charts.

Forest Department's role in tourism:

A major consideration will be the function of the Forest Department not only as a regulating and controlling body but in its role as the agency responsible for conservation of wildlife and natural resources.

Nature conservation and wildlife management are the responsibility of the Forest Department. Since the SRF incorporates a significant proportion of the country's wildlife resources (See Table 16), it can be anticipated that a substantial effort will be made to introduce effective administration of this aspect of integrated resource management.

Any input that will be made to help conserve habitats and species, manage the sanctuary areas, manage critical species such as tiger, crocodiles and turtles, implement re-introductions and provide monitoring, interpretative and extension services, can only benefit tourism and should be welcomed and encouraged.

The Forest Department has a vital and professional role to play in development of tourism in the SRF. Whilst it is clear that it should not attempt to run touristic enterprises it should train and appoint staff to handle regulations, controlling, monitoring and interpretative functions. These would include the following:

- Control of entry and collection of Entry Permit fees. .
- Calling for sealed bids or tenders for Concession Licenses with no obligation to accept by the Department acting on behalf of GOB. Rights to operate tours in the SRF should not be undersold since these should become a source of hard currency revenue for the FD and should also reflect the economic value of the forest's tourism assets.
- Regulation of methods and areas of touristic operations in accordance with pre-determined and agreed rules.
- Enforcement of Conservation Laws.
- Provision of properly trained Escort Guards and SRF Guides. This would be a public Sector Service for which payment might be made by operators and proper training facilities established by the FD.
- Provision of interpretative literature, video tapes, maps etc for use by operators and the general public.
- In the first phase of development of tourism the Department would be the 'Executing Agency' as envisaged in the Model Development Plan and it is considered that this role is appropriate and that, given the right GOB support, it is well within its capability.

Recommendations for management planning:

- It is recommended that at the national level, setting of standards, regulation and monitoring should be a GOB responsibility and that relevant Government departments and BPC especially should endeavour to enforce regulations to help improve performance within the tourism sector.
- For the SRF the Forest Department should be the regulatory and enforcement agency and should set up an administrative organisation to attend to conservation and wildlife matters in the sanctuaries and proposed national park.
- The FD in the SRF operates under exceptionally difficult circumstances on a revenue budget of less than 40% of an international standard of costs for vulnerable species conservation alone. Tourism and wildlife conservation will inevitably make further demands on the Department's resources. It is recommended therefore that structure and costs should be carefully reviewed to reconcile essential administrative responsibilities

and their costs. Sustainability will be possible only if administration, regulation and monitoring are properly funded.

- The specialist requirements of personal security and anti-dacoity action in particular should be determined through consultation with the Bangladesh Navy, the Coast Guard and river police and appropriate combative initiatives implemented as soon as possible.
- Training of Forest Department staff for activities connected with tourism such as acting as escort guards for wilderness trails, guides, community extension workers and special interest tour group ornithologists will require specialised training outside the mainstream of forestry. It is recommended that staff who will be inducted into the conservation and wildlife wing of the Department should be given specialist training outside Bangladesh assuming that the resources are not available within the country.
- Escort guards, who will accompany small groups on the wilderness trail between Katka and Kachikali, should receive training by experienced trail leaders working with them for at least one season before being permitted to escort tour groups in the SRF. New rifles of calibres exceeding .375 magnum and special firearms training will be needed. This work should on no account be left to guards who are not skilled shikaris and who have not got proven knowledge of the behaviour of tigers.
- FD staff should not be allowed become involved in lodge management at any level other than those who may be needed for dangerous animal escort duty or for specialist interpretative services, such as guiding round forest management operations or wildlife sanctuaries or working at the ECoVillage and Visitors' Centre.
- It is recommended that study tours be organised for those who may be involved in the development of the Sundarbans Experience Jungle Camps and Lodges project : one to Chitwan in Nepal and Kanha and West Bengal in India and the second to Egypt, Kenya and Zimbabwe in Africa. These would provide exposure to similar operations as proposed for the SRF and would also give a broad insight into the activities of the competition.

24 OTHER NON-WOOD PRODUCTS - SPECIAL MANAGEMENT CONSIDERATIONS

There are some non-wood products with associated activities which receive little attention or are not yet of any great commercial significance but which should be included in operational plans. These have been discussed in Part 1 Section 11.7 and are covered in more detail in Shiva (1994). Further research is recommended in conjunction with suitable NGOs with a view to expanding cottage industries and finding new employment for small-scale users in the Border Zone as follows :

- Charcoal and Briquetting
- Tannins and Dyes
- Mushrooms and other edible plants
- Aromatic plants and oils

Provision should also be made to be aware of demands for rights to collect clay for pots, river sand and even oil and mineral exploration rights.

Likewise professional legal advice should be sought at the time that tourism facilities are developed on land leases and management agreements, operating concessions, filming rights and special permits to operate commercial enterprises within the SRF.

25 SUNDRI TOP-DYING, PESTS AND DISEASES

Pests and diseases of plants and animals were studied briefly by Rahman (1993), Ciesla (1994) and Chowdhury (1995). Most efforts were concentrated on the Sundri Top-dying syndrome and Chowdhury investigated the role of invertebrates. These reports should be referred to for further information.

Pests and Diseases:

Severe insect depredation calling for preventive or control measures were not detected by Professor Chowdhury during his recent study on the entomology of the SRF. Maintenance of biodiversity is expected to keep the population of injurious species within acceptable limits.

Investigations did not reveal any causal relationship between Sundri Top-dying and insects. Insect attacks, in most cases, were found to be of a secondary nature affecting diseased and weakened trees and hastening their death and decay.

Severe infection of Sundri, Gewa, Baen and Passur by molluscan borers was detected. An intensive search for extent of damage on submerged wooden structures and live trees is deemed necessary.

The Sundri top-dying phenomenon:

This is a subject which has been of great concern to the FD for a considerable time because of the loss in timber value which occurs as a result of the condition. Generally it is felt that the cause is likely to be a combination of factors outside anyone's control. Thus the matter resolves to discontinuing expenditure of scarce resources looking for the cause about which nothing can be done but more on making the correct harvesting and stock management decisions.

Nevertheless a summary is provided of factors connected with the syndrome for reference and to help in making silvicultural management decisions.

Some of the causal factors which have been discussed in relation to Top dying of Sundri include:

- Reduction of fresh water supply due to upstream diversion resulting in increased salinity and reduced flow of nutrients.
- The moratorium on tree felling between 1972 and 1976.
- Occurrence of a gall canker caused by the fungus, ***Botrysphaeria ribis***.
- Infestation by a wood boring beetle, ***Chysocroa*** sp. (Coleoptera: Buprestidae).
- Tree damage resulting from cyclones.
- Variation in the depth and frequency of flooding.
- Siltation.
- Normal senescence as part of the phenological cycle.

Rahman (1994) investigated the status and causes of Top dying of Sundri and key findings included :

- Descriptions of the symptoms and causes of a number of diseases and disorders of trees in the Sundarbans are provided for the first time. Of particular interest is the detection and diagnosis of two conditions which may have previously been confused with Top dying of Sundri. One is the occurrence of localised areas of "massive" dieback and mortality of Sundri, due to siltation and inundation of the pneumatophores. The second disorder is infection of roots by the fungus, ***Ganoderma lucidum*** which causes death of trees in small groups.
- Top dieback of Sundri is clearly the most serious disease problem affecting the forests of the Sundarbans.
- A high incidence of sapwood decay caused by fungi was found in Top dying and dead Sundri. These fungi have not yet been identified and their role in the Top dying of Sundri is still unclear.
- There is presently a high incidence of Top-dying of Sundri in at least 4 compartments in addition to those reported by the ODA inventory. This indicates that the condition may be expanding over a wider area.

Pre-disposing factors:

Long term factors such as low soil nutrients, unfavourable site conditions, presence of root decay fungi, inadequate moisture or low levels of air pollution which place trees and forests under stress.

Inciting factors:

Sudden, short term events which place trees under an additional stress and incite symptoms of decline or dieback. Examples of inciting factors include; outbreaks of defoliating insects, drought, excess rainfall, deep freeze events or high levels of environmental pollutants.

Contributing factors:

Biotic factors such as weak pathogenic fungi, bark beetles, wood boring insects which are capable of overcoming trees weakened by the predisposing and inciting factors and eventually kill the tree. These are often easily recognised and incorrectly designated as the primary causal factor.

These factors are set out in Table 77.

Table 77 Summary of factors which could result in Top-dying of Sundri

PRE-DISPOSING FACTORS	INCITING FACTORS	CONTRIBUTING FACTORS
Relatively low tolerance to salinity Nutrient poor soils Reduced water flow due to upstream diversion resulting in: Lower rates of delivery of alluvium and organic matter. Increased salinity. Presence of tall trees susceptible to wind damage	Frequent storms and tidal surges Defoliation of Sundri by high winds. Deposition of marine sediments. Mechanical injury to standing trees.	Invasion of wounds by decay fungi and the gall canker fungus, ***Botrysphaeria ribis.*** Wood boring insects eg ***Chrysocroa*** sp.

(Ciesla, 1994)

Current felling and extraction policy for Top-dying Sundri

Felling and extraction of Sundri affected by Top dying in selected compartments is one of the few exceptions to a current moratorium on timber harvesting in the Sundarbans. According to (Rahman 1994), approximately 16% of the Sundri affected by Top dying in these is totally dead. The wood is degraded by fungi and insect attack and is no longer suitable for timber production. This material can be used only for hardboard production and commands a much lower price.

Of particular interest is a decay caused by unidentified fungi which cause a white sap rot. Of the total volume of wood harvested during the course of the Sundarbans Sundri Top dying extraction program from partially dead Sundri, 42.7% has been degraded. The combined volume loss from degrade in dead and partially dead Sundri exceeds 50% of the total volume harvested under this program. This represents a significant economic loss.

Random extraction of Top dying trees is also in potential conflict with conservation of cultural resources. These sites have historical value and are attractive to tourists such as the Shekertek Temple in Compartment 39. The site dates back some 500 years and is a unique asset where timber felling should be very selective or not at all.

Conclusions on the Top-dying Sundri phenomenon

- Neither the symptoms nor its distribution in the Sundarbans or the fact that it has been reported since the early 1900s is consistent with increased salinity due to recent upstream diversion. While salinity cannot be totally disregarded as a causal factor, it cannot be regarded as the sole cause of this disorder.
- The spatial distribution and severity of Top dying of Sundri could be successfully mapped in low level aerial survey. Periodic aerial surveys of the Sundarbans would provide valuable information on changes in the status of this condition at a reasonable cost.
- Most of the Forest Department PSPs have a low incidence of Top dying of Sundri when compared to the 1983/84 ODA sample plot classifications of severity of this disorder. Use of these plots for monitoring trends in this condition will therefore not provide data representative of changes which will occur in areas of high severity.
- Top-dying of Sundri fits within the definition of decline or dieback and is the result of several interacting abiotic and biotic factors.
- The present policy of felling and extraction of Sundri in areas of severe top dieback results in low recovery rates. In addition, present layout of timber extraction areas (coupes) does not take into consideration sites of cultural or historical interest.

Recommendations

- Information presently being collected on soils, hydrology, disease incidence and other disciplines should be analysed in an interdisciplinary manner to develop a forest model which defines the key factors that influence susceptibility of stands to Top dying of Sundri. This may require specialised expertise in multivariate statistical analyses and mathematical modelling(Leech,1995).
- Pending availability of a suitable aircraft, conduct aerial sketchmap surveys over the Sundarbans a minimum of every two years to map the spatial distribution and intensity of Top dying of Sundri. Surveys should be flown using a high-wing aircraft. If available, an aircraft equipped with float devices should be used. Conduct aerial surveys from an average flying height of 300 meters above the terrain along east west flight lines spaced at intervals of approximately 4 km. Damage classes for aerial mapping will have to be defined based on the visibility of damage from the air. Use aerial sketchmap surveys to detect other forest damage in addition to top dieback of Sundri such as defoliation or mechanical injury from severe storms.
- Establish a data theme in the project GIS for storage, analysis and retrieval of locational data on top dieback obtained from aerial surveys. Store data for each survey (year) as a separate data theme. Use these data layers to determine change in the status and distribution of dieback over time.
- Based on aerial survey information, establish a series of supplemental PSPs in areas of known concentrations of Top dying of Sundri to acquire information on changes in:
    - Number of trees and related volume in various top dieback classes.
    - Status and condition of natural regeneration by species and height class.
    - Salinity of soil and water at different periods of the year.
    - Condition of other tree species associated with Sundri.
    - Continue to investigate the role of decay fungi, particularly sapwood rots in the onset of top dieback. Identify the mechanisms through which sap rotting fungi gain entrance to trees, the rates of decay and site and stand related factors which might predispose trees to decay.

- Maintain a historical record in the GIS of the location and dates of timber harvesting operations for removal of Top-dying Sundri. This will provide valuable information on the rates of recurrence of top dieback in areas which have been harvested.
- Identify areas of cultural and historic interest in the Sundarbans such as shrines, temples and other sites and store locations in the project GIS. If such sites are located near or within areas affected by top dieback, establish buffer zones around the sites where no timber extraction will be done to protect the integrity of these sites.

Dieback and other diseases:

It should be part of the forester's day to day routines to keep a watchful eye on severe incidences of pathogenic conditions and disease amongst plants and animals. There are few records in the literature on this subject and future surveys should make full use if the IDB for records of occurrences of significance. The following conditions were reported on by Rahman (1994) :

- Dieback of Passur ***Xylocarpus mekongensis***
- Dieback of Keora
- Canker and dieback of Goran
- Heart rot
- Mistletoe (**Loranthaceae**) and epiphytic infections
- Creeper damage
- Wood decay fungi
- Dry rot

26 INTEGRATED RESOURCE MANAGEMENT PLAN

26.1 Requirements

In order to carry through the proposals made in this plan policy decisions should be made to establish the institutional arrangements and financing strategies that will be required during the early implementation phases.

The unifying theme throughout has been to demonstrate the difference between earlier working plans and an integrated resource management plan which accommodates holistic ecosystem management giving equal emphasis to all resources and to the associated human population.

This plan examines the findings of the specialists who studied the status of the mangrove ecosystem. The results of their work and the recommendations they made together form the keystone for the integrated strategy and guidelines for management and development.

The pressing requirement is to identify the common thread and co-ordinate the functions and linkages between the several resource bases and management systems. The strategy is shaped by the conclusions reached on the following:

- The ecological changes in the ecosystem.
- The statuses of the various aquatic and terrestrial resources.
- The effectiveness of current administration and management systems.
- The requirements for environmentally and socially sustainable development.

A synthesis of these is provided in this plan but further details must be obtained in the technical reports themselves, listed in Appendix A3.

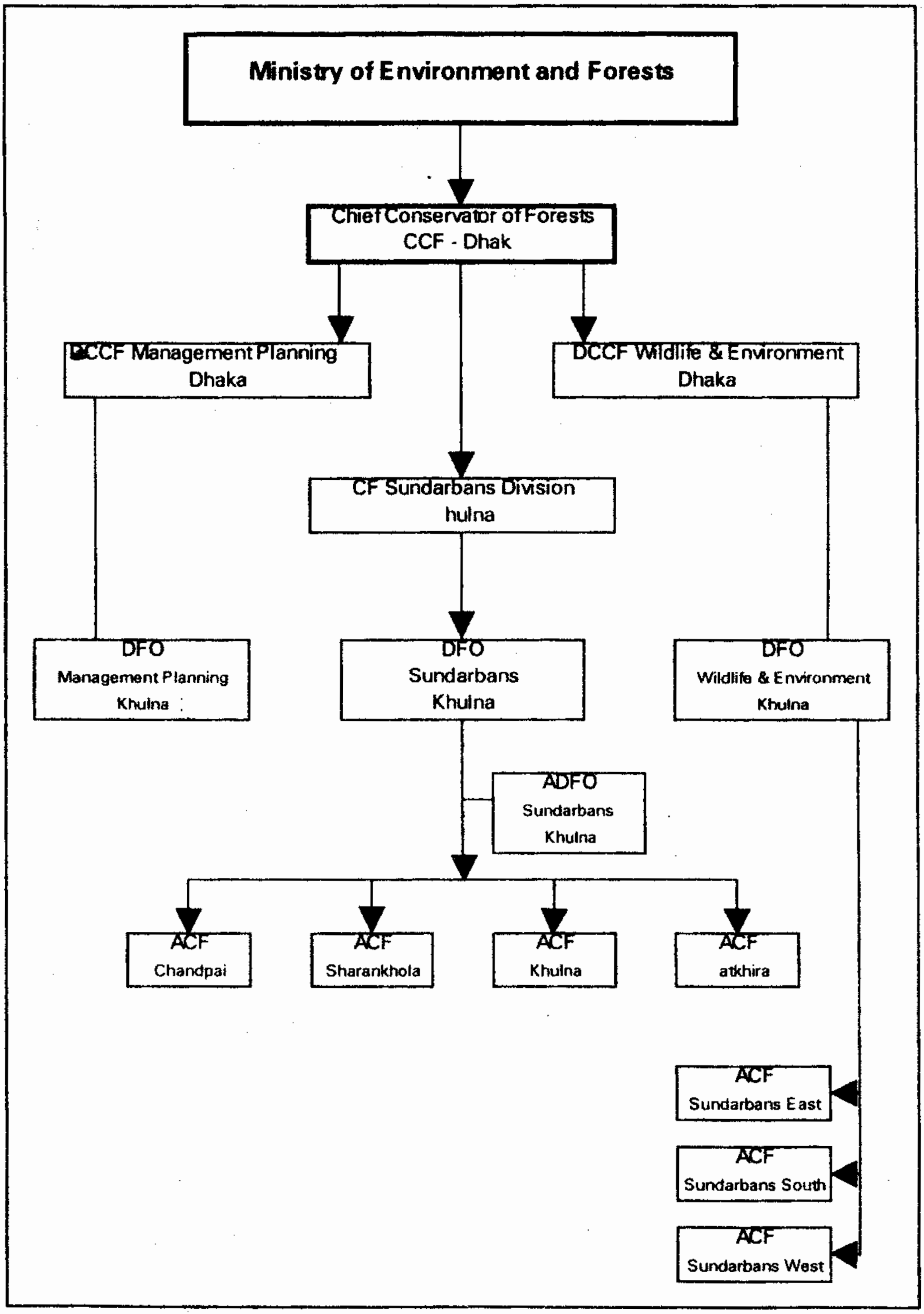
Implementation of the plan is based on an objective view and does not attempt to go beyond offering scientifically sound proposals and recommendations.

On the one hand there is detailed new evidence on the status of the forest's wood and non-wood resources but for the timber stocks this was hampered by a lack of an up to date inventory. Data gaps are identified and discussed for future research. There is a thorough analysis from more than one perspective on the possible approaches to interdependent multisectoral integrated systems management. All are viewed as parts of ecosystem management as opposed to only timber resource management.

The main question for any policy and accompanying practical strategy to enhance sustainable development and to improve employment opportunities, incomes, nutrition and other benefits to local people, with particular focus upon women and disadvantaged groups required in the terms of reference for the plan, was to see what can be done within the existing system to attain these goals, some of which are local, some national and some international. If the existing system is inadequate then what can be done realistically to reform and improve the system? What are the technical, financial, and social requirements and constraints what will be the likely consequences of the proposed implementation plan in the short- and long-terms?

Proposals for introduction of improvements to management and production have been made for each resource independently and these should be examined as required but the ability to manage all in a cohesive and balanced manner depends wholly upon the institutional and financial arrangements to follow. The SRF by law is an administrative responsibility of the Forest Department and its ability to do this has been reviewed concurrently in the analyses made of the environment, harvestable resources and socio-economic factors.

Figure 5 Current Sundarbans Division Staff Structure



26.2 The institutional position

The structure and organisation of the Forest Department as a whole and for the SRF in particular has been described in some detail in Section 8.1. The staffing structure of the Sundarbans Division is presented diagrammatically in Figure 5 and the broad functions can be summarised as follows:

- A law enforcement body receiving its authority from the Forest Act, 1927.
- Management of the various resources and selling the produce and the rights to exploit them on behalf of the nation.
- A planning, research and monitoring organisation.

It is generally accepted that the institutional framework of the Forest Department has a number of weaknesses. For example the Forestry Masterplan (1992) states that it is not considered rational to have the enterprise and law enforcement functions within any one organisation. Different internal rules and regulations are required. Added to this the organisation's work quality and effectiveness is hampered through of a lack of qualified manpower, deficiency in specific technical skills, lack of incentives and the lack of resources to be able respond to new demands (Rahman, 1995). It is therefore apparent that institutional reform and investment are needed if the SRF is to be managed better and this has been reported on in detail by Mitchell (1995).

The current management system is deficient in some key areas mostly attributable to inadequate funding over the years but some are intrinsic to the system itself. The issues are summarised as follows:

- **The technical management of the ecosystem is outmoded and continues to place most emphasis on timber and wood products, with little management or planning effort put into non-wood resources, the environment or the community.**
- Emphasis of management is on revenue collection *per se* and not on sustainability.
- There is a lack of integration with other concerned agencies and departments with whom appropriate collaboration is needed to strengthen technical capacity.
- The removal of produce tends to be inaccurate and the full economic values are not realised.
- The system does not provide for adequate consultation with user groups.
- Resource users face many hardships involving both the environment and an insensitive social and economic environment within in which they are compelled to work for their livelihoods in which they play no part in decision making or management.
- Even though the SRF contributes much more than it costs to the exchequer each year, it has not been possible to obtain essential capital and recurrent funding to improve terms and conditions for staff and nearly all infrastructure and equipment now requires up-grading, replacement and modernisation.
- There is little continuity of management with key staff being transferred every second or third year.
- Staff are poorly motivated with low pay scales and difficult, often dangerous, conditions of work.
- Reporting and accounting procedures are inaccurate with poor data storage and retrieval facilities.
- There is inadequate transparency and public accountability.
- The existing system does not provide the information base required for management planning.

To improve management various options for development are suggested. Whichever way is chosen, a feasibility study will be required beyond the scope of this plan. The goal is to reform management into a multi-sectoral organisation giving support to the FD and to the communities living in the border zone.

Assumptions are made which are common to all options. For example a silvicultural trial programme will cost the same whichever option is chosen and as such represents a separate sub-project included in plans for future investment. Each option assumes that current FD infrastructure, fleet of launches and vehicles and nearly the whole network of field offices require replacing. However, it is a corollary that further investment in development should only be contemplated if this will result in a more equitable return to disadvantaged user groups and to the Nation.

Common features are :

- That the change must be permanent and that the new organisation must be wholly supported by GOB or be self financing and not dependent on donor finance; new funding mechanisms should be devised.
- That by improving efficiency, accountability and transparency, the return from the resources of the SRF will be nearer the full economic value thus justifying the increased expenditure on management.
- That all the options must develop the capacity of the FD to continually collect data and monitor the resources so that an updated integrated database is available at all times for the preparation of management plans. Accurate data are essential if the resources are to be managed to the intensity required to ensure optimum use, sustainability and conservation.
- That the recommendations regarding changing the FD revenue system will be implemented to achieve the expected increase in revenue.

The first scenario - Option 1- improves the existing management structure by up-grading the Department's technical capabilities and providing the capital investment for new infrastructure and equipment.

The second scenario - Option 2 supports the Forest Department as the pivotal organisation involved in managing and policing the reserve but at the same time it establishes the National Mangrove Steering Committee (NMC) and the Operational Unit (OPSUNIT) which will undertake inter-sectoral environmental monitoring, planning, research and capacity building functions. This option markedly differs from the first in that it draws in expertise of other departments and agencies where the FD is not traditionally skilled.

A third possibility is to introduce more radical adjustments but the consensus to date favours investment, cross-sectoral expansion of FD functions and improvement rather than total transformation which would probably be socially and technically untenable. In any case all reform should be considered in the context of the need to maintain stability within the system which has endured for a long time against increasing odds.

It is proposed that implementation of operational management plans would be through the Forest Department's greatly strengthened staffing structure with multisectoral collaboration and support. The Department would need to recruit specialists to undertake management of an environmental research programme, fisheries, tourism and Border Zone livelihood projects and matters with regional dimensions such as marine zone protection and water pollution.

A national steering Committee for the Sundarbans:

The National Mangrove Committee is proposed for policy formulation, development and establishment of better financial regulation, independent ecosystem audit, law reform and to increase the degree of co-ordination and integration with other concerned ministries national agencies and people's organisations at the highest level. It would help the FD co-ordinate mangrove ecosystem management at all levels.

Management of the Sundarbans entails many technical functions including protection, management of production, monitoring and evaluation, research, management planning and implementation all of which now require a practicable capacity for the FD to be modernised and become more involved in extension and education and to assist community development in the Border Zone.

Within the scope of the two main options the Forest Department would be the main management agency for these functions and in Option 2 will have support and direction from the NMC and the comprehensive inter-sectoral role of the Operational Unit. In addition the NMC would rely on a local technical co-ordinating committee - the Integrated management Committee (IMC). This option clearly establishes a way forward within the FD for the proper integration of holistic resource management to meet new challenges.

Option I Improving the *status quo*

Rationale:

The FD has not had the necessary funding or backing to cope with growing demands. Inflexibility of the funding system has prevented operations which yield much more than they cost. It is proposed that the FD is provided capital for new equipment and that a revolving fund of sufficient size is established to allow profit making silvicultural operations to be undertaken, such as thinning and improvement felling, the proceeds from which would replenish the fund after the sale of the produce. Other sources of sustainable long-term finance will also be considered, such as returns from leases, tourism, levies on commercial shipping, off-shore exploration etc.

Proposed Structure:

The proposed structure of Option 1 is presented graphically as Figure 7. A new staffing arrangement is proposed and the entire staffing position of the Sundarbans Division would be rationalised. For example there is an out of date establishment of about 550 boatmen who are no longer needed to operate boats and they could be re-trained to become speed boat drivers, forest guards, engine men, hydrological survey assistants or skilled labourers.

If the FD management is to re-orient its approach away from control by issuing permits, more towards development objectives where it lacks expertise in many areas such as fisheries management, marine biology, hydrology, tourism and wildlife utilisation, it will need to recruit specialists in these fields. Further training of foresters from within the department is not viable; the skills are required immediately and it is a waste of funding if staff are trained twice.

The present system is unbalanced and there is too large a workload for a single DFO. In order to create a more balanced spread of responsibilities it is proposed that the Sundarbans Division is split, dividing the four ranges equally between two DFOs. A fifth range which will be responsible for the management of aquatic resources throughout the SRF will be established in association with the Fisheries Directorate. The Fisheries ACF will report directly to the CF.

In the present system, the DFOs responsible for Management Planning and for Environment and Conservation do not work directly to the CF Sundarbans but to two DCCFs based in Dhaka (see Figure 6). There is already a lack of co-ordination between sections resulting in widespread inefficiency. It is therefore proposed that the CF should co-ordinate all staff and resources including the DFOs Management Planning and Environment, wood and NWFP functions and research.

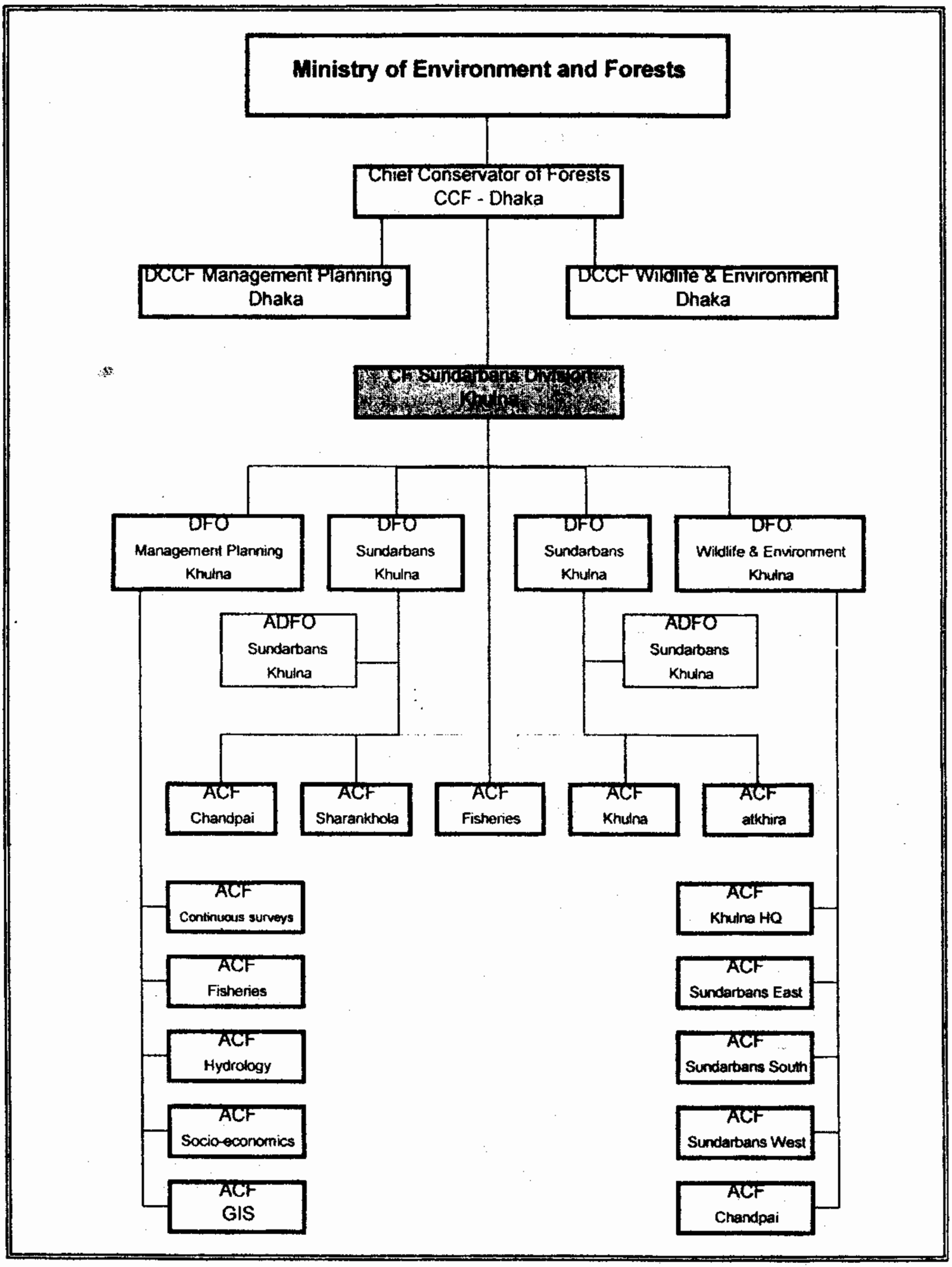
It is also required that the Department increases its technical capacity. It is therefore proposed that under the direction of the DFO Management Planning there should be a new echelon of specialists recruited that would collect data and be responsible for the preparation of management plans. Additional ACFs would be responsible for data collection as follows:

- Continuous surveys.
- Aquatic resources and fish stock surveys with the fisheries directorate.
- Hydrology with swmc.
- Socio-economics and extension services.
- GIS and IDB management.

There should be both external training and international technical assistance to augment technical capabilities. Specialist training and new staff positions should be contractually linked to long-term appointments to the SRF Division to overcome the problems caused by the intra-departmental transfer system;

The Environment and Conservation division should be boosted by the addition of two extra ACFs, one to be posted as a staff officer to the DFO and the other to be stationed at Chandpai.

Figure 6 Proposed Structure for Option 1



Infrastructure and equipment :

- The SRF field offices need replacing; 55 new permanent forest stations, 20 temporary forest stations, 5 permanent wildlife sanctuary offices and one nature conservation centre are required. It is estimated that the capital investment for new buildings would be about US$ 2.0 million.
- Nearly all the FD's boats are obsolete and must be replaced. There should be at least one launch per range, one for each of the DFOs and one for headquarters. At least 2 additional launches would be needed for surveys. The total replacement fleet is estimated at 9 launches, 5 survey vessels, 25 accommodation boats and 20 speed boats plus an estimated 11 new vehicles. The total transport funding required over a ten year period would be about US$ 6 million. This figure will be much higher if the Marine Zone is to be protected by the new organisation.
- Replacement firearms, an extended radio network, office furniture and computer equipment will be required at an estimated cost of US$ 1 million.
- Provision must be made for scientific and mensuration equipment and services, contractual services with the SWMC and new satellite imagery.
- There will be a need for additional overseas fellowships and training and also considerable on the job training. Short term international TA will supplement local requirements to provide advice, training and capacity building (not to actually undertake field management work which should be the function of national staff).

The investment cost estimate for Option 1 is about US$ 21 million over existing budgets for a ten year period.

Option 2 The Forest Department with the National Mangrove Committee and Operational Unit

Option 2 makes two similar proposals. 2A (Figure 7) and 2B (Figure 8) both of which propose continuity of the FD's role in implementing management operations but with realistic and practical changes to meet the demands of integrated resource management. The introduction of the National Mangrove Steering Committee, the local Integrated Management Committee and the Operational Unit (OPSUNIT) increases co-operation and collaboration with other agencies and provides a mechanism for policy co-ordination, direction and advice.

It is a tenet of integrated resource management that experienced technical agencies with specific skills such as civil administration, law and order, sociology, fisheries management and hydraulics are involved in the formation of policy and the promulgation of the necessary legal reforms. In Option 2B the position of the OPSUNIT is clarified by including this as a direct responsibility of the CF Sundarbans Division and the role of the NMC is emphasised by indicating its position more clearly at the highest level of Government.

The OPSUNIT will be a semi-autonomous body concerned with research and monitoring, continuous surveys, inventories, socio-economic surveys, preparation of management and operational plans, data organisation and resource utilisation analyses. The OPSUNIT will be directed by the Integrated Management Committee which will be chaired by the CCF and administered by the CF Khulna Circle.

Figure 7 Proposed Structure of Option 2 A

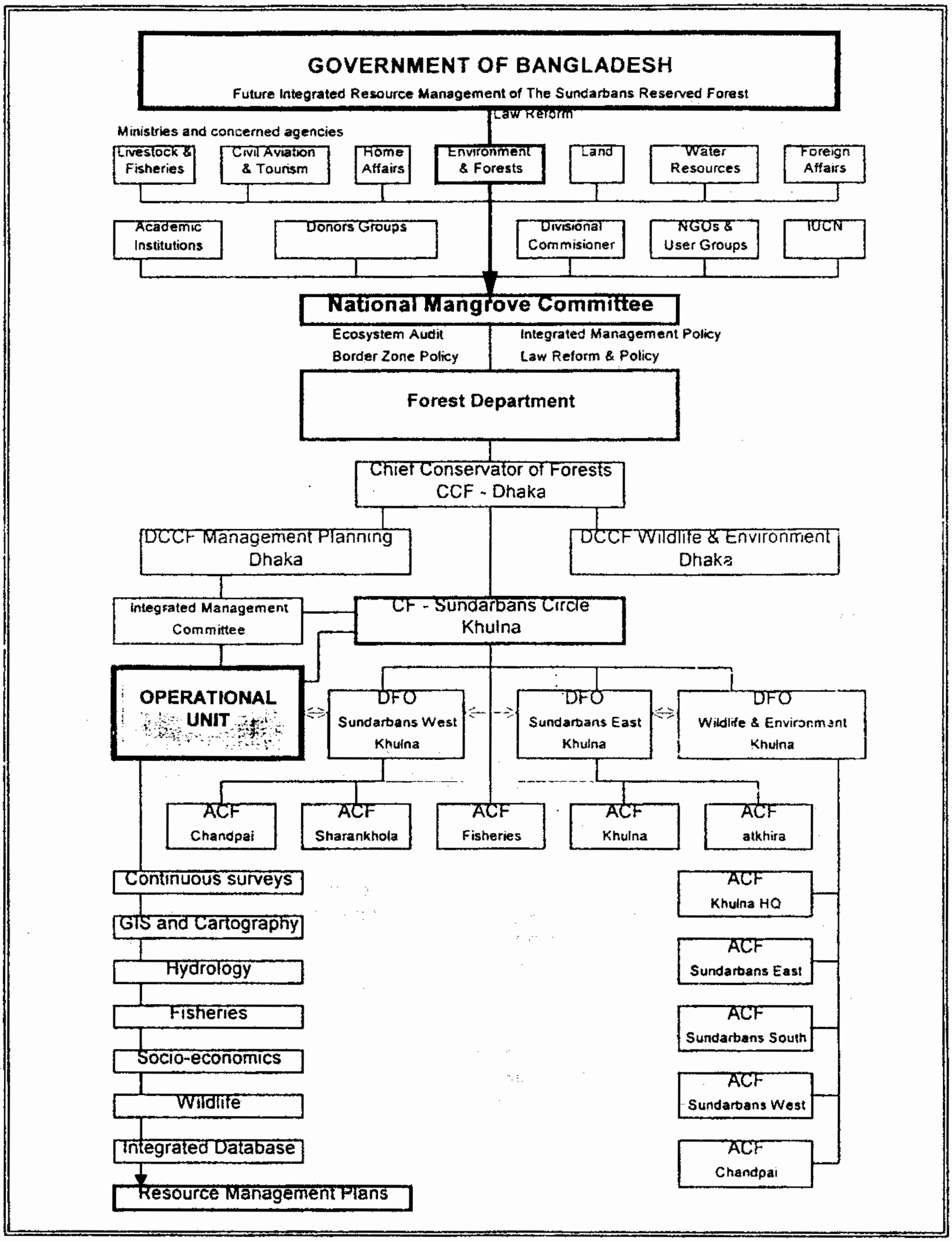


Figure 8 Option 2B

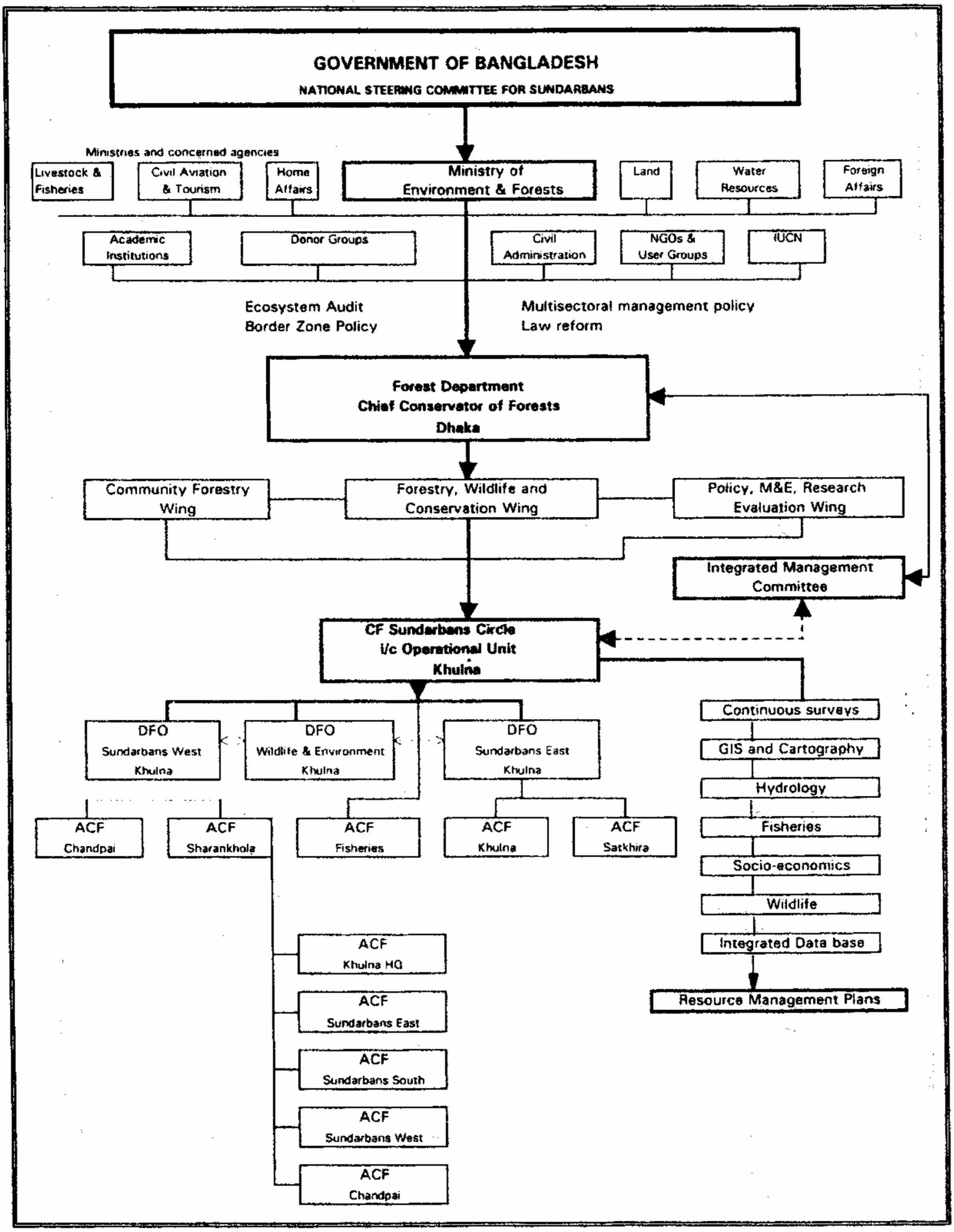
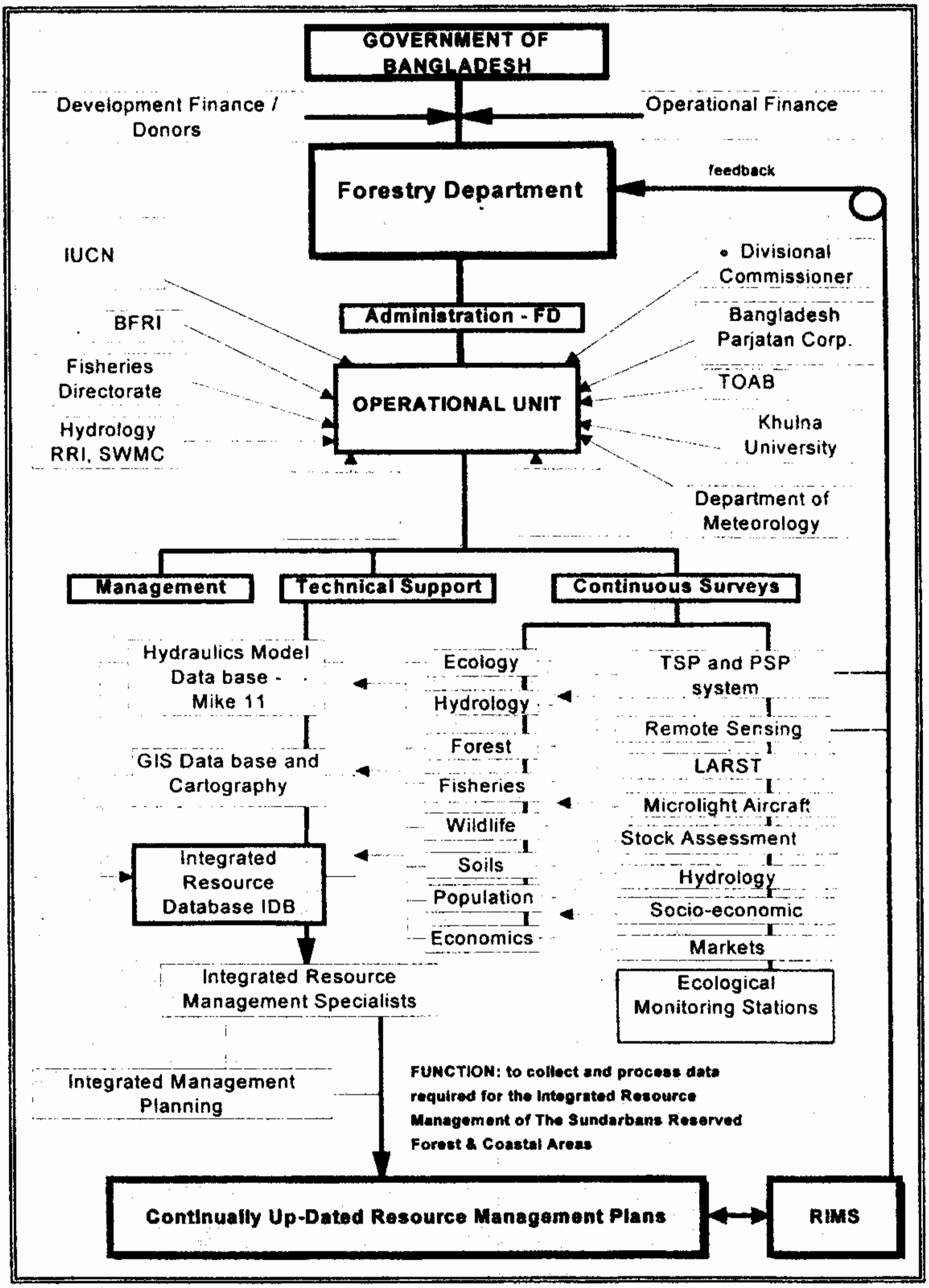


Figure 9 Proposed Structure of the Operational Unit (OPSUNIT)



By involving other institutions, such as BFRI and Khulna University, it will be possible to co-ordinate fundamental and applied research activities with long-term commitment and continuity thereby avoiding duplication of effort. The Integrated Database (IDB) developed during the preparation of the IRMP, will provide for the storage and retrieval of data. This will become a platform for all research with many economies of scale. The Sundarbans has great research potential and given the resources of the OPSUNIT and the co-operation of the associated institutions, it should be possible to develop a world-wide centre of excellence for research and management of a threatened coastal zone resource.

Option 2 Proposed Structure

The proposed structure of Option 2 is presented in Figures 8 and 9. The NMC would involve all concerned government agencies, headed by MOEF, including other organisations such as aid donors, NGOs and SRF resource user groups. The Divisional re-organisation is as for Option 1 with additional ACF's for the DFO Environment and Conservation

The proposed structure of the OPSUNIT is presented in Figure 9. The OPSUNIT would be organised by the Forest Department, initially funded by external donors. Its policies and functions would be set and directed by the Integrated Management Committee (IMC) which would be chaired by the CF Khulna and would be made up of all concerned agencies at a local or divisional level. The IMC would decide policy matters subject to direction on national planning by the NMC.

The data and resource information generated by the OPSUNIT would be linked with the RIMS (Resource Information System) based at the Forest Department's headquarters. It is estimated that the cost to set up and fund the operational unit for a ten year period is about US$ 13 million.

Key objectives of this reorganisation:

- Multi-sectoral integration, accountability and transparency. impartial monitoring and evaluation.
- Reduction in confrontation.
- Improvement and differentiation of management skills.
- Wood and NWFPs will receive equal attention.
- Resource conservation with higher economic returns.

User groups and NGOs will be represented in the NMC and the Integrated Management Committee directing the Operational Unit. It is hoped that all these factors taken together will usher in a new era of co-operation between users and managers and begin the separation of law enforcement from enterprise management.

Infrastructure and equipment:

It is assumed that the FD's fleet of launches, vehicles and field offices will require replacement or upgrading. Additional specialist equipment will also be required, LARST satellite receiving station, Petrel Amphibian Ultralight survey aircraft, and equipment for ecology research stations. The estimated costs are the same as for Option 1 except where specialist items have been included in the funding of the OPSUNIT. The estimated total investment required for Option2 is in the region of $ 27 million for a ten year period.

The level of investment will be dependent upon whether marine and border zone activities are expended. Much will depend upon the findings of a feasibility study but the total cost be to the order of US$ 35 million.

The institutional option most appropriate for implementing the IRMP:

The foregoing section outlines scenarios for an institutional framework to effect sustainable integrated resource management. Each has merits which will need careful review and should be measured against its ability to attain the Nation's social, economic and environmental goals.

26.3 Institutional reform considerations

Issues which must be addressed:

1. Improvement of technical management

Option 1 acknowledges deficiencies in the technical management capacity of the FD and seeks to rectify this by expanding the staffing levels of the Management Planning Division, recruiting new ACFs with special skills, more training and employing international TA to undertake key activities, advising local staff and transferring equipment and technology etc. This approach seems unlikely to overcome the main problems due to the following:

- The civil service pay scales are so low that it is unlikely that it will be possible to recruit people of a sufficiently high level of training and experience to fill the new positions.
- Training FD staff has in the past led trained staff to leave for better paid positions in the private sector or abroad, or they are promoted away from the position for which they are trained. Training would not solve the immediate skills deficit.
- As the FD foresters will remain the managers it is probable that the non-wood resources will still not receive sufficient attention.

Foresters will still manage other resources such as fisheries, wildlife, tourism, honey and hydrology. These are highly skilled sectors in their own right and require specialist technical management; there are no independent checks to ensure the that the management plans are being implemented correctly.Option 2 - The level of technical management is increased through the introduction of the OPSUNIT, the use of training and by employing international TA to bolster key areas, directed by an inter-ministerial committee and local management steering committee. For implementation, monitoring and control, the constraints described for Option 1 remain although with a scope for an acceptable degree of independent control. The implementation staff would mostly be employed on Government pay scales. Independent environmental audit could be arranged through the NMC which could be enhanced to perform these functions. The OPSUNIT should ensure a balanced approach to preparation of management plans.

2. Integration with other concerned agencies:

Traditionally the FD has resisted sharing any functions with other organisations and there is little to suggest that Option 1 will alter this. Option 2 offer a good opportunity for involvement of other departments and agencies in integrated multisectoral management.

3. Realisation of the full economic value of the resources of the SRF:

Whichever form of institutional restructuring is utilised it must be agreed as a precursor that new revenue systems will be introduced and that there will be a new system for measuring and assessing removals. It is unrealistic to expect a complete change in attitude and there must be sufficient incentive to ensure better revenue collection.

Development of the OPSUNIT will help promote proper measurement of removals and their monitoring and proper economic evaluation. Given suitable direction from the proposed committees there is a realistic prospect for more equitable realisation of true economic values. By introducing proper accountability and transparency of operations managed in separate divisions. Option 2 will be the best avenue for achieving this important goal.

4. Co-operation between the managers and resource users:

Option 1 continues with existing institutional structures and even if management practices change it will be difficult to expect real improvement in conflict resolution with user groups. Involving local communities, People's Organisations and NGOs in the decision making process, proposed in both, could start the process of greater co-operation. In due course the law and order functions will need to be separated from management functions and having better trained and better paid protection staff, the managers of the forest could be accepted by the local population as guardians of resources in which all people are stakeholders having a vested interest in protection and productivity. If restructuring is accompanied by a participatory approach by the FD, especially by encouraging free enterprise, the resulting co-operation will do much to ensure sustainablity.

5. Continuity of management:

It is important that any changes should be directed to ensure stability and minimum disruption to routine management. Option 1 retains most of the existing structure and offers a good basis for training and promotion within the ranks. The major constraint is that key members of staff will continue to be transferred into and away from the management and technical positions. Options 2 offers a better degree of permanence and continuity for professionals, especially within the OPSUNIT.

26.4 Implementation of the options

Clearly Option 1 would be the easiest to implement. Changes would not be needed in the existing legislation. Option 2 requires institutional adjustment, the setting up of the high level committees and development of new legally mandated institutional linkages.

Feasibility:

No one option can possibly address all the issues raised throughout this plan. It is clearly impossible to design a panacea that will solve all the problems. Taking into account the main factors of technical efficiency, entrenched attitudes and growing social and economic imperatives, a thorough and objective feasibility study should be commissioned by the Government to study each of the alternatives and the specific objectives.

Whichever avenue is chosen the IRMP has analysed the issues, identified the gaps, has provided guidelines to address them with adequate up to date information. Policy makers may study the options in greater depth to find a sustainable way to manage the Sundarbans. All options will require substantial investment in staff organisation, technical training, infrastructure and equipment, for without the resources no option is viable.

Education and training:

Investment in education and technical training predicates the entire strategy for improving management of the SRF. All options will require extensive training programmes for new staff and new technologies in the following fields :

- Staff with special responsibilities, data base management, use of LARST
- Ecological monitoring and data base management
- Forest mensuration and continuous survey
- Wildlife management; special techniques; consumptive utilisation and large cat research
- Tourism liaison
- Apiculture extension and processing
- Fisheries management and liaison
- Silviculture new techniques
- Community relations and NGOs
- Pilots for microlight survey and management aircraft

Accommodation, boats, vehicles, aircraft, communications and other equipment:

As for training, whichever choice is made for integrated resource management additional equipment will be needed for the Sundarbans Division and the OPSUNIT. The mangrove environment is exceptionally difficult to live and work in for most of the year and although the FRMP will make some improvements, if the full reforms and development implementation schemes recommended in this plan are pursued, further capital investment will be needed as described in the investment profiles for specific fields of operation described in Section 27 below.

Investors and managers must be aware and sensitive to the particular needs of waterborne access, logistical support for field staff working in a hostile tidal environment subjected to cyclonic storms, a large mobile human population, dangerous animals, lack of drinking water and poor communications. Each poses its own challenges for the type and quality of buildings and equipment required to work efficiently in the field.

- Staff housing should be cyclone proof and pre-stressed concrete modular buildings are locally available and should be included in any feasibility study. FD staff housing should be given priority attention.
- In the absence of electricity, all lighting in new accommodation and radio communications installations should utilise photo-voltaic solar power.
- Launches, speedboats and use of amphibian ultralight aircraft are mentioned under separate sections and in investment proposals. Notions that investment in modern equipment is not cost effective should be weighed against the demands now placed upon DFOs whose staff work in remote and dangerous places and whose authority is increasingly defied day and

night by miscreants and thieves who employ fast moving boats and lethal equipment with modern communications systems.
- improvement to potable water supplies is discussed in Section 3.5.9.

Access to medical services and facilities for families should be given proper consideration in development planning. These matters are seldom faced in planning reports and new management plans for the coastal divisions should address these issues in the light of the social conditions of today. There is little hope of implementing management plans if the technical and physical aspects of these plans are not balanced by proper consideration for staff and their families.

27 INVESTMENT PROPOSALS

The level of revenue derived from the SRF, provides ample justification for investment in reform in every sector and this strategy is backed by a set of investment profiles summarised below.

Whilst it may be argued that the government should itself invest further in the SRF from income derived from the forest there is no mechanism at present other than through the normal official estimating procedures to effect this and in the face of higher national priorities a sector which only contributes 3% to GDP is unlikely in the near future to receive even the minimum capital required to meet the proposed targets. Thus these investments will need to be considered by those donors who may wish to make direct contribution to improving sustainable management of the SRF.

27.1 Investment Profiles

Some indicative profiles are described below as a start in developing a full investment strategy for the follow on development programme.

Project 1: Investment in Institutional Reform Option 1

Title	Rehabilitation of The Forest Department - Sundarbans Division
Implementing Agency	MOEF and Forest Department with donors.
Location	Khulna
Duration	10 years
Estimated Cost	US $ 21.03 million

Background:

The background to this project is provided in Section 26.2.

Objectives:

- To allow the Forest Department to more effectively manage the Sundarbans Reserved Forest SRF through institutional strengthening and replacing worn out infrastructure.
- To create an up to date and effective data collection and management planning wing based at Khulna through expansion of the Management Planning Division.
- To create the in-house capability to manage all the resources of the SRF (including the non wood resources).
- To introduce new systems to accurately measure the resource removals and to enhance the level of return from the sale of all products.
- To introduce new revenue systems.

Description:

The project is described in Section 26.2.

Outputs:

- The preparation of management plans that allow for sustainable production and conservation of resources.
- The implementation of the management plans described above.
- The correct assessment of the removals of resources, and the ability in house to continually monitor the condition of the ecosystem.
- The realisation of revenue nearer to the true economic value of the resources.
- The reduction of exploitation of the users of the resource by money lenders, middlemen, dacoits and officials.
- The improve the capability of the Forest Department through overseas training, in country training and assistance from foreign consultants, to manage the ecosystem to agreed objectives in perpetuity

Finance:

The funding requirements are detailed in Appendix A17 and are summarised below :

Inputs	US $ '000s
CAPITAL	
Buildings	1219
Transport	5860
Data collection & processing	385
Satellite imagery	122
Field and Lab Equipment	662
Office Equipment	232
International Consultants	3520
National Consultants	17
International Contracts	200
National Contracts	74
Training	1164
subtotal	13454
OPERATION AND MAINTENANCE COSTS	
Buildings (including utilities)	498
Rent and Utilities	
Fuel, lubricants, servicing and spare parts	2332
subtotal	2830
SALARY COSTS	1197
Total	17480
CONTINGENCIES	3548
GRAND TOTAL	21028
Foreign exchange component	14897
Local costs	6131

Project 2: Investment in Institutional Reform Option 2

Title	The Sundarbans Integrated Resources Management Project
Implementing Agency	Forest Department, MOEF
Location	Khulna
Duration	10 years
Estimated Cost	US $ 26.54 million

Background :

This project has been described in some detail under section 26.2.

Objectives:

- To enable the FD to more effectively manage the SRF through institutional strengthening and replacing worn out infrastructure.
- To create an up to date and effective data collection and management planning Operational Unit based at Khulna by building on the resources and skills developed during the FAO/UNDP project BGD/84/056
- To create the capability within the FD to manage all the resources of the SRF (including the non wood resources).
- To introduce new systems to accurately measure the resource removals and to enhance the level of return from the sale of all products.
- To introduce new revenue systems.

Description:

The project has been described in Section 26.2.

Outputs:

- The preparation of management plans that allow for sustainable production and conservation of resources.
- The implementation of the management plans described above.
- The correct assessment of the removals of resources, and the ability in house to continually monitor the condition of the ecosystem.
- The realisation of revenue nearer to the true economic value of the resources.
- The reduction of exploitation of the users of the resource by money lenders, middlemen, dacoits and officials.
- The improve the capability of the Forest Department through the creation of a permanent Operational Unit and overseas training, in country training and assistance from foreign consultants, to manage the ecosystem to agreed objectives in perpetuity.

Finance

The funding requirements are given in more detail Appendix A17 and are summarised below:

Inputs	US $ '000s
CAPITAL	
Buildings	1715
Transport	6431
Data collection & processing	385
SPOT Coverage	122
Field and Lab Equipment	662
Office Equipment	258
International Consultants	3520
National Consultants	74

International Contracts	200
National Contracts	74
Training	522
subtotal	13963
OPERATION AND MAINTENANCE COSTS	
Buildings (including utilities)	550
Rent and Utilities	120
Fuel, lubricants, servicing and spare parts	2474
subtotal	3144
SALARY COSTS	4666
Total	21773
CONTINGENCIES	4742
GRAND TOTAL	26525
Foreign exchange component	15327
Local costs	11198

Project 3: Silvicultural Trials Programme

Title	Sundarbans Silvicultural Trials Programme
Implementing Agency	MOEF and Forest Department
Location	Khulna
Duration	5 years
Estimated Cost :	US $ 0.97 million

Background:

The SRF been managed on a relatively low intensity system based on natural regeneration. There have been no scientifically and statistically valid trials. All areas of silviculture suffer from a lack of key data which makes management planning virtually impossible. Evidence from PSPs shows that managing endemic species more intensively could make considerable gains in productivity. Work should be done to see if indigenous or exotic plantations could increase the net production. The PSPs show that the current net productivity is around 0.8 m^3/ha/yr. Evidence from Thailand (FAO, 1994) shows that mangrove plantations can achieve a productivity of around 13 m^3/ha/yr. This indicates that plantations could have a major impact on the productivity of the SRF. Plantations in the past in the SRF have been damaged by browsing deer. No trials have been undertaken to see which types of fencing, if any, are cost effective. Due to the ban on hunting it has not been possible to protect the plantations by culling the deer in the plantation areas. Throughout the forest there are scattered areas, which from experience, would appear to require thinning and improvement fellings. In the past thinning has been undertaken but the results have never been monitored to see if the operations are cost effective. Clearly this needs to be studied.

Objectives:

- To undertake trials to gather essential silvicultural data necessary for planning.
- To develop appropriate cost effective silvicultural techniques for the extension of the trial programme into future practical implementation phases.
- To prepare future intensive forest management programmes for selected blank or depleted areas.

Description:

In all options there is a need for international silviculture consultants to work with local silviculturists. Working together they will design the silvicultural trial programme. Once designed the trials would be implemented by the local silviculturists using contract labour and contract growing of seedlings. The consultant would return on short missions to help monitor the trials, assist in ensuring accurate measurement, and help write up the results. The results would then be used in preparing new management plans for implementation and a new research programme.

Finance:

The costs quoted are for all the costs of physically implementing the trial programme. It has been assumed that the costs of clearing areas for plantations, thinning and improvement felling, will be covered by the sale of the produce.

Inputs	US $ '000s
Seedlings	200
Planting	20
Replacing failures	79
Weeding	75
Transport	44
Fencing	402
subtotal	820
Contingencies	145
TOTAL	965

Outputs:

- Over a five year period an estimated total of 2 000 ha of plantations will be established, 75% of which will be as plantations of at least 20 ha in size. The remaining 25% of the plantations will be enrichment plantings within areas of poor natural regeneration.
- The trial programme will, over the 5 year period, establish trials which will by completion already give good indications but will ultimately provide key information on: species/site selection, plantation spacing, weeding requirements, growth rates, planting techniques, survival rates, fencing types and requirements, protection from deer, costings, and thinning and improvement felling regimes.

Project 4: Wildlife Management

Title	Sundarbans Wildlife Management Programme	
Implementing Agency	MOEF and Forest Department and private sector	
Location	Khulna	
Duration	5 years Estimated Cost :	US $ 2.12 million

Background:

The wildlife of the SRF represents a largely under-managed and under utilised resource. There is a large population of spotted deer (approximately 90 000) which currently is not legally harvested. There has been little work done to see if the populations could withstand sustained yield harvesting. There is every possibility of setting up industries based on hunting and meat and other products from a harvesting programme. Deer farming has been shown in other countries to be a commercial success. In Bangladesh illegally harvested deer meat sells above the prices of beef and mutton. Deer farms would also provide new employment opportunities and data to help assess the levels of sustainable harvest from the wild population.

The tigers of the SRF have not been studied in detail. Only rough estimates are available of population size and their life cycle is not known. Every year there are at least 20 human deaths officially reported due to tiger predation (the actual total including unreported deaths is more likely to be around 40). The tiger is classified as endangered and this agreement prohibits the trade in tigers completely. Tigers are being poached from the SRF. The estimated population of around 400 tigers is the only population of tigers in Bangladesh and probably represents one of the largest populations of the species

Panthera tigris tigris anywhere in the world. Nothing is done to manage the population or to ensure its continued existence. An autecology study is urgently needed.

Crocodile farming in other countries has proved a commercial success. There were originally 2 species of crocodile in the SRF, one of which is now thought to be extirpated. A commercial crocodile farm which could help in biodiversity conservation and reintroductions should be considered. A contribution would also be made to the local leather industry and tourism.

The loss of large animals from the SRF such as buffalo, hog and swamp deer, and rhinoceros must have had a negative effect on the ecology of the area. The scope for wildlife tourism would be increased substantially if these animals were re-established as part of the SRF's natural fauna.

In many countries there are successful industries built up around wildlife by-products such as hides, antlers, bones and feathers. Bangladesh currently has no such industries but in other areas of handicraft production is seen to be very adept. It is therefore proposed that a feasibility study for setting up a wildlife by-products industry should be considered.

Objectives:

- To set up a commercially viable deer farm which would act as a breeding station and training centre in the long run for further private sector investment.
- To improve the understanding and management of wildlife to allow sustained yield consumptive utilisation.
- To undertake a Project Tiger - Global Tiger Forum study which would investigate in detail the ecology of the tiger.
- To undertake feasibility studies into other areas of wildlife management such as crocodile farming, reintroductions and the establishment of a secondary industry based on the by-products of wildlife harvesting from captive breeding programmes and natural surpluses.

Description:

It is assumed that the various components of this project will be co-ordinated and assisted by either the OPSUNIT or the management planning wing of the FD in Khulna. If this institutional support is not forthcoming more resources will be required for implementation. The project overall contains a number of sub-projects, which will be co-ordinated by the wildlife specialist in the OPSUNIT in conjunction with the DFO Environment and Conservation.

The project will, during the first phase, undertake a feasibility study to design and cost the development of a deer farm at Karamjal (Animal Breeding Centre). This would be implemented as phase 2. It is estimated that the development would require fencing around 100 ha of forest, capturing live animals for stocking the area, monitoring and harvesting surpluses. During the development phase, training will be undertaken abroad and in-service. By the time the development phase is complete, the farm should be running on a commercial basis and should be self-financing. The deer farm will also be used to train local entrepreneurs who are interested in setting up their own deer farms. The farm will be able to sell them the live animals required to start their own enterprise.

Further to the deer farm the project will undertake a Project Tiger conservation programme, a sustained yield management project and feasibility studies into crocodile farming, reintroduction and the setting up of cottage industries based on wildlife by products.

Outputs:

- During the project period a deer farm covering some 100 ha at Karamjal would be set up. After the initial investment and training period during the project life time the farm would become commercially viable through the sale of meat, and through training and sale of live animals to private sector investors. The project would also provide essential information regarding the natural life cycles and fecundity of the spotted deer, which would be required in sustained yield management of the wild population in the Sundarbans.
- A detailed study would be undertaken during the project which would provide all the information for sustained yield management and the future consumptive utilisation of the deer and wild boar populations. A implementation plan will be prepared which will set the level of harvest, how the harvest is to be undertaken, the possibilities of setting up hunting safaris, and the methodologies required to monitor the populations once sustained yield consumption has begun.
- The Project Tiger programme would accurately assess the population of tigers, undertake detailed studies on its life cycle, physiology and habits and provide guidelines for future management. The study would investigate the occurrences of man eaters and try to find the reasons behind this behaviour. Possibilities of selling licenses to shoot man-eaters would be explored. Co-operation and dialogue with Project Tiger in the Indian Sundarbans will be established during this project.
- The commercial viability of crocodile farming and the setting up of cottage industries based on wildlife by-products, deer and crocodile farming will be examined. The feasibility of increasing the biodiversity of the Sundarbans by reintroducing large mammals such as buffalo, hog deer, swamp deer and rhino will also be investigated.

Finance:

Inputs US $ '000s

1. Feasibility studies	
deer farm	32
crocodile farm	36
reintroduction	87
Bangladesh Wildlife Products industries	36
2. Implementation consultants	
deer farm	288
sustained yield management - consumptive utilisation	192
Project Tiger	144
3. Training	
deer farm	72
sustained yield management - consumptive utilisation	36
Project Tiger	36
4. Infrastructure	
deer farm	325
sustained yield management - consumptive utilisation	25
Project Tiger	50
5. Operations and Maintenance	
deer farm	54
sustained yield management - consumptive utilisation	4
Project Tiger	13

6. Staffing	
deer farm	290
sustained yield management - consumptive utilisation	129
Project Tiger	137
subtotal	1985
7. Contingencies	221
TOTAL	2206
Foreign exchange cost	1439
Local cost	767

Project 5: Development of Tourism

Title	Tourism Development Project
Implementing Agency	Ministry of Environment and Forests / Forest Department / Sundarbans Authority / Bangladesh Parjatan Corporation
Location	Sundarbans Reserved Forest
Duration	5 years
Estimated Cost	US $ 5.83 million

Background and Justification:

Over the period 1986-87 to 1992-93 the average number of tourists visiting the SRF was around 5 300 but of those only 300 were foreigners. The average total income from fees paid by tourists was US $ 775 (Tk 31 000) per year. No accommodation, transport, interpretative services or specialist guides have ever been organised for tourists in the SRF. The only concessions have been the construction of two game viewing towers and the *ad hoc* use of the two rest houses at Nilkamal and Katka. Despite the lack of dedicated infrastructure there has been over the last seven years an average annual increase in the numbers of people visiting the SRF of 3.8%. It is also apparent that the level of fees recorded by the FD is not sufficient to cover the costs involved in administering the tourists and for the services rendered when estimates for overheads are included. From this it can be seen tourism is very underdeveloped in the SRF.

Based on its location, good winter climate, wilderness values and other unique features, the SRF offers a viable opportunity to develop culturally acceptable and environmentally friendly ecotourism for domestic and foreign visitors. The development of tourism is also a stated Government policy featuring in the Strategic Masterplan of 1988 for the ten year period from 1990. Moss (1994) has provided a ten year development model (TYDP) which if followed could establish a low volume, high value foreign exchange earning industry.

Objectives:

The objectives of investment in tourism for the Sundarbans are to generate income and employment without damaging the environment. These are :

- to conserve and utilise attractions base on unspoiled forest, wildlife and wilderness values;
- to provide facilities which will cater for the low volume high spending segment of the market, usually, but not exclusively, international ecotourists;
- to generate foreign exchange for the exchequer and revenue for sustainable management;
- to provide business and employment opportunities both locally and nationally in the service industry by providing accommodation, food, entertainment, transport and the development of cottage industries producing handicrafts for tourists;
- to encourage private sector investment in local and international in tourism in Bangladesh.

Description of the Project:

The initial stage of the development of tourism will involve a detailed project design study which would expand the existing development proposals (TYDP). This study would include the preparation of drawings and specifications of the jungle lodges and cruise ships.

The scope of the implementation phase of this project would be to provide funds to the Government of Bangladesh so that jungle lodges could be constructed at a number of key sites in the SRF. At the same time 2 high quality tourist cruise ships to take the tourists to and from Dhaka and around the SRF would be commissioned. The right to operate these lodges and cruise ships could then be either auctioned or sold by sealed bid international tenders, following pre-determined guidelines and contractual obligations, for a given period of time. In order to make the operation of the jungle lodges and ships an interesting investment for potential bidders, it is suggested that exclusive concessions should be considered in selected parts of the SRF.

During the initial phase, whichever option for institutional development is chosen, it will be necessary for training of key FD personnel, who will be involved in providing escort and interpretative services. This will help develop the cadre of knowledgeable and highly professional staff required by high value ecotourism. Once trained this team will be recruited on a permanent basis and will form a small dynamic unit to service the international tourism trade in the SRF.

Outputs:

- A detailed Project Design study into the development of tourism in the Sundarbans.
- The construction of jungle lodges to cater for 24 up to 48 beds, and the construction of two high quality cruise ships plus the supporting infrastructure for ecotourism.
- Auctions or sealed bid tenders of the rights to operate the lodges and ships by joint venture national/international tourism companies.
- An increase in the numbers of high cost low quantity ecotourists.
- An increase in the numbers of low cost national tourists.
- A substantial increase in the direct and indirect revenue collected.
- A substantial increase in the amount of tourist dependent business providing new employment opportunities for women as well as men.

FinanceUS $ '000s

A. PROJECT DESIGN STUDY

Consultants	International	288
	National	8
	Travel	55
Infrastructure		70
Operation + maintenance		4
Local staff		35
subtotal 459		
Contingencies		37
TOTAL 496		
Foreign exchange component		427
Local costs		69

B. CONSTRUCTION AND IMPLEMENTATION

Infrastructure	Jungle lodges	500
	Cruise Ships	1000
	Buildings	75
	Transport	290
	Equipment	200
Consultants	International	816
	National	8
International Auditors		250
Training		600
Local Staff		940
Operations + maintenance		91
subtotal 4770		
Contingencies		562
TOTAL 5331		
Foreign exchange component		2970
Local costs		2362

Total Tourism Development Costs 5827

Project 6:	Sundarbans Community Development Programme
Title	Sundarbans Community Development Feasibility Study
Implementing Agency	MOEF and Forest Department with People's Organisations and others
Location	Sundarbans + 10 Km Border Zone
Duration	7 months
Estimated Cost	US $ 1.65 million

Background and Justification:

Within a 20 Km fringe of the SRF there is a human population of approximately 2 million with an average growth rate of 2.04% which will double by the year 2025. A socio-economic survey (MARC, 1995) has shown that within this population there is a very high incidence of poverty and landlessness. It has been estimated that around half a million people access the reserved forest for some part of their livelihood during some part of the year. Further analysis undertaken (MARC and DDC, 1995) has shown that the people accessing the resource to extract mainly firewood and non wood forest products are themselves exploited by unscrupulous intermediaries.

This situation fuels over-exploitation of resources to cover the losses. However, even taking the extra removals into account the users are still only breaking even with little or no profit for their labour. Thus there is no contingency for accidents or even repairs and maintenance. This leads in most cases to dependence on money lenders and traders who in general charge high interest rates and expect that the produce should be sold to them at lower than market prices.

The net result is that the resources are harvested beyond sustainability (known as Maximum Social Yield) , and that the users are caught up in a never ending poverty trap. Added to this is the fact that the Nation itself is not receiving the full economic value of the resource. This in turn means that the SRF does not receive the necessary inputs and investment in management planning.

The levels of technology and techniques used in extracting forest resources are often at a very basic level. This results in high levels of waste, poor productivity and in some cases there is a high incidence of accidents.

Objectives:

The objectives of the community development project is to make access to resources more equitable, to help reduce poverty and reduce unsustainable off-takes. At this stage it is only possible to recommend that a feasibility study is undertaken to design a project which will have the following objectives:

- To provide capital to local user groups so that resources can be purchased without having to rely on middlemen and traders.
- To provide education and training to the workers to reduce waste and the number of accidents and to improve productivity. This would also involve making available new tools and technology to the user groups at realistic prices.
- To organize traditional user groups to safeguard their interests.
- To assess procedures for determination of usufruct rights.
- To help the Nation receive the full economic benefits of the Sundarbans.
- To develop livelihood projects and cottage industries based on the products of the SRF which will help to generate employment and thus help alleviate poverty.

Description of the Project:

A detailed participatory feasibility study will be needed to help communities design a project that is both practicable to implement and acceptable to the proposed beneficiaries. The study must cover all aspects of the utilisation of all the Sundarbans Resources.

Outputs:

- A detailed Project Feasibility Study which will identify a project which will not only achieve the stated objectives but will be fully costed and shown to be economically viable and environmentally sustainable.
- The Study should lead on to an implementation phase as soon as is possible.

27.2 Summary of Investment Profiles

The follow on development programme will require detailed design. Investment profiles are provided here as an indication of the wide range of requirements which must be met in order to improve management and better resource utilisation.

Table 78 Summary of Investment Profiles

Investment Profile	Duration	Investment (US$ millions)		
	Yrs	Foreign	Local	Total
Institutional Development				
Option 1	10	14.90	6.13	21.03
Option 2	10	15.33	11.2	26.53
Development Projects				
Silvicultural trials	5		0.97	0.97
Wildlife management	5	1.44	0.77	2.21
Tourism	5	3.40	2.43	5.83
Sundarbans Community Development Programme	0.5	1.21	0.44	1.65
sub total		6.05	4.61	10.66
Total by Option				
Option 1		20.95	10.59	31.54
Option 2		21.38	15.65	37.03

28 TEN YEAR IMPLEMENTATION SCHEDULE

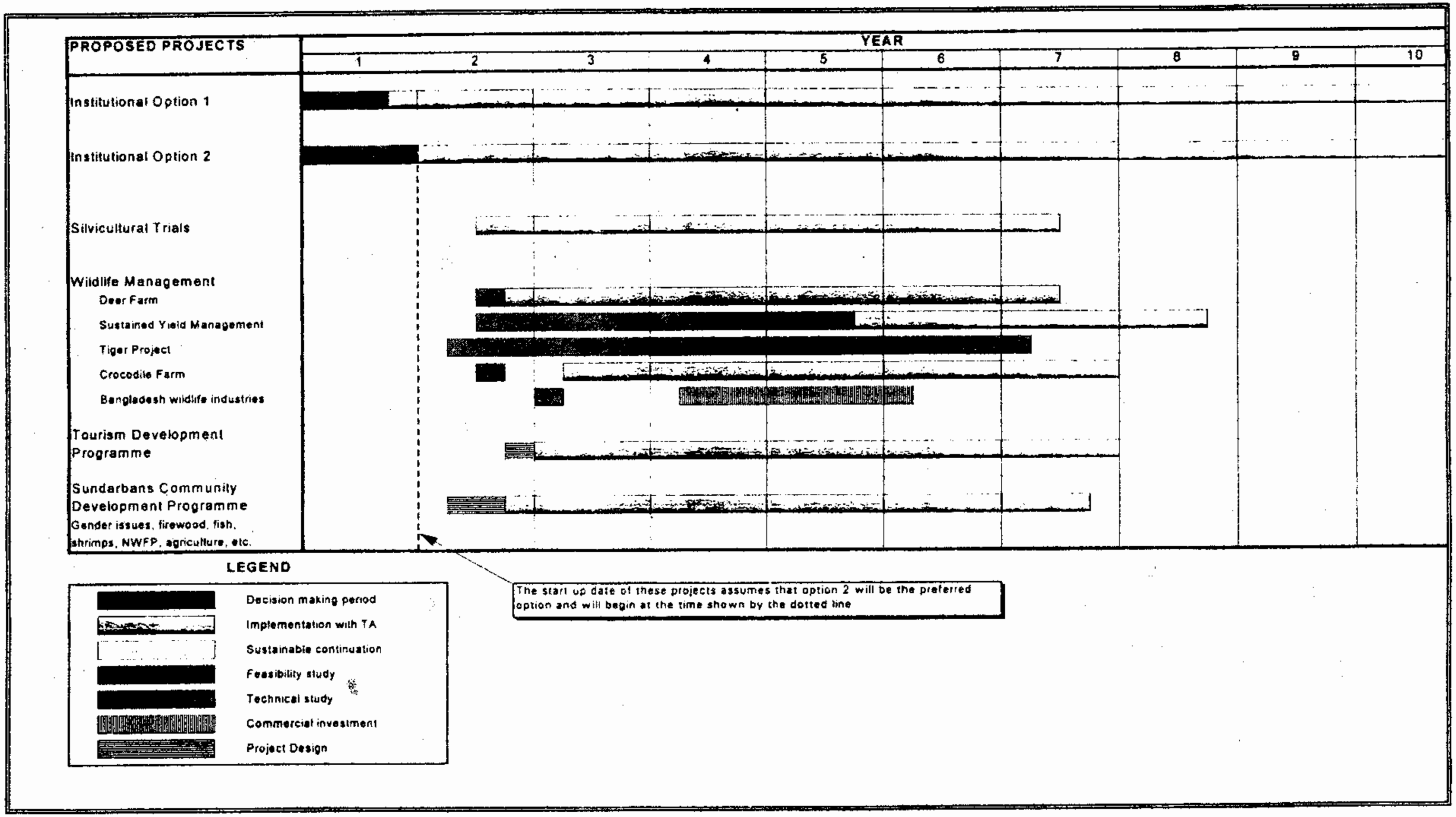
This plan analyses the status of the mangrove ecosystem and describes proposals for improvement in its management. .The speed at which changes can be made is dependent upon GOB decisions, tangible commitments and the ability to attract the necessary finance. It is obvious that substantial reform is needed to achieve the goals of sustainability, greater productivity and social equity.

As with any development programme there is a timebound design which focuses on the main issues and incorporates ideas for development in a unified scheme which will ultimately meet the environmental, social and economic targets.
The components of this scheme have been discussed separately under each section relating to specific environmental factors or resources and introduced here in a composite investment and implementation schedule as a Ten -Year Plan set out in Figure 10. The funding estimates are summarised in Table 77.

As with any development plan, successful implementation depends on the will of the government and those implementing the project. The first step will be for the Government of Bangladesh to decide how to strengthen the institutions which will carry out the work. Once this has been taken it will be necessary for a feasibility study to be commissioned and completed. Only then can the plan be actually put into action.

The Sundarbans Reserved Forest has been actively managed by the Forest Department for over a hundred years. The future of the forest depends upon improving management capacity and ensuring commensurate benefits in the surrounding countryside where the resource users reside. The decisions which must be taken are crucial to the very survival of the Forest in the face of strong competing interests. The IRMP (volumes 1-3) represents a substantial contribution to understanding the system and its management. Hopefully the results and recommendations of the plan will help the decision-makers in shaping the future management of this unique ecosystem.

Figure 10 Ten Year Implementation Schedule



The action plan and timing of events would obviously depend upon Government's overarching policy for the Forestry Sector and the interlocking of the proposals of this plan with other programmes such as the IDA FRMP referred to frequently in this report might be as follows:

1995 -1996 Phase 1 : after receipt, amendment and acceptance of this plan there would be a period of about three months for policy decision making.

Depending upon the choice of option for institutional development studies would be commissioned to make further decisions upon the nature and scale of the reforms and development programme.

1996 - 1997 Phase 2 : this would be follow the findings of the feasibility studies and would include all the approved development projects and investment proposals described for the following :

- Improvement to the capability of the FD or in the introduction of the Sundarbans Authority.
- Silvicultural trials.
- Wildlife management.
- Tourism development.
- Community development projects which include better management and uses for NWFPs especially fish, crabs and shrimps.

1997-2000 Phase 3 : completion of priority projects and self-supporting sustainable management of the SRF and lead to follow-on projects as identified in the feasibility studies..

29 REVISION OF THE IRMP - MONITORING AND EVALUATION

After the first year of implementation, based on the results of the monitoring and evaluation programme, the IRMP should be amended so that operational plans and revisions may be included. It should be a priority task for the Conservator and DFOs to arrange for the up-dated plan to be submitted to the NMC for ratification prior to preparation of the Division's Annual Workplan.

Recommendations are made throughout this plan on requirements for improving management. Assuming that some recommendations in the IRMP will be accepted then it will be essential to ensure that in the earliest stages of implementation suitable independent monitoring and evaluation provisions are arranged. A preliminary M and E Workplan is attached in Appendix 36 as a strategic framework. The following approaches might be considered under the direction of the National Mangrove Steering Committee:

- Contract international project evaluation and monitoring specialists.
- Prior to proceeding with development projects ensure that the NMC and the Integrated Management Committee are positioned to organise M and E tasks as appropriate.
- Ensure that the OPSUNIT is maintained and in association with international specialists and the IMC develop practical indicators and reporting procedures.
- Whichever method is chosen the NMC should be equipped to receive evaluation reports and make recommendations on changes or adjustments as necessary.

The results of the FRMP inventory will enable decisions to be made on future AACs, harvesting rotations and silvicultural activities and these should be integrated in a continuous survey and monitoring plan which should be carried out by the OPSUNIT under the immediate direction of the CCF and CF, Khulna Circle. Protected area and wildlife management components of the operational plan could be embodied in a single Annual Workplan Plan as the basis for field activities and reporting.

The environmental parameters which will require ongoing monitoring should be linked to the same continuous survey programme with data being stored and analysed using the GIS, IDB and Hydraulics data bases situated at Khulna and linked with RIMS at Forestry Headquarters in Dhaka. IUCN could be contracted to undertake independent ecosystem audit, monitoring and reporting for the NMC.

All monitoring activities should be planned so that duplication of effort is avoided and so that the phases of implementation of the various sub-projects of the IRMP are fully synchronised for regular appraisal and evaluation. Reports should be prepared by the monitoring bodies which should have a majority representation outside the FD and forwarded at pre-agreed reporting intervals to the MOEF and other concerned agencies.

30 RECOMMENDATIONS

Administrative responsibility rests in the hands of the Forest Department and recommendations are made which emphasise collaboration, integration of enhanced management, research and monitoring functions and which seek ways to alleviate poverty.

It is recommended that by following a policy for integrated management the FD would move forward in the certain knowledge that its actions accord with the multifarious needs of society and that its technical base has the backing of other specialist agencies.

Specific recommendations R1 - R20:

R1 Conservation, integrated management and development

In order to ensure optimal utilisation of resources without disturbing the ecological balance inter-departmental co-operation and co-ordination of functions will be needed. It is recommended that future institutional and structural planning should clearly define the following functions and areas of responsibility:

- Management operations
- Conservation
- Research activities
- Training
- Commercial enterprises
- Protection
- Legal and audit functions
- Monitoring systems
- Information, education and extension

R2. Management Committees

It is recommended that regular meetings between concerned ministries, departments and other agencies should be structured by inter-ministerial agreement which would steer and direct the implementation of the IRMP and future management of the SRF. The following should be should be considered:

- The National Mangrove Committee (NMC)
- Sundarbans Integrated Management Committee (IMC)
- Sundarbans Tourism Advisory Sub - Committee

Initially it is recommended that the proposed National Mangrove Committee and the Integrated Management Committee should be established as precursors to IRMP implementation and for on-going monitoring of management impacts on the SRF. Detailed terms of reference should be determined by exploratory meetings to exchange ideas and ascertain spheres of interest on policy, legislation, development, research, monitoring etc and to organise a *modus operandi.*

R3. Institutional framework : administration and management

It has been concluded that the institutional structure for improved management of the SRF requires some adjustment and two alternatives are described. It is recommended that an early decision be made by the government on the best way forward to meet future management goals. Details are in Sections 26 and 27.

R4. The Operational Unit

It is recommended that the Operational Unit illustrated in Figure 9 and described in Section 26 in Options 2 should be maintained as the first follow-on project in the IRMP. Financial arrangements are detailed in Appendix A17. If interim funding becomes available it is recommended the unit should be linked administratively and functionally to the ongoing FRMP RIMS operations.

Early transitional arrangements will be needed to ensure continuity and it is recommended that this should be treated as a high priority for possible inclusion in any review of the FRMP and for donor consideration. Its capacity should be developed and financed in a special bridging period of say two years using any discretionary finance that may be available.

R5. Integrated planning system

In the absence of inventory data which are to be acquired in 1996-97 by the FRMP IDA project, it has not been possible to prepare a new detailed Working Plan for the SRF and it is recommended that the new forest inventory data should up-date and add to the existing multiple-resources data on a continuous basis using the methodology defined in this plan (section 9.1).

R6 Environmental and ecological parameters for follow-on activities

It is recommended that priority topics for follow-on applied research on the mangrove ecosystem should be to focus initially on the broad fields listed below on which work has started but is far from complete:

- comparative vegetation mapping 1933, 1960, 1985,1996
- meteorology - new SRF ecological research stations
- hydrology - shared waters and pollution
- soils, erosion and accretion
- biodiversity, fish stocks and other wildlife
- stakeholders' participation - People's Organisations, NGO's and donors
- baseline surveys of biodiversity in the wildlife sanctuaries and Border Zone
- analyse prospects for investment in economic developments in the 10 km border area especially tourism, cottage industries and post-harvest technology
- studies on the impact of land use practices in surrounding and upstream areas
- detailed studies of resources, ecology and protection of the 12 nautical mile marine zone.

R7 Future survey and monitoring

It is recommended that the Forest Department should change from a stratified random sampling methodology to continuous survey systematic sampling Leech (1995).

R8 The wood resource

Although the project was able to measure 69 of the Permanent Sample Plots it was not able to complete the task. There is a great deal of useful growth and yield information that could be utilised. The remaining plots should be measured as soon as possible. Likewise the environmental/site parameters which have been recorded also should be analysed and used to develop baseline data against which future measurements can be made. It is recommended that this activity should be carried out by the continuous survey team working with the FRMP team as a matter of high priority using the methodology derived by the project (Leech,1995).

- It is recommended that the Forest Department use a volume control methodology for setting the allowable cut (AAC) from the Sundarbans rather than basing allowable cut on area control.

- It is recommended that simulation models be devised to determine, not only the effect that different levels of cut might have on growing stock estimates thus enabling computer sensitivity analyses to be carried out for determination of the most appropriate AAC for sustainable harvesting, but also for proper management of all other resources.

- Details of silvicultural research and monitoring, plantation trials, and nurseries Karim (1995) and growth and yield modelling, harvesting and inventory methodologies are set out in Leech (1995) and Mitchell (1995) and these are discussed as guidelines for future implementation:

R9 Production forest resource management

It is recommended that the following key issues be addressed in determining priorities for production forest management:

- The FRMP inventory to assess the current status of the wood resource is required. It is recommended that this should follow the TSP/ PSP survey system proposed by Leech (1995).
- Following the results of the new inventory design and implement a production management plan outlined by Leech (1995).
- Develop a new system for measuring all wood removals. It is recommended that timber sizes should be based on the metric system, firewood on metric stack measurements and pulpwood based on metric weights as it enters the mill (Mitchell, 1995).
- A new system of passing the removal records up the line for collation needs to be developed, so that all the information by the lowest level of resolution can be centrally processed.
- A new system of continually up dating compartment records should be devised. This system must include records of all treatments undertaken in any part of the forest.
- Standardised computer menu reporting forms should be devised so that compartment information can be provided by station or range offices for regular collation. This would record the chronology and status of forest operations.
- Institute a system of periodical independent random auditing of all revenue systems.
- Improve silvicultural practices through tending, thinning, and improvement fellings.
- It is recommended that the timber Moratorium should continue pending the results of the FRMP inventory.
- Immediately re-define the criteria for selection of Top-dying Sundri so that healthy trees are not harvested.
- Introduce salvage removal of wind blown trees as a priority higher than removal of Top-dying Sundri.
- It is recommended that all Sundri logs be graded so that parcels of graded timber can be sold at auctions.
- Privileged selection of REB poles from the forest should be discontinued. These poles should be bought at open auction in the free market and not be harvested selectively.
- Revised felling rules are recommended for Sundri such as use of cross cuts and hand tools;
- Trials of enrichment planting and large scale plantations should be implemented.
- Trials of new silvicultural systems for Goran and Gewa harvesting need to undertaken.
- A plantation extension unit should be set up to encourage tree planting .
- A nursery development programme needs to be instigated as appropriate.

R10. Products : management, harvesting and economics

The relentless pressure on wood and non-wood products, aquatic and terrestrial resources, and palpable threats to the whole integrity of the environment which sustains them, are reflected in daily demands for other kinds of development. These compel continuous up-dating of information not only on the statuses of products but also on harvesting methods, market economics and public opinion. Management proposals are geared fulfil the needs of the present without compromising the ability of future generations to meet their needs as well.

It is recommended that early consideration be given to reorganising the revenue system and that the system of measuring produce which should be standardised using metric units.

R11. Wood products

It is recommended that after completion of the FRMP inventory priority consideration should be given to the following for improvement of yields and management of wood products Larsen (1994):

- Estimate the likely effects of lifting or relaxing the Moratorium before the year 2000.
- Re-define the harvesting criteria applied to Top-dying Sundri if the Moratorium is to remain.
- Assess the cost-benefit of utilising species such as Baen ***Avicennia officinalis*** and Jhanna ***Rhizophora mucronata*** for poles and piles currently wasted and only harvested unofficially.
- Assess the cost-benefit of harvesting wind-blown and fallen trees.
- Gewa is harvested as an exception to the moratorium for use by the Khulna Newsprint Mill. In the event that the mill becomes uncompetitive and faces closure alternative use for Gewa must be researched.

R12. Non-wood resources

The increase in emphasis on non-wood forest products (NWFP) has accelerated in recent years firstly because of high social and commercial values (higher in total value than the wood resource) and secondly because the immediate consequence of the growth in interest in these products has been the increase in demands placed upon the FD for day to day management. The Department has barely had the means for managing the timber resources and thus a big shortfall in capacity exists in its ability to handle the new, often highly specialised requirements, of modern management of both plant and animal based produce. It is recommended that this matter be given priority attention in future investment programmes.

The large numbers of people connected with harvesting NWFP's bring with them a host of management problems connected with harvesting methods Shiva (1994), ecological and environmental disturbances, distribution of benefits, marketing, transportation, investment and social equity, many of which are directly associated with institutions and the activities of people outside the SRF. For future improvement in NWFPs management, it is recommended that the FD work with NGOs, the civil administration and all other relevant parties. Steering this should be one of the preliminary functions of the IMC.

R13. Plant based NWFP'S

In the order of priorities it is recommended that Golpatta, Hantal and Bhola are given priority attention in terms of making a proper determination of their distribution and statuses because of the exceptionally high social value which is attributed to these products.

Golpatta management requires early attention.

It is recommended that :

- An assessment of the area and total standing stock of Golpatta should be made as soon as possible.
- A research programme into growth and yield and also the effects of different cutting regimes should be implemented.
- The measurement of Golpatta removals by BLC should be changed to either selling the area standing at auction or stack measuring the boat loads.
- New cutting rules should be introduced to reduce the amount that is currently wasted by trimming fronds.

R14. Animal-based NWFP'S

The Fishery : management of the Sundarbans fishery involves issues which affect the wildlife sanctuaries, forest resource conservation, socio-economics, international boundaries and border area agriculture. This matter involves many agencies and areas well beyond the SRF. It is not a case of giving foresters more training in another specialised field or of developing a new division with a multitude of skills overlapping with other institutions but a matter of integrating existing complementary functions, skills and responsibilities to mutual benefit under the auspices of the FD.

The fishery resource includes commercially important finfish as well as shrimps, oysters and crabs, values for which have escalated enormously in recent years. Several administrative, management and research issues must be resolved and it is recommended that early attention be paid to establish co-ordinated management involving agencies concerned with:

- straddled fish stocks especially ***Hilsha ilisha*, *Lates calcarifer*** and shrimps which have part of their life cycle outside the mangrove forest;
- international trespass in marine waters;
- migratory seasonal fishermen, in particular winter visitors to SRF from Chittagong and elsewhere;
- management of shrimps, crabs and oysters; conservation biology, harvesting and post-harvest treatment;
- practical measures to increase the minimum sizes of fish and shrimps caught;
- proper assessment of closed seasons and their enforcement;
- integration of research and monitoring data collection and sharing of information between the Forest Department, Fisheries Department, Fisheries Research Institute, universities and regional fisheries projects.

A summary of recommendations is provided below to assist integrated fishery management:

- Collect monthly length-frequency data for commercially important species.
- Attempt to age fishes using hard structures, otoliths and scales to provide an alternative to length-frequency data.
- Measure the abundance of fish and crustacean stocks.
- Collect length-weight data for commercially important species and use the constant b, defined in the IRMP, in the length-weight relationship to monitor the body condition of fish stocks over time.
- Record the distribution of fish species including seasonal movements in the SRF.
- Make an independent assessment of the numbers of fishermen, fishing gears and catch composition.
- Collect data on the catch size and composition of the offshore set bag-net fishery.
- Determine where and when ***Hilsa ilisha*** that pass through the SRF spawn.
- Identify different fish stocks and their movements in and outside the SRF
- Research the effects of capture by rod and line on the survival of ***Macrobrachium rosenbergii*.**

- Introduce a minimum catch size for ***Lates calcarifer*** of 30 cm TL and 10 cm TL for ***Johnius argentatus***.
- Restrict the numbers of hilsa gill nets, pangash gill nets and gill nets operating in the SRF or endeavour to keep to current levels.
- Endeavour to hold exploitation of commercially important species (except ***Penaeus monodon*** fry) constant at present levels.

It is recommended that for straddled stocks and species which spawn outside the SRF, either in the open ocean such as ***Lates calcarifer*** or upstream ***Hilsha ilisha*** , effective stock management control over the entire life-cycle of a stock should be introduced.

Regulatory systems, including new revenue controls, closed seasons, net mesh limits and stock conservation rules should be established as a matter of urgency by co-ordination of responsibilities and management, in and outside the SRF.

Wildlife: with the establishment in 1994 under the FRMP of the Environment Management and Nature Conservation Division (DCCF in Dhaka) and appointment in Khulna of a DFO Environment and Nature Conservation with three ACF's who are responsible for the SRF Wildlife Sanctuaries, it is recommended that early implementation of wildlife management, conservation and research programmes should be instituted in consultation with IMC and with particular regard to:

- definition by the CCF and DDCF Environment Management and the Conservator, Khulna Circle, of areas of responsibility and integration of activities of all the DFO's working in the SRF especially overlapping functions which stem from the Forest, Wildlife and Fisheries Acts;
- finalisation of Wildlife Sanctuary extensions ; protection and production area zoning and boundary descriptions as soon as possible; - Map 13.
- training of staff connected with wildlife management;
- implementation of the Wildlife Management Plan outlined in the IRMP in furtherance of the objectives of the FRMP;
- follow up on research already started on the ecology of the tiger, spotted deer, wild boar, muntjac, turtle, dolphins and crocodile populations;
- ensure integration of management, protection, research and monitoring activities with other forestry and fisheries staff and link data collection, storage and analysis with the CST, GIS and IDB data bases;
- establish biodiversity conservation priorities in collaboration with IUCN and with due regard to NEMAP and the NCS.
- consider reintroducing extirpated species such as rhinoceros, buffalo, swamp deer, hog deer and marsh crocodile.

Other wildlife related matters on which recommendations are made include:

- Zoning
- Vegetation studies
- Legislation and Regulations
- Saltwater crocodile
- Boundary delineation
- Deer and crocodile farming
- Ecology of tigers
- Wildlife Management Plans

R15. Tourism and recreation

Recommendations for socially and culturally acceptable tourism and recreation are based upon the judicious implementation of a Ten-year Development Plan referred to as the TYDP which makes proposals for ecotourism development, investment and management (Moss, 1993; Mitchell, 1995). Optimum use of the wilderness asset is proposed without exposing the SRF to environmental degradation in any way. This is in line with the policy of the FD and the National Tourism Policy (NTO, 1992):

It is recommended that a Tourism Advisory sub-Committee be convened as soon as possible to examine and co-ordinate in particular:

- SRF tourism development responsibilities and functions of the Public Sector, Parastatal organisations and the Private Sector, especially integration of the roles of the Forest Department, the Parjatan Corporation, the Tour Operators' Association of Bangladesh (TOAB) and private investors.
- Development of domestic tourism and international tourism, especially hard-currency earning ecotourism based upon development of the one-week (6 nights 7 days) 'Bangladesh Module' - Dhaka, river journeys and the Sundarbans Experience of 'Jungle Camps and Lodges' (Moss, 1993).
- The validity of the proposed TYDP tourism development model and strategies for its implementation. The outline TYDP plan is shown in Table 71.
- Zones, concession arrangements, management agreements, leases, standards, controls and monitoring.
- Domestic tourism facilities should be developed only at Mongla and Munshiganj. International ecotourism should start with the TYDP in the Katka - Kachikali area, followed soon thereafter by Nilkamal and Mandabaria areas.

Other tourism matters covered in the plan on which recommendations are made include :

- Training
- Common objectives, commitment and policy
- Prioritise product development
- Prioritise development plans
- Publicity and marketing
- Development without destruction
- Tourism targets
- Regulation and monitoring

R16. Apiculture

Honey has been collected in the Sundarbans by Mowallis from time immemorial but the interests of this subsistence user group have never featured highly in traditional management plans. It is recommended that the entire system of apiculture management be reviewed and that arrangements should be made for more equitable access to the resource on the one hand and better resource management on the other.

- An extension specialist in apiculture is needed to prepare and distribute information on honey collection and beekeeping to Mowallis and beekeepers. Work should commence as soon as possible as a follow on project (Zmarlicki, 1994).
- For training of honey collectors, apiaries in the Sundarbans should be maintained every year during the honey flow season and serve as demonstration apiaries. The apiculture handbook should be translated and published in Bangla.
- The honey processing establishment should be targeted to train and assist honey collectors from the SRF and other local small-scale producers who could benefit directly through improving the quality of their product. This could be achieved by combining resources through revolving funds and with small-scale credit facilities to facilitate packaging and marketing.
- It is recommended that a plan for effective utilisation of the apiculture equipment which will be transferred to the FD should be prepared. Joint management between the Forest Department and an NGO should be approved to ensure that the processing plant is used to assist Mowallis and local producers, especially women and other disadvantaged groups.

R17. Socio-economics : resource utilisation and community affairs

Preliminary findings (MARC 1997) confirm firstly the growing number of people, probably at least half a million, who participate to a greater or lesser extent in SRF resource utilisation and secondly the need to revise some harvesting and marketing practices which do not satisfy criteria for social justice.

Whilst many people consider that their food and clothing needs are met personal security is reported to be the single most important concern for people who access the SRF. This is a matter which should be given high priority in future development planning.

Literacy rates are well below the national average low and although incomes are above the national average by 45% (13 000 Tk pa) in the border area it is clear that there should be a more equitable distribution of direct benefits to local communities. For example nearly all firewood is exported to Dhaka and thus there are negligible direct economic or social benefits derived from the Goran firewood resource locally.

R18. Integrated management strategy : the common goal

Integrated multiple resource management implies setting and agreeing common goals which can be shared between disparate managers and users for the common good. It is a tenet of modern management that separate specialised technical departments and agencies should work together where a common need justifies combined effort, pooling of resources and economies of scale.

Today the inexorable growth of human populations accompanied by the alarm of diminishing resources, increasing gap between rich and poor, universal access to media information and the increasing international awareness that sustainable conservation and development of resources will only be achieved if managers can ensure that benefits go back to locally dependent people, should be a cornerstone of new policies.

This will require innovative management and commitment. This plan discusses the means for better management and development through constructive arrangements of the FD with other agencies whilst at the same time retaining overall administrative authority.

It is recommended that the aims of the IRMP are carried through with full cross-sectoral technical agreement since expectations have been heightened and the pressures at all levels are acute:

- GOB to approve the proposed management - the NMC Steering Committee and IMC and re-affirms the Forest Department as the administrative agency for the Sundarbans Reserved Forest.
- Steps be taken by UNDP/FAO and GOB to ensure the continuity of the OPSUNIT as the base for future long-term research, monitoring and evaluation.
- Consideration should be given by the FD to collaborate where appropriate with other concerned agencies and stakeholders to determine areas of mutual concern.
- Ensure that the scope of the Forestry Master Plan FRMP/IDA includes adequate training of Forest Department staff in integrated resources management.
- Ensure that the FRMP inventory results are added to existing data to enable the prescriptive part of this plan to be completed.

R19. Implementation, development and investment

Proposals for investment leading to follow-on projects and development assemble all the different components of the SRF and together they form a plan for phased and sustainable development with capital and recurrent expenditure over 10 years estimated at least US$ 30 - 40 million. Each is discussed in Section 27 and it is recommended that these are given early consideration by MOEF and the FD so that detailed financing and implementation can follow with minimum delay using the guidelines for priority requirements listed below:

- The Forest Department — staffing, capacity building, training, equipment and infrastructure
- The operational unit — for integrated research, GIS, continuous ecosystem survey
- Fisheries — post harvest technology, marketing, extension services, training
- Institutions — development options, NMC, IMC, OPSUNIT, BFRI, Khulna University, BWDB etc, training, equipment and infrastructure

• Wildlife management	Project Tiger (autecology study), sustained yield harvesting, biodiversity management, captive animal breeding programmes, re-introductions, protected areas, boundary demarcation
• Tourism	develop the TYDP ecotourism Jungle Camps and Lodges model
• Wood resource	silviculture, firewood, harvesting methods, revenue systems
• Non-wood resources	apiculture, golpatta, hantal, shrimps, shells, crabs and others
• Socio-economics	community participation, human development, revolving funds, small-scale credit, employment generation, NGO's, user groups.

There are three target clusters which will require different approaches to implementation:

1. Projects which concentrate on management within the SRF.
2. Projects which affect both the SRF and the Border Zone.
3. Projects which have regional or broader international dimensions.

R20. Official commitment

To achieve sustainable development much will depend upon official commitment, investment and strategic planning and further technical assistance.

An early policy decision by the Government on the recommended reforms would provide a tangible indication of the way forward for implementing integrated management systems for the Sundarbans. It is recommended that the feasibility studies to augment policy decisions be implemented as soon as possible against the targets of the Indicative Investment Programme outlined in Table 78 of the plan.

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