INTEGRATED RESOURCE DEVELOPMENT OF THE SUNDARBANS RESERVED FOREST - FAO/UNDP PROJECT BGD/84/056
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DP 9/10 - REG 06/94

19 February 1994

To : Mr. Nurul Islam Howlader
National Project Director, BGD/84/056 &
Conservator of Forests, Plantation Circle
Khulna

From : I Gusti M. Tantra
Officer-in-Charge
BGD/84/056, Khulna, Bangladesh

Sub : BGD/84/056 - Wildlife Management Plan for the Sundarbans Reserved Forest by Dr. Kirti M. Tamang

I am pleased to enclose herewith a copy of the report of Dr. Kirti M. Tamang on "Wildlife Management Plan for the Sundarbans Reserved Forest" which has technically been cleared by FAO Headquarters, Rome. A copy of the letter from Mr. M.K. Muthoo, Director, FODO, FAO Headquarters in this regard is also attached herewith.

I look forward to receiving your comments and/or suggestions as soon as possible on the above-mentioned report, if you have any, so that I can incorporate those suggestions in the final version of the report which will soon be reproduced as a Field Document.

Thanking you.

With kind regards.

No.02/Dev-16/94/9 22/02/94
M. Anwarul Islam of FO Khulna Sir.
Please go through the enclosed document
& Comments/suggestions if there be any by 25/2/94
Thx 24/2/94

বন-সংরক্ষক,
খুলনা সার্কেল, খুলনা।

cc: - Mr. M. Mozzammel Hussain, Chief Conservator of Forests, Forest Department, Ban Bhaban, Mohakhali, Dhaka

- Mr. Peter J. Myers, FAO Representative in Bangladesh, Dhaka
for your kind information (without copy of the report)

1249

TO: Mr. Gusti M. Tantra,
Officer-in-Charge, BGD/84/056

DATE: 2 FEB 1994

FROM: M.K. Muthoo
Director, FODO(P)

SUBJECT: BGD/84/056 - Wildlife Management Plan for the Sundarbans Reserved Forest by Dr. Kirti M. Tamang

I am pleased to enclose the revised version of the above-mentioned report that has been technically cleared, together with a diskette. Please print this report as a project field document and let us have eight copies of the final printed version for distribution in headquarters. Pages 2, 5, 11, 24, 28, 43, 89, 92, 95, 97 and 103 containing maps and figures are not in the diskette and need to be photocopied separately, to be included in the field document. The report needs to be incorporated into the final Integrated Management Plan for the Sundarbans.

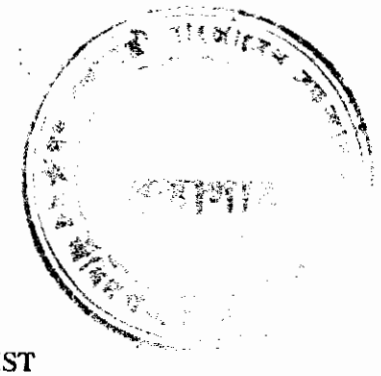
Regards.

KT/mf
cc: Tamang
Muttiah
Walugembe
Chrono (Fright)
FO Registry (2) DP 9/10 BGD/84/056

FAO/UNDP PROJECT BGD/84/056

INTEGRATED RESOURCE DEVELOPMENT OF THE SUNDARBANS RESERVED FOREST

WILDLIFE MANAGEMENT PLAN FOR THE SUNDARBANS RESERVED FOREST



BY

DR. KIRTI M. TAMANG
WILDLIFE MANAGEMENT SPECIALIST

PROJECT
BGD/84/056

INTEGRATED RESOURCE DEVELOPMENT
OF THE SUNDARBANS RESERVED FOREST
KHULNA, BANGLADESH

Rome 1993

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1. INTRODUCTION

Bangladesh covers an area of about 144,000 Km^2, between 20°30' and 26° north latitudes and between 88° and 92°50' east longitudes. The country is bounded by India on its north, east and west with a small stretch of common border in the southeast with Myanmar (Burma). Bay of Bengal is the southern border (Fig.1). The country has a population of approximately 120 million with a growth rate of 2.4 percent per year. Over 90 percent of the people live in rural areas and the economy is based on agriculture. The per capita gross national product (GNP) of Bangladesh is one of the lowest in the world and is about US$210.

The country has a rich biological heritage as a consequence of its location at the confluence of the three major biotic regions – the Himalayas, Indochina and the Indian Peninsula. It falls in the Bengal Assam Bio-Unit of the Indo-Malayan Realm (Mackinnon and Mackinnon, 1986). Being situated in an important transition zone, the unit was rich in species and supported the greatest diversity of mammals and birdlife.

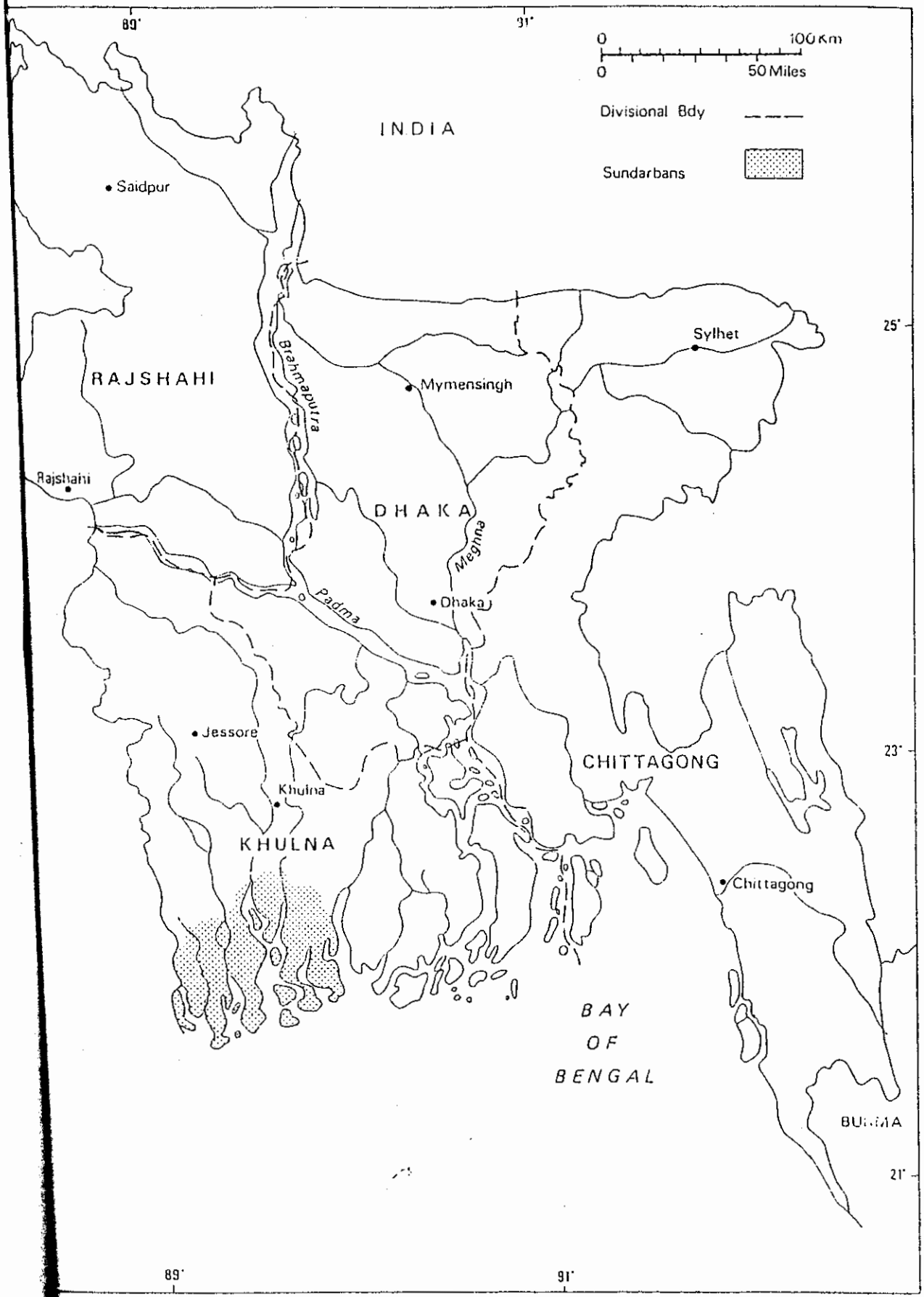
The Bangladesh Sundarbans mangrove forests and associated waterways covering 5770 Km^2, comprise the largest remaining block of continuous forest cover in Bangladesh. The area is immediately adjacent to the 4160 Km^2 Indian Sundarbans. Taken together these two forests, which are a single ecological unit, form one of the largest areas of mangrove vegetation in the world. The Sundarbans is also an extremely important wildlife habitat, supporting among others large populations of the endangered Royal Bengal Tiger and associated prey species, and a depleted population of the estuarine or saltwater crocodile, a reptile of potentially great economic value.

In the past the Sundarbans was primarily managed for the production of wood and other forest products. Recognizing the important potential for increased benefits from the natural resources of the area, the Government of Bangladesh in cooperation with FAO and UNDP launched the Integrated Resource Development of the Sundarbans Reserved Forest Project (BGD/84/056) to prepare an integrated plan to encompass all aspects of natural resource management. The project included the services of a wildlife expert for 10 months with the following terms of reference.

1. assess population, distribution and status of tiger, spotted deer and salt water crocodile in the Sundarbans;

2. make recommendations on possible solutions to the problem of man-eating behaviour of tigers in the Sundarbans;

3. develop appropriate methods for capture of deer, monkey and tiger;



Location of the Sundarbans

4. make recommendations on the utilization of wildlife and development of tourism in the Sundarbans;

5. prepare a comprehensive wildlife management plan for the Sundarbans;

6. determine manpower requirements of the various wildlife management and related activities to be undertaken in accordance with the findings;

7. make estimates of budgetary requirements for these activities;

8. outline a work plan for tourism development with inputs from the Consultant on Tourism and Recreation keeping in view its ecological and environmental effects in the Sundarbans;

9. prepare environmentally friendly management and operational guidelines of tourism activities of the Sundarbans; and

10. prepare a comprehensive report giving consolidated recommendations on the basis of findings in the technical document.

This work was undertaken from October 1992 to August 1993. The expert was stationed at Khulna project office and made field trips to the Sundarbans to evaluate wildlife populations and habitats. The report is divided into three main sections beginning with an overview of basic information on the Sundarbans; followed by an assessment of wildlife populations and concludes with management prescriptions in Chapter 4 related to the implementation of the management plan. Chapter 5 provides information on Wildlife Training Course for Forestry Officers conducted from 11-16 July 1993. The portion of the terms of reference related to tourism and recreation has not been covered since a Consultant was recruited for six month (May-July and Sept-Dec 1993) to cover tourism and recreational aspects.

The expert wishes to acknowledge his gratitude to the Chief Technical Adviser of the Project Mr. I Gusti M. Tantra, the National Project Director (NPD) Mr. Syed Salamat Ali, Conservator of Forests, Plantation Circle, the Deputy NPD Mr. Munshi Anwarul Islam, DFO Sundarbans, Mr. M.N.A. Katebi, Chief Conservator of Forests, Dhaka and other government officials who were most helpful in providing cooperation and assistance.

2. THE SUNDARBANS RESERVED FOREST

2.1 General Information

The Sundarbans Reserved Forest is located at the south west corner of the Ganges River Delta close to the Bay of Bengal. It occupies the area between 21°30'N and 22°30'N latitudes and 89°E and 89°55'E longitudes. The Sundarbans forests extends to Baleswar River in the east; the international boundary along the Harinbhanga-Raimangal-Kalindi River system in the west; the cultivated land in the north; and the Bay of Bengal in the south—spread over three districts of Khulna, Bagerhat and Satkhira. The whole of Sundarbans including the Indian part occupies an area of about 10,000 km^2. Taken together these two forests form a single ecological unit and one of the largest single mangrove vegetation in the world.

The Bangladesh Sundarbans covers an area of 5,772 km^2 of which 3955 km^2 is land and the rest is water (rivers and khals). The forests of Sundarbans constitutes 44 percent of the forest area of Bangladesh and contributes about 50 percent of the revenue from the forestry sector.

2.2 Topography

The land surface is essentially flat and runs from north to south at a slope of 0.30 m vertically per km of horizontal distance. Within the Sundarbans, the microtopographical variation is the result of the actions of the rivers and khals inside the area and the semi-diurnal tidal flow. The forest floor is 0.91 m to 2.11 m above the sea level. All the rivers in Sundarbans were connected with the Ganges until recently but now however, only one Baleswar river is directly connected to Ganges and is responsible for fresh water supply in the eastern part of the Sundarbans. Other rivers such as Passur, Sipsah, Arpangasia, Malancha, Jamuna and Raimangal receive overflow of the Ganges during rains. These rivers receive a considerable amount of drainage locally from surrounding areas mainly during the monsoon (Fig.2).

2.3 Soils

Geologically Sundarbans is of recent origin and formed originally by the subsidence of an earlier land surface below sea level. The delta now consists of alluvium washed down from the Himalayas overlying older sediments, formed by the action of the Ganges, Jamuna and Meghna rivers. The bulk of the alluvium is now being deposited to the east of Baleswar River with progressively less deposition west of Baleswar. In the western Sundarbans even the surface soil has settled down to a hard mass and the ground is much less suitable for tree growth.

Mangrove soils contain soluble salts, due to its vicinity to the interface of land and sea, that impair growth of normal plants. The soluble salts in the soils consists of various proportions of the cations Na, K, Ca and Mg and the anions Cl, SO_2,

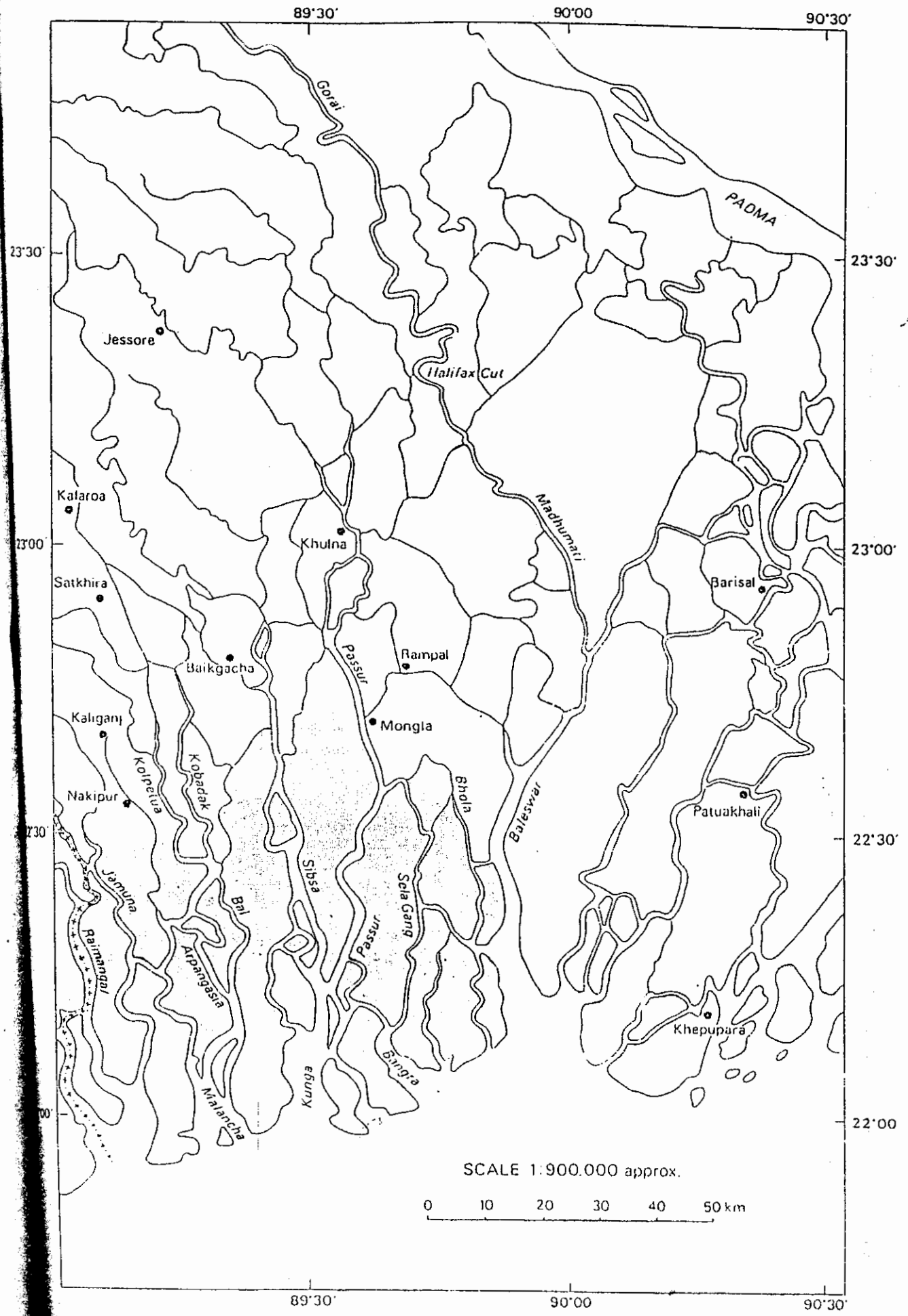


FIG.2 River systems

HCO_3 and NO_3. All soluble salts in the mangrove soil are received from the external sources such as tidal and surf wave action and are known as cyclic salt (Das and Siddiqi 1983). Soils of the Sundarbans are unreclaimed, partly ripened or unripened and grey in color. The soils are neutral to mildly alkaline in reaction under the field conditions but in some areas the p^H value of dried up subsoil samples go down to 6.5 (Hassan and Razzaq 1981, as quoted by Das and Siddiqi 1985). The alluvium on the river bank in the eastern part is slightly calcareous. The soils are slightly saline in the east/north east and moderately saline in the west/southwest areas (Das and Siddiqi 1985).

2.4 Tides

Tides in the Sundarbans are of semi-diurnal type with a small diurnal irregularity. The influence of tide depends upon the stream flow, on the time of the year and the connection the river has with a fresh water supply. In the eastern Sundarbans it is less and in the west much more marked. The speed of the tidal bore varies from 50 km/hr at the sea face to 25 km/hr in the upper reaches. Tidal currents usually vary from 35 km/hr at the sea face to 7 km/hr in the upper reaches of the forest and 10 km/hr during ebb in the rainy season. The decrease in speed is caused by the gradual constriction of rivers in the upper reaches. Largest rise and fall of the tides occur where currents are swiftest which is usually in the northern part of the forest. The tidal wave goes from west to east. The time of high tide at Kutubdia Island and Passur River (Hiron Point) lags behind the north of the Hoogly by one hour forty five minutes.

2.5 Climate

The climate of the Sundarbans is humid. The south east monsoon divide the year into three distinct seasons: June to September; October to February and March to May. The monsoon usually begins in mid June and continue until September/October. The monsoon is characterized by high temperatures, high relative humidity (above 80 percent), overcast skies and prolonged rainstorms that may last for several days at a time. Cool season lasts from October/November to February when rainfall, temperature and relative humidity remain less and skies remain clear. Temperatures begin to rise in February/March and are highest in April and May. Maximum mean temperature is 32°c in the month of May and mean minimum of 12°c in January.

The rainfall in the Sundarbans range from 1640 - 2000 mm per year. On average 80 percent of the rainfall occurs from June to October. On the sea face mean rainfall is about 2,790 mm annually and at Khulna mean is about 1,800 mm. From October to May winds are generally from the north or northwest and from June to October from the south east. The main period for cyclonic storms is during April and May and are usually more severe. However, there have been devastating cyclones after the monsoons as late as November as for example in 1970, 1972 and 1988.

2.6 Vegetation

The natural vegetation of the Sundarbans forest is composed of halophytic tree species, which can loosely be termed mangrove (Chaffey et.al 1985). The forest canopy is seldom more than about 10 m above ground level. Much of the forest is two - storied, with scattered trees attaining heights of above 20 m. Stem diameters are less than 20 cm at breast height although a few species attain diameters upto above 1 m. Epiphytes are common and woody parasitic species are also common on tree crowns.

Since the Sundarbans vegetation has to adapt to the salinity the forest flora is not rich in species. It is dominated mostly by two species sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha)*. There are above 25 other tree species which are common but considerably less frequent in their occurrence than the above two species. A list of the important plants of the Sundarbans are given in Table 1.

In general the forest in the northern and eastern parts of the Sundarbans, better supplied with freshwater, is floristically richer than that in the south and west. Golpatta palm (*Nypa fruticans)* which forms thick fringes along river sides in the north and east becomes progressively less frequent towards the south and west. Species such as jhanna (*Rhizophora mucronata)* and goran *(Ceriops decandra)* members of the Rhizophoraceae and most frequent in the most saline areas also occur in the north and east, although infrequently.

With *Heritiera* spp. (sundri) from the Sterculiaceae family, the three other plant families which may be regarded as key component of the mangrove flora of the Sundarbans are the *Avicenniaceae*, *Rhizophoraceae*, and *Sonneratiaceae*. Baen *(Avicennia officinalis)* Sada baen *(A. alba)* represent Avicenniaceae; goran, jhanna and kankra *(Bruguiera gymnorrhiza)* represent Rhizophoraceae; and Keora *(Sonneratia apetala)*, and ora *(S. acida)* represent Sonneratiaceae.

Five other families although typically associated with dry land habitats are also represented in Sundarbans. These are Combretaceae, Euphorbiaceae, Meliaceae, Myrsinaceae and Plumbaginaceae. Some of the species which occur in places of lower salinity, usually on raised areas, are more commonly found as components of dry - land forests and are only marginally salt-tolerant. Examples of these are: Jir *(Ficus spp)*, jam *(Eugenia fruticosa)* and gab *(Diospyrus peregrina)*. Floristic composition of the Sundarbans is provided in Appendix 1.

A number of factors are involved in controlling the Sundarbans ecosystem is addition to soil and plant interactions. The ecological conditions which are essential for development of mangrove vegetation are: shallow water with thick mud, high humidity in the atmosphere and cloudy weather and clayey, silty - clay to sandy - clay soil with a fair amount of organic matter (Alim 1984). The trees

TABLE 1

A LIST OF COMMON IMPORTANT PLANTS OF THE SUNDARBANS

FAMILY	SCIENTIFIC NAME	VERNACULAR NAME
TREES AND SHRUBS		
Avicenniaceae	*Avicennia officinalis*	Baen
Combretaceae	*Lumnitzera racemosa*	Kirpa
Euphorbiaceae	*Excoecaria agallocha*	Gewa
Leguminosae	*Cynometra ramiflora*	Shingra
	Pongamia pinnata	Karanja
Malvaceae	*Hibiscus tiliaceus*	Bhola
Meliaceae	*Amoora cucullata*	Amur
	Xylocarpus granatum	Dhundal
	Xylocarpus mekongensis	Passur
Myrsinaceae	*Aegiceras corniculatum*	Khalshi
Palmae	*Nypa fruticans*	Golpata
	Phoenix paludosa	Hantal
Rhizophoraceae	*Bruguiera gymnorrhiza*	Kankra
	Ceriops decandra	Goran
	Rhizophora mucronata	Garjan
Sonneratiaceae	*Sonneratia apetala*	Keora
	Sonneratia caseolaris (acida)	Ora
Sterculiaceae	*Heritiera fomes*	Sundri
GRASSES		
	Eriochloa procera	Nol gash
Gramineae	*Saccharum cylindricum*	Ullu
	Typha elephantina	Hogla

of the Sundarbans exhibit various of the hydrophytic and halophytic adaptations which facilitate survival in waterlogged and saline conditions. They have to contend not only with these factors but with the fluctuations in them resulting from change of tide and river flow. A number of the tree species in the Sundarbans have pneumatophores. These are vertical, woody extensions of the root system, well provided with lenticels and with specialized, internal tissue; they project above the soil and afford a means of gaseous exchange. The height of the pneumatophores of some species, e.g. sundri, varies with site, according to the high-tide level, and they are longest where the water becomes deepest, ensuring that they remain always partially exposed. Seven species have pneumatophores, namely amur *(Amoora cucullata)*, baen, keora, Ora, Passur *(Xylocarpus mekongensis)*, sada baen and sundri. In forest dominated by Sundri, pneumatophores tend to grow particularly densely and making difficult to walk on foot.

Certain other species exhibit another form of visible root adaptation to swamp conditions, that of surface rooting. Gewa produces small, raised 'knees' at the soil surface and kankra roots tend to form shallow loops above the ground. In each case the exposed root surface are densely provided with lenticels. Dagor *(Cerbera manghas)* and khalshi *(Aegiceras corniculatum)* also produce surface roots. Aerial roots, arising from the bole or branches but not penetrating the ground, are produced by jhanna and baen.

Four species have stilt roots of the sort typically associated with mangrove forest. These are goran, jhanna and kirpa (Lumnitzera racemosa). Only in jhanna are the stilt roots well developed; they form a widely spaced framework supporting the main stem. In goran they are small and usually hidden beneath accumulation of mud thrown up by crabs which are particularly numerous under dense vegetation. Stilt roots are poorly developed in kirpa and only sometimes present.

A plant inhabiting a saline environment must be physiologically adapted to regulate the concentration of salt in its tissues. Four main methods of salt regulation are recognized (Chaffey et.al. 1985 after Teas 1979) and all are exhibited by the flora of the Sundarbans. These methods are salt exclusion, salt excretion, succulence and the discarding of tissue in which salt has been accumulated. Some species employ more than one of these methods.

The species in the Rhizophoraceae, namely; goran, jhanna and kankra, all have the ability to reduce the amount of salt entering their tissue by a process of ultra-filtration. Baen and khalshi are examples of species which permit the entry of salt water but remove excess salt by excretion through salt glands in the aerial parts of the plant. Succulence, achieved by absorbing additional water to dilute accumulated salt is exhibited by, for example, gewa, keora, kirpa and ora. The discarding of salt laden tissues is a feature of, among other species, gewa.

An essential process in the biology of the Sundarbans, as in any natural forest, is that of seed dispersal and germination. The mangrove species of the Rhizophoraceae are viviparous and the photosynthetic propagules which develop on the parent tree are able rapidly to produce seedlings once released. The seeds of baen and khalshi also germinate while on the parent tree but their development before release does not proceed as far as in the case of goran, kankra and jhanna. The shape of the propagules of these last four species facilitates immediate implantation in the mud beneath the parent tree, in the event of soil conditions being favourable, but most are dispersed by floating. The other species in the Sundarbans do not exhibit viviparity. Once released their seeds depend on being trapped by obstructions such as undergrowth or pneumatophores with which they float on tide. Most of the non-viviparous species of the Sundarbans, with the notable exception of gewa, have large seeds whose size facilitates their being trapped and whose food reserves permit lengthy dispersal periods under wet conditions and support rapid early growth of the seedling. Gewa is unusual in having minute seeds. The fruit of keora are eaten by deer and monkey.

2.7 Ecological zonation

Based upon salinity and species composition three ecological zones have been recognized within the Sundarbans : Freshwater, Moderately Saltwater and Saltwater Zones (Fig.3). The zonation of the Sundarbans is defined by the distributions of the three species, sundri, gewa and goran. All three occur throughout the Sundarbans but in different proportions depending on salinity. Sundri is the characteristic species of the Freshwater Zone, gewa of the Moderately Saltwater Zone and goran of the Saltwater Zone.

Freshwater Zone

The sundri forest which is typical of the Freshwater Zone consists of good quality stands of sundri, of height about 15 m, with varying amounts of gewa. A distinct form of sundri forest, which occurs in the northern central part of the Freshwater Zone, is one which contains, in addition to sundri, high proportions of passur and kankra. The kankra, where present, may form almost pure stands. Undergrowth in the sundri and mixed sundri forest types is usually sparse, but gaps are colonized by gewa or by scrub and climber species.

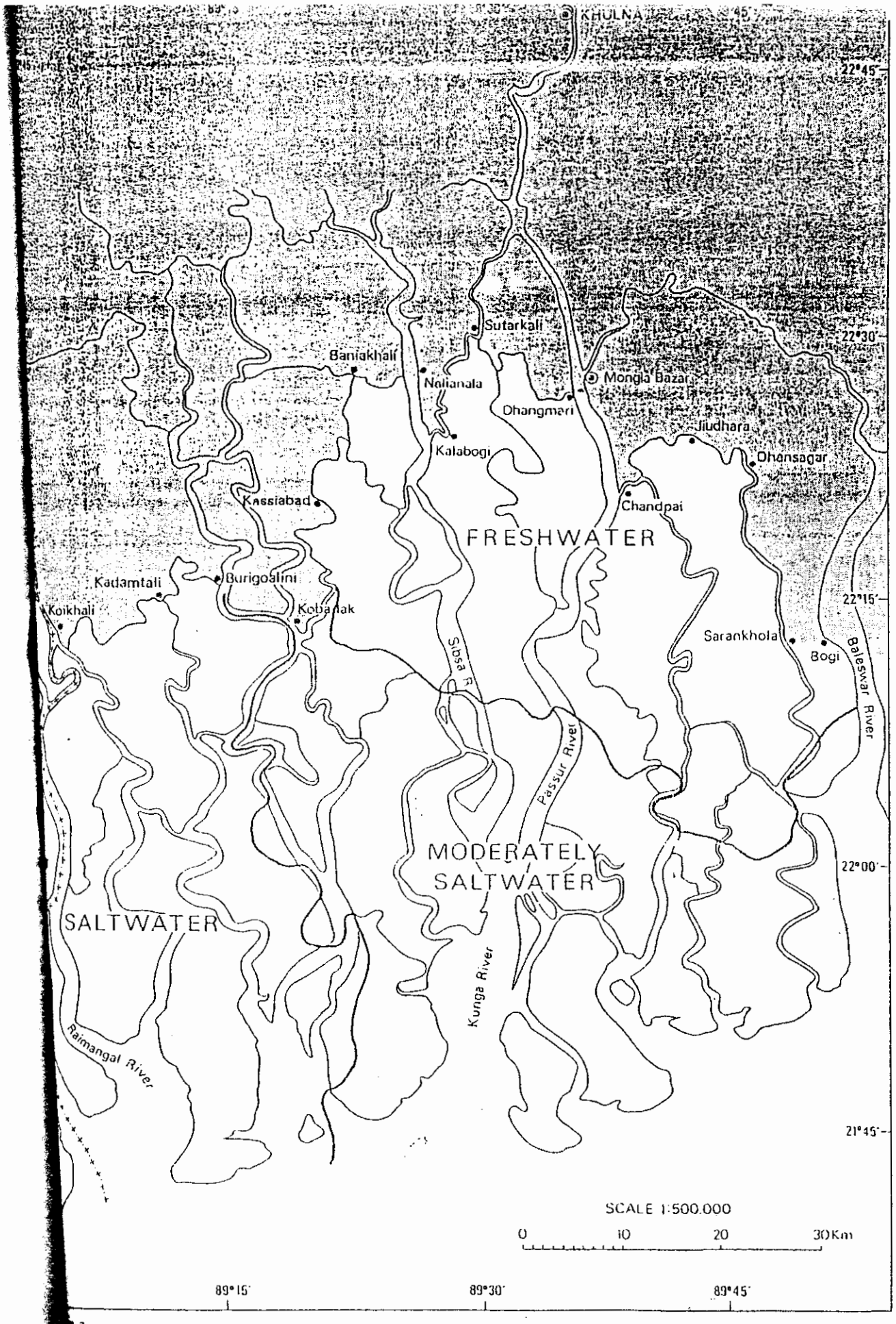
Moderately Saltwater Zone

The forest of the Moderately Saltwater Zone is typically a mixture of gewa and sundri with varying amounts of goran and other species. The canopy height is generally less than 10 m, although emergent species such as sundri, passur, dhundal (*Xylocarpus granatum*) and baen may attain a greater height.

The frequency of sundri and the size of individual trees of the species decreases from north to south. So also does the frequency of passur, which tends to be replaced by dhundal in the southern part of this zone. East of the Kunga Estuary, kirpa frequently occurs in mixture with gewa. In forest in which gewa is the predominant species there is frequently a patchy understorey of goran.

Saltwater Zone

The forest in the Saltwater Zone is typically a more or less closed understorey of goran with a broken and often widely dispersed overstorey of gewa, passur and dhundal. The goran is generally about 4 m in height. Keora, baen, kankra and jhanna occur as isolated or widely spaced individuals and the first two especially tend to form relatively large emergents. Although frequently dense, the goran understorey is variable and may not be present at all. In such areas the gewa is poorly developed also. The formation called gewa mathal represents an extreme, in which goran and other species are absent and the gewa consists entirely of stunted, widely spaced clumps of coppice regrowth.



6.3 Ecological zones

In the Sundarbans generally, passur tends to be replaced by dhundal towards the southern part of the Saltwater Zone. The northwestern part of the Saltwater Zone contains patches of pure sundri but the trees are stunted and have a poor form.

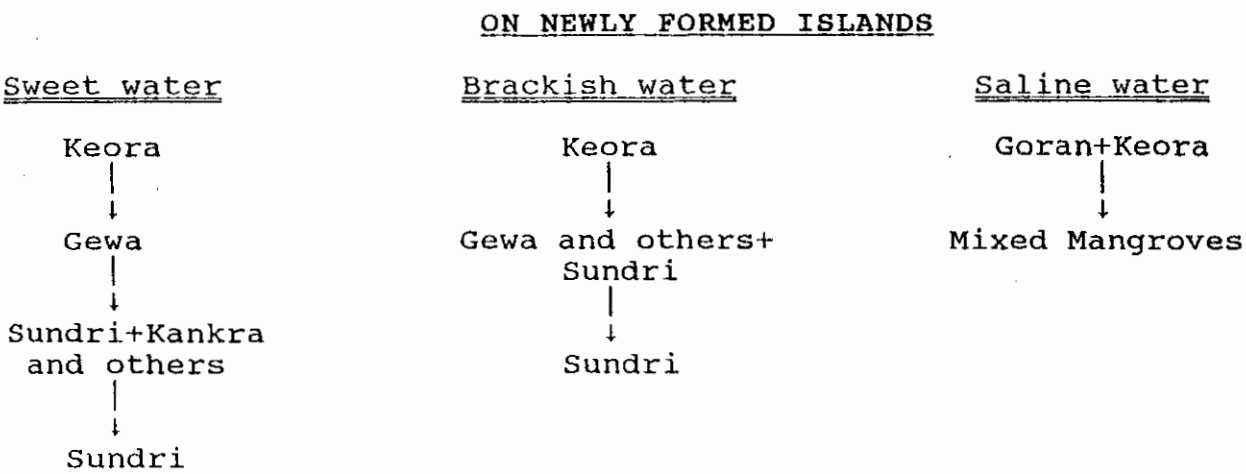
There are also pure stands of baen in this area, especially along river banks. Another frequent riverine species is hantal (*Phoenix paludosa*), the thorny palm which occurs throughout the Sundarbans but which in this area is particularly common.

2.8 Ecological Succession

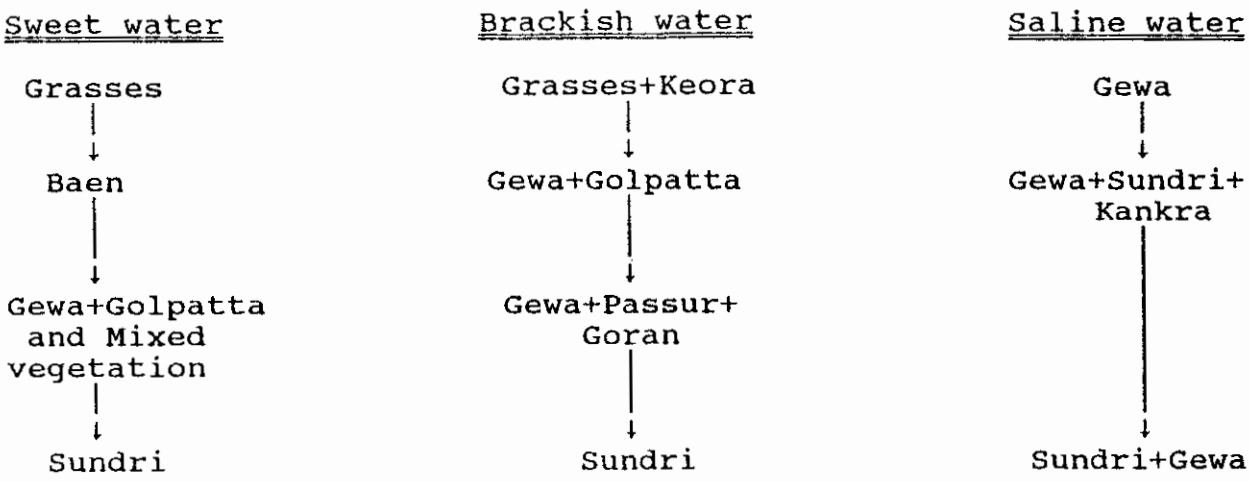
The vegetation which colonizes newly accreted land is a single pioneer species keora. Once land has accreted to a stage at which it can support woody vegetation, which is normally preceded by grass, stands of keora develop. These are normally pure but may contain some ora and khalshi. Keora stands attain a height of 15 m or more and tend to be divided into more or less even aged bands running parallel to watercourses, each band representing a different period of year of colonization. Behind the keora, there is frequently baen, stands of which are often the next successional stage after keora. Keora stands are short-lived, reaching maturity in 50 years or so, after which they begin to deteriorate and other species, e.g. baen, sundri or gewa, start to establish themselves in succession. There is little or no undergrowth to keora.

As the ground level rises by accretion and the land then is only occasionally flooded by the tide, Sundri makes its appearance. It is not uncommon to find Sundri coming up under large dying Sundri trees. Sundri is the climax species for the Sundarbans. The succession is mainly influenced by the changes that take place in the soil.

The natural succession near the sea-face and on the river banks the first colonizer varies according to the salinity of soil and water. In all cases the climax is attained by Sundri but follows different routes as illustrated below (Das and Siddiqi 1985).



ON RIVER BANKS



2.9 Fauna

At least thirty two mammal species are known to occur or to have occurred in the Sundarbans (Salter 1984). A list of mammals in the Sundarbans and adjacent areas is given in Table 2.

TABLE 2

LIST OF MAMMALS IN THE SUNDARBANS AND ADJACENT AREAS

INSECTIVORA	
Suncus murinus	House Shrew
CHIROPTERA	
Cynopterus sphinx	Greater Short-nosed Fruit Bat
Pteropus giganteus	Flying Fox
Taphozous longimanus	Long-winged Tomb
Magaderma lyra	Greater False Vampire Bat
Hispposideros hicolor	Bicolor Roundleaf Bat
Coelops frithi	East Asiatic Tailless Roundleaf Bat
Pipistrellus mimus	Pygmy Pipistrelle
P. coromandra	Pipistrelle
Scotophilus kuhlii	Lesser Yellow Bat
S. heathi	Greater Yellow Bat
S. luteus	Bengal Yellow Bat
Rhinopome hardwickii	Lesser Rat-tailed Bat

PRIMATES

Macaca mulatta	Rhesus Macaque

RODENTIA

Dremomys sp.	
Vandeleuria oleracea	Tree Mouse
Bandicota indica	Great Bandicoot Rat
B. bengalensis	Mole Rat
Rattus rattus	Roof rat
Mus cervicolor	Fawn-coloured Mouse
M. booduga	Field Mouse
Hystrix hodgsoni	Crestless Malay Porcupine
Callosiurus pygerythus	Himalayan Squirrel
Funambulus pennanti	Five-striped Palm Squirrel

CETACEA

Sotalia plumbea	Plumbeous Dolphin
Delphinus delphis	Common Dolphin
Occaella brevirostris	Irrawaddy Dolphin
Neomeris phocanoides	Little Porpoise
Platanista gangetica	Gangetic Dolphin

CARNIVORA

Vulpes bengalensis	Bengal Fox
Canis aureus	Jackal
Lutra perspicillata	Smooth Otter
Herpestes edwardsi	Mongoose
H. javanicus	Javan Mongoose
Paradoxurus hemaphroditus	Palm Civet
Viverra zibetha	Large Indian Civet
Panthera tigris	Tiger
Felis viverrina	Fishing Cat
F. bengalensis	Leopard Cat
F. chaus	Jungle Cat

ARTIODACTYLA

Sus scrofa	Wild Boar
Muntiacus muntjak	Barking Deer
Axis axis	Spotted Deer

MAMMALS

At least four major large mammal species, the Javan rhinoceros (*Rhinoceros sondaicus*), wild buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvauceli*) and hog deer (*Axis porcinus*) have become extinct since the beginning of this century. At present the larger

terrestrial mammals found in the Sundarbans are : tiger (*Panthera tigris*), the spotted deer or chital (*Axis axis*), barking deer (*Muntiacus muntjak*), wild boar (*Sus scrofa*), Rhesus macaque (*Macaca mulatta*) and smooth Indian otter (*Lutra perspicillata*). Various rough population estimates for these mammals have been given. Hendrichs (1975) gave the following rough estimate :

Tiger	350
Spotted deer	80,000
Wild boar	20,000
Rhesus Macaque	40,000
Otter	20,000

TIGER (*Panthera tigris*)

Tigers exist throughout the Sundarbans both in Bangladesh and the Indian side. It has been listed as an endangered species from 1969 in the Red Data book of the IUCN. The Sundarbans population is one of the largest surviving population of tigers. However, this population (in Bangladesh and India combined) is completely isolated since there is no adjoining tiger habitat outside the Sundarbans and no genetic interchange between this and other population of tigers.

The tiger is treated as the king of the jungle. It has a unique place in the culture, religion and history of the people of Asian countries. The tiger is admired, feared and respected by the human population for its beauty, grace, strength, ruthlessness and other natural and supernatural attributes. Claws adapted to strike and hold struggling prey, canines designed for biting and killing, short strong jaws controlled by powerful muscles, soft pads for stealth approach make this carnivore capable of sudden speed and bursts of power. Combined with highly developed sense of hearing, vision and smell its species adaptations and characteristics make the tiger a perfect carnivore. As the herbivores have evolved increasingly-effective defenses, the carnivores have developed efficient anatomical "weapons" and hunting methods. Members of the Order Carnivora are the most highly developed specialists among meat-eating mammals.

The precarious status of tiger was formally recognized at the 1969 meeting of the general assembly of the IUCN in Delhi, India. Since then, national and international efforts have been focused on the conservation and protection of this magnificent species.

Basic background information on its ecology and behaviour is vital to making the proper management decisions for maintaining viable tiger populations in the wild. Such data, however, are either scarce or lacking. Not only are the tigers secretive, of low density and essentially solitary hunters, but surviving population are isolated, scattered and mostly confined to parks, reserves and adjoining forests. On other areas, habitat alteration, encroachment and disturbance by man is overwhelming the few remaining animals.

The home range sizes of resident males are much larger than those of the resident female tigers. The resident female tigers occupy much smaller home range sizes,

evidently depending upon the age and mobility of their 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 in fact represents the territory of the resident tiger and is exclusively used by the resident. 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 precise age at which tigers are sexually mature and capable of mating is not known but the onset of first estrus was noticed at age 28 months in the Royal Chitawan National Park in Nepal (Tamang 1982). Heat periods are indicated by distinct roarings and an association with an adult male. It is difficult to determine estrus condition based entirely on either vocalization or association only since resident males associate with resident females at other times and at kills. The frequency of roarings reaches a peak on the third to the fourth day, after the onset of estrus, when roarings become almost continuous. The length of time tigresses in estrus remain receptive has been reported to average 5-7 days and the average interval between estrus cycles have been recorded at 3-4 weeks in Chitawan, Nepal (Tamang 1982). A male becomes sexually mature at about the same age as female at about 2.5 years.

The gestation period for tigers has been given as 100-108 days (Crandall 1964) and 98-112 days (Perry 1964). A wild tigress remains confined with the cubs for several days after giving birth. Although litter sizes apparently vary between 1 and 6, 2 to 4 seems to be the usual number of cubs seen with tigresses. The maximum life expectancy for wild tigers may be around 20 years (Schaller 1967, Sankhala 1977). A total of six litters could be produced in a life time if a tigress produces her first litter at 3 years of age, produced a litter every 2 years until the maximum reproductive age is reached at 15 years. Assuming an average litter size of 2.5 cubs, 15 cubs could be produced by such a female in her life time. The welfare of the tiger population is dependent upon maintenance of its habitat, including its prey species. The role of tiger in its ecosystem can be assessed properly only with a parallel determination of the status and characteristics of the prey populations. In the Sundarbans the spotted deer (Chital) and wild boar are fairly abundant and comprise the principal prey species of the tiger. The Sundarbans tigers also prey on macaques, barking deer (in the north and northeast), otters, monitor lizards, reptiles, frogs, fish, crabs, other small carnivores and occasionally man. Tiger predation on spotted deer and wild boar contribute greatly in keeping their numbers in check and in controlling the damage to the forest and forest regeneration by these animals in the Sundarbans. No leopards or other large carnivore exist in the Sundarbans. Conservation and maintenance of a viable population of tigers is necessary and essential for the maintenance of the ecosystem in the Sundarbans and should be a primary objective of management.

THE SPOTTED DEER (*Axis axis*)

The spotted deer also called Chital or axis deer is considered the most beautiful of all cervids. It is widely distributed in the subcontinent and are considered to be among the most primitive of the true cervids (Schaller 1967). Spotted deer are found throughout the Sundarbans but are most abundant in the south, where stretches of extensive grassland and scattered forests of keora trees occur. Grasslands provide excellent grazing grounds, and keora leaves and fruits are preferred food for the deer. Such combination of vegetations are found in Sundarbans East (Tiger Point), Sundarbans South (Hiron Point or Nil Kamal) and Sundarbans West wildlife sanctuaries. In all these areas in the south, plentiful spotted deer sometimes numbering more than a hundred can be seen grazing in the meadow-like grasslands. Many times spotted deer are observed in association with Rhesus macaques and feeding on keora leaves and fruits dropped by the monkeys. The forests get denser and closed towards the north and the density of deer population is less in the north. There is little herbage in the ground and relatively lower carrying capacity on account of less food being available in comparison to the south.

Herd size of the spotted deer vary considerably with the season and availability of food and water. They gather in large numbers after grass areas were burned and new forage became plentiful from March to May in the grasslands. They indicate a preference for grasslands and keora forests. Over 70 percent of the herds were observed in these forests.

The females keep their newborn young hidden for varying lengths of time before joining a herd. When fawns are observed with females in a herd, it gives only a relative idea of the births in any one month. Most spotted deer fawns were born between January and March, the peak fawning period. Some fawns were, however, seen at other months of the year. The spotted deer females in captivity show a continuous series of diestrous cycles throughout the year, each lasting about 3 weeks. Therefore Chital females are capable of conceiving during any month of the year when not pregnant. The gestation period for spotted deer is 7.5 months (Graf and Nichols 1966, Russ 1973). Antler replacement occurs in an annual cycle. Bucks (males) shed their antlers yearly after the rutting (mating season) and replaced by "velvet" antlers that develop to full size while covered with fur. These velvet antlers turn hard when they shed the skin at the onset of the next rutting period. Almost all bucks are in hard antlers by the peak rutting period, which is between April and June for the Sundarbans. Bellowing is the most commonly heard or observed behaviour associated with breeding among spotted deer males. The frequency of these vocalizations suggests a major breeding (rutting) season from April to June.

WILD BOAR (*Sus scrofa*)

The wild boar inhabits various forest types and are found throughout the Sundarbans. Young ones are brown with dark stripes. They lose their stripes in a few months and become dark brown and black as they grow older. Next to the spotted deer, wild boar comprise the most important among common ungulates in the Sundarbans both in terms of numbers and biomass, and as principal prey species for the tigers.

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.

Wildboar in the Sundarbans perhaps pair in December/January since the youngs were seen in April/May. The gestation period is 3.5 months and four to six or more young are born in a litter. Mortality among young ones may be high due to predation and other causes. A wild boar sow seen with 8 young ones on 15 March 1993 drinking at the pond behind the Katka forest guest house, (the same) was seen with only 2 youngs five weeks later. Wild boar is not subject to poaching since there is little demand for its meat.

BARKING DEER (*Muntiacus muntjak*)

The barking deer is a widely distributed species in Asia but is confined to the north and northeast in the Sundarbans. They are small and an adult weighs from 20-23 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. The barking deer is not a grassland animal. Their absence in the south may be related to habitat and vegetation cover conditions. Barking deer are solitary animals with a rare association of more than two individuals. Females with young or a male with a female may be found together. Barking deer breed at all seasons but the main rut takes place in winter (December/January).

Rhesus Macaque (*Macaca mulatta*)

Large numbers of rhesus macaques were formerly trapped from the wild and exported for medical research. The practice has been banned and no more trapping takes place in the Sundarbans. Density estimates vary but natural forest areas support higher densities compared to the scrub forest. Rhesus macaques live in groups of 10-30 or more individuals, often observed in close association with spotted deer.

The diet consists of plant materials such as keora leaves, young golpatta, grasses and crabs and fish. Mudbanks along streams and stands of keora trees are important foraging habitats for rhesus macaques. No other primate species is found in the Sundarbans.

OTTER (*Lutra perspicillata*)

The smooth Indian otter is distributed throughout the Sundarbans and are more abundant in the north. This aquatic predator forage along mudbanks and in river channels eating fish, crabs, frogs and crustaceans. Some local fishermen use tame otters to drive school of fish into nets. Some otters are captured from the wild and some are reportedly bred in captivity.

BIRDS

There is a wide variety and colorful birdlife in the Sundarbans. Of the 260 species of birds reported to be occurring in Bangladesh mangrove ecosystems (Khan n.d.) at least 186 have been recorded in the Sundarbans and it is likely many more will be added in the future since the list is incomplete (Salter 1984). The avifauna of the Sundarbans is one of the biggest attractions and important for conservation of some species that are rare in other areas. An estimated 25 percent are migrants present only during the winter months. The Sundarbans provide roosting and breeding sites for a number of bird species that feed in adjacent cultivated areas. A bird checklist of the Sundarbans is presented in Appendix 2.

2.10 Reptiles and Amphibia

At least 35 species of reptiles and 8 species of frogs and toads have been recorded from the Sundarbans (Table 3). The mugger or marsh crocodile (*Crocodylus palustris*), once abundant, is now extinct probably due to over exploitation. The saltwater crocodile (*Crocodylus porosus*) still survives in very reduced numbers through hunting and trapping for skins in the past. This species is occasionally seen these days. It is vulnerable to extinction in the Sundarbans unless effectively protected. Although poaching is now minimal the population shows little sign of recovery and may even be decreasing (Whitaker 1982).

Three species of monitor lizards are found in the Sundarbans. These species were exploited for their skins in the past. To what extent these animals are harvested at present is not known. Monitors are reported killed for food when encountered by forest laborers. Occasionally, monitors are sighted in different areas in the Sundarbans. Rock Python (*Python molurus*) listed as vulnerable to extinction by the IUCN is rather rare.

Five species of marine turtles : the olive ridley, green, loggerhead, hawksbill and leatherback are reported from the Sundarbans out of which green turtles are reportedly most abundant. Marine turtles are reported to nest on a number of sandy islands offshore and suitable beaches all along the southern coast of the Sundarbans. Turtle eggs are collected and eaten by fishermen and some are marketed but the numbers and extent of harvesting is not known. Some turtles

caught in the fishing nets are eaten and some are sold. Some turtles and turtle eggs are available in the markets outside of the Sundarbans.

The common batagur or estuarine terrapin (*Batagus baska*), listed as an endangered species by IUCN nests along Katka and Konga river. Local fishermen reportedly 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. Altogether eighteen species of snakes have been recorded including the king cobra, spectacled cobra, three vipers and six sea-snakes. Bangladesh Wildlife (Preservation) Act 1973 has listed several species of reptiles as protected including the estuarine crocodile, rock python, three species of monitor lizards and the black mud turtle.

TABLE 3

AMPHIBIA

Bufo melanostictus	Toad
Rhacophorus maculatus	Tree frog
Rana cyanophlyctia	Frog
R. limnocharis	
R. tigrina	
R. hexadactyla	Green Frog
R. Temporalis	Gach Bang
Microhyla ornata	

REPTILIA

CROCODILIA

Crocodylus palustris	Mugger (no longer found)
C. porosus	Estuarine crocodile
Gavialis gangeticus	Gavial (no longer found)

SQUAMATA

Hemidactylus flaviviridis	Wall gecko
Eublepharis fasciolatus	Leopard gecko
Gekko gecko	Tokay
Mabuya dissimilis	Five-lined skunk
Calotes versicolor	
Chamaeleon zeylanicus	Indian chameleon
Varanus bengalensis	Bengal monitor
V. salvator	Yellow monitor
V. flavescens	Ruddy sub-nosed monitor
Naja naja	Cobra
Typhlops porractus	Blind snake
T. acutus	Blind snake

Ahaetulla ahaeulla	Whip snake
A. cyanochloris	
Python molurus	Rock python
Natrix stolata	Keel back
Enhydris enbydris	
Fordonia leucoblia	
Bungards lividus	Krait
Acrochordus	Wart snake
Hydrophis obscurus	
H. nigrocinctus	
Microcephalophis cantoris	Sea snake
Engydrina achistoss	Beaked deep sea snake
Ptyas mucosus	Rat snake
Spalerosophis diadema	
Vipera russelli	Russell's viper
Pligodon arnensis	Kukri snake
Oligodon dorsalis	
Dryophis mycterigans	Tree snake
Lycondon aulicus	Common wolf snake
Eryx conicus	Russell's sand boa
Psammophts candouarus	

TESTUDINATE

Pelochelys bironi	Coast shell turtle
Morenia petersi	Bengal terrapin
Batagur baska	River terrapin
Lepidochelys olivaca	Ridley turtle
Cheonia mydas	Green turtle
Trionyx hurun	Peacock soft-shell turtle
T. gageticus	Ganges soft-shell turtle
Lissemys punctata	India flap-shell turtle
Kachuga tecta	India roofed turtle
K. smithi	
K. kachuga	

Source : Hendrichs 1975, Mukherjee 1975

2.11 Fish and Crustaceans

Over 100 species of fish are reportedly caught by commercial fisherman in the Sundarbans. Eighty fish specimens have been collected by our project fisheries biologist in the last ten months (Dr. S. Chantarasri - personal communication) in the Sundarbans. The largest proportion of animal biomass is represented by the crustaceans : 140 million kg of fiddler crabs and 100 million kg of mud crabs in the

Sundarbans (Hendricks 1975). The Sundarbans produce a considerable harvest of shrimps and prawns which together with Bagda or Giant tiger prawn fries (*Penalus monodon*) provide livelihood for several hundred thousand fishermen and women operating in the Sundarbans and adjacent areas throughout the year. Over 110 million Bagda fries were collected in 1992 for seeding shrimp ponds. The mud-skippers or gobys, common to mangrove swamps, occur in abundance and are a characteristic feature of the Sundarbans.

2.12 Insects

The Sundarbans supports a wide variety of insect populations. The most commercially important products include honey and beeswax from wild-honey-bee (*Apis dorsata*) in the Sundarbans collected in the months of April and May. One hundred sixty tons of honey and 43 tons of beeswax were collected from the Sundarbans in 1992 for a revenue of about Tk. 640,000 (Islam 1992).

The larvae of a moth (*Hymenoptichyis sordida*) destroy fruits (Curtis 1933). Colorful butterflies are found but since no detail study of the insect life of the Sundarbans appears to have been carried out so far, no data are available.

2.13 Socio-Economic Importance

The Sundarbans alone generate more than 50 percent of the revenue from the forestry sector in Bangladesh and provide employment for over 350,000 people working as woodcutters, fishermen, honey gatherers, golpatta and thatching grass collectors and others. In addition, lots of people living in areas surrounding the Sundarbans depend on the resources of the Sundarbans such as timber, firewood, building materials, fish, shrimps for their daily necessities and livelihood. The Sundarbans Forest Division provided a revenue of Tk. 152,484,000 in 1992 (July '91 - June '92) and the expenditure for the same year was a total of Tk.30,759,000 (Islam 1992). Table 4 provides revenues collected from some of the resources in the Sundarbans other than timber in the fiscal year 1991-1992 (Islam 1992).

TABLE 4

REVENUE DERIVED FROM THE SUNDARBANS (1991-1992) FROM NON-TIMBER SOURCES

Gewa (KNM*-Pulp)	Tk. 639,000	Fish, Shrimp and Crabs	Tk. 14,562,000
Bolly (BFIDC**)	Tk. 6,041,000	Oysters	Tk. 78,000
Goran (firewood)	Tk. 5,478,000	Honey	Tk. 465,000
Golpatta(thatching)	Tk. 4,889,000	Beeswax	Tk. 174,000
Hental	Tk. 437,000		

KNM* = Khulna Newsprint Mill

BFIDC** = Bangladesh Forest Industry Development Corporation

2.14 Conservation Value

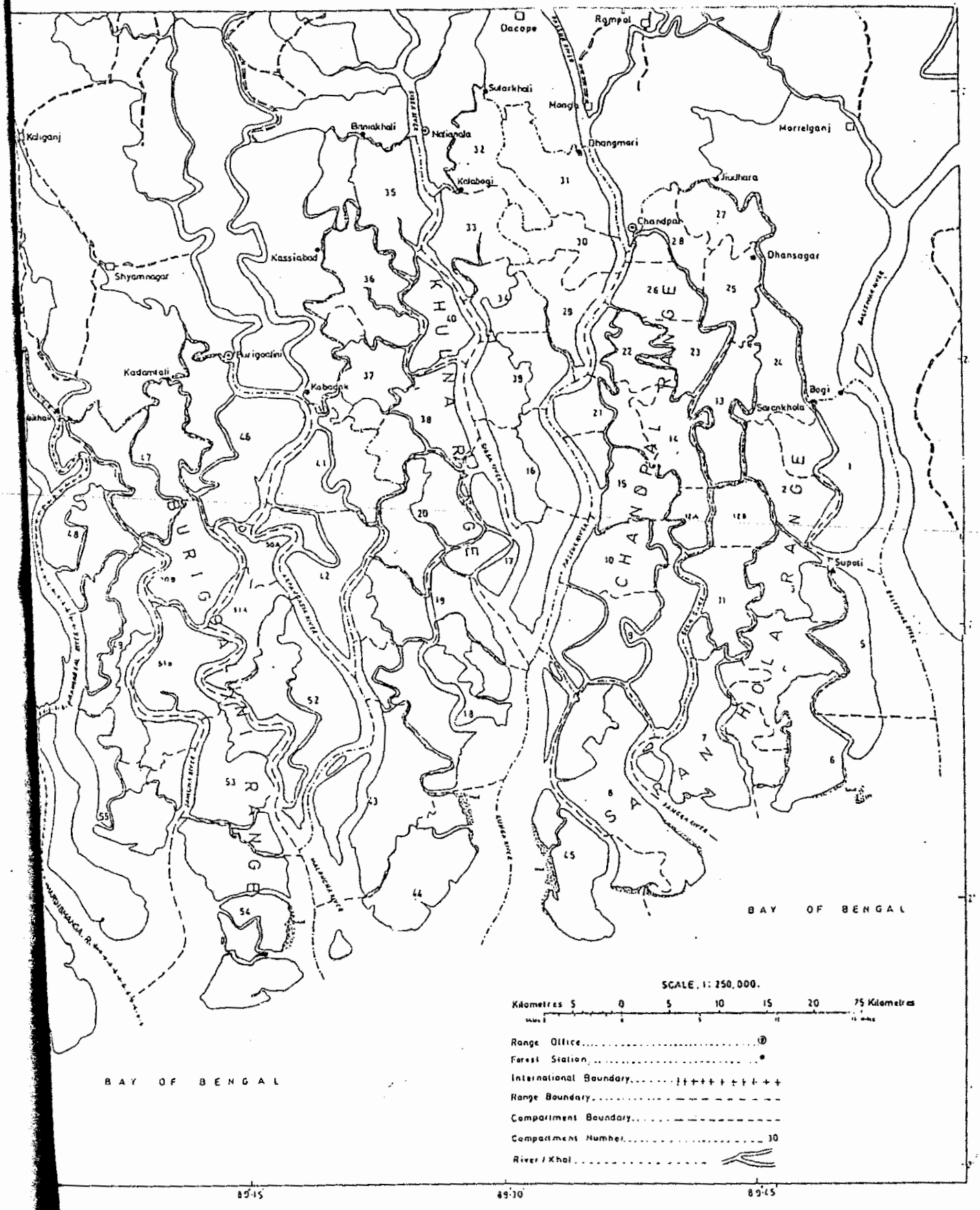
Apart from the economic aspect, the Sundarbans is a unique natural area not only to Bangladesh but also of great importance to the outside world. Nature conservation in the Sundarbans is of great international significance. Protection of the Sundarbans ecosystem have direct and indirect implications. It physically serves as a buffer zone between the populated cultivated areas in the north and the Bay of Bengal, protecting it from the full force of the periodic cyclonic storms and tidal waves. The Sundarbans mangrove swamps and the flora and fauna found therein differ from other mangrove areas in the world. It is of great scientific and educational value, and there are no other such areas in Bangladesh that offer such variety of vegetation, wildlife and scenic beauty. It is home for a viable population of tigers, an endangered species, survival of which is of great concern and interest to the world. Other species of wildlife including the spotted deer, the saltwater crocodile, monitor lizards, other reptiles and a rich variety of birdlife makes the Sundarbans an outstanding asset that needs protection and conservation.

3. ASSESSMENT OF WILDLIFE POPULATIONS

3.1 Methods

Field work related to the assessment of wildlife populations was carried out from October 1992 to July 1993. The Sundarbans Forest Division is subdivided into 55 compartments, each varying in size from 4000-16000 ha (Fig.4). Visit to the

MAP OF SUNDARBANs FOREST, BANGLADESh



4 MAP SHOWING 55 COMPARTMENTS

Sundarbans forest is possible only by launch or houseboat. Forest Department launch was used for transport from Khulna to the Sundarbans and speedboat was used for movement through smaller water channels and khals in the Sundarbans. General reconnaissance was made by visiting all the compartments. Intensive data collection work was carried out in 28 compartments including Sundarbans East, Sundarbans South and Sundarbans West Wildlife Sanctuaries. Wildlife observations were carried out in these areas from launch, speedboat, traversing on foot in the forest and grasslands from observation towers. Sightings of the birdlife was also recorded.

All mammals seen were observed and classified by species, sex, herd size and according to the type of vegetation occupied. Using binoculars, specimens were classified as young, yearlings or adults. The age of young ungulates were estimated on the basis of comparative size. Bucks were considered to be yearlings until they lost their spikes at 18 to 24 months of age. Herd composition counts throughout the study period were used to determine average herd size, herd composition and sex and age ratios. Footprints of deer and wildboar were also observed and recorded.

Vegetation remained dense and visibility was poor in all forest types at all times during monsoon, post-monsoon and other seasons except in some coastal grass areas and keora forests. Direct observation of ungulates to estimate their abundance was impossible most of the year. Poor visibility combined with the lack of roads and trails made it impractical to census animals from foot.

Indirect method of censusing the spotted deer was tried in various vegetation types in 100 m^2 plots from January to May. Counting pellet groups (deer defecations) is an indirect censusing technique which is used to determine population size and distribution. The counting of accumulated fecal pellet groups remains one of the most widely used methods for estimating deer population levels. It is a technique which can also provide an index to the density of species. It has been used for a variety of research and management objectives. The methods is based on the assumption that periodic accumulations of animal defections are related to population density.

The usefulness of pellet groups as an indicator of deer presence and abundance has been tested extensively for deer herd studies since about 1938. The interest of game managers and researchers in pellet group counts as a census method and indicator of range used by game animals has increased in recent years. The use of pellet group counts as a census method is dependent upon several assumptions : deer defecate at a rather constant frequency, pellet groups persist long enough to be counted, groups can be found and counted accurately, a deposition period can be delineated, and groups found can be aged relative to the deposition period.

This technique necessitated knowing the defection rate of the animal to establish the size of the population, otherwise pellet group counts only indicate relative

numbers and distribution of animals. The number of pellet groups released per animal per day has been used to estimate the number of animals in a given area.

Pugmarks (footprints) of tiger were traced to determine its population. The use of pugmarks as a census technique was developed in India. The technique requires a "pugmark tracer" which can easily be made locally. It requires an experienced and skilled observer to interpret pugmark tracings in relation to space and time as well as other important clues. Both the accuracy in tracing of pugmarks and the ability to interpret, require practice and experience. One will then be able to identify individual animals and, if the survey covers all suitable habitat, arrive at a total population of the species within the park or sanctuary. In addition, the data will allow one to determine sex ratio and age structure of the population. If the survey covers large areas and if it is done continuously, one may even be able to determine the boundaries of home ranges and detect variations in them over a given time period.

Equipment for the pugmark tracer consists of the following :

- 1 pane of colorless glass (20cmX25cmX3mm) with holes drilled in the corners.
- Four metal screws, about 5cm long, with wingnuts, nuts and washers to fit; these become the "legs" of the tracer.
- Thin paper to transfer the tracing from the glass.
- Rubber bands to hold the tracing paper onto the glass pane.
- A felt pen which can write on glass (and be erased).
- A measuring tape (100cm).

An impression of the rear pug should be selected, preferably from a series of tracks along a road, sandy stream-bed etc. If no perfect impression can be found, a composite tracing should be made using two or three pugmarks of the same animals. Left and right pugs should be identical mirror images, but if one shows a deformity, that side should be taken, because it can always be easily identified.

Tigers lead solitary lives except mothers and their offspring. However, there are times when males join the "family" for short periods. Because of simultaneous movements distortion of tracks may occur as marks of one individual get superimposed by another. Great care must be taken in identifying pugmarks of an individual in the series of multiple tracks and only then should tracing be attempted.

The size of the pugmark of the same individual may vary depending upon the texture and consistency of the ground surface. In mud, deep dust or sand, the track size will be larger but all the characteristics will remain unchanged.

If an estimate of population size and structure is the purpose of survey, it should be carried out over a period of several weeks during the time when tiger tracks can be most conveniently located. Records to determine home range and utilization of different habitats within a given area, require the survey to be extended through a full seasonal cycle. In the course of a pugmark based count of tigers within a given area, intensive survey for tiger tracks and their tracings have to be made. The pugmark records obtained are compared every day and individual locations entered on a map. In a few weeks these will lead to identification of all individuals using the area.

Reasonably accurate sexing of adults can be made from the overall comparative shape of the pugmarks. Pugmarks of the young are smaller. Cubs less than three months old are seldom taken out and cubs upto a year old do not move except with the mother. Sexing and ageing is thus possible from pugmark records.

The tracer is directly placed above a clear track. The legs of the tracer is pushed into the soil until the glass pane is just above the track surface. If the ground is hard, the glass pane is lowered by adjusting the wing-nuts which hold it in place. Tracing is drawn with both knees on the ground left and right of the tracer and looking straight down. By moving the head while drawing, so as to keep the eyes vertically above the tip of the pen and the portion of the mark under tracing, the error of parallax is avoided and an accurate tracing is made.

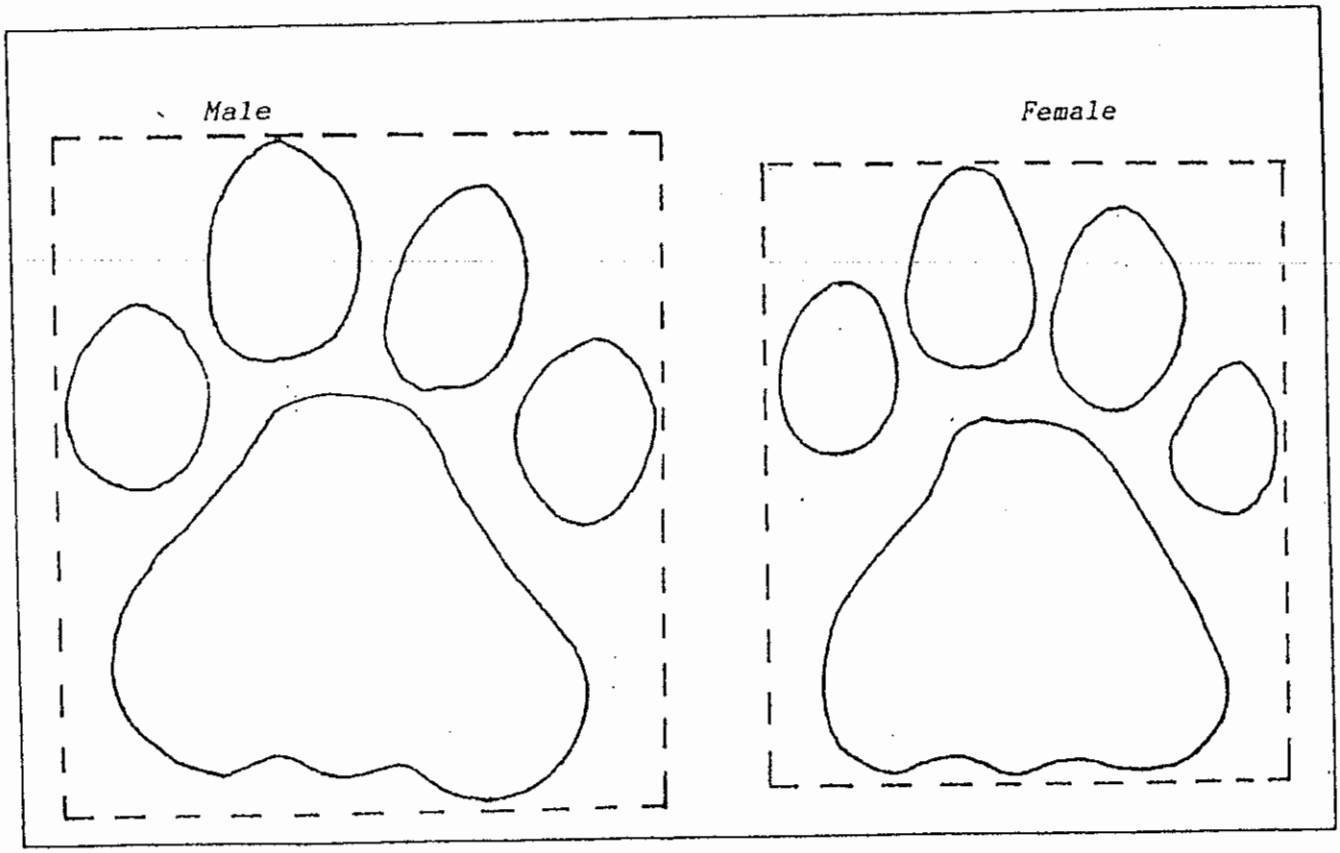
To transfer the pugmark from the glass to paper, tracing paper is attached to the glass by means of rubber bands and, holding it up against the light, the pugmark outline is drawn taking care to avoid the error of parallax.

A walking tiger in normal gait places the rear foot on top of the impression made of the front foot. The positioning, however, changes with the speed of walking, but rear pugmarks always remain undisturbed because the rear pug either superimposes the front pugmark or overshoots it. This is one reason for choosing pugmarks made by the rear pug. Rear pugs are invariably smaller then front pugs. Of the superimposed pugs, the inner outline is outline of the rear pug.

Another reason is that only the rear pugmark is different between males and females. The distinction is one of size (male pugs are larger) and shape. A "box" drawn around the pugmark of the male is almost a square. A box drawn around the pugmark of the female, on the other hand, is clearly rectangular (Fig.5).

FIGURE 5

TRACING OF TIGER PUGMARKS (REAR)



3.2 Results

Ungulates

The spotted deer herd sizes varied considerably with the season and availability of food, water and cover (Table 5). The spotted deer gathered in large herds after the grass area meadows were burnt or cut and new forage became plentiful. Average herd size for spotted deer was 5.4 with maxima of over 100 animals in March, April and May. These large herds were observed in the grass meadows in the Sundarbans East Wildlife Sanctuary (Katka, Jamtolla, Kachikhali, Tiger Point areas). Based on observations, the spotted deer indicated a preference for grassland-keora-mixed forest combination prevalent in the southern coastal areas and in the three wildlife sanctuaries.

TABLE 5

RELATIVE ABUNDANCE AND HERD SIZES FOR SPOTTED DEER SUNDARBANS FOREST DIVISION, 1993

Number of Herds in ( )	Average Herd Size	Herd Sized - %							
		1	2	3	4	5-10	11-20	21-30	31+
	5.4	6%	20%	16%	22%	24%	9%	2%	1%
(371)		(24)	(73)	(59)	(83)	(89)	(32)	(7)	(4)

A pronounced disparity of the sexes 48 males to 100 females in the adult population of spotted deer shows the sex ratio in favor of females 48♂:100♀ (Table 6). This disproportion in sex ratio may be due to a number of factors such as an unequal sex ratio at birth, higher mortality in young males and selective predation by tigers on adult males.

TABLE 6

PROPORTION OF ADULT MALES AND JUVENILES PER 100 ADULT FEMALES FOR SPOTTED DEER SUNDARBANS FOREST DIVISION, 1993

SPECIES	NUMBER	ADULT : JUVENILES
Axis axis	1990	48 : 46

Estimates of numerical and biomass density were determined from pellet group counting method and direct observation of spotted deer in different vegetation types. The ODA forest inventory (Chaffey et al 1985) has classified the Sundarbans forest into 11 forest types, Table 7.

TABLE 7

AREAS OF FOREST TYPES Km^2
SUNDARBANS FOREST DIVISION

	FOREST TYPE	AREA Km^2	
1.	Sundri	831	
2.	Sundri-Gewa	1164	Type I
3.	Sundri-Passur	22	2082 Km^2
4.	Sundri-Passur-Kankra	65	
5.	Gewa	196	
6.	Gewa-Sundri	585	Type II
7.	Gewa-Goran	362	1143 Km^2
8.	Goran-Gewa	572	Type III
9.	Goran	93	665 Km^2
10.	Keora	33	Type IV
11.	Grassland, Scrub, Bareground	32	65 Km^2

Forest types are named according to the predominant species. The Scientific names of species are given in Table 1.

For the purpose of wildlife abundance and density estimation the above forest types were grouped into 4 major types :

- Type I Sundri, Sundri-Gewa, Sundri-Passur-Kankra = 2082 Km^2
- Type II Gewa, Gewa-Sundri, Gewa-Goran = 1143 Km^2
- Type III Goran-Gewa, Goran = 665 Km^2
- Type IV Keora, Grassland, Scrub and Bareground = 65 Km^2
  (Total = 3,955 Km^2)

Average weight of 50 kg per spotted deer was used assuming 75 kg per adult male, 50 kg per adult female and adjusting for percentages of sexes and age classes. Similarly, average weights of 17 kg for barking deer (*Muntiacus muntjak*) and 50 kg for wildboar (*Sus scrofa*) was used for determining biomass weights.

In the case of barking deer 14 animals per Km^2 was derived from pellet group counting in the Sundri, Sundri-Gewa, Sundri-Passur-Kankra forests (Type I) covering an area of 2082 Km^2. It was assumed that distribution of barking deer is limited to this type of forests in the north and northeastern area of the Sundarbans. Wildboar is distributed throughout the Sundarbans. Sighting and observation of wildboar is only occasional due to its nature of remaining in cover most of the day and poor visibility in the forests because of thick vegetative density. Relative abundance of footprints of wildboar to that of the spotted deer was used as an index and numerical density for wildboar as 50 percent of the spotted deer in all forests. Average weight per wildboar was estimated at 50 kg per animal.

Both in terms of numbers and biomass weights, the spotted deer were the most abundant of all large mammals in the Sundarbans as a whole. Density of spotted deer was highest in Keora-grassland-mixed forests of the southern coastal areas indicating a preference for this type of habitat and indicating a high carrying capacity/productivity of such habitat. The overall crude biomass estimate of the ungulates for the entire Sundarbans was 1826 kg/Km^2 (Table 8). This, however, does not include rhesus macaque, monitor lizards, otter, crabs etc which contribute significantly to the total biomass of the Sundarbans.

TABLE 8

NUMERICAL DENSITIES AND BIOMASS WEIGHTS (KG) OF UNGULATES PER SQUARE KILOMETER SUNDARBANS FOREST DIVISION, 1993

SPECIES	AVERAGE WT(KG)	SUNDRI MIXED FOREST TYPE I		GEWA MIXED FOREST TYPE II		GORAN MIXED FOREST TYPE III		KEORA, GRASS MIXED FOREST, TYPE IV		COMBINED AREAS	
		Numbers	Weights	Numbers	Weights	Numbers	Weights	Numbers	Weights	Numbers	Weights
Axis axis	50	24	1200	23	1150	16	800	56	2800	23	1150
Muntiacus muntjak	17	14	238	-	-	-	-	-	-	7.4	126
Sus scrofa	50	12	600	11.5	575	8	400	28	1400	11	550
Totals		50	2,038	34.5	1,725	24	1,200	84	4,200	41.4	1826

Sundarbans Forest Area 3955 Km^2:

Sundri, Sundri with Gewa, and Sundri with Passur and Gewa (Type I)	=	2082 Km^2
Gewa, Gewa-Sundri, Gewa-Goran (Type II)	=	1143 Km^2
Goran-Gewa and Goran (Type III)	=	665 Km^2
Keora, Grassland and other mixed (Type IV)	=	65 Km^2
		3955 Km^2

Tiger

Tigers are found throughout the Sundarbans. Various estimates have been made of the tiger populations size in the past. The total population was estimated at 50-100 (Mountfort 1969); 425 (Sarker 1982); 430-450 (Gittins and Akonda 1982) according to Salter 1984. Hendrich's (1975) estimate was 350 tigers. Sarker (1982) reported a population of 15 tigers in the Sundarbans South Wildlife Sanctuary (area approx. 180 Km^2) and Forest Department estimate 8 tigers in Sundarbans East Wildlife Sanctuary (area 55 Km^2).

Based on the pugmark studies in seven compartments in the south covering an area of 350 Km^2 that included the three wildlife sanctuaries, a population of 33 tigers was estimated. It consisted of 6 males, 13 females, and 14 juveniles and cubs. Similarly an estimate of population was made of 36 tigers covering 7 compartments with an area of 414 Km^2 in the north in Chandpai Range with 6 males, 16 females and 14 juveniles and cubs. This provides a crude estimate of 1 tiger per 10.9 Km^2 or roughly 362 tigers in the Sundarbans. However, these numbers are estimates that can be improved greatly in accuracy with continued efforts with trained people over a long period of time. Compared to other tiger reserves elsewhere, this represents a high density for tigers and a result of continued protection of the Sundarbans forest habitat from encroachment.

An unbalanced sex ratio of female to males of 2-3 females to 1 male seems to be the norm and typical of tiger population everywhere as reported by Perry (1964), Schaller (1967), Sankhala (1977), Panwar (1979) and Tamang (1982). Males have larger home ranges and territories and wander more widely than females. Females with much smaller territories are restricted most of their breeding lives with raising cubs.

Pugmarks indicated two cubs associated with a tigress in most of the instances whenever a female was accompanied by cubs. Actual sighting of a female once in Sapla Khal on 30.1.93 and another time Sundari Khal near Katka on 15.3.93 were accompanied by two juveniles in each case. This indicates a good reproductive rate of the tiger population.

Rhesus macaque

Since the promulgation of Wildlife Preservation Act 1973, and subsequent ban on the export, the rhesus macaque population reportedly recorded and increased in numbers. They were observed in all vegetation types in the Sundarbans. They were observed feeding on keora leaves, young golpatta, crabs, fruits from Eugenia, Ficus and other trees. Keora, grassland and mixed forests in the southern region appears to have higher densities than the scrub forests to the west. They were seen in groups of 4-37 individuals, often closely associated with the spotted deer. On the basis of our observations an average density of 10 animals per Km^2 was estimated. This crude estimate amounts to about 40,000 for the whole of Sundarbans. Various estimates have been made in the past as quoted by Salter (1984) : 88,000 (Khan and Ahsan 1982); 126,000 (Gittins and Akonda 1981). Hendrich (1975) estimated at 40,000.

Saltwater or Estuarine Crocodile

Heavy commercial exploitation for crocodile skins until the 1970's depleted the saltwater crocodile populations in Bangladesh (Whitaker 1982). Although poaching is minimal at this time, the populations shows little sign of recovery in the Sundarbans. It may even be decreasing (Whitaker 1982). In the 1700 Km^2 of waterways in the Sundarbans, the main habitat of the crocodiles, very few individuals were seen. A total of 10 crocodiles were actually sighted. Out of the individuals sighted six were seen in December, January and February basking on mudbanks in Sapla Khal, Bhodra Gang, Morabhola river. The rest were seen in water in Sela gang, Pathuria gang, Araibeki Khal, Morabhola river during the month of May. The crocodile population has depleted severely. All our efforts in locating crocodile nests or broken nests with the help of fishermen and forest department staff were unsuccessful. No estimate could be made of the crocodile population.

3.3 Man-Eating Tigers

The Sundarbans have been notorious for its man-eating tigers. Literatures reveal record of man-eating incidents dating as far back as 1670 in the Sundarbans. Curtis (1933) gives a record of 427 people killed by tigers between 1912 and 1921. He also reports 452 tigers killed by hunters during the same period in the Sundarbans. Tiger hunting was banned since promulgation of the Wildlife Preservation Act 1973, although established man-killers are declared man-eaters and killed by the Forest Department. Sundarbans Forest Division Office record reveals that 429 people were killed by tigers between 1976 and 1992, an average of 25 persons per year.

Records from the same office shows that 19 tigers were killed, 15 illegally and 4 declared as man-eaters, between 1976 and 1992. Tigers wandering outside of the reserved forests are liable to be killed by villagers. In some cases "cattle lifters" are killed by poisoning their kills with the use of endrin, pesticides or other chemicals.

Although the number of man killed per year is relatively low considering the number of men working in the area, the question why tigers kill proportionately more people in the Sundarbans in comparison to other tiger habitats elsewhere is pertinent to future management of tigers. Various theories have been put forward by different people. Among the relevant ones are under the following circumstances :

(1) when surprised at a kill or protecting a kill;
(2) unable to capture a prey due to old age or injury;
(3) when protecting young cubs;
(4) when, after killing a man under other circumstances, a tiger learns a man can be eaten as any other natural prey and easier to capture.

A variety of factors may be involved in man-killing behaviour of a tiger. Hendrichs (1975) suggests a possible linkage between a high level of salinity of water with man-eating behaviour of tigers in the Sundarbans. Salter (1984) suggests a direct correlation between the man-killing behaviour and availability of easy prey (men) and on the frequency of man-tiger contacts.

During our study period (November 1992 - July 1993) one man-killer was most active in Chandpai Range in nine compartments. The tiger killed at least 22 people between 6 February 1993 and 23 May 1993. Judging from the sequence of the man-killing incidents in this area and the dates of occurrence it appears that only one tiger was responsible for all the killings. Since no person can enter the reserved forests without a permit, persons without permits killed by tigers are not reported or recorded. In other words, more incidents go unrecorded than the reports indicate. Between 1984 and 1993 out of a total of 301 people killed by tigers : 125 (42 percent) were fishermen; 55 (18 percent) were firewood collectors; 49 (16 percent) were honey gatherers; 26 (9 percent) were golpatta cutters and the remaining 46 (15 percent) were illicit wood cutters; 13, gewa collectors, 8; thatching grass cutters 7, hantal collectors 8, mollusc shell gatherers 2; forestry staff 3 and others 6.

3.4 Discussion

Productivity

Grassland and keora forest was the most productive habitat with 4200 kg/km^2 biomass versus sundri, sundri with gewa, sundri with passur, gewa, kankra forest with 2038 kg/Km^2; gewa, gewa with sundri, gewa with goran forest with 1725 kg/Km^2; and goran and gewa goran forest the least productive with 1200 kg/Km^2 ungulate biomass. The overall crude ungulate biomass estimate for the entire Sundarbans was 1826 kg/Km^2 (Table 8). Both in terms of numbers and biomass weights, the spotted deer were the most abundant of all large mammals in all forest types and aggregate in the Sundarbans as a whole.

Predator-Prey Interactions

Much of the tigers activities revolve around its food supply. Tigers are mostly nocturnal and hunt their prey between dusk and dawn, and are most active when their prey are also most actively feeding in the late afternoon, night and early morning. During the hot part of the day from mid-morning to mid-afternoon, they usually rest close to water.

Predators, like other animals, require food energy and must forage in such a way that the net rate of energy intake is maximized (Schoener 1971). The ease with which prey animals can be found, killed and consumed differ substantially for different prey species and in their nutritive value to the predator.

Benefits to the tiger should be greatest when the time required to obtain a required amount of food is minimized and the energy gained per unit time is maximized. Optimal foraging theory, in attempting to explain the many aspects of foraging behaviour in animals (Emlen 1966; Schoener 1971; Pyke et al. 1977), assumes that the fitness of an animal's foraging behaviour has been maximized by natural selection.

The degree to which the behaviour of a predator will affect the abundance of its prey in the future depends in part on the degree to which the predator has exclusive use of an area. If an animal has such exclusive use, it could utilize its resources for sustained yields rather than maximize initial yields at the cost of poorer yields later (Charnov 1973). This particularly could be true for the tiger which is harvesting a self-renewing resource.

After a tiger makes its kill, the kill is dragged into dense cover before eating. The distance dragged will depend on the proximity of cover, type of terrain, degree of disturbance by humans or wild animals and perhaps tide. If the size of the prey permits it to last more than a night, the carcass may be covered with leaves and grass for concealment against scavengers. Feeding is resumed the next evening. An adult spotted deer may last for 2 days. Except for skin and bones, all edible meat usually is consumed.

The spotted deer and wildboar are the principal prey of tigers in the Sundarbans. Because of the relative importance of these two ungulate species in the tiger's diet, their availability and abundance in the area is of great significance for the survival of tigers. Barking deer is another prey that is important in the north and north-eastern part of the Sundarbans. Other prey animals include rhesus macaques, otters, smaller carnivores, monitor lizards and other reptiles, frogs, fish and crabs. To what extent these small animals contribute to the tiger's diet could not be estimated.

Food Consumption

Estimates on the actual amount of meat needed on a sustained basis vary between 6-10 kg per day. Taking into consideration the normal activities of a free-ranging tiger in the wild which include a number of days when no feeding occurs and plentiful supply of prey—a requirement of 7 kg of meat on an average seems to be reasonable estimate (Tamang 1979).

Based on experience with baits and wild prey from past studies 30 percent of the total weight of the prey can be considered inedible. In order to obtain 2555 kg (7kg X 365 days) of meat per year, a tiger would be required to kill an estimated 3650 kg of large prey biomass in a year. That weight would be equal to 73 spotted deer or wildboar.

Impact of Tiger Predation on Wild Ungulates

The Sundarbans tiger population estimate of 362 includes adults, sub-adults and young in an area of 3955 Km^2. The consumption of a sub-adult can be assumed as equal to that of an adult. A juvenile or a cub may consume less, estimated an equivalent of 25 percent. The combined annual requirement for the tiger population would be a total of 919,800 kg of large prey biomass.

The crude biomass available to tigers amounts to 7,221,800 kg (1826kg/km^2 X 3955km^2. Table 8) for the whole of Sundarbans. The total requirement for tigers of 919,800 kg/year, therefore, would account only for 13 percent of the standing crop of ungulate biomass in the Sundarbans. Schaller (1972) estimated removal of roughly 10 percent of the prey biomass by predators in the Serengeti National Park. Considering total tiger predation of 13 percent of the standing crop, it seems that by no means does tiger predation limit the prey population in the Sundarbans.

Tiger Management

The key to the survival of wild tigers in the long run is the maintenance of tiger habitats. These must be sufficiently large to support the number of animals which provides for an adequate genetic diversity. "Buffer area" habitats adjoining protected areas must be maintained to provide for an adequate and diverse gene pool.

The effect of human population growth with consequent habitat alteration and disturbance over the past generation or two has overwhelmed the tiger populations in Asia. Surviving populations are isolated, scattered and mostly confined to parks, reserves and adjoining forest areas. The Sundarbans is an area that holds a good number of tigers which is better than many other tiger habitats. The population seems to be stable and maintaining itself under the existing environmental conditions.

Tigers are solitary hunters. Their territorial behaviour insures that they are not overcrowded and remain at low density. There is no reasonable possibility, therefore, of large increases in tiger number in any protected areas where natural densities prevail. Intraspecific competition keeps their numbers down. Confrontation between individuals and the lack of suitable additional habitat areas for the establishment of new populations after dispersal as individuals approaching maturity are factors that limit tiger density. Mortality as a result of direct conflict with man and his activities, such as the poisoning of livestock killed by tigers, also takes its toll.

In Sundarbans, the protection and maintenance of existing forest areas is absolutely vital. The existing popular demand for the reassignment of wildlife habitats for other uses is bound to grow more intense with the increase in human population. If the historic, cultural, scientific, recreational and economic benefits of nature conservation areas as living museums are to be preserved for future

generations, it may be advisable to strengthen the provisions in the Wildlife Preservation Act 1973 against further encroachments on the domains of tigers and the associated fauna and flora with which they are inextricably linked.

Changes in vegetative stages and successional development induces corresponding changes in the types and abundance of wildlife inhabiting the area. Areas in early stages of vegetative succession are some of the best wildlife habitats. The properly-planned harvesting of mature and overmatured forests in selected areas outside of the Wildlife Sanctuaries under the supervision of Forest Department authorities, benefits wildlife by returning such areas to early stages of vegetative and faunal succession.

The majority of tigers are not man-killers. People who died as a result of encounters with tigers were not necessarily deliberately hunted or once killed, actually eaten. There are a few tigers that become man-eaters and deliberately kill man as prey. Most of the Sundarbans forest is unusually dense and visibility limited to a few meters. Inevitably some of the many honey-collectors and others who wander about come suddenly on a tiger, perhaps a tigress with cubs, which reacts with instinctive aggression to what it perceives as a threat, perhaps inflicting severe wounds and killing the victim. This type of incident, though regrettable, cannot be regarded as "man-eating", but rather as an accident which the victim has brought on himself by venturing unwarily into tiger habitat.

The way to minimize such fatalities would be to minimize by a combination of precautions and provision of effective sanctuaries of adequate size where wildlife including tiger is free from constant human disturbance. Established man-eaters that deliberately goes for human prey should be destroyed by the Forest Department. However, these are few in numbers. Presently there is one active man-eater in Chandpai Range and may be another one in Satkhira Range.

3.5. Conclusions

Conservation Importance of the Sundarbans

The Sundarbans is an important nature conservation area for many reasons. It is important both nationally and internationally.

- It is the only example of mangrove forests in Bangladesh and has remained protected as reserved forest since 1875 free from encroachment from agriculture.
- It contains substantial populations of large ungulates : the spotted deer, wildboar and barking deer that are becoming rare elsewhere in Bangladesh.
- It contains a number of endangered and rare species of wildlife, reptiles and birds such as the tiger, the saltwater crocodile, turtles, rock python and others.

- The area is the only solid chunk of habitat for wildlife that has remained intact in Bangladesh. It is the last remaining habitat for tigers in Bangladesh.
- It is an area of importance for conservation, research, training and as a model management area.

Forest and Agriculture Potential of the Area

The Sundarbans forest has been under management since 1875. Harvesting of timber resources, firewood, golpatta and grass for thatching, honey and beeswax, fish and crustaceans contributes significantly to the economy of Bangladesh. Logging of Sundri, the main timber species, has been banned (except for the removal of top dying sundri).

The Sundarbans forest has remained intact inspite of the overwhelming human population pressure mainly due to its unsuitability for agriculture, tides, scarcity of drinking water and rigid protection provided by the Forest Department. There are no human habitation within the Sundarbans Reserved Forest.

Compatibility of Conservation and Utilization

Although there is provision for hunting licenses in the Wildlife (Preservation) Act 1973, no licenses are issued and hunting is strictly prohibited in the Sundarbans. In this sense, the three wildlife sanctuaries (Sundarbans East, Sundarbans South and Sundarbans West) and the remaining forest area have the same status and treatment.

Harvesting of wildlife on a sustained basis would be theoretically possible without destroying its habitat or depleting wildlife populations. However, practical problems of controlling such harvesting and economy of such operation would make it incompatible with conservation objectives.

Reports from the 1970's and 1980's (Hendrichs 1975, Salter 1984, Blower 1985) indicate serious poaching problems in the Sundarbans. The situation has much improved presently, judging from the wildlife observed, the numbers seen and their response to human visitors. Some fringe areas close to the villages in the north and east and areas close to the Indian border may still have some problems.

Endangered Species

The Sundarbans population is one of the largest surviving population of tigers. It is completely isolated in the sense that there are no adjoining habitats to make genetic interchange possible except to the west with the remaining Indian Sundarbans forest. It is also the only remaining population of this endangered species important nationally and internationally.

The estuarine or salt water crocodile (*Crocodylus porosus*) has become extremely depleted in numbers in the recent years. The marsh mugger (*C. palustris*) has

already become extinct in the recent past. With the extinction of rhino, wild water-buffalo, swamp deer, and hog deer recently it has become critical to protect the biodiversity of the Sundarbans both in respect of flora and fauna.

Potential for Tourism Development

There is a great tourism potential in the future in the Sundarbans. However, the infrastructure, facilities, transportation available makes it rather difficult to visit the Sundarbans under the present circumstances. Gradual development of these facilities will provide opportunities for tourism in the future.

Research Needs and Potential

The Sundarbans provide an excellent natural laboratory for the pursuit of field biology, ecology and conservation management research. The study and research will help to strengthen protection and management. Study and research work is totally compatible with conservation objectives.

Summary

Nature conservation in the Sundarbans is of highest priority in Bangladesh and must be provided with adequate protection. Although there are three wildlife sanctuaries in the Sundarbans, the whole of Sundarbans needs to be treated as a single unit and managed as such. The three wildlife sanctuaries needs staffing, protection and management. All the three sanctuaries are located in the southern coastal areas and do not represent areas from the fresh water ecological zone. Additional protected area should be established in the north to represent freshwater ecological unit. Sundarbans East Wildlife Sanctuary is too small in area and needs expansion as originally intended in 1977 when it was established. Sundarbans West Wildlife Sanctuary needs expansion to include the area adjoining the Indian border to make it an homogeneous unit with the Indian Sundarbans National Park.

The development of research and tourism appear to be complementary to the conservation objectives of the Sundarbans. It should be developed gradually depending on the demand.

The current levels of the utilization of forest resources from the Sundarbans is quite substantial, contributes a great deal to the economy in terms of goods and services, and should be managed on a sustained basis to ensure that the resources are not depleted. The wildlife sanctuaries should be managed and protected from any kind of exploitation as provided by the law.

4. MANAGEMENT PRESCRIPTIONS

4.1 Boundaries and Zoning

i) The Sundarbans Wildlife Division

The boundaries of the Sundarbans Wildlife Division will remain the same as that of the Sundarbans Reserved Forest (or the Sundarbans Forest Division). There will be four wildlife sanctuaries (WS) within the wildlife division.

ii) Wildlife Sanctuaries (WS)

The main purpose of the network of wildlife sanctuaries is to provide protection to representative samples of each of the ecosystems in the Sundarbans and to maintain the biological diversity. The three wildlife sanctuaries (WS); Sundarbans East, Sundarbans South and Sundarbans West; were established in 1977 but were abolished in 1982 and the staff were reassigned to the Forest Department. These three existing areas should be restored as wildlife sanctuaries, expanded to include vital areas and strengthened to bring the sanctuaries under management and necessary protection. A fourth wildlife sanctuary should be established to include a sample of freshwater ecological zone which has not been represented.

The existing Sundarbans East WS covers an area of 5439 ha, a part of compartment 6. It has been recognized 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). It is recommended that Sundarbans East WS should be expanded 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.

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 the spotted deer, wildboar and tigers. The area for this sanctuary is considered adequate for the present.

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 cross-frontier 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. This expansion to the west is of vital importance for the long-term welfare of tigers 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.

All the three existing wildlife sanctuaries are bounded to the south by the Bay of Bengal and are located in the moderately saltwater and saltwater ecological zones. It is essential to include an area to represent the freshwater ecological zone in the network of protected areas. Compartment 27 and 28 in the northeast in Chandpai Range is proposed as a wildlife sanctuary. This fourth wildlife sanctuary will represent the freshwater ecological zone in the network of protected areas in the Sundarbans.

Figure 6 shows the existing wildlife sanctuaries with proposed expansions and the newly proposed Chandpai Wildlife Sanctuary (Compartment 27 and 28).

iii) Zoning

The Sundarbans Wildlife Division will be divided into four distinct management zones as follows:

a. Strict Protection Zone

All the four wildlife sanctuaries will be in the strict protection zone except areas designated under c and d.

b. Production Zone

The whole of the Sundarbans Wildlife Division outside of the four wildlife sanctuaries will be in the production zone managed by the Sundarbans Forest Division on a sustainable management. The wildlife resources in the production zone will be under the jurisdiction of the Wildlife Division.

c. Visitor Zone

Designated areas within the wildlife sanctuaries which will be open to visitors for wildlife viewing, recreational uses and tourism development.

d. Intensive Use Zone

Several smaller areas of the sanctuary which are needed for buildings and gardens to meet the needs of the management staff.

4.2 Legislation and Regulations

i) Legislation

The Bangladesh Wildlife Preservation Act 1973 is currently in effect and provides for establishment and management of wildlife sanctuaries and other protected areas. Meanwhile the Divisional Conservation Officer (DCO) will establish suitable regulations. Although the 1973 Act provides for issuing of hunting licenses, no licenses have been issued so far for hunting in the Sundarbans. This restriction should be continued in the future.

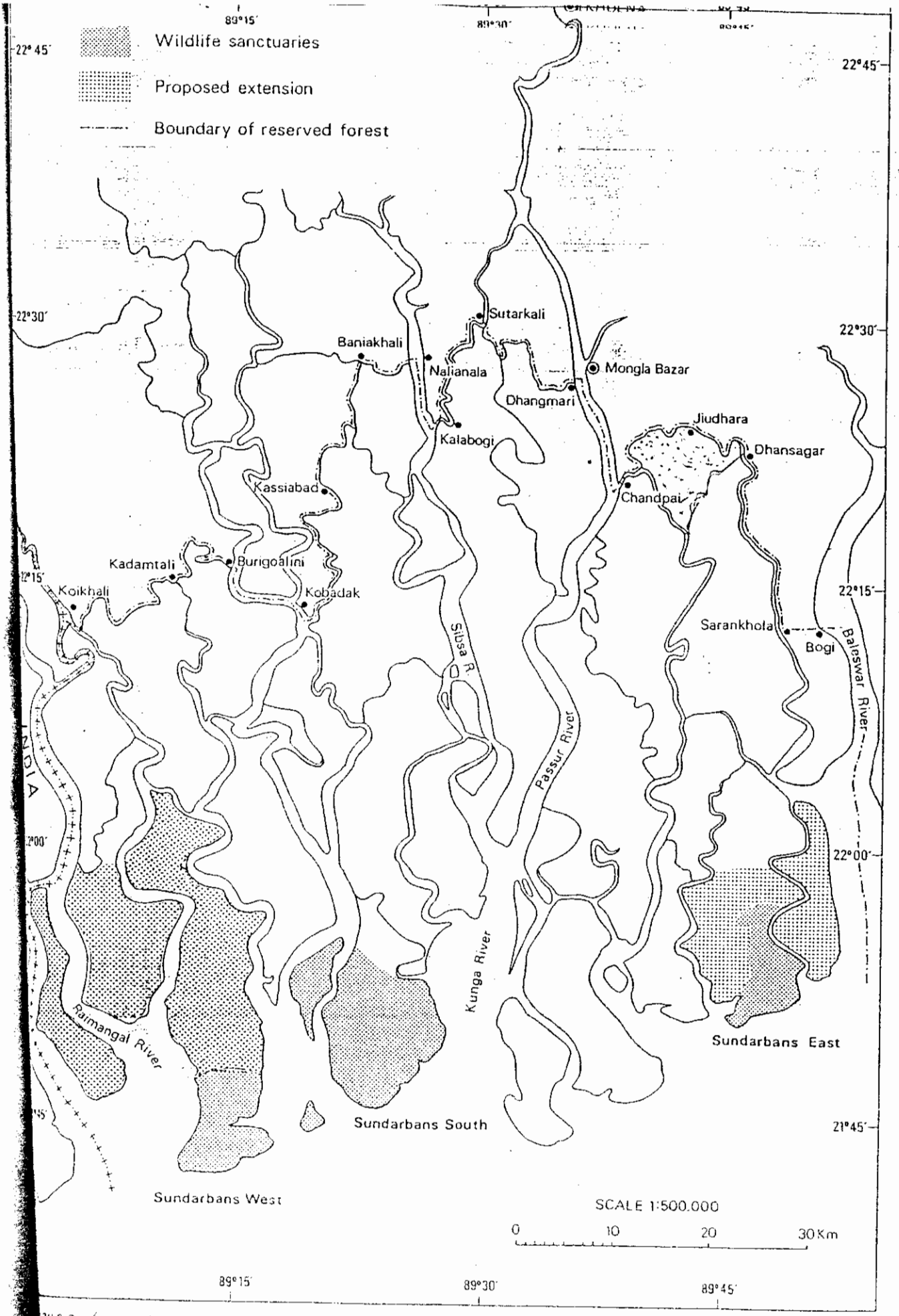


Figure 6 Wildlife sanctuaries

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ii) Sanctuary Regulations

The following regulations should apply to the four sanctuaries.

a. Visitor use and scientific research are permitted only under permit granted by the DCO, Khulna. All visitors must report to the sanctuary staff on first arrival at the sanctuary.

b. no hunting is permitted;

c. no clearing of primary vegetation is allowed;

d. no burning of natural vegetation is allowed, except as part of a prescribed management measure;

e. the bringing of firearms, nets, traps, poisons or explosives into the sanctuary is prohibited except for official security reasons;

f. the bringing of dogs, cats or free ranging domestic animals and the introduction of any exotic wild animals or plants is prohibited;

g. special permission from the Environment Management Wing or the Divisional Conservation Officer at Khulna is required for the collection of Scientific specimens from nature or the undertaking of commercial photography in the Sundarbans.

In addition special regulations shall apply to particular zones. Table 9 summarizes the activities that are allowed or prohibited in the different zones.

Table 9
Permitted Activity by Management Zone

Activity/Zone	Strict Protection Zone	Production Zone	Visitor Zone	Intensive use Zone
Hunting	No	No	No	No
Camping	No	With permit	With permit	Yes
Collect honey	No	With permit	No	Yes
Collect medicinal plant	No	With permit	No	Yes
Burning vegetation	No	Managed	Managed	Managed
Tourists visits	No	Managed	Yes	Yes
Collect firewood	No	With permit	No	Yes
Logging	No	Managed	No	Clearing
Habitat Management	No	Yes	Yes	Yes
Construction	No	No	Minor	Yes
Scientific Observation	Yes	Yes	Yes	Yes
Scientific Collection	No	With permit	With permit	Yes
Grazing domestic animals	No	No	No	Yes

4.3 Organization

The whole of Sundarbans Reserved Forest (or Sundarbans Forest Division) was declared as reserved forest in 1875. Within the reserved forests, there are no human habitation or villages and there are no recognized local public rights of any kind except for ocean-going vessels which have rights of passage through the Sundarbans by way of Passur River to Mongla Port. Entry to the entire reserved forests is subject to permits issued by the Forest Department. Fishing and the collection of forest produce (firewood, golpatta, hantal, honey, etc) are also subject to Forest Department permit. Under the Bangladesh Wildlife Preservation Act 1973, the department has authority to issue hunting licenses.

In practice, however, no licenses are issued and the whole Sundarbans is thus effectively closed to legal hunting.

The three existing wildlife sanctuaries in the southern portion of the Sundarbans were declared and established in 1977 under article 23 of the above act. Provisions of the act prohibit activities such as residence, cultivation of land, damage to vegetation, hunting, introduction of domestic or exotic species of animals and the setting of fires within any sanctuary area.

A wildlife Working Circle was established within the Forest Department (1977) with responsibility for wildlife and nature conservation matters and was headed by a Senior Conservator of Forests (CF) responsible directly to the Chief Conservator of Forests (CCF). This initial development suffered a drastic setback when the Wildlife Development Scheme (1977) was abandoned and the embryonic organization was stopped "in the interests of the economy" in 1982. The staff in the sanctuary were reassigned to the Forest Department duties with no specific responsibilities for wildlife management in the sanctuaries. Following the downgrading of wildlife and nature conservation and dismantling of the organization wildlife matters became the responsibility of the Divisional Forest Officer (DFO) of Sundarbans Forest Division, Khulna. Presently the forestry staff manning the three sanctuaries in the Sundarbans Forest Division are as follows:

	Forest Ranger	Forester	Forest Guard	Boatman	Total
Sundarbans East WS (At Katka and Tiger Point Stations)	-	2	2	9	13
Sundarbans South WS	1	1	2	4	8
Sundarbans West WS	-	1	2	4	7

In many other countries there is a separate agency or department responsible for wildlife, nature conservation and protected areas. In Bangladesh it is under the Forest Department. For the present it seems appropriate that it should remain a responsibility of the Forest Department. As proposed by the World Bank Forestry III Project, the government has approved and began implementing the establishment since January 1993 of a new Environmental Management Wing (EMW) in the Forest Department headed by a Deputy Chief Conservator of Forests (DCCF). The DCCF and a CF positions have been established under the CCF with necessary staff in the centre at the Forest Department headquarters at Dhaka. The EMW will have three branches: Information and Planning; Conservation Operations and Environment Management. Management and implementation of conservation activities in the sanctuaries and national parks will be under the Jurisdiction of the Conservation Operations branch. There will be two forest divisions under the EMW: one in Khulna (Sundarbans Wildlife Division) and another in Chittagong.

Structural organization of the proposed Wildlife and Nature Conservation staff in the Sundarbans Wildlife Division (the whole of Sundarbans forest division area) is as follows:

i) A Divisional Conservation Officer (DCO) of the rank of Deputy Conservator of Forests (DCF equivalent to DFO) should be stationed at Khulna incharge of the Sundarbans Wildlife Division with overall responsibility for management of wildlife resources for the whole of Sundarbans reserved forests. He should have one Assistant Conservation Officer (ACO) of the rank of Assistant Conservator of Forests (ACF) under him stationed at Khulna. The Divisional Administration Office would have the following staff.

Sundarbans Wildlife Division
Khulna

Divisional Conservation Officer (DCO)	1
Assistant Conservation Officer (ACO)	1
Accounts Officer	1
Head Assistant	1
U D Assistant	1
Stenotypist	1
L D Assistant	1
Driver	1
Miscellaneous	2
FOR LAUNCH (House- Boat)	
Surreng	1
Pilot	1
Assistant Engineer	1
Mechanic	1
Cook	2
Total	16

Additional wildlife operations staff stationed at Khulna under the DCO would be as follows:

Chief Ranger	1
Senior Ranger	1
Driver	1
Speedboat Driver	1
Total	4

ii) There would be a total of four Assistant Conservation Officer (ACOs) of the rank of ACF, one stationed at each of the wildlife sanctuaries: Sundarbans East, Sundarbans South, Sundarbans West and Chandpai (proposed new sanctuary comprising compartment 27 and 28). Sanctuary headquarters for each of the four WS are proposed at - Katka for Sundarbans East, Hiron point for Sundarbans South, Mandarbharia (on the west bank of Malancha River) for Sundarbans West and Chandpai for the newly proposed Chandpai WS.

iii) Eight additional posts to be called "Conservation Stations" are proposed, two in each of the four WSs. The two conservation stations in the Sundarbans East WS will be located at Tiger Point (Kachikhali at its present location) and one in the northwest close to Betmar Gang and Dora Khal. For Sundarbans South WS, Hiron Point would be upgraded as sanctuary headquarters and two conservation stations will be located one in the north and one at the southern end of the sanctuary. Sanctuary headquarters for the Sundarbans West WS should be located on the west bank of Malancha River at a suitable location close to the existing temporary forest station at Mandarbharia. The two conservation stations for the Sundarbans West WS should be located one in compartment 54 and the other in 55. For Chandpai WS, one conservation station should be located at Jiudhara and the other at Dhansagar.

iv) A "Nature Conservation Centre" should be established at Mongla to provide information and education on conservation programme in the Sundarbans. Since most of the visitors to the Sundarbans have to enter via Mongla, Mongla seems to be the appropriate location for such centre to provide information not only to the visitors but also to educate the local residents and create awareness of the conservation programmes and activities in the Sundarbans. Brochures or information booklets on the wildlife sanctuaries in Bengali and English languages, and audio-visual presentations on the salient features of the conservation activities in the Sundarbans will be provided to the visitors. Extension services in the form of visits to the local villages surrounding the Sundarbans and making audio-visual presentations designed to explain the purposes of nature conservation and benefits

to be derived from conservation activities will enhance awareness to win local support for conservation management.

Staff required at the Nature Conservation Centre, Mongla will be:

Senior Ranger	1
Ranger	1
L D Assistant	1
Boatman	1
Miscellaneous	2
Total	6

A list of total staff requirement for the Sundarbans Wildlife Division is summarized in Table 10. It includes the Divisional headquarters at Khulna, 4 Wildlife Sanctuary (WS) headquarters, 8 Conservation Stations and the "Nature Conservation Centre" at Mongla.

Table 10

Total Staff Requirement of the Sundarbans Wildlife Division

Category	Division HQ Khulna	In 4 WS HQs	In 8 Conservation Stations	Nature Centre Mongla	Total
DCO (Divisional Conservation Officer)	1		-	-	1
ACO (Asst. Conservation Officer)	1	4	-	-	5
Chief Ranger	1	4	-	-	5
Senior Ranger	1	-	8	1	10
Ranger	-	4	8	1	13
Scout	-	16	40	-	56
Speedboat Driver	1	4	8	-	13
Boatman	-	4	8	1	13
IN OFFICE					
Accounts Officer	1	-	-	-	1
Head Asst.	1	-	-	-	1
U D Asst.	1	4	-	-	5
Stenotypist	1	4	-	-	5
L D Asst.	1	-	-	1	2
Driver	2	-	-	-	2
Miscellaneous	2	8	16	2	28
FOR LAUNCH					
Surreng	1	-	-	-	1
Pilot	1	-	-	-	1
Asst. Engineer	1	-	-	-	1
Mechanic	1	-	-	-	1
Cook	2	-	-	-	2
Total	20	52	88	6	166

N.B.

1. Includes existing staff at Katka, Kachikhali and Hiron Point Stations in the existing wildlife sanctuaries.

2. Terms (titles) used are those proposed for the new organization in World Bank Forestry III Project. Equivalents are:

Divisional Conservation Officer (DCO)	=	Deputy Conservator of Forests
Assistant Conservation Officer (ACO)	=	Assist. Conservator of Forests
Chief Ranger	=	Forest Ranger
Senior Ranger	=	Deputy Forest Ranger
Ranger	=	Forester
Scout	=	Forest Guard.

4.4 Staff Duties and Responsibilities

The following terms of reference apply to the respective offices:

Sundarbans Wildlife Division Office, Khulna

- will be responsible to the Environment Management Wing (EMW), Conservation Operations in the Forest Department for the management and operation of the Sundarbans Wildlife Division including law enforcement and carrying out various programmes of management outlined in the Wildlife Management Plan;

- liaison with local authorities of the surrounding districts and the Divisional Forest Officer (DFO) of the Sundarbans Forest Division and his staff;

- liaison with local communities living around the Reserve Forest to establish harmonious relationship between the protected area staff by demonstrating, the real benefits to be derived by local communities through good management of the protected area;

- handle legal prosecutions resulting from infringements of protected area (wildlife sanctuary) regulations;

- handle the recruitment and training of staff necessary to implement the management plan;

- report fully on all aspects of management of the protected areas to the Environment Management Wing (EMW) of the Forest Department;

- prepare and submit for approval and funding annual plan of operations for implementing the management plan.

The Divisional Conservation Officer (DCO) will be incharge of the Sundarbans Wildlife Division with overall responsibility for management of wildlife resources for the whole of Sundarbans reserved forests. The DCO would be assisted in these tasks by a number of officers with the following specific duties.

The Assistant Conservation Officer (ACO) would be responsible to the DCO for handling overall administration, legal matters and coordination between various wildlife sanctuaries, their staff, tourism activities, construction, maintenance, purchases, vehicles, launch and personnel matters including recruitment, postings, training, staff health, staff complaints and relations with local communities.

The Accounts Officer would be incharge of purchasing, expenditure, wages, accounting etc under the supervision of the DCO and ACO.

The Head Asst. under the guidance of the DCO and ACO will be incharge of the equipment, servicing of equipment, vehicles, launch, boats, maintenance of buildings, supervision of construction and other works, responsible for clerical paperwork, accounts, procurement, payment of wages, allocation of vehicles and boats, supervision of drivers, responsible for the storage and maintenance of equipment, keeping ledgers on equipment allocation and condition of equipment and new purchase needs. He will be assisted by other staff in the office in performing these duties.

Protection

The Divisional Conservation Officer will have the overall responsibility for the management and protection of wildlife resources for the whole of the Sundarbans Wildlife Division. The four Asst. Conservation Officers (ACOs), each incharge of the four Wildlife Sanctuaries, will be responsible to the DCO for the effective protection of the division's wildlife resources and physical estate and the enforcement of laws and regulations including regular patrolling, apprehension of lawbreakers and subsequent prosecution. The Chief Ranger, Senior Ranger, Ranger and Scouts assigned to the Wildlife Sanctuary headquarters and the Conservation Stations would be responsible to the ACOs and carry out the protection programme, regular patrolling, handling legal prosecutions, supervision of scouts, collection of data from patrol forms etc. The Chief Ranger and Senior Ranger assigned to the Division Office at Khulna will assist the DCO and ACO in coordinating the field activities in all the four sanctuaries and conservation stations.

In addition it should be noted the protection staff including the ACOs, Chief Ranger, Senior Ranger, Ranger and Scouts should spend most of the time in monitoring the general condition of the protected areas, recording biological information and act in cases of emergency such as fire, poaching. All scouts in the sanctuaries and conservation stations are expected to complete about 20 days patrolling per month under the supervision of their superiors Ranger, Senior Ranger and Chief Rangers.

All the four Wildlife Sanctuary headquarters and the eight conservation stations should be linked to the Divisional Headquarters at Khulna by Radio-network. Each conservation station and sanctuary headquarters will have a speed-boat and a country-boat.

Maintenance of Staff Discipline

The Divisional Conservation Officer will be held responsible by the Forest Department (Environment Management Wing) for all aspects of management of wildlife resources in the Sundarbans Wildlife Division. He must delegate his duties wisely but obviously must retain firm control of the whole area. This necessitates the maintenance of high standards of discipline. Such discipline is achieved by a combination of clear orders being passed down the line of authority and clear reporting passing up, good supervision of subordinate activities by senior levels, regular checking to maintain standards and interest shown in subordinate's work, respect given to senior authority but also earned by good example and fair treatment.

The DCO must establish a reward and penalty system to motivate high work standards and discourage inefficiency or dishonesty. Good workers should be given promotion, preference in postings, upgrading training courses for encouragement. Bad performance should earn reprimand, demotion or lack of promotion, loss of privileges etc. The DCO must maintain firm control over his staff and be willing to take unpopular decisions when necessary in the interests of efficient management.

Staff must present a good image at all time. They represent the Conservation Management and reflects its standards. They should be well dressed in uniforms and tidy in appearance, efficient in their work and actions and polite and courteous in their attitudes with visitors but firm in their dealings with misusers or abusers of the protected areas.

4.5 Field Research Programme and Monitoring

The Wildlife Division should plan a programme of research. The programme will also serve the purpose of monitoring the conditions of the Sundarbans. Research projects should be encouraged in areas where more data, information or better understanding is needed for practical management purposes and add to the knowledge of the Sundarbans fauna and flora.

The research programme will cover 5 main topics.

i) Fauna and Flora inventories

Available species list for plants, mammals, birds, reptiles and amphibians are not complete. Information on nocturnal mammals such as bats, rodents, insectivores are inadequate. Except for the bees, there is no information available on invertebrates. Inventories should be carried out to fill this void. Emphasis should be given to more quantitative information on relative abundance of species, distribution and habitat preference. Visiting scientists, taxonomic specialists will be needed to complete the inventories.

ii) Distribution and Seasonal Movements

A clearer picture of species distribution and movements is needed. This can be achieved through routine scout patrolling reports and observations made during monitoring trips. It is generally known for example, that barking deer presently occur only in the northern part of the Sundarbans but the exact geographical limit of their distribution is not known. These information would be of immense value, for the management of various species.

iii) Ecology of Tigers

The Royal Bengal Tiger is the star attraction of the Sundarbans. No tiger population remain elsewhere in Bangladesh. The tiger is included in the IUCN Red Data Book of seriously endangered species throughout its range and the very existence of the tiger is threatened everywhere. The Sundarbans population (in Bangladesh and India combined) is one of the largest surviving population of tigers. However, this population is completely isolated since there is no tiger habitat adjoining the Sundarbans. The demise of this tiger population means the loss of a most valuable asset. The continued existence of this magnificent and irreplaceable species can be assured only with carefully planned policy and management programme based on sound ecological and behavioural data. No such information exist in Bangladesh. A research study on the ecology of tigers will advance the scientific understanding of the tigers to provide a foundation for its long-term conservation in the Sundarbans.

A research study proposal on the ecology of tiger has been included in Appendix 3. The proposal study will be to capture, mark and fit radio-transmitter collars on a population of tigers for study. The state of the art bio-telemetry methodology will provide rapid insight in understanding the population density, sex and age composition, reproductive behaviour, mortality and population turnover rate for determining the population structure and dynamics of the tigers in the Sundarbans. By studying the daily and seasonal activities and movements, range size and characteristics, tiger interaction patterns and relating these to the population composition, density and feeding habits, it will be possible to get an insight of the tiger spatial-social system. The study will enable us to assess the impact of the tiger population on its principal prey species, to determine tiger's living requirements and assess the tiger's response to environmental changes.

iv) Ecology of Large Ungulates

Large ungulates are the main interest of the Sundarbans. The study on the ecology of the spotted deer, barking deer and wildboar would fill out the understanding of: their population size, composition and distribution, seasonal movements and ranging patterns; reproductive levels and survival rates; mortality levels by prime factors such as poaching, disease and predators; and habitat preferences and feeding ecology; etc. Information on the large ungulates may be collected by traditional methods of field observation. In addition, study on the ecology of the ungulates would be carried out parallel to the study of tigers with

radio-telemetry methodology by radio-collaring a number of ungulates of each species.

v) Vegetation Studies

Vegetation studies should be carried out on a long-term basis concentrating on the dynamic processes of mortality, recruitment and seral succession patterns. Long-term permanent sample plots already established in different forest types should be used for this purpose. If necessary additional sample plots should be established. Plots should be remeasured each year to study progress and changes.

Regulations for Research

1. No research should be carried out in the Sundarbans without permit from the Environmental Management Wing (EMW) or the Divisional Conservation Officer (DCO), Khulna.

2. Scientist should negotiate with the DCO concerning accommodation, transport or other needed facilities and charges/fees if necessary.

3. Basic research permit would allow non-destructive research only

4. Collection permits would be required for collection of specimens.

5. On completion of fieldwork, all scientist must leave a preliminary finding report with the DCO. The DCO may request a verbal presentation on the findings.

6. All the resulting papers from the research must be copied to the DCO and the EMW and acknowledgements should be made for the help and assistance received from the staff.

7. In cases of collected specimens, duplicate specimen should be deposited with the DCO. Identification list must be supplied to the DCO of the collected specimens.

8. Any individuals or institutions failing to abide by these regulations will be refused further research permits.

9. The DCO can refuse permits for any research work that is considered scientifically unnecessary or contrary to the interests of the protected area.

vi) Development of a research museum, library and herbarium

A small research museum, library and herbarium will be developed at Khulna Wildlife Division Office. Interesting biological materials found or collected in the Sundarbans will be stored here to build up or develop into a useful reference collection for research information. It is not planned to develop a large-scale museum or herbarium. Bones, skulls and antlers should be labelled and stored in

a museum room. Duplicate botanical specimen should be labelled and stored in the herbarium room. A small reference library of key books and papers should be established to help the conservation staff in management of the resources of the Sundarbans.

4.6 Programme for Tourism Development

The Sundarbans has high potential for tourism development and this is in line with the aspirations of the Tourism Development (Parjatan authorities). The area offers an excellent opportunity for general viewing of forests and wildlife from boats and on foot in some areas. It offers good opportunities for birdwatching, camping in some areas and a view of the interesting life style of some of the people surrounding the forests in the northern part of the Sundarbans.

However, due to lack of facilities and the current problems of transportation, it is not yet suitable to invest in major tourism development. With an appropriate plan for development, tourism can grow step by step as the flow of visitor demands. Tourism and recreation consultant will cover in detail the programme for tourism and recreational development in the Sundarbans.

4.7 Physical Construction

All the building requirements must be constructed. The following list gives details of the planned buildings.

Structure		Size	Location	Year
Divisional Office (including museum library herbarium)	1	2000 ft^2.	Khulna	1994
DCO's residence	1	1200 ft^2.	Khulna	1994
ACO's residence	1	1200 ft^2.	Khulna	1994
WS Offices	4	1000x4 ft^2.	In 4 ws	1994-95
ACO's residence	4	1200x4 ft^2.	In 4 ws	1994-95
Staff And Scout quarters	8	1500x8 ft^2.	2 in each 4 ws	1994-95
Conservation Stations	8	2000x8 ft^2.	All Conservation Stations	1994-95
Nature Centre	1	1000 ft^2.	Mongla	1995

4.8 Staff Training

i) Scouts Training

A training course for scouts lasting 6 weeks should be designed and held at Khulna to be taught by visiting national and international experts. Training materials will be left with the Division Office at Khulna so that it can be rerun by the staff when new scouts need training and in addition hold refresher courses each year for existing scouts. Scout training would cover the following topics:

- use of maps and compass reading
- first aid
- jungle craft: how to conduct oneself and survive in forest
- conservation law
- scout duties
- law enforcement procedures
- reporting requirements
- basic knowledge of flora and fauna
- recognition of mammal foot-print and signs
- recognition of protected species
- use of scout patrol forms for reporting
- maintenance of buildings, roads and structures
- use and maintenance of firearms
- use of binoculars, cameras including care of equipment
- public relations

Use of scout patrol forms is very important. This will be the main form of monitoring the condition of the protected area. Findings of the patrols should be recorded. Simple form can contain a lot of information about the forest condition and phenology, about the abundance, movements and breeding of wildlife and about the levels of human intrusion.

ii) Wildlife Manager's Training

Wildlife manager's training should be initially organized at Khulna for 2 months based on the IUCN Handbook for Managing Protected Areas in the Tropics. The posts of Chief Ranger, Senior Ranger and Ranger will be filled with qualified Forest Ranger and Foresters trained in Chittagong with training as Wildlife Managers. A number of such training courses should be organized in other protected areas and national parks around the country. The course would be organized by EMW in cooperation with the DCO at Khulna. The manager's course should quickly cover the material that scouts are expected to know but should go much further into the following fields:

- population dynamics, statistics
- habitat management
- wildlife management

- sampling and monitoring wildlife populations
- report design and writing
- management plans
- operational planning workplan for the year and budgets
- control of personnel
- control of tourism, visitors
- control of pest species
- extension and awareness techniques.

The course should be illustrated by practical fieldwork and reference to real management examples from Bangladesh and other relevant countries.

iii) The positions of DCO and ACOs should be filled with DCF and ACFs with additional professional training overseas on nature conservation, wildlife management and management of protected areas for 2 years at graduate degree level.

iv) Additional specialized training should be organized at regional level in neighbouring countries (India, Nepal, Thailand etc.) for DCO, ACOs, Chief Ranger, Senior Ranger and Ranger levels.

4.9 Maintenance of Building and Other Facilities

Building and other facilities are a big investment and should be properly maintained to make it last for many years. Adequate budgets must be included for maintenance, repairs and upkeep. Usually 5% of the original construction or purchase cost should be made available each year for maintenance and repair.

4.10 Preparation of Annual Workplans and Budgets

The Management Plan provided overall guidance for the Sundarbans wildlife management and development together with projected costs over a ten year period. This must be translated into a specific workplan year by year.

Such workplans and budgets should be prepared by the DCO and his staff and submitted to the EMW of the Ministry of Forestry for approval in good time so that new budgets can be made available for the approved workplan promptly at the start of the new fiscal year.

The annual workplan should include a general summary of the current state of management and the previous year's progress, a statement of any particular management problems or constraints and a general outline of the proposed action for the forthcoming year. This outline should include those activities proposed for the next year in the Management Plan, any activities not yet completed from the current year and any deviations from the Management Plan that the DCO wishes to make with good justification (activities dropped because proved useless or redundant, or new activities necessitated by unforeseen circumstances).

The various activities should then be listed under such headings as:

- routine management activities (listed by type)
- patrolling and reporting
- annual surveys
- staff training
- management operations
- physical developments
- purchases
- contracts

Each activity should be costed in terms of man-months and in terms of financial budget needed.

The timing of activities through the year should be indicated in a bar chart. Some activities will be continuous through the year, others can be done only at specific seasons and yet others can be fitted in almost anytime. Some activities depend on the prior completion of others. In constructing such a bar chart the DCO should fix the more flexible activities around these to give an even work load over the whole year.

Budgets should be totalled into two components: regular (routine) budget and development budget.

If funds are inadequate to cover all the activities the DCO wants, the workplan may need revision one or more times before it can be approved. This is another reason why it should be submitted in good time.

4.11 Preparation of Operational Plans

More detailed plans will have to be prepared for some aspects of management. Site plans must be made for major physical development, plans for surveys, emergency plans to coordinate animal rescue etc.

These plans will have to be made for the DCO's approval by the various ACO offices so that the DCO can approve the works and prepare for the necessary budgets in his own annual workplan.

4.12 Review and Revision Procedures

The Management Plan is designed to guide management and development of the Sundarbans for 10 years. It is proposed to hold two review meetings to evaluate progress of implementation and to propose revisions that may become necessary.

The first meeting should take place about two years into implementation - long enough to see if things are working as planned but early enough to think again if there are major problems of implementation.

The second review should take place after 5 years of implementation and should be an evaluation of management success with specific terms of reference to make recommendations for future needs of the next management plan.

The review board of each meeting should comprise the senior management, administration and research leaders of the Sundarbans, EMW together with outside scientific and ministry experts.

Minutes of the review meetings should be kept and edited at the end of the meetings for board approval as a summary of its recommendations. This solves the need for longer delay in the preparation of a fuller report.

4.13 Saltwater Crocodile

The saltwater crocodile population has depleted to a critical point. Before it becomes extinct, every effort should be made to save it.

i) Sapla khal and Bhadra gang should be closed to fishing and other traffic to stop the disturbance to provide for possible nesting ground for the crocodiles.

ii) A crocodile expert should be recruited for six months to look into the possibility of raising crocodiles in captivity, to collect eggs and raise hatchlings to replenish the natural population.

4.14 Deer Farming

i) Although theoretically it would be possible to harvest wildlife on a sustained basis from the Sundarbans without destroying its habitat or depleting wildlife populations, distance from the markets, basic facilities needed for refrigeration and the cost of harvesting would make it uneconomical. Besides the first priority, under the present circumstances, should be to bring the sanctuaries and the reserve forest under protection from poaching of wildlife and bring it under wildlife management.

ii) Deer farming outside of the Sundarbans under private ownership and enterprise may be a viable option. The spotted deer in captivity in the zoo are available for breeding purposes. If necessary, deer in the wild may be permitted to be captured under close supervision of the Forest Department.

4.15 Budget

BUDGET ESTIMATED FOR 10 YEARS FOR THE SUNDARBANS WILDLIFE DIVISION

DURATION : 10 years (1994 - 2003)

Personnel National	Amount US$ in 000's
Salary (staff as per Table 10)	2,000
Duty Travel	100
Training	
Fellowship Abroad	200
Fellowship Regional	100
Study Tours	100
In-service Seminars, Tours, Workshops	100
Equipment-Expendable	
Office Supplies, Stationery, Camping Equip. and Uniforms	200
Non-Expendable Equipment	
Micro-computers 5, Typewriters 5, Photocopy Machines 5, etc.	60
Equipment for Radio-communication Network + Installation	100
Launch	300
Speedboats 15	75
Country-boats 20	20
Vehicles 6	180
Motor-bikes 20	30
Firearms, Cameras, Video, Binoculars, etc	100
Buildings	
Office and residential (42,200 sq.ft) (please see 4.7 Physical Construction)	530
Furnitures for the above buildings	125
Operations and Maintenance	1,000
Contingency 10%	532
Sundry	148
TOTAL	6,000

NATIONAL PERSONNEL
SALARY LEVEL

tegory	BGD Taka/yr	Number	Total Taka
CO	81,200	1	81,200
CO	51,200	5	261,000
ief Ranger	45,300	5	226,500
nior ranger	31,400	10	314,000
nger	27,000	13	351,000
out	22,000	56	1,232,000
eedboat Driver	22,000	13	286,000
atman	11,800	13	153,400
Office			
counts Officer	52,200	1	52,200
ad Asst.	31,400	1	31,400
) Asst.	31,400	5	157,000
no-typist	31,400	5	157,000
) Asst.	22,000	2	44,000
iver	22,000	2	44,000
scellaneous	11,800	28	330,000
r Launch			
reng	45,300	1	45,300
ot	31,400	1	31,400
st.Engineer	27,000	1	27,000
chanic	22,000	1	22,000
ok	18,000	2	36,000
		---	---
TAL		166	**3,882,800**

prox. US$100,000 per year. For 10 years including increment/inflation etc. estimated $2,000,000/= for national staff provided in Table 10.

erations and Maintenance include:

1. Cost of operating launch, boats, vehicles, motorbikes
2. Maintenance and repairs of the above equipment per year

- 5% for vehicles, buildings
- 10% for speedboats, motorbikes

3. The World Bank Forestry III Project being implemented already provides for the budget for 7 years for the Environmental Management Wing in the Forest Department, which includes the above budget needs.

WILDLIFE TRAINING COURSE

A Wildlife Training Course for Forestry Officers was organized from 11-16 July 1993. The first day was spent in Khulna devoted to Wildlife Census methods, general information on wildlife in the Sundarbans, instructions on the use of capture equipment and familiarization with the handling of capture equipment. Remaining three days were spent in the field in Sundarbans.

The training course was conducted in July because of the late delivery of the capture equipment and drugs. Monsoon season is the worst time of the year to carry out such training because of the flooding in the Sundarbans and the high temperature and humitidy. Target practice was conducted at Katchikhali forest station with the capture gun and equipment.

The performance of the gun and equipment was satisfactory. However, attempts in darting spotted deer was not successful due to flooded conditions and inexperience of the trainees. Basic deficiency of the trainees was in jungle-craft, in approaching animals in the wild, loud talking, sudden movements, pointing fingers showing animals, etc. It was clear that a longer course of at least two weeks is necessary for such a training. Details of the training materials used for the training is given in Appendix 4. Mr. Munshi Anwarul Islam, DFO accompanied the trainees to the field.

Name of the eight trainees were as follows:

1.Tapan Kumar Dey	Asst.Conservator of Forests
2.Md.Ali Kabir Haider	"
3.Dewan Zafrul Hassan	"
4.Md Asaduzzaman	Forest Ranger
5.Md Lutfar Rahman Sharif	"
6.Md Hurun-ar-Rashid Mazumdar	"
7.Md Keramat Ali	"
8.Md Sirajul Hoque	Forester

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FLORISTIC COMPOSITION OF THE SUNDARBANS

Scientific Name	Family	Vernacular Name	Type of Plant
Acanthus ilicifolius	Acanthaceae	Hargoza	Scrambling, woody, thorny herb
Acrostichum aureum	Pteridiaceae	Hoda, hodo, tiger fern	Gregarious fern
Aegialitis rotundifolia	Plumbaginaceae	Dhalchaka	Small tree
Aegiceras corniculatum	Myrsinaceae	Khalisha Khalshi	Shrub or small tree
Amoora cucullata	Meliaceae	Amur	Small tree
Avicennia alba and/or A. marina	Avicenniaceae	Sadda baen	Small tree
Avicennia officinalis	Avicenniaceae	Baen	Tree
Barringtonia racemosa	Barringtoniaciae	Kumb, kumb	Small tree
Blumea sp.	Compositae	Bari a gash bon gash	Aromatic herb
Brownlowia tersa	Tiliaceae	Sundri lota, Lota Sundri	Scandent shrub
Bruguiera gymnorrhiza	Rhizophoraceae	Kankra	Tree
Caesalpinia crista	Leguminosae	Kutum katta	Scandent, armed shrub
Cerbera manghas	Apocynaceae	Dagor	Small tree
Ceriops decandra	Rhizophoraceae	Goran	Shrub or small tree, usually coppice
Clerodendrum inerme	Verbenaceae	Sitka, siki	Scandent shrub
Cynimetra ramiflora	Leguminisae	Shingra	Shrub
Cyperus javanicus	Cyperaceae	Kucha, Kusha	Grass-loke he(sedge)
Dalbergia Candenatensis	Leguminosae	Chandra lota	Scrambling climber
Dalbergia spinosa	Leguminosae	Chanda katta	Scandent, armed shrub
Dendrophthoe falcata	Loranthaceae	Poragassa	Woody parasity in tree crown
Derris trifoliata	Leguminosae	Gilalota, Gwae lota, Khali lota	Climber

Scientific Name	Family	Vernacular Name	Type of Plant
ucuna gigantea	Leguminosae	Doyal	Climber; large seed pods have irritant hairs
ylriostachya wightiana	Gramineae	Dhanshi	Grass, common on new accretions.
ypa fruticans	Palmae	Golpata	Palm with under ground stem.
ndanus foetidus	Pandanaceae	Kewa katta	Prickly, succculent screw-pine.
etunga roxburghii	Rubiaceae	Narikili	Samll tree.
hoenix paludosa	Palmae	Hantal	Thorny palm.
ragmites karka	Gramineae	Nol kagra	Grass.
ngamia pinnata	Leguminosae	Karanj, karanja	Small tree.
emna ?corymbosa	Verbenaceae	Serpoli,setpoli	Shrub or small tree.
hizophora mucronata	Rhizopnoraceae	Gorjan, Jhanna	Tree with stilt roots.
lacia chinensis	Celastraceae	Choyt barai	Small tree
rcolobus globosus	Asclepiadaceae	Bowali lota	Climber
nneratia caseolaris	Sonneratiaceae	Choyla, ora	Small tree
nneratia apetala	Sonneratiaceae	Keora	Tree
enochlaena palustris	Blechnaceae	Deki lota	Climbing fern
marix indica	Tamaricaceae	Jhao, nonajhao	Small tree
trastingma bracteolatum	Vitidiaceae	Golgoti lota	Climber
unbergia sp.	Thunbergiaceae	Jermani lota	Climber
scum monoicum	Loranthaceae	Shamu lota	Woody parasite in tree crowns
locarpus granatum	Meliaceae	Dhundul	Small tree
locarpus mekongensis	Meliaceae	Passur	Tree

rce : Chaffey and Sandom (1985)

APPENDIX 2

Checklist of Birds in the Sundarbans

PODICIPEDIDAE

Podiceps ruficollis	Little Grebe

PELECANIDAE

Pelecanus philippensis	Spot-billed Pelican

PHALACROCORACIDAE

Phalacrocorax carbo	Cormorant
P. niger	Little Cormorant
Anhinga rufa	Darter

ARDEIDAE

Ardea goliath	Giant Heron
A. cinerea	Grey Heron
A. purpurea	Purple Heron
Butorides stristus	Little Green Heron
Ardeola grayii	Pond Heron
Bulbulcus idis	Cattle Heron
Egretta alba	Great White Egret
E. intermedia	Intermediate Egret
E. garzette	Little Egret
Nycticorax nycticorax	Night Heron
Ixobrychus cinnamomeus	Chestnut Bittern

CICONIIDAE

Ibis leucocephalus	Painted Stork
Anastomus oscitans	Open-billed Stork
Leptoptilos dubius	Adjutant Stork
L. javanicus	Lesser Adjutant Stork
Xenorhynchus asiaticus	Black-necked Stork

THRESKIORNITHIDAE

Threskiornis melanocephala	Black-headed Ibis

ATIDAE

Anas acuta	Pintail
Nettapus coromandelianus	Cotton Teal
Dendrocygna javanica	Lesser Tree Duck
Anas crecca	Common Teal
Todorna ferruginea	Brahminy Duck
Aythys nyroca	White-eyed Pochard
Netta rufina	Red-crested Pochard

CIPITRIDAE

Milvus migrans	Black Kite
Haliastur indus	Brahminy Kite
Aquilarapax	Tawny Eagle
A. pemarina	Lesser Spotted Eagle
Haliaeetus leucogaster	White-bellied Sea Eagle
H. leucoryphus	Pallas Fishing Eagle
Lacthyophaga inchthyaetus	Grey-headed Fishing Eagle
Cyps fulvus	Griffon Vulture
C. bengalensis	White-backed Vulture
Spilornis cheela	Crested Serpent Eagle
Accipiter badius	Shikra
A. trivirgatus	Crested Goshawk
Cirus aeruginosus	Marsh Harrier

NDIONIDAE

Pandion haliaetus	Osprey

LCONIDAE

Falco chicquera	Red-headed Merlin
F. peregrinus	Peregrine Falcon
F. severus	Oriental Hobby
F. tinnunculus	Kestrel

ASIANIDAE

Francolinus gularis	Swamp Partridge
Gallus gallus	Red Jungle Fowl

LLIDAE

Amaurornis phoenicurus	White-breasted Waterhen
Gallinula chloropus	Moorhen
Fulica atra	Coot

CANIDAE

Metopidius indicus	Bronze-winged Jacana
Hydrophasianus chirurgus	Pheasant-tailed Jacana

ROSTRATULIDAE

Rostratula bengalensis	Painted Snipe

CHARADRIIDAE

Vanellus indicus	Red-wattled Lapwing
Pluvialis squatarola	Grey Plover
Charadrius leschenaultii	Large Sand Plover
C. dubius	Little Ringed Plover
Numenius phaeopus	Whimbrei
N arquata	Curlew
Tringa glareola	Wood Sandpiper
T. terek	Terek Sandpiper
T. nebularis	Greenshank
T. hypoleucos	Common Sandpiper
Capella gallinago	Fantail Snipe
Calidris minute	Little Stint
C. ferruginea	Curlew Sandpiper
C. alpina	Dunlin

RECURVIROSTRIDAE

Recurvirostra avocetta	Avocet
Esacus magnirostris	Great Stone Plover

LARIDAE

Chlidonias hybrida	Whiskered Tern
Gelochelidon nilotica	Gull-billed Tern
Sterna aurantia	River Tern
S. hirundo	Common Tern
S. albifrons	Little Tern
S. fuscata	Sooty Tern
S. bengalensis	Lesser Crested Tern
S. bergii	Large Crested Tern
Hydriorigne caspis	Caspian Tern
Larus argentatus	Herring Gull
L. ridibundus	Black-headed Gull
L. brunnicephalus	Brown-headed Gull

NCHOPIDAE

Rynchops albicollis	Indian Skimmer

LUMBIDAE

Treron curvirostra	Thick-billed Green Pigeon
T. phoenicoptera	Green Pigeon
Ducula aenea	Green Imperial Pigeon
Columba livia	Blue Rock Pigeon
Streptopelia decaocto	Collared Dove
S. tranquebarica	Red Turtle Dove
S. chinensis	Spotted Dove
Chalcophaps indica	Emerald Dove

TTACIDAE

Psittacula krameri	Red-ringed Parakeet

CULIDAE

Phopodytes tristis	Large Green-billed Malkoha

TONIDAE

Tyto alba	Barn Owl

RIGIDAE

Otus scops	Scops Owl
Athene brama	Spotted Owlet
Bubo zeylonensis	Brown Fish Owl

PRIMULGIDAE

Caprimulgus indicus	Indian Jungle Nightjar
C. macrurus	Long-tailed Nightjar
C. affinis	Franklin's Nightjar

CEDINIDAE

Cyrule rudis	Lesser Pied Kingfisher
Alcedo atthis	Common Kingfisher
Pelargopis amauroptera	Brown-winged Kingfisher
P. capensis	Stork-billed Kingfisher
Halcyon coromanda	Ruddy Kingfisher
H. smyrnensis	White-breasted Kingfisher
H. chloris	White-collared Kingfisher
H. pileata	Black-capped Kingfisher

EROPIDAE	
Merops orientalis	Green bee-eater
UPIDAE	
Upupa eops	Hoopoe
CIDAE	
Picus flacinucha	Large Yellow-naped Woodpecker
Dendrocopos mahrattensis	Yellow-fronted Pied Woodpecker
D. nanus	Pygmy Woodpecker
Chrysocolaptes lucidus	large Golden-backed Woodpecker
ICRURIDAE	
Dicrurus adsimilis	Black Drongo
D. aeneus	Bronzed Drongo
ORVIDAE	
Dendrocitta vagabunda	Indian Tree Pie
Corvus splendens	House Crow
ERTHIIDAE	
Certhis himalayana	Barotailed Tree
ICNONOTIDAE	
Pycononotus jocosus	Red-whiskered Bulbul
USCICAPIDAE	
Muscicapa thalassina	Verditer Flycatcher
Saxiclodies fulicata	Indian Robin
Copsychus saularis	Magpie Robin
Zoothera citrina	Orange-headed Ground Thrush
ACHYCERHALIDAE	
Pachycephala cinerea	Mangrove Whistler
OTACILLIDAE	
Motacilla maderaspatensis	Large Pied Wagtail

NIDAE		
	Lanius schach	Black-headed shrike
URNIDAE		
	Aplonis panayensis	Glossy Starling
	Sturnus malabaricus	Chestnut-tailed Starling
	S. contra	Pied Myna
	Acridotheres tristis	Common Myna
	A. ginginianus	Black Myna
	A. fuscus	Jungle Myna
CTARINIDAE		
	Nectarinia asiatica	Purple Sunbird
0CEIDAE		
	Passer rutilans	Russet Sparrow

PROPOSAL FOR TIGER RESEARCH IN THE SUNDARBANS, BANGLADESH

Title

Ecology of the Tiger (Panthera tigris)

Starting Date and Duration of Research

Field research in the Sundarbans, data analysis and write-up - 4 years

Abstract

The Royal Bengal Tiger is the star attraction of the Sundarbans. No tiger population remains elsewhere in Bangladesh. The tiger is included in the IUCN Red Data Book of seriously endangered species throughout its range and the very existence of the tiger is threatened everywhere. The Sundarbans population (in Bangladesh and India combined) is one of the largest surviving population of tigers. However, this population is completely isolated since there is no tiger habitat adjoining the Sundarbans. The demise of this tiger population means the loss of a most valuable asset. The continued existence of this magnificent and irreplaceable species can be assured only with carefully planned policy and management programme based on sound ecological and behavioral data. No such information exist in Bangladesh. A research study on the ecology of tigers will advance the scientific understanding of the tigers to provide a foundation for its long-term conservation in the Sundarbans.

The proposed study will be to capture, mark and fit radio-transmitter collars on a population of tigers for study. The state of the art bio-telemetry methodology will provide rapid insight in understanding the population density, sex and age composition, reproductive behaviour, mortality and population turnover rate for determining the population structure and dynamics of the tigers in the Sundarbans. By studying the daily and seasonal activities and movements, range size and characteristics, tiger interaction patterns and relating these to the population composition, density and feeding habits, it will be possible to get an insight of the tiger spatial-social system. The study will enable us to assess the impact of the tiger population on its principle prey species, to determine tiger's living requirements and assess the tiger's response to environmental changes.

The study on the ecology of the spotted deer, barking deer and wildboar, the principal prey of the tiger in the Sundarbans, would fill out the understanding of: their population size, composition and distribution, seasonal movements and ranging patterns; reproductive levels and survival rates; mortality levels by the prime factors such as poatching, disease and predators; and habitat preferences and feeding ecology; etc. Information on the large ungulates may be collected by traditional methods of field observation. In additional, study on the

ecology of the ungulates would be carried out parallel to the study of tigers with radio-telemetry methodology by radio-collaring a number of prey animals of each species.

Description of Research

(a) Objectives:

1. To study the population structure and dynamics of the tiger in the Sundarbans, Bangladesh, by determining population density, sex and age composition, minimum breeding age, reproductive capacity, mortality rate, and population turnover rate;

(2) To study the tiger spatial-social system by determining daily seasonal activities and movements, range size and characteristics, tiger interaction patterns and relating these to population composition, density and feeding habits;

(3) To assess the impact of the tiger population on its principal prey species; and

(4) To determine tiger living requirements and assess the tiger's response to environmental changes.

(b) Justification:

Through overhunting, habitat modification, and competition from domestic livestock the wild ungulate species of the Indian subcontinent have been reduced in number and distribution to but a token of what they were even at the end of World War II. The decimation has been so complete for some species that their existence is endangered.

Paralleling the decline of the wild ungulates and also suffering from habitat modification and particularly from over-exploitation are the great cats, such as tigers, in Asia. The extreme plight of the Asiatic lion (P. leo persica) is well known. The leopard (P. pardus) is greatly reduced in numbers; so too is the largest of the cats--the tiger. Everywhere throughout its former range the tiger population is greatly reduced or the tiger no longer exists. Without question, the continued existence of the world's largest living felid is in a critical situation.

The demise of wildlife populations means the loss of a most valuable asset. Only with a carefully planned policy management program based on sound ecological and behavioral data conducted in a spirit of cooperation and urgency will the continued existence of the tiger and other magnificent and irreplaceable species be assured.

(c) Relation to the State of Knowledge in the Field:

Few quantitative studies of large felid population behaviour and dynamics have been conducted. The notable exceptions include the studies of the African lion (P.l. leo)

(Schaller, 1972), Asiatic lion (Joslin 1970), and the North American mountain lion *(Felis concolor)* (Hornocker 1970).

The study of the tiger and its prey have been carried out in India by Sankhala (1977), Schaller (1967) and Tamang (1982). The Government of India started 'Project Tiger' in 1973 with 19 Project Tiger Reserves and has undertaken an intensive tiger census based primarily on pugmarks in an attempt to gain further insight into tiger distribution and numbers. and estimated 1,327 tigers (1989) in 19 tiger reserves with a total area of 29,716 km2. Dr. Hubert Hendrich (1975) conducted an enquiry into man-killing tigers in the Sundarbans.

Any enlightened scheme for preserving and managing a wildlife species must have as a foundation sound quantitative data regarding its population dynamics, social-spatial system, response to man, his domestic animals and environmental manipulations. These data do not exist with sufficient precision for the tiger in the Sundarbans.

(d) Description of the Project Site

The Sundarbans Wildlife Division will serve as the study area. The description of the study area including other details such as location, topography, climate, vegetation, fauna, etc. have been provided in Chapter 2 of this report.

(e) Plan of Work and Procedure:

(1) Research emphasis and methods

(a) General. Nocturnal, secretive mammals inhabiting dense vegetation are difficult to study, especially when the species are solitary and potentially dangerous. Methods of capture, immobilization, and individual marking must be devised. Most importantly, indirect means of location and "observation" must be employed in order to obtain the necessary qualitative data.

The secretive habits of this large carnivore and the difficulties in handling such a formidable animal makes intensive studies extremely difficult. Using indirect observational methods the movements and activities of tigers can be monitored and data gathered.

(b) Research emphasis. The research will be coordinated to enable data acquisition in the following subject areas: (1) tiger population structure and dynamics (2) spatial and social organization (3) feeding habits and predator-prey interactions. There will be no neglect of opportunities to collect other information that will contribute in a meaningful way to the knowledge of the Sundarbans eco-system.

(c) Population structure and dynamics. The procedure will consist essentially of capturing tigers at baits, immobilizing them with drugs, individually marking, and releasing them back to the population for future identification and study. The

individuals will be fitted with radio transmitters so that their movements and activities can be studied undisturbed throughout the seasons and from year to year. This approach represents the highest state of the art for studying the population behaviour and dynamics of a large, dangerous and secretive carnivore.

This procedure will develop a quantative view of tiger population dynamics in the study area. Factors affecting mortality and natality rates will of course be given particular attention. The study will accurately determine population density, sex ratio, and age structure. The radiotracking procedure allows for rapid analysis of the population as to the kind of individuals comprising it: resident adults, transient adults, temporary residents, etc. Minimum breeding age and the conditions that influence this will be investigated. The study will seek to determine litter size at birth, the extent of cub mortality, age of weaning, and age of self-sufficiency. Causes of adult mortality will be investigated and rate determined.

(d) Social-spatial system No species can be managed effectively without detailed knowledge of its land-tenure system. This knowledge of tiger movements can only be gained by utilizing a ratio-tracking system. By studying the day-to-day movements and activities of tigers, quantitative data on activity patterns, net movements, extent of movements (i.e., home area), seasonal and year-to-year variation in range use, home area characteristics, area occupancy distribution, and the factors that influence tiger movements, will be collected. By simultaneously monitoring radiotagged tigers we can determine patterns of social interaction, patterns of tiger movements in relation to each other, degree of spatiat overlap, and dispersal. This will provide insight into how the land-tenure system operates, why it evolved, and how it is maintained. It will give insight into how the land-tenure system may act as a population-density determinant.

The bulk of the movement data will be recorded in a manner that will facilitate summary and analysis with the aid of a computer.

(e) Feeding habits and predation. The tiger's impact on the wild ungulates of the Sundarbans will be given considerable attention. To assess predation and its effects upon a population of prey animals involves consideration of: (1) density of predator(s), (2) characteristics of the predator(s) including prey selection and preferences, mode of hunting and food requirements, (3) density of prey, and (4) characteristics of the prey such as physical condition, habitat utilization, and anti-predator behaviour, etc.

Tiger feeding habits will be determined by following radiotagged individuals and by searching for the remains of tiger kills. This will determine the species, sex, and age composition and the physical condition of the kill, the degree of prey utilization, and frequency of killing.

Estimates of the abundance, distribution, sex and age structure of the wild ungulate populations will be established through periodic censuses. Through systematic observations we will gain insight into the social systems of the various ungulate species. Particular attention will be paid to competition, interactive segregation and ecological separation between the ungulate species.

(2) Work Schedule

The initial research effort will be toward perfecting the methods of capture, handling and marking tigers. A systematic scheme will be initiated with the objective of capturing, marking and radiotagging the tiger population in the area. The movements and activities of instrumented tigers will be intensively monitored.

Effort will be devoted toward gathering the requisite data on the ungulate populations: numbers, sex ratio, age structure, and habitat utilization.

The coordinated research approach of the study will lead to meaningful results that not only can be used readily in the conservation and management of the wildlife of the Sundarbans but in the preservation and management of the tiger throughout its range.

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APPENDIX 4

WILDLIFE TRAINING COURSE FOR FORESTRY OFFICERS

11 - 16 JULY 1993

July 1993 KHULNA PROJECT OFFICE CONFERENCE ROOM

0900-1200 HRS	General Information on Wildlife in Sundarbans. Wildlife Census Methods
1400-1700 HRS	Instruction for use of Capture Equipment. Familiarization with handling of Capture Equipment

JULY 1993

0800 HRS	Departure from Khulna by "Bono Kanya" Launch to Sarankhola
-14 JULY 1993	Field Training at Kachikhali
JULY 1993	Kachikhali to Sarankhola. Training at Sarankhola
JULY 1993	Departure from Sarankhola to Khulna by Launch

aining conducted by Dr. Kirti M. Tamang, Wildlife Management Specialist, BGD/84/056, Khulna.

WILDLIFE TRAINING COURSE
TABLE OF CONTENTS

WILDLIFE CENSUS METHODS

derstanding animal abundance, distribution and movement patterns is a very important aspect of llife management. Measuring abundance of animal populations essentially means census. Some sus methods may require complex statistical treatment of the data which perhaps deters managers n trying to improve their knowledge of census techniques.
, the simple techniques, with a minimum of statistical treatment, will yield useful results if ertaken with a clear understanding of assumptions and limitations.

ensus technique yields numerical information like population estimates per area, information ut relative abundance, or trends. The adjectives "absent, rare, occasional, common, abundant" ote measures of relative abundance, but even this basic information is lacking for most species rotected areas in Bangladesh. If one can determine the relative abundance of a species over time ay be possible to recognize trends of population change or stability. Discovering such trends is of the most useful outcomes of a census and is the essence of monitoring wildlife populations.

sus techniques are based on direct sightings (e.g. waterhole census technique, or animal counts ransects) or indirect evidence (pugmark or dung counts). Population sizes can be ascertained on basis of total counts or estimated from sample counts. Some, like the waterhole, the pugmark and block count census techniques have been widely used. However, their implementation in the field ot always as it should be. Limitations and necessary preparations are therefore stressed.

ANNING A CENSUS

biological and management needs, in most cases it is not necessary to know the total population . For example, many censuses are to determine trends (indices of population change with time) o make comparisons between different areas, seasons or different treatments.

the manager, to know whether the populations of certain species are increasing or not, repeating same census technique covering only a part of the total area may yield the desired information. ean number of 5.2 chital seen per km of forest road in 1984 and 8.1 in 1986, probably indicates ncrease in population size.

wever, in practice, the desire of the public and administrator is to talk total numbers, means that ost cases a census operation will have to produce a total population size. Nevertheless, it is often ferable to express population size in relative rather than absolute figures. Stating that 1,000 chital in Sundarbans east wildlife sanctuary and 3,000 in Nilkamal tells us less than stating " density of al in Sundarbans east is 18 per sq km and in Nilkamal 7 per sq km".

er planning considerations concern the most appropriate census technique and the timing of the sus operation.

NSUS OBJECTIVES

st reasons for undertaking a census fall into the following categories :

To determine whether a population of a species is increasing, stable or decreasing, i.e. the trend.

To determine how well introduced stock is doing.

To compare densities of wildlife in an area before and after management intervention, like burning.

To compare densities in different areas e.g. core and buffer, or habitats e.g. plantation and natural forest.

AIN CONSIDERATIONS

hich Species to Census

r management purposes it is obviously impossible to census all species in the area concerned. The nager has to make a choice such as one of the following :

Species which may require management intervention (over-grazing, competition).

Internationally or locally endangered species.

Species of national or local importance.

Species of economic significance, e.g. causing crop damage.

Species which are tourist attractions.

Important prey species.

rect or Indirect Census Technique

ecies occurring in relatively high densities, in habitat in which they are visible when searched for, n be counted by direct sighting methods. This applies to most populations of medium to large gulates: rhino and elephant.

ecies occurring in very low densities, or which are difficult to see because of poor habitat visibility cryptic behavior, should be censused either by carefully planned, intensive samples, or by indirect thods, such as dung or pugmark counts. This applies to most carnivores and small or nocturnal mmals, as well as to some large mammal populations in particularly dense habitat types.

should be noted that most indirect methods (pellet counts, pugmarks) are only suitable for taining relative indices of population size and only rarely yield a good estimate of actual population mbers.

tal or Sample Counts

r a total count the entire area under consideration is searched. A disadvantage of total counts is t one cannot account for unavoidable errors (especially when the count is spread over more than e day) or treat the data statistically. Area size, species, terrain, cover and available resources decide en a total count becomes prohibitively expensive or simply impossible.
e alternative is to count a part of the area only. This is accomplished by conducting a number of mple counts. The cumulative area covered by these sample counts is a known (calculated) oportion of the total area, hence the total population size can be estimated by extrapolating the tcome of the sample count to the entire area. This population estimate can be subjected to tistical treatment, as the data are based on a number of independent counts. This way, the manager ll have a range of maximum and minimum numbers within which the actual population size will l. He will also be able to assess the level of confidence he can have in the final population size timate.

most cases sample counts, if skillfully planned and conducted, are more efficient than total counts d hence will allow repetition, which is the basis of monitoring. It is this factor, combined with the vantage of statistical analysis, that normally makes sample counts the preferred choice.

ming of the Census

e optimal time depends on the type of census and the reason for which it is being conducted. For ample, for the waterhole census the height of the dry season is best, as animals are concentrated ound limited water sources. but do not wait too long, as flush of green after pre-monsoon rains may duce dependence on surface water.

sibility, which shows marked seasonal variations in many habitat types, e.g. deciduous forest or assland, also has to be taken into account.

you want to monitor the changes in density over an area through the dry season, then that sets the ne frame within which a number of censuses have to be done.

general, avoid periods of extensive disturbance, like timber working, fire, height of the tourist ason.

affing and Resource Requirements

l techniques require sufficient trained and dependable staff. The actual number of people needed r a census, however, varies according to the technique adopted. A total count requires, in general, any more people and resources than a well planned sample count. The manager should select the nsus technique for which he knows staff and resources are readily available. Once a method is lected, stick to it. The same method repeated by the same team will give the best basis for mparing results from different areas or habitats, or for assessing population trends over consecutive mple intervals.

AJOR CONSIDERATIONS FOR SAMPLE COUNTS

a sample count, you concentrate the counting effort within "sampling units" which constitute a own proportion (the "sample fraction") of the whole area being censused. Limiting the counting fort to these units requires a smaller commitment in terms of staff and budget than total counts, t they require careful planning, especially in respect to size, number and distribution of sample its.

e ability to statistically define precision and establish confidence limits is an important aspect of mpling.

MPLING AREAS AND SAMPLING UNITS

e sampling area, often called the "sampling universe" is the area for which a population estimate to be made. It is often identical with the protected area or a sub-section of it. Such sub-sections n be defined as habitat types or land forms (grassland, riverine forest, wooded valley, grassy ateau), but may also be management units (compartments, blocks, buffer zone).

mpling units are the individual portions of the sampling area which sample area could be counted, t in practice only a fraction of the potential units will actually be counted. These units should be osen at random and are usually scattered throughout the sampling area. More often than not the ape of a unit will be irregular. The only regularly shaped sampling unit mentioned in this section the strip transect or the roadside count which has a known width and length.

SSUMPTIONS

e basic assumption in sampling is that the sample(s) should be representative of the entire mpling area. Obviously, selecting sample areas from only the core zone or along cut roadsides will t give a representative sample for the whole area.

hen undertaking sample counts one makes three additional major assumptions..

The sighting of one animal does not influence the chances of sighting another.

The conditions affecting observer/object encounter do not change during the sampling operation.

The objects to be sampled are distributed at random (uniformly) in the area being sampled.

umption (a) is true for more or less solitary animals. A herd of animals is more easily spotted than individuals in it. In this case, from theoretical considerations, one should base population mates on mean group size and herd density estimates, rather than on individual animals. However, anation of the mathematics involved is beyond the scope of this course.

umption (b) is generally met if the observations are taken during the same period, e.g. late dry son or postmonsoon, and at the appropriate time(s) of the day or night. Also, animal reaction to observer should not change, e.g. animals should not become more shy as a result of disturbance ing the census operation.

umption (c) is more difficult to understand and know whether it holds. The individual trees in a ntation are uniformly distributed, because they had no "choice" of rooting elsewhere. Animals and mal herds are never as uniformly distributed as this. Depending on species, they prefer certain as, often according to season or time of day. However, within a homogeneous environment, say oodplain grassland, they come closer to being uniformly distributed at random and not further regated around specific features.

MPLING

ere is considerable variation in all attributes of natural populations. For example, the weights of tal males are not exactly the same; the ages of male sexual maturity vary from place to place. The sity of chital from place to place will also vary. In a particular location density will also vary. If have a 100 sq km sanctuary with exactly 1000 chital there will be a density of 10 chital per sq km. is does not mean every sq km has 10 chital - some will have none, some may have 50! An area h no chital today may have 50 tomorrow,, so notice that density distributions continuously vary in ce and time. It is this variation which makes sampling a little complex to understand and plement.

order to understand the basic principles of sample counts and some of the mathematics involved nsider examples (a) and (b) in Box I. The sampling area is a rectangular area of 10 by 5 km, and as a chital population of 100 animals. Example (a) shows a random distribution, (b) shows a non-dom patchy distribution pattern. This sampling area is divided into 10 strips, each of 1 km width, sampling units. One or more strips may be selected and counted, and the total population imated from this sample count.

wever, taking one sample only would give plenty of opportunity for a large error in the population imate. If in (a) it happens to be sampling unit 7,total population would be estimated as 10 x 4 = chital, in case of sampling unit 8 it would be 10 x 17 = 170 chital. This error would be reduced matically by counting more than one unit, and using the mean of all counts to estimate the total pulation size. Examples of this are worked out in Box I. We can see that there is inherent variation the population itself and there is also variation due to our level of sampling. A small sample will e more variable results than a large sample, no matter how the animals are distributed. In case of nonrandom distribution you need a much larger sample to get a better estimate.

om these examples several questions arise :

Can I gain knowledge about the level of variation ?

How can this help me in making the estimated results more reliable?

How many sampling units do I need to count so as to get an acceptable amount of possible error in my final estimation?

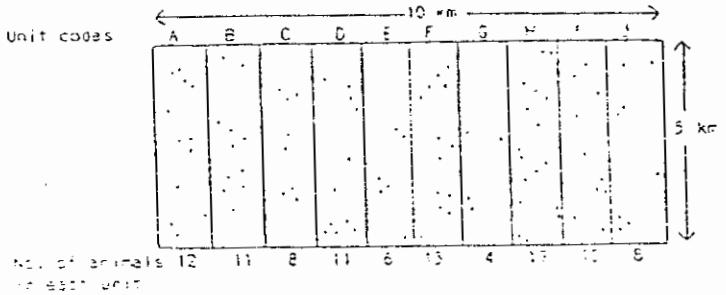
o answer these questions we will have to discuss some statistical method and terminology.

I

EXAMPLES OF ANIMAL DISTRIBUTION AND POPULATION ESTIMATES AS A FUNCTION OF THE SIZE OF THE SAMPLE TAKEN

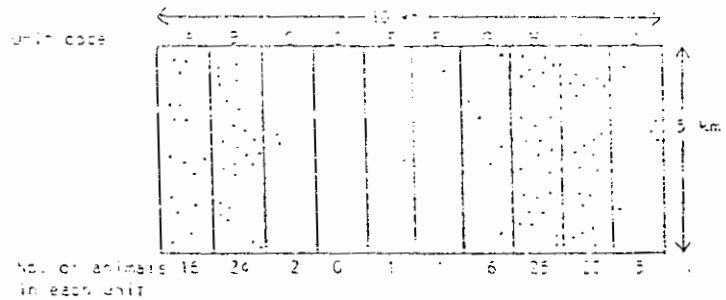
a) random, b) non-random (patchy) distribution. Sampling area = 50 sq km. Each sampling unit = 5 sq km (1/10th). Population size = 100. Each dot represents one animal.

a)



Unit counts	Sample size (% of total area)	Mean number of animals/unit	Total population estimate (mean number/unit x 10)
A E F I J			
12	10%	12/1 = 12	12 x 10 = 120
12 6	20%	18/2 = 9	9 x 10 = 90
12 6 13	30%	31/3 = 10.3	10.3 x 10 = 103
12 6 13 10	40%	41/4 = 10.2	10.2 x 10 = 102
12 6 13 10 8	50%	49/5 = 9.8	9.8 x 10 = 98

b)



Unit counts	Sample size (% of total area)	Mean number of animals/unit	Total population estimate (mean number/unit x 10)
B C E G I J			
24	10%	24/1 = 24	24 x 10 = 240
24 2	20%	26/2 = 13	13 x 10 = 130
24 2 1	30%	27/3 = 9	9 x 10 = 90
24 2 1 6	40%	33/4 = 8.2	8.2 x 10 = 82
24 2 1 6 20	50%	53/5 = 10.6	10.6 x 10 = 106
24 2 1 6 20 5	60%	58/6 = 9.7	9.7 X 10 = 97

e Standard Deviation

ery population can be described by two things, the mean and a measure of variation around that an. We estimate these by sampling, hence we have an estimated mean and estimated so called iance. The variance is a measure of how far the individual counts are from the mean. Obviously y are much farther apart in the second example (Box Ib). For the sample, the variance is culated as the cumulative sum of the mean minus the value for each count. Finally this sum is ided by the number of sampling units counted minus 1. Some are bigger and some are smaller than e mean, so to prevent negative values from cancelling out positive values, we use the squared values the measurements for the variance. The square root of this is called the Standard Deviation of the tribution around the mean, and is often referred to as "s". This is the beginning of many statistical culations. The latter Box (II) gives an example of how to calculate the standard deviation, but ny pocket calculators give this value directly.

e Standard Error

e now have to combine the variability in the population with the variability due to our sampling. we saw earlier, the population estimate varies greatly due to changes in sample intensity, i.e. the mber of units counted.

mbining these two variabilities into one value of variability for our estimated mean gives the andard Error. This is simply the standard deviation divided by the square root of the sample size = number of samples counted) or $s/\sqrt{n}$. The standard error around a mean tells you how close the timated mean comes to the real value in the population. Obviously the standard error will get aller as your sample size gets bigger. See box II for examples of standard errors.

nfidence Limits

e standard error gives a statistical assessment of the probable range of values for the real mean. ow confident are we that this is correct ? Remember we are taking samples; there is always a ance that our samples fell in mainly high or low values and so the estimate could still be much rse than expected. We get over this by setting ourselves "limits of confidence" . In biology, the west level of confidence that is in wide use is the "95% confidence limit", which means that "I am nfident that in 95 out of 100 occasions the true mean will lie between so much....of the estimated ean". There is still a 5% chance left that the true mean lies outside the given range! A 99% nfidence limit would therefore have a larger range, as we are confident it could be wrong only 1 100 times. The calculations of confidence limits uses three things :

The standard error around the estimated mean.

The sample size (as again we have more confidence in bigger samples).

The level of confidence required, e.g. 95, 99, 99.9%.

nfidence limits are expressed as : Estimated Mean Value ± Confidence Limit. They are calculated the Standard Error (SE) times a constant (Z), which is dependent on the sample size and nfidence level required. For large samples (30 or more units counted) the constant is :

95%	99%	99.9%
Z = 1.96	Z = 2.58	Z = 3.29

II

CALCULATION OF STANDARD DEVIATION, STANDARD ERROR AND CONFIDENCE LIMITS FOR ESTIMATING POPULATION SIZES.

a) data from Box Ia (5 samples), b) data from Box Ib (6 samples)

a) No. counted in sampling units : 12, 6, 13, 10, 8

No. of samples (n) = 5. Total No. of samples possible (N) = 10

Mean/sampling unit = (12+6+13+10+8)/n = 49/5 = 9.8

Variance (s^2) = $[(9.8-12)^2 + (9.8-6)^2 + (9.8-13)^2 + (9.8-10)^2 + (9.8-8)^2]/(n-1)$
= $[4.84+14.44+10.24+0.04+3.24]/(5-1)$
= $32.8/4 = 8.2$

Standard Deviation (S) = $\sqrt{s^2} = \sqrt{8.2} = 2.2864$

Standard Error (SE) = $s/\sqrt{n} = 2.864/\sqrt{5} = 1.28$

Confidence Limits (L), 95% level, n = 5, hence (from t-values) t = 2.57
$L = t \times SE = 2.57 \times 1.28 = 3.29$

Population estimate = $N \times (\text{mean} \pm L) = 10 \times (9.8 \pm 3.29)$
$= 98 \pm 32.9$

b) No. counted in sampling units = 24, 2, 1, 6, 20, 5.

No. of samples (n) = 6. Total number of samples possible (N) = 10

Mean/sampling unit = (24+2+1+6+20+5)/n = 58/6 = 9.7

Variance (s^2) = $[(9.7-24)^2 + (9.7-2)^2 + (9.7-1)^2 + (9.7-6)^2 + (9.7-20)^2 + (9.7-5)^2]/(n-1)$
= $[204.49+59.29+75.69+13.69+106.09+22.09]/(6-1)$
= $481.34/5 = 96.27$

Standard Deviation (s) = $\sqrt{s^2} = \sqrt{96.27} = 9.812$

Standard Error (SE) = $s/\sqrt{n} = 9.812/6 = 4.01$

Confidence Limits (L), 95% level, N = 6, hence (from t-values) t = 2.57
$L = t \times SE = 2.57 \times 4.01 = 10.31$

Population estimate = $N \times (\text{mean} \pm L) = 10 \times (9.7 \pm 10.31)$
$= 97 \pm 103.1$

r sample sizes smaller than 30, the sample size has much more influence. For these cases a ferent factor is needed, which is taken from "t" tables in statistical handbooks, For our purposes e relevant t-values are given in the table below. Select the one that comes closest to your sample e and use that as value for Z.

lly worked out examples of these statistical procedures are given in Box II.

nfidence Limits

nfidence limits give a measure of precision (see box) to the sample estimate and are essential to e interpretation of census data. If a density of 10 chital per sq km is found in year 1 and 12 in year is this then an increase or is it merely due to sample variation? If the confidence limits around the spective means do not overlap, you have a given measure of certainty (95, 99%) that the estimated nsities indicate a real difference.

mple Size

ow large a sample (how many units) do I need to take? This question is not easy to answer, and pends largely on the level of precision desired (see box). Basically, the manager has two methods hich he could apply.

he first one involves the use of some of the statistics described above. First, we must set a limit (L) ithin which we want our estimated mean to be. Next we select the probability that our estimate will e within the range of mean $\pm$ L, say 95%.

t-values for Different Sample Sizes and Confidence Levels.

Sample size	5	10	15	20	25
t-value, 95%	2.57	2.23	2.13	2.09	2.06
t-value, 99%	4.03	3.17	2.95	2.85	2.79
t-value, 99.9%	6.87	4.59	4.07	3.85	3.73

second simpler, but less precise method requires that we keep a record of the amount of variation round the mean from samples as they are counted, while the sampling process is in progress. With is method we determine whether further samples will increase the precision of the estimation unit ean by calculating successive means (also referred to as "running mean"). The mean of, say, the first

, 10 15 etc counts is calculated and plotted against the sample size. This mean will at first oscillate iolently, but oscillation will gradually fade out as the sample size increases. This allows us, once the irve has smoothed out, to decide that we have reached a large enough sample size. Otherwise ampling should continue.

xamples of both methods are given in Box III. From these examples it is clear that a randomly istributed population requires far less intensive sampling than a population with a nonrandom istribution. Hence, in the latter case, stratified sampling, meaning sampling sub-areas with different nimal densities separately is highly recommended. The "running mean" method would indicate a nuch less intensive sampling, but remember that the result here is very imprecise indeed. This is hown by the Confidence Limits of + 33 and + 103 respectively (see Box II). Hence, the manager hould refrain from using this method, unless absolutely necessary.

Methods and examples given here are simplified, but will suit most manager's needs. For more omplicated sample census operations it is recommended that the manager seeks the advice of a rained statistician.

III

HOW TO CALCULATE THE SAMPLE SIZE REQUIRED

A1 : using desired confidence limits, data from Box Ia; A2 : "running mean" method, same data; B1 and B2, same as A1 and A2 respectively, but data from Box Ib.

A1. 1. *Set the limit for L, say L = ± 10 animals.*
2. *Select the desired Confidence level, say 95%, hence Z = 1.96.*
3 *Select the Standard Deviation (literature, previous work), here s = 2.864.*
4. *Determine the ratio of the sampling unit size to the sampling area, here r = 0.1 (each sampling unit is 1/10 th of the sampling area).*

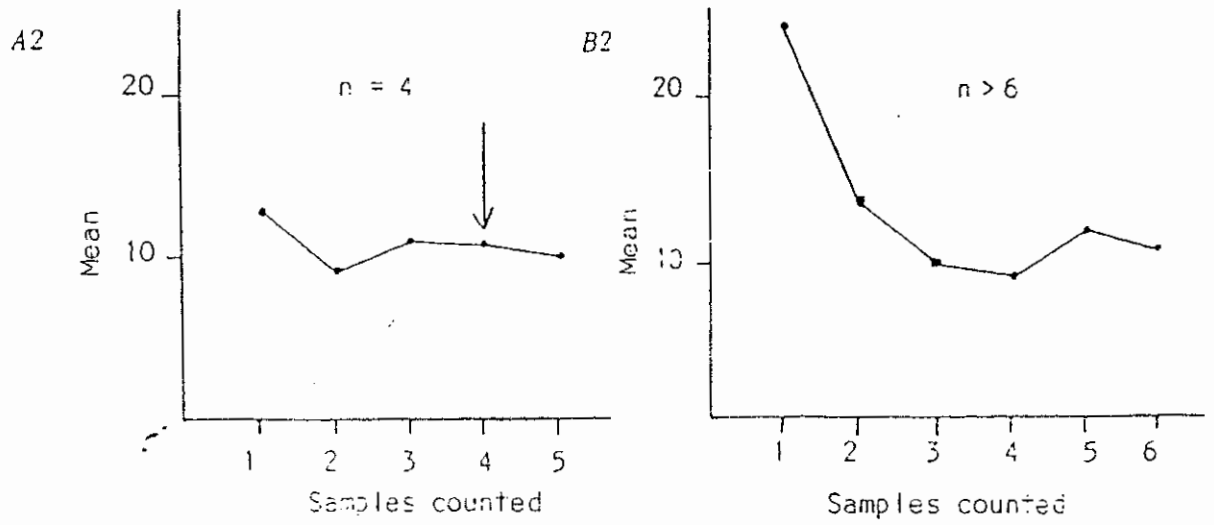
The number of sampling units needed is now calculated as:

$$n = Z^2 \times S^2/(r \times L)^2$$
$$= (1.96)^2 \times (2.864)^2/(0.1 \times 10)^2$$
$$= 31.5/1 = 32$$

B1. 1. *Set the limit for L, say L = ± 10 animals.*
2. *Select the desired Confidence level, say 95%, hence Z = 1.96.*
3. *Select the Standard Deviation (literature, previous work), here s = 9.9812.*
4. *Determine the ratio of the sampling unit size to the sampling area, here r = 0.1 (each sampling unit is 1/10 th of the sampling area).*

The number of sampling units needed is now calculated as:

$$n = Z^2 \times s^2/(r \times L)^2$$
$$= (1.96)^2 \times (9.812)^2/(0.1 \times 10)^2$$
$$= 369.8/1 \approx 370$$



ACCURACY AND PRECISION

n estimate of population size is characterized by two attributes : accuracy and precision.

ccuracy depends mostly on minimizing human errors. For example : counting animals in tall ass means young will be missed, hence a negative bias (of unknown magnitude.); a careless census am sights only 50 out of 100 animals present in a sampling units, a negative bias of 50%.

recision means minimizing the confidence limits around the estimated mean population size. It is us a measure of repeatability : if I repeat the census in the same way I will get a similar figure, i.e. e results are precise.

xample : Real population size = 2300 animals

Estimated population size = 1400 $\pm$ 70 animals

his result has a bias of -40%, hence is inaccurate, but it has a high precision, with confidence limits f only 5%.

high accuracy may be needed for estimating total population size. Accuracy can be improved rough training of census staff, by choosing the best method for the particular purpose of the census, nd by applying correction factors obtained through careful testing, to allow for known, constant levels f bias. A high precision is needed when monitoring the trend of a population, as I want to be sure o detect changes. Precision will improve by increasing the sample size, and consistently repeating the ame technique.

rom the 95% confidence limits we know that there is 95% chance that our estimate lies within the ange for the estimated mean. This range is set by the Standard Error (SE) times a factor Z = 1.96, nd a factor r indicating the ratio of the size of the sampling unit to the sampling area. This gives the quation:

$$1.96 \times s/\sqrt{N} = r \times L$$

hich is solved for n.

his equation requires some knowledge of s, which we will have to get from previous work on this r similar populations. As this is a bit of a guess, the formula use the rounded off value of Z = 2, so becomes :

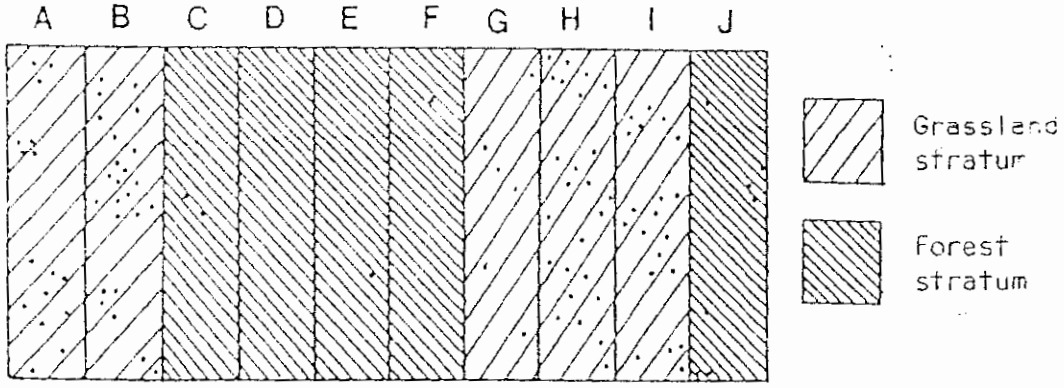
$$n = 4 \times s^2/L^2$$

STRATIFICATION

The distribution of animals is expected to be random within an area with a homogeneous habitat, like Anogeissus forest, alpine meadow, evergreen rain forest, riverine forest or tall grassland. A sampling area, for example, a National Park, will usually have more than one habitat type but ideally sampling units should contain only a single (homogeneous) type. This is achieved by dividing the sampling area into sub areas ("strata") of relat- ively homogeneous habitat characteristics - and is known as stratification.

Subsequently, sampling and data analysis is done for each stratum separately. This is called stratified sampling.

Stratified sampling can also include sampling in different management units, like core and buffer zone.



N.B. Dots represent animals; in this case densities are obviously different between strata.

In general, the sampling effort in each stratum should be proportionate to the area covered by this stratum in relation to the total area. In the example above, the "forest" stratum and the "grassland" stratum each cover 50% of the total area. Hence half of the total sample effort would normally be allotted to the sampling of each stratum separately.

E PLANNING AND IMPLEMENTATION OF BLOCK COUNTS.

block count observers move through an area in a predetermined pattern. The main assumptions that they see all the animals of the target species and that double counting can be avoided.

term "block" in this context refers to a small area with natural and/or artificial boundaries which be easily identified on maps as well as in the field. This area must be small enough so that, if asonable investment of time and resources is used, a total count in it can be conducted.

term "block" as used here does not refer to forest blocks which typically cover an area of between and 30 sq km. However, it may fit a forest compartment or part of a compartment.

conduct a census based on block count, the entire protected area is first divided up into counting cks. The total numbers of animals in this protected area may then be ascertained either by nting all the blocks and adding up the figures thus obtained, i.e. a total count; or, the preferred thod, estimated from figures obtained by counting a certain proportion of the blocks only, i.e. a mple count.

EPARATIONS

or to conducting a block count, the following must be done.

Determine which species (target animals)are to be sampled.

Select the census method (see below).

Using a map of the area to be counted, divide this area into blocks. Block size will be different depending on the habitat features (very small in dense forest, larger in open meadows), and the size and habits of the target animals (in general larger if target animal is bigger, and smaller the more elusive it is).

Boundary choice may depend on the type of count conducted. If stratification is desired then that sets secondary limits to the boundaries.

e Drive Count

a line drive count a large number of observers proceed in an extended line abreast along a given mpass bearing at a steady pace, from a well defined and reasonably straight baseline to the far e of the block to be counted. Do not conduct a line drive if you cannot start it from such a seline. Fire-lines or roads can frequently be used as a baseline. The finishing line should be easily ntifiable in the field e.g. a river or cliff edge.

e count works on the assumption that no target animals remain undetected between neighboring servers.

e observers must start and finish together, and neighbouring observers should see each other or within earshot from one another. These prerequisites determine the size of the individual blocks. s they depend largely on habitat features (e.g. density of vegetation, ruggedness of terrain), block e will vary accordingly. The line of observers tends to break up with increasing distance from the seline. In dense forest this usually happens after only 1 km! Similarly, lateral distances between bservers are set according to the habitat features of the block.

ELD OPERATIONS

bserver Training

are in preparation of all participants in a census can eliminate many misunderstanding and sources error.

Thoroughly brief and train all observers in the tasks expected from them on the day(s) prior to commencement of the census.

Define the census area clearly with the help of maps, pointing out boundary features such as roads, tracks or rivers.

Identify the transects to be walked or the stations to be occupied (when and for what period) and allocate individuals or teams to each.

Explain carefully how the record sheet is to be filled in, leaving no possibility of ambiguity.

Emphasise the importance of accuracy - a nil return is as important as one showing a large number of animals!

Have a brief trial run before the census proper begins to further eliminate any misunderstandings.

quipment and Supplies

lake sure that all items essential for the operation are available, in required quantities, in advance f the starting date. Examples :

Vehicle(s) to carry personnel to starting points.

Food - as appropriate.

Bedding if census to occupy more than one day in field.

Firearms and ammunition if census team likely to encounter dangerous species.

Map for each team showing boundaries of census area and counting blocks.

Binoculars (if possible) - one per team.

Compasses (if possible) - one per team.

Watches - one per team.

Recording sheets (proforma) and pencils.

ine Drive Count

total of twenty observers (or observer groups) is about the most that can be managed in the field. hey should be lined up, at the proper lateral distance along the baseline. The observers should all art at the same time and proceed at the same speed. Maintaining the given compass bearing is very nportant. They finish, again all at the same time, whenever the landmark which marks the end of e block is reached. Note, observers at the beginning and end of the line count only inwards from ne line.

Sampling Area _____ Block No._____ Station No._____

Date _____ Starting Time _____ Finishing Time _____

Observer(s) _____

Sl No.	Time	Species	Total No.	Age/Sex Composition	Direction of Movement
1					
2					
3					
etc					

LL THE BLOCKS OR A SAMPLE

is of course possible to count all the blocks, and then to calculate the total population size in the ea concerned by adding up all the individual block counts. This approach is usually not commended. It is much better, both time-wise and for data analysis, to use each block as a sampling it and count only a proportion of them. The total population size is then estimated from this mple.

ROBLEMS

robably the biggest problem with block counts is to avoid double counting of animals. The most ommon source of this is animal movement during the census operation. With the line count method startled animal could be sent "down the line", and thus be recorded by several observers. Some of his error can be removed by carefully comparing times of observation and direction of movement ntered in the data sheets for each sighting.

TRANSECT LINE

ost problems of ground counting can be tackled by variations on two strategies: by counting on a nsect of fixed width, the width being determined by the animal's behavior and sightability, or by unting all animals seen from a line of march.

ansacts of fixed width. The first strategy leads to a more simple analysis and it is particularly propriate when densities are high. The distance from the line of march to the transect boundary ralleling it on either side is set at the distance within which all animals present will be seen. It may a metre when frogs are counted, 10 m when large mammals are counted in heavy forest, or 500 when animals of this size are censused in grassland. The decision on whether an animal is 'in' or ut' is critical; a range finder is necessary when the transect is wider than 100 m. If the censused ecies is undisturbed by human presence an animal should not be tallied until the observer reaches e point closest to it on his line of march. From this position he is best able to estimate the 'right-gle distance', and hence to decide whether the animal is within the transect. But individuals longing to timid species, or those that are seen as they flush, must be judged immediately as inside outside the transect. Unless it is obvious, a compass angle and a distance from the observer in eeded to calculate whether the animal should be tallied.

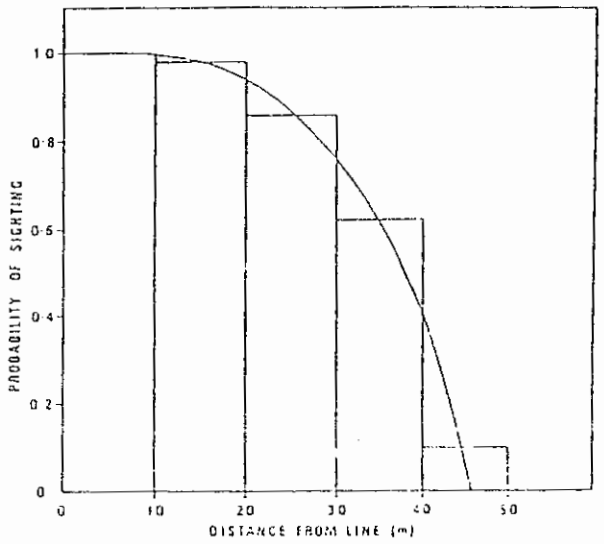
xperimental design and analysis for fixed-width transacts is the same as that given for unequal-sized mpling units. The area is stratified on a map, both by density of animals and by visibility. Within stratum transect width is determined by sightability, and the appropriate number of transacts is termined by the size of the stratum, the transect width, and animal density. The last can be timated roughly by a small pilot survey.

ansacts of indefinite width. Since the precision of a density estimate is proportional to the square ot of the number of animals counted during a survey, it is highly desirable that all animals seen ould be recorded. Data of this kind are analysed differently from counts on transects of fixed width. he following additional information is needed :

- the right-angle distance of each animal from the line of march (the fixedwidth transect method requires only an 'in' or 'out' decision),
- form of the curve relating the probability of seeing an animal to the distance it stands from the line, and
- the slope of this curve.

nce each of these estimates is subject to error, the decision on whether to use transects of fixed or definite width must balance the simplicity and reduced experimental error of the first against the dded precision accruing from the greater number of animals counted by use of the second, In neral, the second design is more appropriate at lower densities.

perimental design and analysis will be illustrated by an imaginary example. Suppose we are imating the density of a species of bird living in grassland.



Probability of seeing an animal at varying distances
from a line of march

ght-angle distances are recorded for all birds seen either side of a 10 km line of march. These cords can be summarized as a histogram (above) constructed by classifying the observations into m intervals and dividing the frequency of each interval by that of the first to form a probability tribution. We assume that the number of birds recorded in the first interval (within 10 m of the e) represents a complete count. The probability of seeing a bird in this distance is therefore set at ty, and beyond, the probabilities fall away with distance from the line.

erhardt (1968) suggested a flexible curve to fit this kind of data :

$$P_x = 1 - \left(\frac{x}{W}\right)^k,$$

ere P_x is the probability of seeing an animal located x metres from the line and W is the maximum ance at which an animal can be seen. The constant k describes the shape of the curve. When k l the regression is linear, convex when $k > 1$ and concave when $k < 1$.

ble outlines the steps in fitting a curve to the probabilities in Figure 1. The constants k an W are mated from the regression of log $(1 - P_x)$ on log x for all intervals other than the first. The ression constants a and b estimate respectively - k log W and k. Table 1 and Figure 1 show that value of k and W estimated in this way generate a curve closely tracking the observed decline of tings with distance.

Having fitted this curve and checked that it mimics the data, we can now

Table 1. Fitting a curve to the probability of seeing bird at varying distances from a line of march

Distance (m) from line	Mid distance x	Birds seen	Probability of sighting P_x	Used for regression	Fitted probability P'_x
				log x log$(1-P_x)$	
0-10	5	50	1.00		1.00
-20	15	49	0.98	1.1761 - 1.6990	0.98
-30	25	43	0.86	1.3979 - 0.8539	0.88
-40	35	31	0.62	1.5441 - 0.4202	0.61
-50	45	5	0.10	1.6532 - 0.0458	0.07
		n = 178			

Regression: $\log (1 - P_x) = k \log x - k \log W$

$= 3.444 \log x - 5.723$

$k = 3.444$; $W = 45.92$ m

$$Hence\ P_x = 1 - \left\{\frac{x}{45.92}\right\}^3$$

$$Mean\ distance = \bar{x} = \frac{(5\times50)+(15\times49)+\ldots+(45\times5)}{178} = 18.93m$$

Number of sightings = n = 178 birds

Length of line = L = 10,000 m

estimate density. By Eberhardt's (1968) model the density per unit area, D, is solved as

$$D = \frac{n(k+1)^2}{4L\bar{x}k(k+2)}$$

where n = the number of animals seen = 178

X = the mean of their right-angle distances from the line = 18.93 m

L = length of the line = 10,000 m.

For the example,

$$D=\frac{178\times 4.444^2}{4\times 10{,}000\times 18.93\times 3.444\times 5.444}$$

$$=0.000248 \textit{ birds per } m^2=248 \textit{ birds per } km^2$$

It is informative to compare this estimate with that from a transect of fixed width. If the first distance interval is used to define the width of the strip, since we assume that all birds were seen on this trip, density is estimated as

$$D=\frac{number\ seen\ on\ the\ transect}{length\times width}$$

$$=50/(10{,}000\times 20)$$

$$=250\ per\ km^2.$$

Note that the transect width is not 10 m, the first distance interval, but 20 m, since birds are counted up to 10 m either side of the line of march. This estimate is about the same as by the previous analysis, but since it is based on a count of only 50 birds, in contrast to the 178 records from the transect of indefinite width, its precision is only half ($\surd 50/\surd 178 = 0.53$) that of the previous estimate.

A model proposed by Hoglund, Nilsson and Stalfelt (1967) and discussed by Eberhardt (1968) assumes that the probability of sighting falls away exponentially with distance. NO bounding distance need therefore be assumed and the estimate of density simplifies to

$$D=\frac{n}{2L\bar{x}}.$$

Eberhardt gave theoretical reasons for suspecting that this model would be appropriate when detection depends on visibility rather than on the behavior of the animals. It may prove to be the best estimate for mortality surveys and for ground surveys of African game. Its applicability can be tested by graphing the log of numbers seen per interval of distance against the mid-points of these intervals. When the regression is approximately linear the exponential model yields a satisfactory estimate of density.

METHOD FOR IDENTIFYING AND COUNTING TIGERS AND LEOPARDS BASED ON A ECORD OF THEIR TRACKS.

he use of pugmarks as a census technique has been developed in India. The technique requires a 'pugmark tracer" which can easily be manufactured locally. Even more important it requires an xperienced and skilled observer (director, research officer or other wildlife officers) to interprete ugmark tracings in relation to space and time as well as other important clues. Staff must be trained o provide accurate and continuous records. Both the accuracy in tracing of pugmarks and the ability o interprete, require practice and experience. One will then be able to identify individual animals nd, if the survey covers all suitable habitat, arrive at a total population of the species within the park r sanctuary. In addition, the data will allow one to determine sex ratio and age structure of the opulation. If the survey covers large areas and if it is done continuously, one may even be able to etermine the boundaries of home ranges and detect variations in them over a given time period.

he technique described here is an adapted version of an article by H. S. Panwar, "A note on Tiger ensus Technique", Tiger Paper 6: 16-18.

QUIPMENT

or the pugmark tracer;

- 1 pane of colourless glass (20 cm x 25 cm x 3 mm) with holes drilled in the corners.
- Four metal screws, about 5 cm long, with wingnuts, nuts and washers to fit; these become the "legs" of the tracer.
- Thin paper to transfer the tracing from the glass.
- Rubber bands to hold the tracing paper onto the glass pane.
- A felt pen which can write on glass (and be erased).
- A measuring tape (100 cm).

HOOSING A TRACK FOR TRACING

elect a well formed impression of the rear pug, preferably from a series of tracks along a road, sandy ream bed etc. If no perfect impression can be found, make a composite tracing using two or three

ugmarks of the same animal. Left and right pugs should be identical mirror images, but if one shows deformity, that side should be taken, because it can always be easily identified.

AUTION WITH MULTIPLE TRACKS

igers lead solitary lives except mothers and their offspring. However, there are times when males in the "family" for short periods. Because of simultaneous movements distortion of tracks occur as arks of one individual get superimposed by another. Great care must be taken in identifying ugmarks of an individual in the series of multiple tracks and only then should tracing be attempted.

THER INFORMATION TO RECORD

additional information should be recorded on the tracing sheet or on a separate paper attached to

- Name of the recorder.
- Date and time of tracking.
- Location, e.g. section of road, ravine or nala.
- Direction of movement.
- Surface type (sand/earth) and condition (dry, wet, muddy, slushy)
- Freshness of the track (fresh, probably last night, yesterday, old etc).

lote that the size of the pugmark of the same individual may vary depending upon the texture and onsistency of the ground surface. In mud, deep dust or sand, the track size will be larger but all the haracteristics will remain unchanged.

IMING OF THE SURVEY

f an estimate of population size and structure is the only purpose of the survey, it should be carried ut over a period of several weeks during the time when tiger tracks can be most conveniently ocated. Records to determine home range and utilization of different habitats within a given area, equire the survey to be extended through a full seasonal cycle. In the course of a pugmark based ount of tigers within a given area, intensive survey for tiger tracks and their tracings have to be nade. The pugmark records obtained are compared every day and individual locations entered on map. In a few weeks these will lead to identification of all individuals using the area.

GEING AND SEXING

easonably accurate sexing of adults can be made from the overall comparative shape of the igmarks as explained earlier. Pugmarks of the young are smaller. Cubs less than three months old e seldom taken out and cubs upto a year old do not move except with the mother. Sexing and eing is thus possible from pugmark records.

NTERPRETING THE TRACK RECORD DATA

nce the pugmark of and individual animal has been positively identified it should be given a number it is easily remembered and referred to. The number can be pinned to a map to indicate locations here its track has been recorded. This will show the general whereabouts of the animal at different ates during the survey.

RACING THE TRACK

lace the tracer directly above a clear track. Push the legs of the tracer into the soil until the glass ane is just above the track surface. If the ground is hard, lower the glass pane by adjusting the wing-uts which hold it in place. With both knees on the ground left and right of the tracer and looking raight down, start tracing. By moving your head while drawing, so as to keep your eyes vertically bove the tip of the pen and the portion of the mark under tracing, you will be able to avoid the rror of parallax and make an accurate tracing. As with all skills, proficiency comes with practice.

o transfer the pugmark from the glass to paper, attach the tracing paper to the glass by means of he rubber bands and, holding it up against the light, draw the pugmark outline, again taking care to void the error of parallax.

ISTINCTIVE FEATURES OF THE TRACK

t is important to draw the following distinctive features of the track correctly:

- Shape of the three lobes at the base of the main pad (and the two small "indents" formed by them) because this is one characteristic of the individual variation. The shape and size of the three lobes, the extent of sag of the right or left leg and the direction of the two "indents" vary with individuals.

- The apex of the pad as this is also an important individual characteristic. This apex line varies in length, curve and inclination from individual to individual.

- Abnormalities which allow easy recognition.

- Stride measurement from track to track when rear pugmark is exactly superimposed on to front pugmark.

However, when conducting a tiger census a decision should be made in advance and rigorously followed to make tracings of either the left rear or the right rear pugmarks. In such a case an additional pugmark - left or right, front or rear - should be recorded as extra evidence of an individual's identification.

A walking tiger (or leopard) in normal gait places the rear foot on top of the impression made of the front foot. The positioning, however, changes with the speed of walking, but rear pugmarks always remain undisturbed because the rear pug either superimposes the front pugmark or overshoots it. This is one reason for choosing pugmarks made by the rear pug. Rear pugs are invariably smaller than front pugs. Of the superimposed pugs, the inner outline is outline of the rear pug.

Another reason is that only the rear pugmark is different between males and females. The distinction is one of size (male pugs are larger) and shape (see box). A "box" drawn around the pugmark of the male is almost a square. A box drawn around the pugmark of the female, on the other hand, is clearly rectangular.

PELLET GROUPS

Counting pellet groups (deer defecations) is an indirect censusing technique which is used to determine population size and distribution. The counting of accumulated fecal pellet groups remains one of the most widely used methods for estimating deer population levels. It is a technique which can also provide an index to the density of species. It has been used for a variety of research and management objectives. It can be sampled by standard field plot techniques or strips that preferably are located by random selection. This method is based on the assumption that periodic accumulations of animal defections are related to population density.

The use of pellet group counts may present problems in different types of geographical communities. In humid and heavily forested regions, pellet group counts may be confined to winter because the growth of plants on the forest floor and falling leaves make counts difficult during other seasons. Pellet group counts have been unworkable at times because of rapid loss of pellets by insect attack or heavy rains, it has limited value in heavy rainfall areas and in
regions where dung beetles are prevalent, because of difficulties in identifying pellets of different species, trampling or because of extremely dense vegetation.

The usefulness of pellet groups as an indicator of deer presence and abundance has been tested extensively for deer herd studies since about 1938. The interest of game managers and researchers in pellet group counts as a census method and indicator of range use by game animals has increased in recent years. The use of pellet group counts as a census method is dependent upon several assumptions : deer defecate at a rather constant frequency, pellet groups persist long enough to be counted, groups can be found and counted accurately, a deposition period can be delineated, and groups found can be aged relative to the deposition period.

This technique necessitated knowing the defection rate of the animal to establish the size of the population, otherwise pellet group counts only indicate relative numbers and distribution of animals. The number of pellet groups released per animal per day has been used to estimate the number of animals in a given area. Defection rates vary, however, depending upon both the quality and quantity of the diets and sex and age of animals.

$$Deer\ Population = \frac{mean\ pellet\ group\ per\ plot \times \frac{1}{plot\ size} \times size\ of\ area}{deposition\ period \times defecation\ rate}$$

CHEMICAL CAPTURE-EQUIPMENT

Drug immobilisation or 'darting' is now a widely used capture method, particularly appropriate for large or dangerous species. Most of the drugs and equipment currently have to be imported.

ior training and the presence of and experienced person, preferably with veterinary knowledge, are sential. There is no substitute for building up field experience over a number of years.

s with all forms of capture, occasional animal fatalities (up to 10%) are experienced but can largely avoided by careful observance of precautions.

DVANTAGES

Compared to mechanical capture methods, immobilisation causes little disturbance to the animal - fear, shock and physical damage are practically eliminated.

It enables the capture of carefully selected individuals.

Time of capture can also be selected.

Equipment is very portable, enabling rapid shifts of field location.

ISADVANTAGES

As with all drug use, undesirable side-effects are possible.

Due to drug induction delay, darted animal is occasionally lost.

Procurement of drugs and equipment from overseas can be tedious and expensive.

Danger to human operator if certain drugs used carelessly.

QUIPMENT

here are two essential items of immobilisation equipment : The projector - blowpipe, rifle, pistol - nd the projectile - 'dart' or 'flying syringe', of which the needle is a vital component. For successful apture, selection of appropriate equipment and familiarity with its use are essential. Target practice, volving anticipated dart sizes and shooting range, are a must before embarking on any capture peration.

lowpipe

his is the simplest type of dart projector, consisting of a straight pvc or aluminum pipe 1 to 2 m in ngth and 8.0 to 10.0 mm in diameter. It propels a small plastic dart over distances of up to 10 m nd is mainly used for thin skinned animals in enclosures. After placing the loaded dart inside its ear end, the blowpipe is held to the mouth and pointed steadily toward the target area of the nimal's anatomy. After taking a deep breath, rapid 'blow' is made to propel the dart.

The blowpipe is entirely silent is operation, causing minimum disturbance to non-target members of a group of animals. It has no operating costs, apart from occasional replacement of dart components.

Manufacturer of immobilisation equipment

"Cap-chur"
Palmer Chemical & Equipment Co. Inc.
PO Box 867
Palmer Village
Douglasville
Georgia 30134
U.S.A.

Powder charged rifles

This lightweight 32 calibre (13 mm) rifle ("Cap-chur") propels darts up to 15 ml capacity to a range of over 50 m by means of an explosive charge, similar to a .22 blank cartridge. Charges are available in a variety of strengths depending on dart weight and target distance. Some brands of rifle also have an adjustable rear sight which enables very accurate shooting. An aluminum dart is assembled according to requirements (drug volume and needle size) and may be re-used many times.

Its accuracy, shooting range and variety of dart types and sizes impart great flexibility to the powder rifle and it is the most widely used darting system at the present time being particularly popular.

CHEMICAL CAPTURE-DRUGS

For a full discussion of drug choice consult one of the standard reference books. Most of the immobilizing drugs used today are central nervous system depressants, which have a relatively wide safety margin and permit some degree of control of the state of the animal by careful adjustment of dosage and use of antagonists. For example, a small dose may merely tranquilise (sedate) an animal, reducing fear or aggression, enabling safe transportation. A larger dose of the same drug will induce immobilisation, in which locomotion ceases and the animal is generally recumbent, allowing handling, taking of blood samples or radio-collaring.

Some of these drugs are highly dangerous to the human operator and should not be handled by inexperienced or junior staff. Familiarisation with accident procedure is essential before such drugs are used. All drugs should be kept under lock and key.

THE IDEAL CAPTURE DRUG

- Only require a small dose (1-5 ml).
- Is readily soluble in water.
- Has a wide dosage margin.
- Absorption and onset of action is rapid.
- Does not interfere with respiration or temperature control.
- Allows the 'righting reflex' - animal can sit up.
- Allows coughing and swallowing reflexes.
- Has a specific antagonist, allowing rapid reversal of immobilisation.
- Is not dangerous to human operator.
- Has no side effects - drug and antidote.
- Is not subject to restrictive legislation.
- Is readily available at reasonable cost.

Xylazine hydrochloride

Marketed as "Rompun" by Bayer, this drug achieves effects ranging from tranquilisation to anaesthesia, combined with muscular relaxation and general elimination of pain (analgesia). It is generally a very safe drug and can be used in a great variety of species particularly ungulates, in dosages varying from 1 to 10 mg per kg body weight. Full effect is normally achieved within 15 minutes of darting.

Rompun is available as a dry powder in 500 mg vials, which can be made up into desired solutions by addition of the solvent provided: 500 mg + 10 ml solvent = 5% solution; 500 mg + 5 ml solvent = 10% solution etc. A slight disadvantage for use with darts is that xylazine is not as readily soluble as some drugs and therefore larger volumes are required. It is often used in combination with other immobilizing drugs such as ketamine or etorphine which provides a synergistic effect, greater than using either drug on its own.

A recently developed antidote for xylazine is Yohimbine which is available. Use of the antidote reduces recovery time from several hours to approximately 5 minutes.

Ketamine hydrochloride

Marketed in a 100 mg/ml solution as 'Ketamine', 'Ketaset' or 'Vetalar', this is the drug of choice for primates, carnivores and birds. An advantage of ketamine is that protective reflexes such as coughing and swallowing are maintained in animals under the drug. It may be used alone or in a mixture with xylazine.

Acepromazine maleate

Available in a 10 mg/ml solution Acetylpromazine (acepromazine maleate) can either be used alone as a tranquiliser or mild sedative, e.g. in transportation, or in conjunction with immobilizing drugs such as etorphine. It has useful anticonvulsant, antispasmodic and antiemetic properties. In some species acepromazine causes hyperthermia and should be used with caution in conditions of extreme ambient temperatures. There is some danger of heart block if acepromazine is given to animals already in an excited state.

Diazepam

Available in 5 mg/ml solution as "Valium", diazepam is used alone as a tranquiliser to reduce excitement when handling or transporting animals and, unlike acepromazine, can safely be given to an already excited animal. A dose of 10 mg/mi was found useful to quieten chital captured with a rocket net.

CHEMICAL CAPTURE-PLAN OF OPERATION

All darting operations, for whatever target species, should only be undertaken after careful planning. Operations which are mounted on the spur of the moment often fail because some key element has been overlooked or some vital precaution not followed.

Before proceeding with immobilization of particular species groups, this section should be carefully studied and all points noted in making the specific plan.

- Select correct darting equipment and drug or drug mixture for the species you plan to capture.

- Even an experienced operator would be wise to have a number of practice shots at a target placed at a similar range to that anticipated in the planned darting operation and using the same size of dart, filled with water in place of the drug. Solid practice needles are provided in most types of dart kit.

- Time of day is an important factor. No capture operation should be undertaken in the middle of the day When the ambient temperature is high as this increases the risk of the animal

suffering from hyperthermia, which can be fatal. Early morning is the optimal time for most capture operations. You have the maximum number of daylight hours ahead of you.

A well organised search party should be on hand to assist in finding the darted animal after the drug is administered. It is important to ensure that the animal is found quickly so that in case it has gone down in a bad position immediate measures may be taken to put this right. If " walkie-talkie" communication is available, radios should be issued to all search parties.

Animals should not be darted close to deep water or precipitous terrain. In the semi-immobilised state preceding and following recumbency they may drown or fall down a steep slope or cliff, inflicting serious injury.

Capture candidates should be chosen with care, ensuring that at least externally they look healthy. The internal condition, of course, cannot be ascertained but poor liver or heart conditions may cause fatalities, resulting from the added stress of immobilization.

Pregnant and obviously lactating mothers should <u>not</u> be selected for immobilization. The chemical or mechanical stress of immobilization can cause a pregnant female to abort. Remains of the drug, even after reversal, can be absorbed by young through feeding if a lactating mother is immobilized, thus jeopardizing the life of the offspring.

The target animal should be stalked cautiously and not chased or otherwise excited prior to darting. Patience may be needed to allow the animal to move into a suitable position for the shot. Never fire unless there is a clear line between you and the target site on the animal. Grass blades or leaves of a bush can deflect the dart and result in a "miss".

Once the animal is darted remain quiet, keeping it in sight as far as possible without disturbing it - a long flight will make the animal difficult to locate, especially after it has gone down. Induction time (between darting and the animal going down) varies considerably, even when using a standard drug dosage with a particular species. Anything between 5 and 20 minutes may be expected with most combinations.

Do not approach the animal immediately it goes down but allow a few minutes for it to settle and the drug effect to deepen. Premature handling or noise may frighten the animal, causing it to struggle against the effect of the drug in an attempt to escape. When you do approach, test reaction of recumbent animal by lightly probing with a stick from the rear.

Make sure the immobilized animal is not in the direct sun by lifting it into shade or constructing artificial shade over it, e.g. tarpaulin.

Check on the position of recumbency, according to the species.

Eyes, if open should be covered (cloth, clean gunny bag) to prevent damage by dust or direct sunlight. Moisten with boiled water, saliva or opthalmic ointment.

If species is very sensitive to noise disturbance, block ear openings with plugs of soft rag or cotton wool.

The dart should be carefully removed and antiseptic ointment (e.g. an antibiotic) applied to the wound. In the case of the barbed darts, a sharp scalpel may be needed to case the exit of the barb from the skin.

Body temperature and respiratory rate should be monitored at approximately 10 minute intervals. Temperatures over 104 degrees F (40 degrees C) are dangerous and should be immediately counteracted by dousing with water or covering the body with gunny bags soaked in water.

In the absence of an antidote, the immobilizing effect of the drug may take several hours to wear off and even after the animal regains its feet it may be unstable and drowzy for a further period. If necessary provide protection from predation until full normality and alertness are restored.

If an antidote is available administer it as soon as the purpose of capture has been accomplished. Intravenous injection provides the most rapid response but some operators prefer to give half the dose via this route and the other half into muscle, which provides a slower antagonistic effect for a longer period. Remember drowziness often persists even after reversal of immobilization with a specific antidote.

CHEMICAL CAPTURE OF UNGULATES

TO CAPTURE MEDIUM TO LARGE UNGULATES BY DRUG IMMOBILIZATION.

Drug capture is ideal for large ungulates such as gaur, sambar and nilgai but may be used, in the absence of more appropriate methods, for species down to the size of chital or blackbuck. The operation is more difficult and risky with the smaller species - they are often harder to approach, present a smaller target and succumb more readily to psychological and other forms of shock.

Choice of drug or drug mixture and dosage for a particular species is, to some extent, a matter of experience. Drug choice and dosages given are as far as possible those which have been tested. Where a dosage range is given, the lower figure is recommended for females and young adult males and the higher figure for fully adult males.

A dosage of 2.5 - 3.0 mg/kg of rompun (xylazine) is used for chital (spotted deer). Rompun usually are available in 100 mg/ml solution. 5 - 10 mg of yohimbine per chital provide an effective reversal of xylazine.

THE DARTING OPERATION

Approach

Observe carefully with all precautions. A maximum range of 35 m for larger ungulates and 25 m for the smaller species is reasonable, unless one is a very experienced marksman with a dart gun and conditions are ideal (no wind, clear line of site without intervening vegetation).

Smaller ungulates such as chital should always be taken from the side, as an attempted shot form the rear can easily stray into the delicate organs in the mid-line (anus, genitalia) in so small a target, causing serious injury.

Care of Immobilized Ruminant

Ruminants should never be left for long in lateral recumbency (lying on their side) as this is conducive to bloat, which can be fatal. Make sure the animal is in sternal recumbency, with the legs tucked under the body in the natural position. The neck should be positioned forward and slightly raised from the body, with the mouth pointing downwards to allow any saliva or vomit to drain out - inhalation of these into the lungs must be avoided. If necessary clear the airway by pulling the tongue forwards and removing any obstructive material with the fingers.

Recovery

The most convenient vein for intravenous administration of an antidote in a ruminant is the jugular. To locate it hold neck upwards and turn head to one side; the vein is in a furrow to the side of the trachea. Clip off excess hair if necessary and clean area with water or alcohol. The vein can be engorged with blood by pressing on it spot with the thumb below the proposed injection site.

Remember most ungulates will be particularly vulnerable to predation during the recovery period, whether an antidote is used or not. Proper monitoring and protection should be provided until full mobility and alertness are restored.

CHEMICAL CAPTURE OF LARGE CARNIVORES

Whilst many carnivores can be readily captured using baited live traps the larger felids such as tiger and leopard present a number of problems, partly deriving from their great strength and ferocity. They frequently injure themselves while trying to escape from traps. Nuisance animals such as cattle lifters, sometimes become wary of traps, particularly if repeated attempts are made to capture them by this means. Chemical capture has altered this scene to some extent, although the wariness and cryptic habits of tiger and leopard still means that they often elude the dart gun.

A good deal of experience in chemical capture of tigers and leopards is now available. The recent availability of effective reversing agents for the preferred immobilizing drugs for large cats, further

enhances the usefulness of the chemical capture method. Report on trial usage of reversing agents such as Yohimbine with felids has been successfully carried out.

DRUGS

Ketamine/xylazine combination is mostly used for felids. Some recommend a dose of 3 to 5 mg/kg ketamine plus 1.0 mg/kg rompun for tiger. Yohimbine at a dose of 5 - 15 mg per adult tiger provides effective reversal of 50 - 150 mg of xylazine per tiger.

THE DARTING OPERATION

It is best to avoid darting cats which have recently eaten a meal because of the possibility of regurgitation, under the influence of the immobilizing drug, which may result in choking.

Approach

It is not easy or safe on foot with tiger or leopard. If baits are used to localise target animals, try and immobilize before the animal has filled his stomach from the bait. The general principle of cautiousness and care not to disturb or harass the animal during the induction period apply.

Care of Immobilized Animal

Cats are prone to hyperthermia when under drugs so always move into shade as soon as immobilization is complete.Lateral recumbency is normal and safe in felids.

Monitor temperature frequently and douse with water at first signs of temperature rise. Respiration should not go below 8 to 10 per minute in cats, which have a higher metabolic rate than herbivores.

Recovery

If using a non reversible drug mixture, a long period of slow recovery should be planned for (up to four or five hours). Watch should be kept over the animal throughout this time bearing in mind that other members of the species may try and take advantage of the defenseless state of the recovering animal to attack it (territorial and other behavioural reasons ?).

Once the animal starts to stagger around on its feet, keep it away from deep water (drowning) or precipices where it could fall over and seriously injure itself.