

**FACTORS AFFECTING HABITAT SELECTION
AND FEEDING HABITS OF SMOOTH COATED
OTTER (*Lutra perspicillata*) IN PERIYAR TIGER
RESERVE, KERALA**

**DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT,
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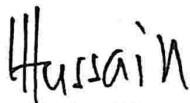


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CERTIFICATE

This is to certify that Anoop, K.R. of the Wildlife Institute of India has carried out a piece of original research work entitled “ **Habitat selection and food habits of smooth coated otters (*Lutra perspicillata*) in Periyar Tiger Reserve, Kerala**” in partial fulfillment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot. These investigations were carried out under my supervision at the Wildlife Institute of India from November, 2000 to July 2001. I also certify that this work has not been submitted for any other degree of any other university.

Date : June 26, 2001
Place : Dehra Dun


Dr. S.A. Hussain
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SUMMARY

Otters are the top predators of the aquatic ecosystems. Despite their important place in the food web and wide distribution, the knowledge on their ecology is relatively scanty as compared to other carnivores. In recent years several of the natural water bodies are being modified by means of dams and conversion for other uses. By changing the flow of water, sediments, nutrients, energy and biota, dams interrupt most of the ecological processes of the rivers. This includes changes in the fish communities because of changes in water current and depth. The aim of this study was to look at how otters adapted themselves for living in a man modified aquatic system.

The factors affecting habitat selection and feeding habits of smooth-coated otter was studied in Periyar Tiger Reserve, Kerala during November 2000 to April 2001. The importance of different habitat parameters influencing habitat selection was assessed using ordination technique. The food habit was examined by analyzing the spraints (scats) using both frequency of occurrence and score-bulk estimate methods.

The habitat of the animal was visualized as a multidimensional space in which the animal selected a few combinations of parameters. Foraging sites with high densities of fish, areas that offer den sites (holts) and grooming sites were found to be unavoidable in supporting the animal in an area. The signs that the animal leaves on the banks while using an area were identified as holts, communal spraint sites, grooming sites and footprints. Presence of these signs were considered as sure indicators of intensive use of an area by the otters. Subsequently, 96 random plots of 250 x 10m (2.5 km² area) were placed along the banks of the reservoir and each plot was characterized by means of 17 habitat variables. Of these variables, three viz. water depth, distance to vegetation cover (escape cover) and numbers of streams joining the lake were outside of the plot. Each of such plots was accordingly assigned to the category of either used or unused by the animal based on the presence or absence of evidences in the plots.

The complex data collected from the plots was reduced to three uncorrelated axes using Principal Components Analysis sacrificing 30% of the variability of the system. These three components were plotted in a three-dimensional scatter plot in which each of

the plots had a position, which characterized them in terms of variety and variability. Then each of the plots was marked as either used or unused based on the evidences found in the plot. It was found in the newly created three-dimensional space, the used and unused areas were segregated in distinct regions. The coordinates of the used plots indicated that the otters selected less rocky areas of the shallower parts of lake, which are narrower and slanting. The number of streams joining these areas was more than other stretches of the lake and the vegetation on the banks was dense. The otters did not use the deeper and wider areas of the lake. Other unused areas were steep and rocky parts of the reservoir where no streams joined. The higher fish congregation in the areas of mouths of streams must be the reason why otters' used those areas more in comparison to other areas. The low water depth made the dives of otters in these areas more effective while foraging. The thick vegetation cover of the banks provided them shelter and narrower areas helped them in patch fishing *i.e.* reducing the chance of fish to escape by forming an arch around the shoals of fish. Mann - Whitney 'U' Test, confirmed this observed pattern.

Then a logistic regression model was developed using animal presence / absence as the dependant variable and the habitat variables as covariates. The model selected only rockiness and number of streams from the complex set of variables to predict the probabilities of otter presence in each of the 94 plots chosen for characterizing the otter habitats. Out of the 70 plots, which showed positive signs of otters, 95.71% were classified in the region of higher probability of occurrence. But out of the 24 plots, which showed no signs of otter occurrence, only 54.17% were correctly classified in the region of lower probability of occurrence. This shows that some of the areas, which showed no signs of otter presence, were potential areas but at the time of this study they were not using these areas for unknown reasons. This may also be due to the inherent problems of using spraints and tracks to assess the degree of use of an area by otters.

Feeding habits of otter were studied by analyzing 94 spraints collected from around the Periyar lake. Prey remains were identified using standard references prepared with identified body parts for 12 fish species that were collected during the study period. Two methods were used to estimate the proportions of different prey items consumed *viz.* frequency of occurrence method and score-bulk estimate method. The former method takes into account the presence or absence of prey items with no consideration of its

quantity whereas the later includes the quantity of each of the prey item consumed, by including proportion of each prey item in the spraint and total weight of the spraint. It was observed that in the frequency of occurrence method the major prey items were underestimated and minor items were over estimated, as it did not take into consideration, the proportions of each item in individual scats.

The number of prey items in a spraint varied between 1 and 7 in a single scat, the average in lower water levels in the reservoir (December, January and February) being 3.21 (varied between 1 and 5) and during higher water levels (March and April) it was 2.73 (varied between 1 and 7). Fish was the major prey item (96.02%), followed by frogs (1.08%), crabs (1.07%), birds (1.07%) and insects (0.76%).

During the study period, remains of six fish species were found in the spraints. Among these, Tilapia (*Oreochromis mossambicus*) was the major prey of otter (51.54% of the total diet) followed by catfish (*Heteropneustes fossilis*), which formed 21.27 % of the diet, curmuca barb (*Gonoproktopterus curmuca*; 12.37%) and European carp (*Cyprinus caprio*; 9.16%). Tilapia and European carp which are exotic fishes that got accidentally introduced into the Periyar lake 10 to 15 years ago and with its vigorous growth capacity and adaptability are now the most common fish in the lake. The higher representation of Tilapia and European carp in the diet of otters is an indication of the abundance of these fish in the lake. A higher intake of bottom dwelling catfish was seen during the low water level periods, which is because of the increased efficiency of otters to forage in the low levels of water.

A linear relationship was established between the total length of the fish and the length of the vertebrae. For this purpose a total of 43 fish belonging to different size classes were used and 215 measurements of vertebrae were taken. From the scat of otters, vertebrae were sorted out and lengths of the corresponding fish were found out. Otters seemed to be consistently taking more fish of size 8.0 cm to 15.0 cm (29% each), followed by 5.0 cm to 8.0 cm class (23.7%) and 14.0 to 17.0 cm class (14.4%). Attempt to quantify fish availability in the lake to determine the preference failed because of the hindrance caused by submerged tree stumps that damaged the fishing nets.

From this study it was concluded that the otters in Periyar lake have adapted to a man modified condition utilizing most common exotic fish species of the lake and selecting those stretches of the lake where the physical constraints of diving did not interfere much with their foraging success. They were also tolerant to a great deal of anthropogenic disturbances such as presence of motorboats and humans. This shows the remarkable adaptability of the species. Furthermore 60 % of the diet was found to be comprised of exotic fish. Thus the changes in the natural habitat both in terms of food and shelter has been successfully compensated by adopting alternate means for survival. As the entire catchment of Mullayar and Periyar are well inside the park boundaries, the pollution and anthropogenic disturbances are minimum in the lake. This may be the reason why Periyar is still supporting a healthy population of otters even though they are getting exterminated from many of its former distribution ranges. So the otter population of Periyar Tiger Reserve should be considered as a precious possession of the park.

1.0 INTRODUCTION

1.1 Otters, a general introduction

Otters are piscivorous mustelids that inhabit in different types of aquatic environments (Pardini, 1998). They occur in all continents except Australia and Antarctica. Out of the 13 species of otters all over the world, Sea otter (*Enhydra lutris*) and Marine otter (*Lutra felina*) are restricted to marine environments and the rest eleven inhabit mostly freshwater habitats (Estes, 1982). Asian region has five species of otters (Foster-Turley *et al.*, (1990); the sea otter (*Enhydra lutris*) the hairy nosed otter (*Lutra sumatrana*), Eurasian otter (*Lutra lutra*), smooth-coated otter (*Lutra perspicillata*) and the Oriental small-clawed otter (*Aonyx cinerea*); out of these the last three are found in the Indian subcontinent (Pocock, 1943; Mason and Macdonald, 1986; Hussain 1993).

Most otter species are quite similar in their external characters and field signs making it difficult to distinguish them from each other especially when they occur sympatrically. In India, three species have been reported from northeast India and Western Ghats (Pocock, 1941). Consequently field studies on otter based on field signs may be erroneous unless the field signs are carefully segregated from each other and other related species (Kruuk *et al.*, 1993; Kruuk *et al.*, 1994; Hussain *in press*).

1.1.1 The smooth-coated otter *Lutra perspicillata*, Geoffroy, 1826

The smooth-coated otter is distributed throughout south and southeast Asia (Pocock 1941, Hussain 1993). Two sub-species were reported by Pocock (1941) (1) *L. p. perspicillata* - in northeast and southern India, Myanmar and Sumatra (2) *L. p. sindica* - in north and north-western India and Pakistan (Sindh province). Another sub-species *L. p. Maxwelli*, whose current status is uncertain, is reported from the marshes of southern Iraq (Mason and Macdonald 1986).

The total length ranges between 1067-1300mm, head to body 655-790mm, tail length 406-505mm (Duplaix and Davis 1981). The weight ranges from 6.5 kg in the case of sub-adult to 7.00 - 11.4 kg in adults (Harris, 1968). The dorsal part of the body colour varies from deep, nearly blackish-brown to lighter brown with a rufous tinge to much paler tawny or sandy brown. The underside is always lighter than the dorsal part, and the paws paler than the back. The upper lip to the edge of the rhinarium, the cheek to the eye and ear, the sides of the neck, the chin and throat is whitish (Pocock, 1941). In its external

characters the smooth-coated otter differs from Eurasian otter by its very smooth, sleek coat, *i.e.* hair texture is velvety. Muzzle is not spotted and the rhinarium is bare, dusky with peaked upper margin (inverted V shaped). The terminal half of the tail is more flattened than the Eurasian otter with a tapered end. Both the fore and the hind paws are large, well webbed, but the third phalanges are free of webbing.

1.1.2 The Eurasian otter *Lutra lutra*, Linnaeus, 1758

The Eurasian otter has the widest distribution range of all the otter species, extending from Europe through northern Africa to Asia as far as Korea, Taiwan and Philippines (Mason and Macdonald 1986). In south Asia its occurrence has been confirmed from Afghanistan, Pakistan, India, Sri Lanka, Bangladesh, Nepal, Bhutan and Myanmar.

Seven sub-species were reported by Pocock (1941) (1) *L. l. Lutra* in Europe and northern Africa, (2) *L. l. nair* in southern India and Sri Lanka, (3) *L. l. Monticola* in northern India (Himachal Pradesh, Sikkim and Assam) Nepal, Bhutan and Myanmar, (4) *L. l. kutab* in northern India - Kashmir, (5) *L. l. Aurobrunnea* in Garhwal Himalayas in northern India and higher altitudes in Nepal, (6) *L. l. Barang* in southeast Asia (Thailand, Indonesia and Malaysia) and (7) *L.l. chiensis* in southern China and Formosa.

In size the Eurasian otter is similar to smooth-coated otter. The total length ranges between 920-1200mm, head to body 550-570mm, tail length 35-375mm (Duplaix and Davis 1981). The weight ranges from 4-12 kg, 4-8 kg in females and 7-12 kg in male (Reuther 1991).

The colour of the dorsal part in the Eurasian otters vary from rusty to dusky-brown, where as ventral side is lighter - sometimes up to grey or whitish. The lips and the throat show individual yellow, grey or white spots. The completely hairy tail is flattened at its terminal half and tapered at its end. The rhinarium is bare, mostly of black colour, sometimes with light spots. The shape of its upper rim shows a "W". All four feet have five toes with strong claws and webs between the toes, which extend at least to the last bone of each digit (Pocock 1941).

1.1.3 Oriental small-clawed otter *Aonyx cinerea* Illiger, 1889

The Oriental small-clawed otter has a large distribution range, from India in the west through Indonesia in southeast Asia to Palawan (Philippines) and Taiwan in the east

and southern China in the north (Pocock 1941). Its presence has been confirmed from India, Nepal, Bhutan, Bangladesh, Myanmar, south China and Hainan Islands, Thailand, Laos PDR, Brunei, Malaysia, Vietnam, Indonesia (Sumatra, Java, Borneo), Taiwan and Philippines (Wozencraft 1993).

Two sub-species were reported by Pocock (1941) (1) *A. c. Concolor* in northeast India and Myanmar extending up to Sumatra (2) *A.c. nirnai* in the hill ranges of southern India.

The Asian small-clawed otter is small in size as compared to all other otter species, head and body measuring 406-635mm, tail length 246-304mm, total length 652-939mm and weight ranging between 2.7-5.4 kg (Walker 1975). The females are on an average only a little smaller than the males. It has distinctive webbed feet with the third and fourth digits markedly longer than second and fifth on each foot and all claws reduced to small rudiments, which do not project beyond the tips of the digits. (Harris 1968).

The dorsal body colour is typically dark brown, sometimes with a tawny or rufous tinge with tip of the contour hair often paler, but rarely white, giving a grey or ashy tint. The ventral side is generally a paler brown than the upper, often showing a grey cast. The edge of the upper lip, chin, cheeks, sides of the neck and throat are grey or nearly white, sometimes sharply and sometimes weakly contrasted with the darker upper tint of the head and the neck (Pocock, 1941).

The Asian small-clawed otter is principally distinguished from the Eurasian and the smooth-coated otter in external characters by the structure of the feet, which are considerably narrower. Shallower, narrower and more emarginated webs, which do not extend along the digital pads and are sparsely covered below, tie the digits close together with short hair. Also the claws, except in small cubs, are minute, erect spikes which do not project beyond the end of the digital pads. The planter pads are better developed, sub-symmetrical and four lobed. The inner main lobe is prolonged backwards. The nose pad is similar to that of smooth-coated otter; its anterior surface directed forwards and its posterior margin straight (Pocock 1941).

(Otters, being the top predators of aquatic ecosystems can be used as an indicator species for a healthy environment] (Sivarothi and Burhanuddin, 1994). Most of the problems associated with otter survival are due to species' extreme specialization in an energetically hostile environment, which is also highly sensitive to disturbances such as poor water quality, toxicity in aquatic food chains and disturbance on the terrestrial

habitats adjacent to waterways. Thus disappearance of otters is often associated with degradation of wetland habitats (Kruuk, 1995). (In India all species of otters are becoming increasingly rare outside of Protected Areas and are threatened in many areas due to reduction in prey biomass, poaching and reduction of habitat (Foster Turley *et al.*, 1990).) The remaining otters in India are in fragmented populations and are rarely encountered outside Protected Areas (Hussain 1998).

1.2 Significance of the study

The spacing patterns, social systems and dispersions in carnivores are widely varied compared to most other mammals (Kruuk, 1995). Almost all of them are territorial, defending an area against others of the same species. In species like tigers, the territories are inhabited by almost solitary individuals but the group living carnivores like otters often defend their own group territory against other packs (Sandell, 1989). It is important to know how the dispersion of the food, shelter and other requirements affect the numbers and densities of predator. Resource availability seems to be the most important factor in deciding the spacing patterns (Macdonald, 1983). In order to manage these animals for their sustained reproduction, it is important to be aware of the limiting factors. This need is urgent, especially for the animals of high conservation priorities such as otter (Kruuk, 1995).

Factors determining habitat use are numerous and differ for each species. Human disturbance, competition and absence of corridors are some of the factors affecting accessibility to potentially suitable areas. Another factor is territorial behavior of animals that decides whether suitable areas are available to the animals as they are already occupied by a conspecific (White & Garrot, 1990). Habitat use as determined by foraging, feeding, reproduction and resting, needs characteristic and specific requirements and all these factors are to be analyzed separately (Perin and Carranza, 2000).

Research on otters is largely questions asked about the otter *per se* as a species, or about otters in a particular area or population. But there are broad biological principles underlying many of these problems, such as relationship between territoriality and resource utilization, the relationship between animal numbers and availability of food, the energetics of hunting and many more (Kruuk, 1995). Little information is available on the relationship between habitat structure and its use by otters (Durbin, 1998). For an

effective conservation strategy, it is essential to determine which factors may be limiting the present population of otters (Mason and Macdonald, 1983).

1.3 Objectives of the study

The major objectives of the study were to :

- i. examine the factors affecting habitat selection by smooth-coated otter in Periyar Lake.
- ii. examine the feeding habits of smooth-coated otter in Periyar Tiger Reserve.

1.4 Review of literature

The systematic studies on otter, which relied primarily on overall similarity of cranial and dental characters combined with different methods of systematic analysis, have led to a number of taxonomic revisions of Lutrinae (the sub family of Mustelidae, to which all otters belong) during this century (Van Zyll de Jong, 1991). There were studies based on classical systematic approaches (Pohle, 1919; Pocock, 1921), evolutionary systematics (Simpson, 1945; Sokolov, 1973; Davis, 1978; Willemsen, 1980), phenetics (Van Zyll de Jong, 1972, 1987) and cladistics (Van Zyll de Jong, 1987). These have reached at different conclusions regarding relationships among otter species. Most of the current classifications (*e.g.* Wozencraft, 1993) have adopted the revision by Van zyll de Jong (1987). Later in 1998, Koepfi and Wayne evaluated the phylogenetic relationships among 13 species of otters and their position in Mustelidae through phylogenetic analysis of complete nucleotide sequence of the mitochondrial cytochrome *b* gene. The results divided the otters into three primary clades that include (1) North American river otter (*Lontra canadensis*), Neotropical otter (*Lontra longicaudis*) and Marine otter (*Lontra felina*) (2) Sea otter (*Enhydra lutris*), Eurasian otter (*Lutra lutra*), Spotted necked otter (*Lutra maculicollis*), Cape clawless otter (*Aonyx capensis*) and Asian small clawed otter (*Aonyx cineria*) and (3) the Giant otter (*Pteronura brasiliensis*). This study did not include four species of otters - Congo clawless otter (*Aonyx congicus*), Southern river otter (*Lontra povocax*), Hairy nosed otter (*Lutra sumatrana*) and Smooth coated otter (*Lutra perspicillata*).

The phylogenetic studies on Indian otters include descriptions by Hodgson (1839), Blanford (1889) and Pocock (1941) followed by revisions of Harris (1968) and Davis

(1978). Still there exists lots of confusion about the four subspecies of *Lutra lutra* (Pocock, 1941) out of which the ranges of three overlap.

1.4.1 Habitat selection by otters

The information available on habitat selection by otters is sketchy as compared to other aspects of their ecology (Durbin, 1998). This is true especially for Asian otter species where there is very little information available on the ecology of otters.

Distributions of field signs (mainly dens, spraints and grooming sites) have traditionally been used to estimate habitat use by otters (e.g. Jenkins and Burrows, 1980; Mason and Macdonald, 1983; Bas, Jenkins and Rothery, 1984; Adrian, Wilden and Delibes, 1985; Kruuk *et al.*, 1986). But these methods were criticized by Kruuk and Conroy (1987) pointing that the patterns of field signs are difficult to interpret because spraints are often deposited as scent marks and are not necessarily associated with the time spent. Then new methods like radio-tracking studies came up, but minor problems remained like unobtrusive and trap shy behavior of the animal and nocturnal activity in some of its distribution ranges (Durbin, 1993).

Published studies on habitat use of otters based on radio telemetry are very few. Durbin (1996, *Lutra lutra*) and Perrin and Carranza (2000) have described use of space by otters. Kruuk *e. al.*, (1993a) restricted their analysis only to one habitat variable (stream width). Van Niekerk *et al* (1998) studied fresh water availability and distribution of Cape clawless otters (*Aonyx capensis*). Durbin examined the relationships between a variety of habitat variables with time allocation by otters. Hussain and Choudhury (1997) studied the habitat use patterns of smooth coated otters (*Lutra perspicillata*).

1.4.2 Dietary studies on otters

Food of otters is one aspect of their ecology which has been studied quite thoroughly in different parts of the world (Eurasian otter Erlinge, 1968; Wise *et. al.*, 1980; Jenkins and Harper, 1980; Wise *et al.*, 1981; Kruuk and Moorhouse, 1990); smooth-coated otter Tiler *et al.* (1989), Foster-Turly (1992); Kruuk *et al.*, (1994), Haque and Vijayan (1995), Hussain and Choudhury, (1997a); Neotropical river otter Pardini, (1998); Cape clawless otter Perrin and Carrugati, (2000) and spotted necked otter Perrin and Carrugati, (2000); small-clawed otter Wayre (1978), Kruuk *et al.*, (1994).

Four methods are being used to find out what the wild otters feed on, namely by direct observation of them feeding, examination of tables or eating places, analysis of stomach contents and by analysis of their droppings which are called spraints (Webb, 1975). Many of the prey items that the otters feed on, could be identified and their size classes could be estimated fairly accurately by direct observation (Kruuk and Moorhouse, 1990) but in areas where they are nocturnal in habit this method was of no use. The eating-places of otter would give clue only about larger prey specimens, which are eaten when the otters are out of water. Most of the fish are eaten in the water itself and therefore this method also is not of much use. Stomach content analysis would be the surest way of discovering what the animal had fed on but there is no question of killing animals for this purpose (Webb, 1975). There is only one published report on food habits of otters by using gut contents' analysis (Fairley, 1972). This was done by analyzing the guts of 33 otters, which were drowned to death in fish traps.

In the Asian region, studies on otters are very few. Aspects of ecology of smooth coated otter has been studied by Hussain (1993) and Satyanarayana (1997). Partitioning of niche between sympatric otters has been studied by Kruuk *et al.*, (1994) and Melisch & Foster-Turley, (1996). There has been one study on food habits of Eurasian otter by De Silva (1997) and several small studies (*e.g.* Kruuk *et al.*, 1993; Umapathy, 2000; Desai, 1974).

2.0 STUDY AREA

2.1 Geographical location

The Periyar Tiger Reserve is one of the well known Tiger Reserves in India, situated in the Cardamom Hills and Pandalam Hills of the Southern Western Ghats between latitudes 9° 15' and 9° 40' N and longitudes 76° 55' and 77° 25' E. Administratively, it falls in Idukki and Pathanamthitta districts of Kerala. The boundary on the north, northeast, and east (90 km) is the state boundary between Tamil Nadu and Kerala. On the north, it is bound by the Madurai district, east by Ramnad and southeast by Tirunelveli districts of Tamil Nadu. On the south, lies the Ranni Forest Division. Pamba River forms the southern boundary. The western side is bordered by Kottayam Division and a few tea estates (Figure 1).

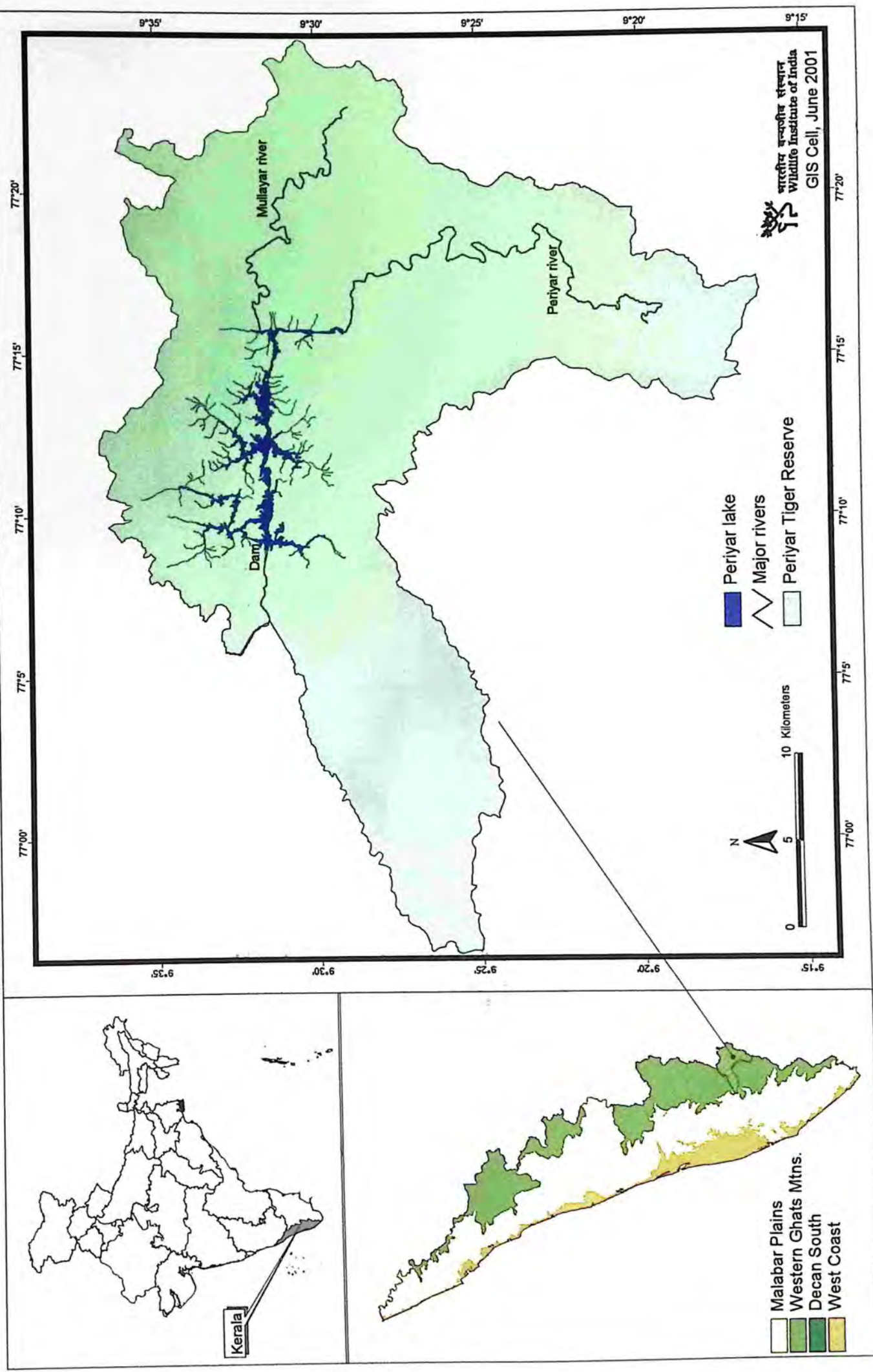
2.2 History and legal status of the Reserve


The Government of the erstwhile Travancore state permitted the Madras state to construct a dam across Periyar river to provide irrigation facilities to Tamil Nadu. The lake was formed in 1895. In the year 1899, the forests around Periyar Lake having an area of 600 sq. km., which was only a part of the present Reserve, were declared as Periyar lake reserve forest No. 39 under Section 18 of Travancore regulation Act 1068. In 1933 the then Maharaja of Travancore appointed Mr. S.C.H. Robinson, a retired Land Commissioner as the Game Warden with a view to constitute and maintain a Wildlife Sanctuary around Periyar Lake. In 1934 the Sanctuary was constituted which was known as 'Nellikampetty Sanctuary'.

Considering the importance of the sanctuary in respect of its tiger population and the urgent need to protect their habitat, the area was brought under Project Tiger in 1978 and the Sanctuary is now called Periyar Tiger Reserve, the 10th Tiger Reserve in the country. The core area of the Tiger Reserve has been declared as a National Park during 1982 vide G.O. (P) 310/82/AD dated. 27-10-1982 of Government of Kerala. The total extent of the Reserve is 777 km² consisting of core, buffer and tourism zones.

In 1991 the area was declared as part of Project Elephant Reserve No.10. The Tiger Reserve functions as one territorial division with its headquarters at Thekkady and has three territorial ranges viz. Thekkady, Vallakkadavu and Tourism. A functional division, grassland afforestation division, with its headquarters at Peermedu also operates

Fig.1 Reservoir and major rivers of Periyar Tiger Reserve




 Wildlife Institute of India
 GIS Cell, June 2001

within 50 km² bounds of the Tiger Reserve without any territorial control. The division was established to raise pulp wood plantation and its extraction. At present there are no extractions done in the park area after the Supreme Court order of February 2000, writ petition 202.

2.3 Topography

The terrain is undulating in many areas and rugged with lofty peaks and precipitous slopes in other areas. The elevation ranges from 100 m (Pambavalley) to 2016 m. (Vellimalai) above sea level. The northern half of the area surrounding the lake is undulating. The average altitude is 800 m. Towards the east adjoining the state boundary, the terrain is very steep. The conspicuous peaks are Vellimala (2016 m), Chokkampattimala (1801 m), Kallimala (1637 m), Sundaramala (1808 m) Pachimala (1800 m), Nagamala (1733 m), Kottamala, Koyilmala etc. There is a conspicuous and extensive table land known as Mount Platen at an altitude of 1400 m towards the western side of the Reserve.

2.4 Climate

The Tiger Reserve has a cool and humid climate with comparatively high rainfall (2000 mm. average /annum). In almost all the months except December and January this area receives at least a few showers. Generally, the period from December to April is considered as dry season. The area receives both the southwest and northeast monsoons with maximum rainfall in July and minimum in January. The average rainfall is 2000 mm annually. Although the area receives both the monsoons, the southwest is responsible for more than half of the total annual rainfall. The temperature varies between 15° C and 31°C with April - May being the hottest and December - January the coolest. The average humidity varies between 60% and 85 % round the year with lowest during the month of February to May.

Since the reserve has its four major perennial rivers as well as the reservoir of around 26 km² area, water is available throughout the year. The water level in the lake may go down during summer *i.e.* February to May exposing muddy banks and islands.

2.5 Vegetation types

Major vegetation types in the Periyar Tiger Reserve are: tropical evergreen and semi evergreen forests (74.6%), moist deciduous forests (12.7%), grasslands (1.5%) and

Eucalyptus plantations (7.1%). Periyar Lake forms an important aquatic ecosystem, which occupies about 3.5% of the area.

According to and Champion & Seth (1968), the vegetation of the Tiger Reserve can be classified into the following types

1. West coast tropical evergreen forests (evergreen)
2. West coast semi-evergreen forests (semi-evergreen)
3. Southern moist mixed deciduous forests (moist deciduous)
4. Southern hill-top tropical evergreen forests (hill top evergreen)
5. Southern montane wet temperate forests (Shola)
6. South Indian sub-tropical hill savannahs (Savannah)
7. Southern wet montane grasslands (grassland)

2.6 Plant and animal diversity

The occurrence of 1966 species of plants identified in an area of 777 km² signifies the richness and diversity among flora of Periyar Tiger Reserve. The estimated number of Angiosperms of Kerala is 3800. The 1966 species of Angiosperms identified from the reserve form more than 50% of entire flowering plants of Kerala. Nowhere in the subcontinent such a large number of taxa have been reported from an area comparable to that of Periyar Tiger Reserve. Out of the 216 orchids reported from Kerala, 145 species are found in Periyar Tiger Reserve.

Among the 1966 species of flowering plants collected from the Tiger Reserve, 515 are endemic to Southern Western Ghats, which form about 26 percent of the total. Among the important families showing relatively high degree of endemism, Orchidaceae stands first with 55 endemic species, Rubiaceae has 35 species, Acanthaceae has 32 species, Poaceae and Fabaceae have 25 species each, Lauraceae, Balsaminaceae and Euphorbiaceae have 25 species each, Lamiaceae has 19 species, Melastomataceae has 18 species and Asteraceae with 11 endemic species. Periyar Tiger Reserve falls within the Anamalai High Range Centre, one among the five centers of endemism in Southern Western Ghats. Out of the estimated 49 species endemic to this region, 25 occur in Periyar Tiger Reserve.

Among the 149 threatened category species of plants collected from the Tiger Periyar Reserve, 17 are considered 'possibly extinct'. Among the plants collected from the Tiger Reserve, 4 are new records for India and 14 are new records for Kerala. The reserve is the only home to the species such as *Habenaria periyarensis*, *Syzygium*

periyarensis and *Mucuna pruriens thekkadiensis*. Besides these, many of the rare and endangered species are seen within the reserve. In the case of Gymnosperms, all the three species that are found in Kerala, are seen in Periyar Tiger Reserve in which the only indigenous conifer of South India, *Podocarpus wallichianus* is seen in the extreme core area of the reserve. The total number of Pteridophytes in Periyar Tiger Reserve is 150. One species of *Ophioglossum* viz. *Ophioglossum pendulum* seen in the core areas of Periyar Tiger Reserve is the first report from the Peninsular India. There are about 350 species of medicinal plants identified.

In Periyar Tiger Reserve the wealth of vertebrate diversity is very rich. 38 species of fish have been reported from Periyar Tiger Reserve. This includes the famous game fish Mahaseer and four species of fishes which are endemic to Periyar Tiger Reserve. These endemic species are *Puntius micropogon periyarensis*, *Crossocheilus periyarensis*, *Lepidopygopsis typus* and *Noemachelus menonii*. Around 16 species of amphibians have been identified in the Park, of which 10 are endemic to Western Ghats. The Malabar Gliding frog, Common Indian toad, Beddomes' frog, Fungoid frog and Bicoloured frog are the most common frogs found in this area. There are 44 species of reptiles including 2 species of Testudines, 11 species of lizards and 30 species of snakes recorded in the Park. Of the 30 species of snakes, 13 are endemic to Western Ghats. The King Cobra, an endangered rainforest reptile, is also found in the evergreen forests of the park.

Over 315 species of birds have so far been recorded in the Park. Cormorants and darters are numerous in the lake and white-necked storks and grey heron are found in the lake fringes. Apart from many common birds, the Great Indian Hornbill, an endemic and endangered species, is found commonly in the Park. The presence of 315 bird species includes the birds of prey (Raptors), water birds, Galliformes, pigeons, woodpeckers and Passerines. The southern Western Ghats is known as an area of high avian endemism. Fourteen endemic species are reported from southern Western Ghats. Except the Nilgiri laughing thrush, all the endemic bird species occur in Periyar. All the 13 species except the Whitebellied Shortwing occur in fairly good numbers in the reserve. Out of these 12 species, the White breasted laughing thrush, the Black and Orange flycatcher and the Nilgiri flycatcher are restricted to high altitude grasslands. The Whitebellied shortwing occurs in the *Strobilanthes* thickets bordering the altitude grasslands.

Besides the endemics, the bird fauna of Southern Western Ghats is also characterized by the disjuncts, that also occur in the eastern Himalayas but are absent in between. Species such as the Black crested Baza (*Aviceda leuphotes*) the Rufousbellied

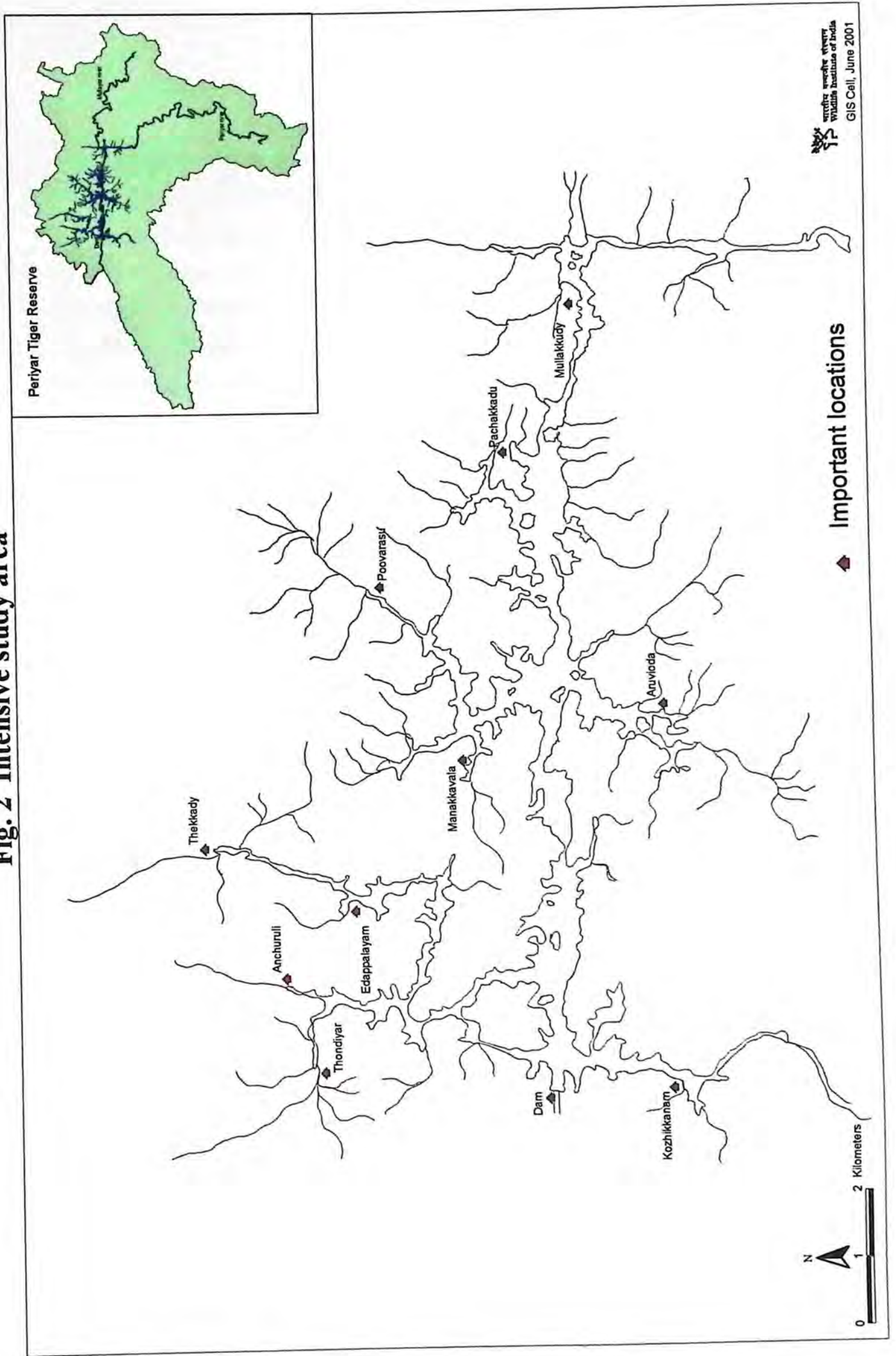
hawk eagle (*Lophotriorchis kienerii*) the Great Indian hornbill (*Buceros bicornis*) the Forest eagle owl (*Bubo nipalenses*), the Ceylon frogmouth (*Batrachostomus monitiger*), the Great eared nightjar (*Eurostopodus macrotis*), the Broadbellied roller (*Eurustomus orientalis*), the Nilgiri thrush (*Zoothera dauma*) and the little Spider hunter (*Arachnothea longipennis*) come under this category. All the disjunct species except the Grass owl (*Tyto cepeansis*) and the Bay owl (*Phadinus babius*) are reported from Periyar. In addition to the above species the Grey jungle fowl (*Gallus sonneratii*) the Painted bush quail (*Perdicula asiatica*) the Whitebellied tree pie (*Dendrocitta leucogastra*) which have a restricted distribution in the Western Ghats and the neighboring hills also occur in Periyar.

There are 62 species of mammals, which includes the Tiger, Leopard, Wild dog, Sloth bear, Nilgiri langur, Lion-tailed macaque, Nilgiri tahr, Small Travancore flying squirrel, Nilgiri marten and Strip necked mongoose. Apart from these, Elephant, Gaur, Sambar deer, Wild boar, Barking deer are among the other herbivorous species. About 94 species of moths and butterflies are recorded from Periyar. Apart from all these, the Periyar Tiger Reserve supports a very good population of smooth-coated otter (Foster-Turly and Santiapillai, 1990).

2.7 Intensive study area

The intensive study area was the confluence of two major rivers and the Periyar lake (Figure 2). River Periyar which originates from Chokkampatti - Kallimala side about 50 km from Thekkady with its varied tributaries forms the main drainage of the area. Another major river is Mullayar which originates from Kotamala and joins with Periyar at Mullakkudy and forms the lake. The lake formed as a result of the construction of Mullaperiyar dam had an area of 26 km². In 1980 the maximum water level was lowered from 156 feet to 136 feet and as a result a large area has been recovered from water, which has been colonized by tree species like *Actinodaphnae hookeri*, *Terminalia paniculata*, *Psidium guava* and shrubs like lantana. Most of the tributaries of the major rivers are not named and among the named, the important ones are Inchipparathode, Vazhukkapparathode, Churakkottathode, Mullathode and Kalvarithode. The distribution of otters was looked for in the entire lake and the rivers. For studying the food habits only the population in the lake was selected, as it was not possible to cover the entire river stretches on a regular basis.

Fig. 2 Intensive study area



3.0 METHODS

3.1 Familiarization with the study animal and signs

The first few weeks were spent in the study area to get an understanding of the variability in the aquatic ecosystem, the different areas of otter distribution, meeting people and enquiring about otters. Subsequently, efforts were made to identify what all signs and evidences the otters leave in the areas that they use and what are the other species whose signs might be confused with that of otter. So wherever the otters were seen landing on the riverbanks, the footprints were examined and differentiated from that of porcupine and mongoose by thorough examination and calibration. Otter spraints (scat) were identified from the communal spraint sites and marking places, which were identified by following the otters as well as by walking along the banks. Holts and grooming sites were also identified.

3.2 Habitat selection by otters

3.2.1 Identification and quantification of habitat parameters

The first problem to be addressed was, what are the variables that can be used indirectly to identify and quantify the habitat of otter. The relevant variables that might affect the otter habitat use were selected by continuously following and observing the animal to understand their behaviour keeping enough distance so as not to disturb them. This was done for nearly a month adding more and more variables then removing some of them and then trying to find the ways to measure them in the best possible way.

Periyar reservoir, which extends over about 26 km² area, comprises of a variety of habitats. To identify and characterise the habitats in terms of variables, the entire lake was walked along the banks. When it was found that the habitat characteristics varied considerably within small stretches of the shoreline, *i.e.* when there were no continuous uniform patches, it was decided to take random plots of 250m x 10m *i.e.* (2.5 km² area) and characterise them with all possible habitat variables. This plot size was so determined because during the reconnaissance it was found that if otters are present in an area, the signs of otter like foot prints, markings, spraints, tracks etc. are most likely to be encountered in 10 m distance from the water edge. This has been substantiated by several studies (Kruuk and Conroy, 1987; Hussain and Choudhary, 1997).

These plots were intensively searched for signs of otter such as foot prints (track sets), communal latrines or spraint sites, markings and dens and the habitat variables were measured. The variables measured were:

- (a) Water depth at the middle of the reservoir,
- (b) water depth at midway between midway and the bank and mid point of the second point and the bank,
- (c) slope,
- (d) mean river width,
- (e) distance to escape cover (mean distance from the edge of water to the point where the under growth starts),
- (f) number of flat mud beds available for basking and grooming,
- (g) number of boulders available for spraint marking, number of dead logs lying along the bank,
- (h) approximate percentage of total area of the plot occupied by rock, grass and soil,
- (i) type of vegetation along the bank, dominant plant species, under growth and average height of the vegetation.
- (j) the signs of otter use like track sets, number of markings on wood, number of markings on rock, number of spraint sets, number of basking places, number of holts,
- (k) overall soil composition of the plot
- (l) distance from human habitation.

The distance measurements were taken with a laser range finder and standard 30 m tapes, depth with a calibrated thread and plumb bob attached to the tip.

The assumptions that were made for the analysis of the data were:

- (a) Intensively used areas will have more signs than areas, which are sparsely used
- (b) The evidences of otter presence that are most likely to be encountered in the plots are: foot prints, markings on rocks and wooden logs, grooming and spraint sites, and holts.

- (c) Areas, which are intensely used by otters, will have holts, grooming and spraint sites. Markings cannot be considered as a sign of intensive use because otters when moving long distances may mark on any rock, boulders or logs on the bank and such markings remain there for a quite long time. So areas where only old markings were found were not considered important use area for analysis.

3.2.2 Locating and characterizing holts (dens)

Two methods were used to find out the holts. One was by looking at the signs associated with holts, like trails showing evidences of continuous movement from water to the vegetation cover, spraint sites, basking sites and infinite number of footprints around such areas. The other method was by tracking otters until they retire to holts. All kinds of signs and characteristics of the holts were studied thoroughly from the first few holts identified and then these evidences were looked for in subsequent surveys. All the holts located were characterized both qualitatively and quantitatively. The habitat variables measured at each holt were:

- (a) distance from water
- (b) distance from maximum water level
- (c) substrate type
- (d) vegetation type
- (e) mean water depth, river width
- (f) shade, slope and accessibility.

3.2.3 Sites for grooming and sprainting

The sites that the otters select for activities like, grooming/basking and foraging were described both qualitatively and quantitatively and the following features of the habitat were noted from such sites:

- (a) distance from the water
- (b) distance from the escape cover
- (c) % of the sand in the rolling place
- (d) % of the mud in the rolling place
- (e) slope of the bank
- (f) % of grass in the rolling place
- (g) water depth in the foraging areas
- (h) under water substratum and
- (i) presence of streams joining the lake and any other interesting observations.

3.3 Food habits

3.3.1 Collection of Spraints

Otters defecate in 'communal sprainting sites', which may be present closer to the entrance of dens (holts), or anywhere in their foraging areas. During the study such 'communal sprainting sites' were located by following the otters. For this study one spraint (scat) is defined as the collection of all the fecal matter of an otter group deposited in one communal spraint site at one communal sprainting event. Once the spraint sites are identified, frequent visits were made to these sites during different days of the week and spraint piles were collected. Looking at the extent of dryness and the color of the spraint, different piles were identified and collected as separate piles. The fresh spraints will be very moist, slimy, fowl smelling and cannot be picked without losing its shape. When deposited freshly, at times there will be air bubbles on the surface of the spraint. If the spraint happens to lie in the sun for one or two days, it will not smell anymore and it will be intact and stiff. Very old spraints would have lost the shape and will be lying scattered. In case if a scat happens to lie in the rain, most of the soluble material gets washed off and rest of the parts will be lying all along the course of the flowing water.

The problem of mixing of piles of different events was avoided by making almost daily collections of spraints. Another method used to differentiate the spraint piles was by looking at the size of the grubs of housefly on the spraint. Around Periyar Lake, the larvae of housefly come out from the scat within a few hours after spraint deposition. A total of 96 spraints were collected during December 2000 to April 2001.

3.3.2 Cleaning of spraints

Within 24 hours of collection, spraints were soaked in detergent solution. After overnight soaking they were washed under tap water by keeping in an iron sieve of mesh size 1mm. They were then dried in shade and stored in polythene zip-lock covers for future analysis. Before analysis, the cleaned spraints were weighed individually, numbered and marked with date and location of collection for future references.

3.3.3 Preparation of the standard reference collection of fish for spraint analysis

Trapping of fish was carried out in different regions of the lake using various fishing equipment like *Cast nets* and *Gill nets* of different mesh sizes, angling with hooks

of different sizes and traditional fishing equipment like plate traps. From the catch one or two specimens from each size category were kept for the purpose of making the reference collection. The shape of the scale and the pattern of the lines of the scales were quite distinct for each species of the fish caught (Webb, 1975). Size of the scale varied in different regions of the fish body but the shape and the pattern of lines remained the same.

The following measurements were taken from each of the fish specimens collected: total length, body length, dorsal fin length, head length, width of the body, scale length, scale width and body mass. Scales were pulled out from the sides of the body of the fish and slides were prepared by mounting them in a drop of glycerine. The slide was sealed and kept labelled to be used at a later stage during scat analysis.

Each of the fish specimens was then boiled for approximately 15 minutes and washed by keeping in a sieve with iron mesh under tap water so as to remove the digestible portions. From this, five vertebrae were randomly picked and the lengths were measured using a vernier calliper with an accuracy of 0.01 mm. Other measurements taken from the remains were the eyeball diameter and spine length in the case of catfish. This whole series of measurements were taken from all the size classes of various species of fish that could be collected. The bony portions and the scales were kept labelled in a polythene cover for reference.

3.3.4. Standardization of the sample weight for detailed analysis

It was nearly impossible to analyze the whole spraint, as it was very time consuming. So representative samples were taken from the spraints by slightly modifying the method described by Mason and Macdonald (1980). Instead of the cumulative number of species, the different size classes of the fish as represented by the different vertebrae lengths were plotted against the weight in grams. This was because of the fact that in the case of spraints where only one or two species of prey are present, this method might lead to under representation of the sample. The point where the asymptotic is reached is determined as the sample weight for detailed analysis (Figure 1)

3.3.5. Sorting of prey items

Based on above findings the standard weight of the cleaned spraint (3.5gms) was placed in a petry dish and kept under the 10 X convex lens in a 'Colony counter'. The spreading of the scat was done from one end of the pile gradually progressing and the

scales, bones and other body parts were separated using forceps and needle. All the vertebrae in the scat were grouped into different length classes of less than 1mm, 1-1.5mm, 1.5-2mm, 2-2.5mm, 2.5-3mm, 3-3.5mm, 3.5-4mm, 4-4.5mm, 4.5-5mm, 5.5-6mm and 6-6.5mm. The venation pattern of the scales were used to identify fish like Tilapia (*Oreochromis mossambicus*), European carp (*Cyprinus caprio communis*), Periyar barb (*Barbus micropogon periyarensis*), Mahseer (*Tor khudree*), Common sucker (*Garra mullya*), Curmuca barb (*Gonoproktopetrus curmuca*), Giant danio (*Danio aequipinnatus*) and Black line rasbora (*Parluciosoma daniconius*). The sharp lateral spines of Catfish (*Heteropneustes fossilis*) made its identification easier. Frog bones could be easily identified by their buff white colour and general shape. Crab remains were identified from the colour and shape of exoskeletal remains although species identification was not possible. No effort was made to identify the frogs and crabs to species level.

3.3.6 Estimation of size of the fish from the remains in the scat.

The basic premise behind this exercise was that there is a positive correlation between vertebral length and eyeball diameter with fish length (Wise, 1980). Using a linear regression the relationship between the eyeball diameter and the vertebrae length with the body size of the fish consumed was established. For this purpose, the fish collected during the sampling were used.

3.3.6.1 Estimating proportions of different size classes of fish eaten

The presence of species was confirmed by scale examination. As Wise (1980) pointed out that it was not possible to determine whether several vertebrae occurring in a scat have originated from the same fish or from more than one individual. In this study this problem was tried to overcome using a new technique with the following assumptions:

1. The total number of vertebrae is almost constant in all species of fish.
2. The chance of single vertebrae passing through the digestive system without any damage is the same for all the vertebrae of all the fish.
3. Also if the otters eat several fish belonging to a particular size class, the vertebrae length corresponding to that size class will be proportionately represented in the otter scat.

The representative sample that was taken from a single spraint for detailed analysis (in the present study 3.5 gm) was made as close as a true subset of the big lot. This was achieved by proper mixing up of the whole scat and spreading it on a flat ground, dividing it to four equal quadrates then discarding opposite ones thereby reducing the quantity without losing the representative ness of the sample. From this sample, the vertebrae belonging to different size classes like 0.5 to 1mm, 1 to 1.5mm etc were sorted. The proportions of these classes will be a true representation of the corresponding size classes of fish eaten (calculated using the regression model).

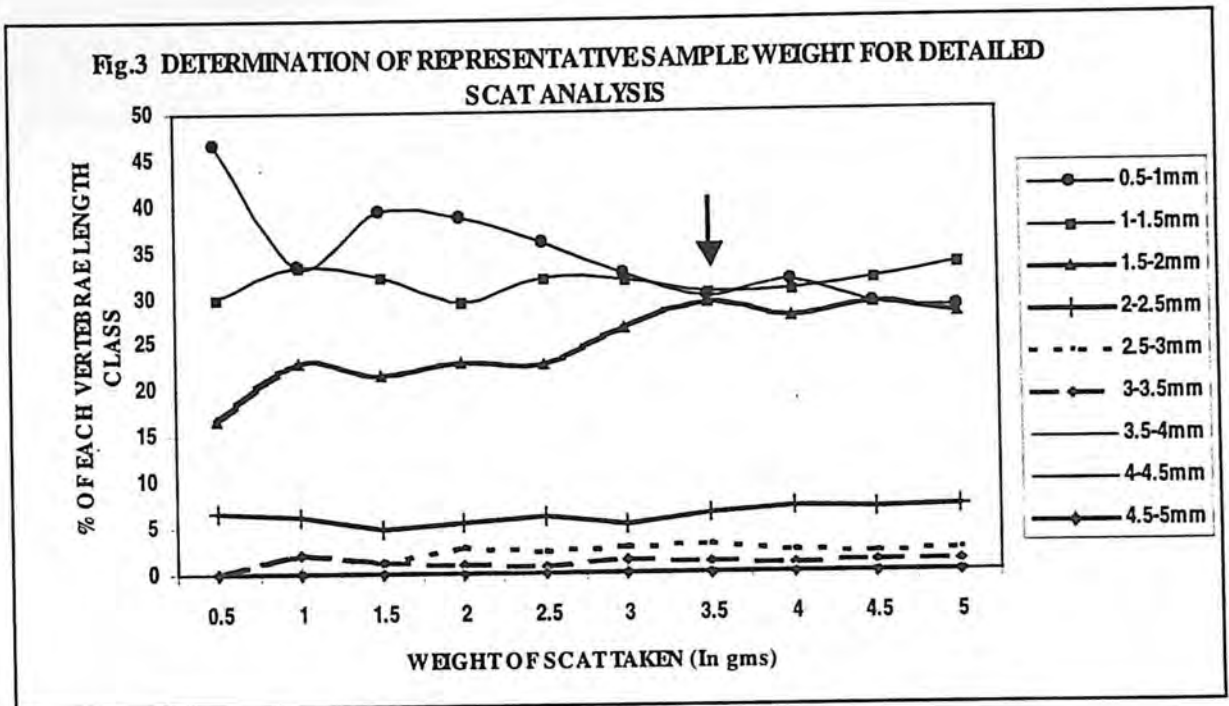
3.3.7 Estimation of proportions of prey items consumed

3.3.7.1 Score – Bulk estimate

The proportion of each prey category was estimated visually. Each prey category represented was given a score from 1-10, so that the total for one spraint was 10. The score for each prey category was then multiplied by the dry weight of the spraint and the resulting figures were summed up for each prey category and expressed as a percentage (Wise *et al.*, 1981; Hussain and Choudhury, 1997).

3.3.7.2 Frequency of occurrence.

The prey categories were noted for each spraint. The number of occurrences of a prey category was expressed as a proportion (%) of the total number of occurrence of all prey categories in a sample, the sum of the frequencies being 100. This method has been used for otter scat analysis by many people (*e.g.* Erlinge, 1968 for Eurasian otter; Melquist and Hornocker, 1983 for Canadian river otter; Hussain and Choudhury, 1998 for smooth-coated otter; Pardini, 1998 for Neotropical river otter; Umapathy, 1998 for Eurasian otter; Fernando *et al.*, 1999 on Giant otter; Perrin and Carrugati, 2000 on spotted necked otter and Cape claw-less otter).



3.3.8. Quantification of prey availability

3.3.8.1. Fish

Fish sampling was carried out using gill nets and cast nets, angling and some traditional fish traps to catch the fish. The nets of different mesh sizes were used to catch different size classes of fish. Gill nets were used mainly in the nights as they are designed to be used at night. Cast nets were thrown from the banks to a maximum distance of 5 to 6 meters. Angling was done to catch the bottom dwelling fishes like eels and catfish, which are never trapped in the nets. The smallest fish were sampled by a traditional fishing method. A bowl like plate covered with a cloth having a small slit was placed in water. Some wheat flour was kept inside the bowl as bait. Fish, which entered the bowl, were not able to come out.

3.3.8.2 Crabs and frogs

Frogs and crabs were sampled using visual encounter surveys by walking along the banks (Martha and Scott, 1994). The time, number of individuals and species were noted at each sighting. The total time is expressed as the number of person hours searching the area. This method is usually used to determine the species richness, to compile the species list, and relative abundance of a species within an assemblage

The assumptions made were:

- * Every individual of every species has the equal chance of getting detected during the sampling session
- * An individual is recorded only once during the survey

3.3.8.3 Birds

Aquatic bird population was assessed by doing a total count of one fourth portion of the lake and extrapolating the results to the whole lake (Gaston, 1975). The identification of the birds was done through 10 X 35 binoculars with the help of Grimmet *et al.*, (1999).

3.4 Analysis of data

3.4.1 Test for normality of the variables

Testing for multivariate normality was not done as the tests are cumbersome. Hence as suggested by Morrison *et al.*, (1992) variable by variable examination of

normality was done. The individual variables of habitat were tested for normality using one-sample Kolmogorov-Smirnov Tests. Those variables which turned out to be not normal ($P < 0.05$), were subjected to standard univariate transformations like $\log(x)$, Arc Tan (x), and Square root (\sqrt{x}). It was assumed that the relationships between the variables are linear as none of the data sets had wide ranges of observations. No attempt was made to linearise the non-linear relationships if any.

3.4.2 Principal components analysis

The objective was to determine if habitat structure varied between several points in the movement range of otters, and if so which structural variables changed and which were similar between points. From the complex data set, new sets of orthogonal (mutually perpendicular thus not correlated) axes were identified in the direction of greatest variance among observations by using principal component analysis. Components with eigen value above 1.0 were selected from the correlation matrix of habitat variables. Both magnitude and direction of the relationship of variables with the principal components were used to infer the relationship. PCA was performed on the SPSS 8.0 software with the options of Pearson Correlation Coefficient as the input and a varimax rotation of the factors, which is an orthogonal rotation method that minimizes the number of variables that have high loading on each factor and it simplifies the interpretation of the factors. To facilitate the visual interpretation of the overall habitat selection patterns of otters, the three principal components which had eigen values more than 1.0 were plotted in a three dimensional scatter plot and the cases were labeled by otter use (presence or absence).

3.4.3 Mann -Whitney 'U' Test

To test whether use and non use areas differ with respect to mean of the factor scores, in other words whether the crucial habitat variables like number of streams joining the area, water depth, river depth, rockiness and vegetation height vary significantly between the used and unused areas, Mann - Whitney 'U' Test was carried out on the PC1, PC2 and PC3 scores.

3.4.4 Logistic regression

Logistic regression was performed with animal presence/absence as the dependant variable and the habitat variables as the covariates. A classification table was made to

obtain the classification rates of correct presences (CP) and correct absences (CA) and overall correct classification. The default model selected four cut off points defined from 0.1 to 1.0 which intervals contain all areas with estimated probabilities between adjacent cut off points. The cut off points were modified later on, so as to optimize the presence/absence as they occur with varying probability along the axis of classification plot. All tests were done using the software package, SPSS 8.0 for Windows and the results were interpreted using with the help of standard biostatistics books and research papers (Shanubhogue and Gore, 1987; Morrison *et al.*, 1992; Zar, 1984).

4.0 RESULTS

4.1 Otters of Periyar, an account of taxonomy

The otter species found in the reservoir was identified as *Lutra perspicillata* (Plate.1). This was confirmed by the shape of the rhinarium (Foster-turley, 1990), flat under side of the tail (Pocock, 1943) the measurements of the footprints, (median length = 9 cm and breadth = 6.75 cm (n=25) (Kruuk *et al.*, 1993) and smooth texture of the coat. The populations in the mountain streams could not be identified to species level but it is suspected that they are *Lutra lutra*. This could not be confirmed because of difficulties in sighting the animals.

4.2 Habitat selection by otters

4.2.1 Ordination of habitat variables

The variables, by means of which the habitats were characterized, were subjected to factor analysis using Principal Components Analysis (PCA) as the extraction method using SPSS software. The PCA extracted three components with eigen values more than 1.0 from the correlation matrix of the habitat variables, which summarized 69 percent of the variation in the system (Table 1).

Principal component I (PC I; 37.7% of the variance) is interpreted as riverbank component (Table 2) separating areas with steep slope (SLOPE) and rockiness (ROCKINESS) from areas with more grass cover (GRACOV) and mud cover (MUDCOV). Both magnitude and direction (+ or -) were used to infer this relationship. PC II (19.2% of the variance) is related to water body component which showed deeper areas (AVGDEP) of the lake are wider (RIVDEP) as well and these areas have very short vegetation (VEGNHT). PC III (11.99% of the variance) has high positive loadings on the number of streams joining the lake which also showed a fewer number of flat mud areas (MUDBEDS) on the positive side.

4.2.2 Crucial factors determining habitat selection by otters

The use / non-use of an area by otters was decided as described in section (3.2.1c). The three principal components were plotted in a 3 dimensional scatter plot and the points were marked as used or unused (Figure 4).

PLATE NO. 1



A group of smooth coated otter in Periyar Tiger Reserve

Table . 1 Total Variance Explained by the Principal components

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.771	37.710	37.710	3.771	37.710	37.710
2	1.920	19.200	56.910	1.920	19.200	56.910
3	1.199	11.992	68.902	1.199	11.992	68.902
4	.808	8.085	76.987			
5	.632	6.319	83.306			
6	.524	5.238	88.544			
7	.441	4.405	92.949			
8	.343	3.429	96.378			
9	.228	2.280	98.658			
10	.134	1.342	100.000			

Extraction Method: Principal Component Analysis.

Table . 2 Summary of the first three principal components

	Component		
	1	2	3
STREAM	-9.227E-02	-9.034E-02	.863
AVGDEP	.370	.736	9.243E-02
SLOPE	.755	7.621E-02	.124
RIVWID	-2.003E-02	.853	3.243E-02
MUDBEDS	-.310	-.375	-.491
BOULDERS	.879	.118	-6.937E-02
VEGNHT	.217	-.651	.452
ROCKINESS	.904	-1.242E-02	.106
GRACOV	-.857	7.096E-02	-.135
MUDCOV	-.641	-.322	.276

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

STREAM	- No. of streams joining in a stretch of the lake
AVGDEP	- Average depth of the stretch
SLOPE	- Slope of the banks
RIVWID	- Average width of the lake
MUDBEDS	- Number of flat mud beds available in the stretch
BOULDERS	- Number of boulders in the stretch
VEGNHT	- Height of the vegetation in the stretch
ROCKINESS	- Percentage rockiness of the stretch
GRACOV	- Percentage grass cover in the stretch
MUDCOV	- Percentage mud cover of the stretch

The PC 1 axis in the positive side indicates steeper and rocky areas, whereas along the negative side, the area becomes more and more slanting and less rocky. On the PC 2 axis the positive side indicates deeper and wider areas of the lake and the negative side indicates shallower and narrower portions of the river. The positive side of the PC 3 axis indicates more number of streams joining the lake, which indicated areas of high fish congregation and the negative side indicates lesser number of streams joining the lake. The number of streams joining a stretch showed a significant positive correlation with the vegetation density ($F = 0.381$, $p < 0.01$), Slope of a stretch showed a significant negative correlation with distance to escape cover ($F = -0.609$, $p < 0.01$) and width of the lake with depth ($F = 0.547$, $p < 0.01$).

There is a significant segregation of the used areas ($n=65$ plots) in regions characterized by low water depth and width, where the area has gentle slope and less rockiness and, where more number of streams, which bring in lots of food material, joins the lake. The unused areas ($n=29$ plots) are located in steep, rocky and wide and deep areas where the number of streams is very less. The Mann-Whitney 'U' test on the PC 1, PC 2 and PC 3 scores to illustrate how results from the above exploratory analysis can be extended to make statistical inferences about the observed patterns (Table.3). The test statistically validated the observed pattern in the used and unused areas of the reservoir along the PC axes ($U= 384$, $z = -3.954$, $P < 0.0001$) for PC 1; $U= 678$, $z = -1.405$, $P < 0.16$; and $U= 582$, $z = -2.237$, $P < 0.025$.

4.2.3 Validation of the findings using logistic regression

The logistic regression predicted the validity of the observations in the field (Table 5 and Table 6). The probability of otter occurrence was predicted for each of the 94 representative areas chosen for characterizing the otter habitats (Table 4). Out of the 70 plots, which showed positive signs of otters, 95.71% were classified in the region of higher probability of occurrence. But out of the 24 plots, which showed no signs of otter occurrence, only 54.17% were correctly classified as lower probability of occurrence. This shows that some of the areas, which showed no signs of otter presence were potential areas but at the time period of this study they were not being used for unknown reasons. This may also be due to the inherent problems of using spraints and tracks to assess the degree of use of an area by otters (Kruuk and Conroy, 1987; Kruuk *et al.*, 1986).

Table . 3 A Summary of the Mann-Whitney 'U' test

	REGR factor score 1 for analysis 1	REGR factor score 2 for analysis 1	REGR factor score 3 for analysis 1
Mann-Whitney U	384.000	678.000	582.000
Wilcoxon W	2869.000	3163.000	882.000
Z	-3.954	-1.405	-2.237
Asymp. Sig. (2-tailed)	.000	.160	.025

a. Grouping Variable: Use / Nonuse

Fig. 4 DIFFERENTIATING STRETCHES OF THE LAKE USED BY OTTERS FROM UNUSED STRETCHES

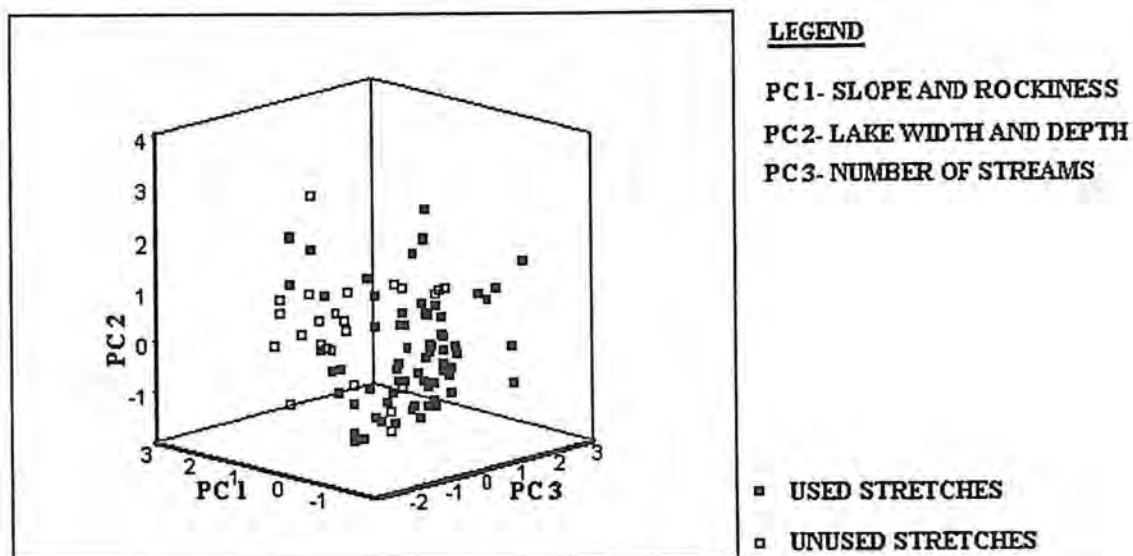


Table.4 Validation of logistic regression model by cross checking the predicted probability of otter use of an area with observed pattern.

Observed	Predicted		Percent Correct
	.00 0	1.00 1	
.00	0	13	54.17%
1.00	1	67	95.71%

Overall 85.11%

1.0 : used area
 0.0 : unused

The Cut Value is a probability of 0.50

Table 5 Summary of logistic regression model

Variable	B	S.E.	Wald	df	Sig	R	Exp(B)
Stream	.1655	.0536	9.5464	1	.0020	.2658	1.1800
Rockiness	-.0331	.0087	14.5405	1	.0001	-.3427	.9675
Constant	1.0554	.4581	5.3069	1	.0212		

Table 6 Significance of the logistic regression model

	Chi-Square	df	Significance
Model	30.807	2	.0000
Block	30.807	2	.0000
Step	13.441	1	.0002

Table.7 The types of otter holts located in Periyar Tiger Reserve (n = 17)

Sl.No.	Type of the den	Number
1	Dug between the roots of trees on the banks	2
2	Dug under the dead trees lying along the banks	3
3	Dug inside the lantana thickets	2
4	Natural rock crevices	2
5	Open bank	4
6	Dug inside the tall grass land	4

4.2.4 Holts of otters

A total of 17 holts were identified in the entire lake (Figure. 5) out of which four were found out by following the otters and 13 were found by intensive search of the bank side areas. Five holts were live (in use) during the study period and the rest were abandoned holts. The places that the otters selected for making holts varied from open banks to rock crevices (Table 7). The average distance of the den from the water level was found to be 18 m (lowest value being 1m and highest 165 meters, n=17) (Figure.6) In a period of 6 months, the group, which was studied intensively, shifted three holts. The common feature for all these three holts was that all of them were dug by the otter under the fallen dead trees, which are not far from the water edge. Most of the holts were above the maximum reservoir water level. Otters seemed to be aware of the unpredictable rains and sudden rise in water levels. The natal den (in which the cubs were born) was 150 meters away from the maximum water level. Otters selected such places, which are above maximum water level but not far from the water (Figure 7). Otter foraging grounds were found mostly in shallow waters in Periyar and consequently most of their holts were also present in the shallow water areas (Figure 8). Those holts, which were located near deeper areas of the lake, were all abandoned ones and they might have been used at some time of the year during inclement conditions.

4.2.5 Grooming and spraint sites of otters

Grooming is the vigorous rubbing of the fur on the loose sand, soil or grass on the ground, or the rolling and blowing of air into the fur. Basking is the inactive state after grooming when they heat up their body with sunlight. Grooming/basking and sprainting behaviors are closely associated with each other. In almost all the observations, sprainting was either followed or preceded by basking and grooming except when the otters were retiring from the foraging grounds for the day. Otters showed a preference for soil with high sand content for grooming (Fig. 9). The association of otter spraints with grooming places was very strong. Out of the 50 grooming sites, 96% had spraint sites within a distance of 3 meters. The grooming places are characterized by a small patch of dry soil with high sand content (Plate 2) and in 99% of the cases it was near an object lying on the banks irrespective of what it is. Otters were seen grooming around tree stumps, rocks and even iron posts (Plate 2).

Fig. 5 Locations of holts (otter dens) around Periyar lake

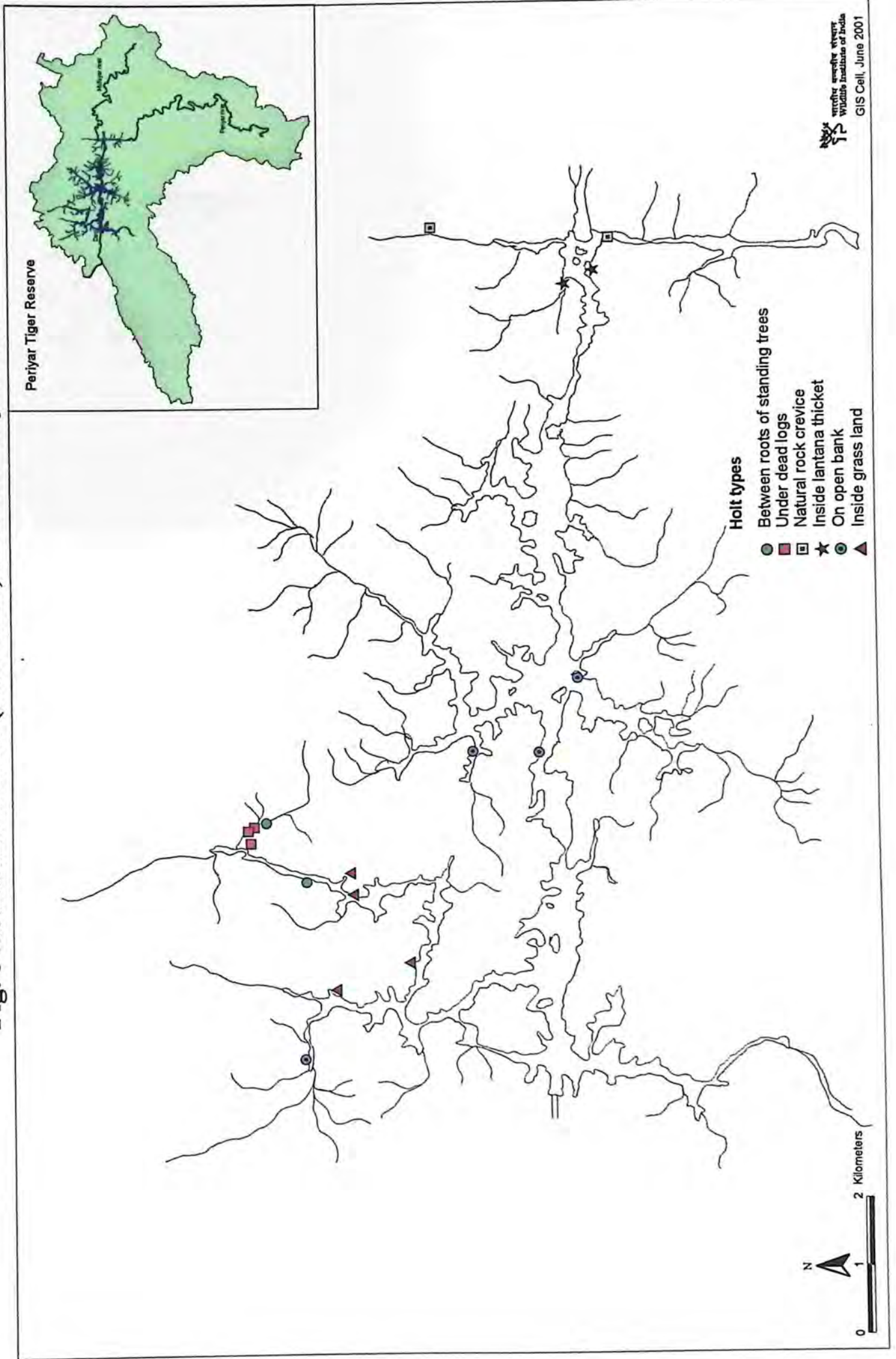


PLATE NO. 2



Grooming/spraint site



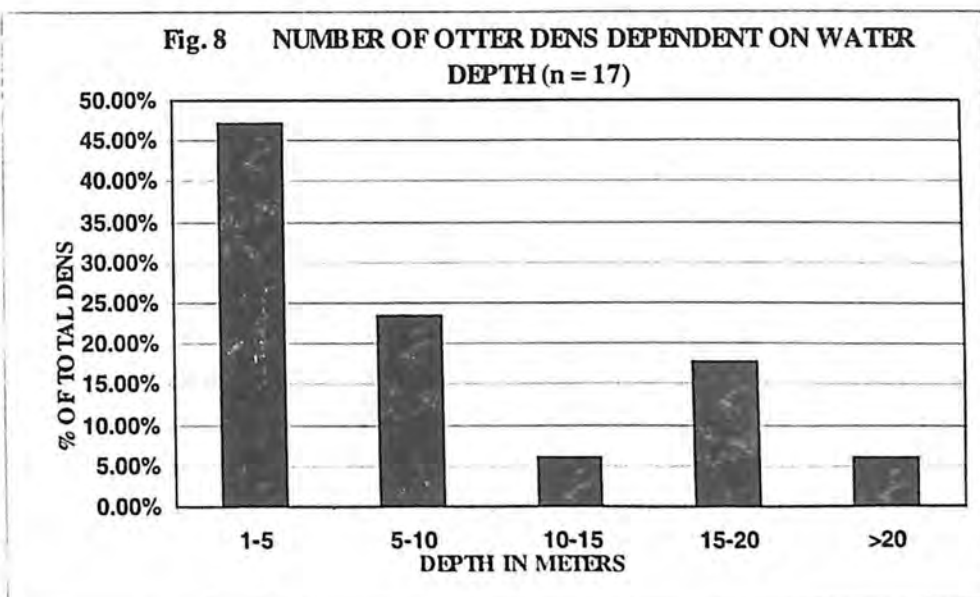
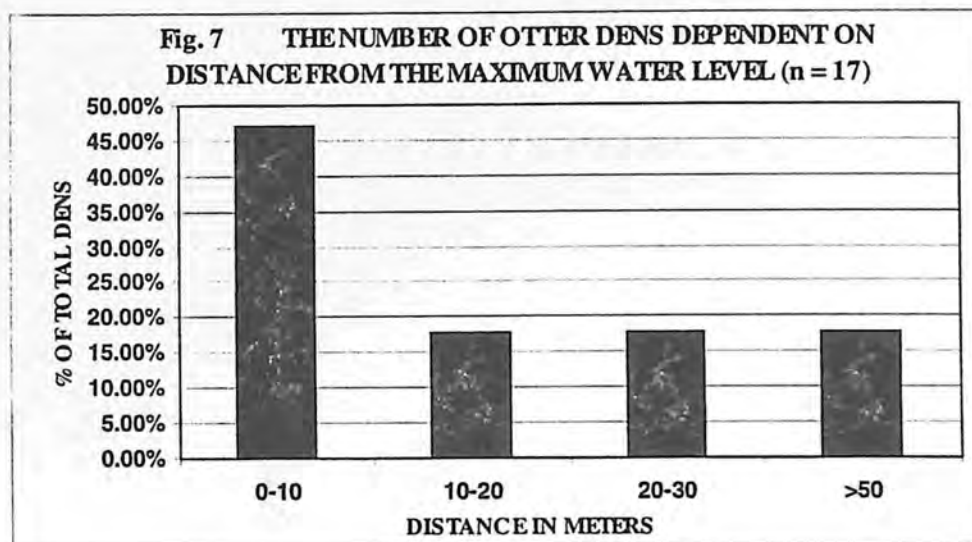
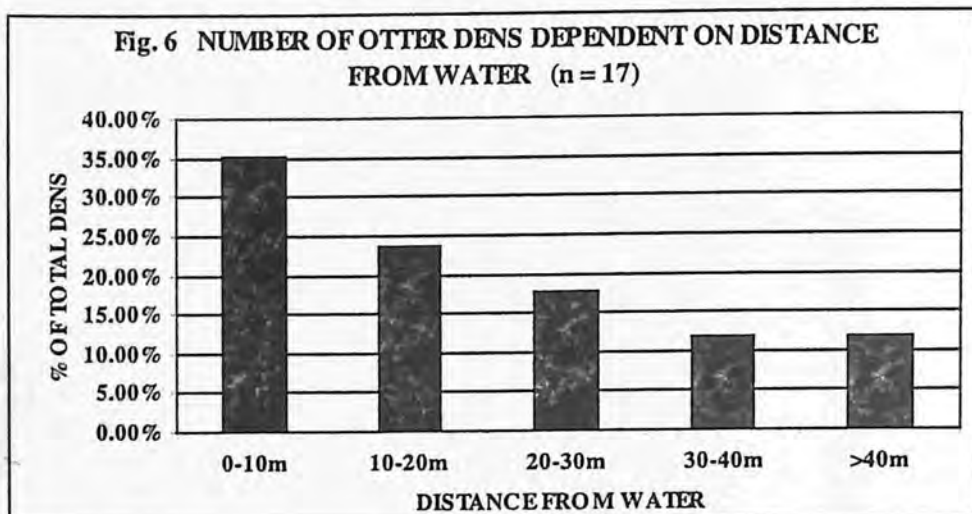
Track set of otter

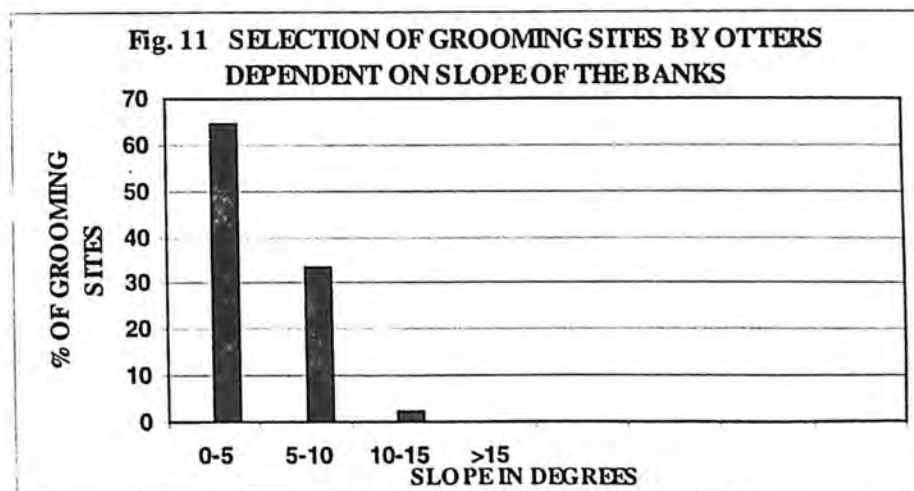
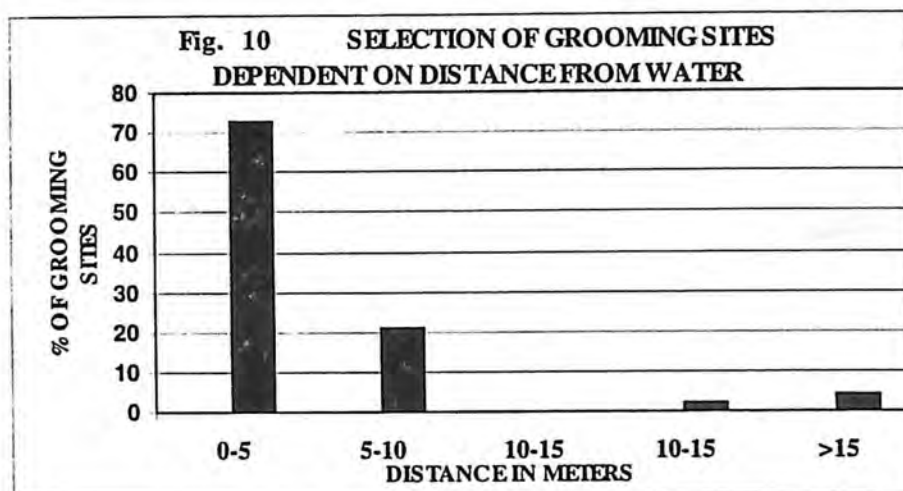
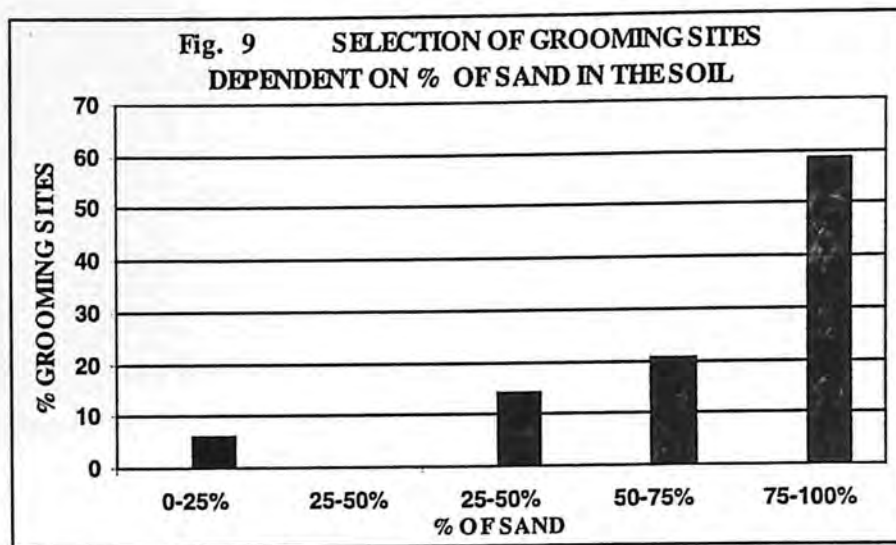


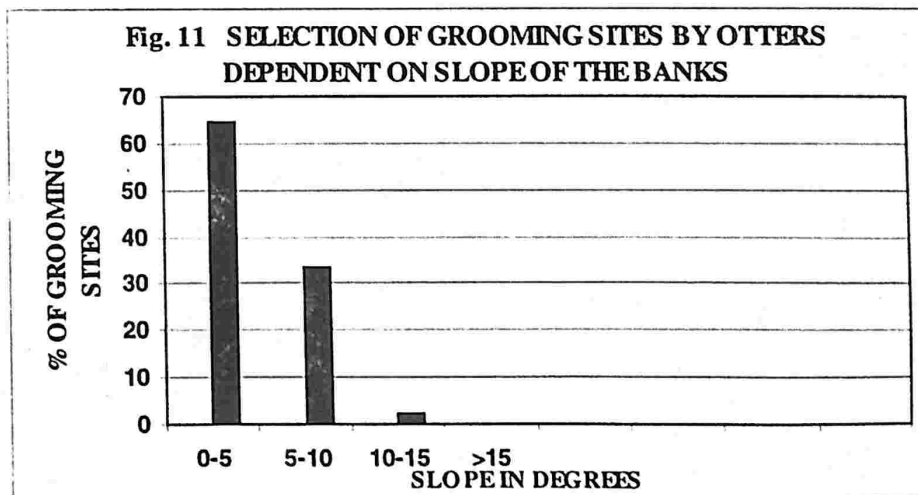
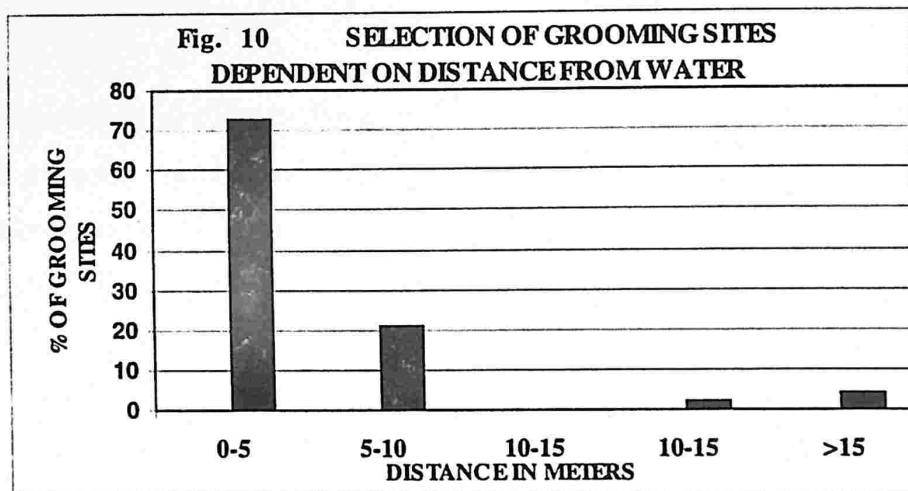
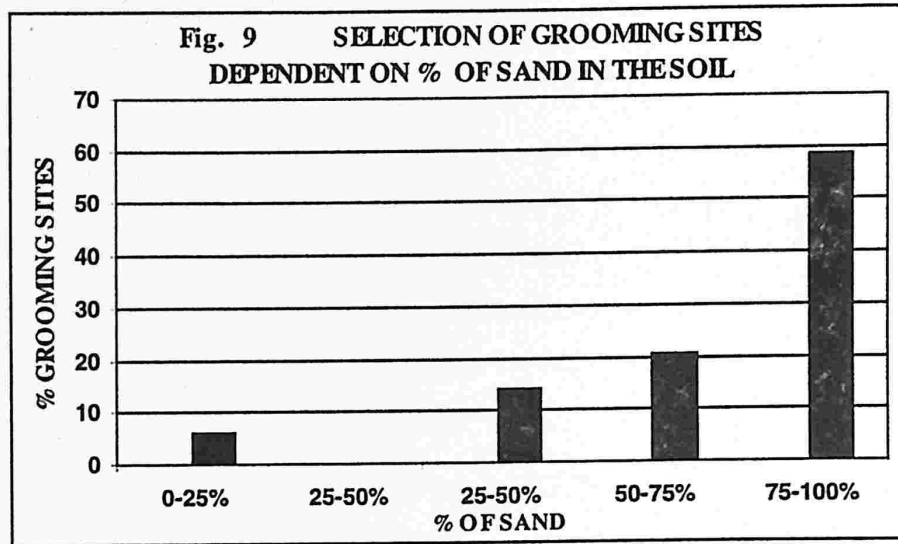
Holt between tree roots



Sprainting otter







Elephants, during their mud baths make lots of plain mud beds in the sloping banks. These mud beds were very important otter grooming places as they offered fine-grained sand and security. 64% of the otter grooming places were found on such elephant facilitated mud beds.

Otters in Periyar seem to be very alert towards predators when they were on land. Their grooming places were as near to water as possible (Fig. 10) All the time at least one animal was found standing on hind foot looking around for predators. Wild dogs are the main otter killers (Local fishermen Pers Comm). People have seen otters being ripped apart by wild dogs. Flat areas were preferred for basking than slopes (Fig. 11). The reason why the otters like to bask around some solid objects may be that it would offer them some protection by not getting noticed easily as against basking in open areas.

4.3 Food habits of otters

4.3.1 Prey population of otter in Periyar lake

The effort made to catch and identify all the species of fish and assess the size and weight class distributions, was a very difficult task because of various reasons. The final conclusion was that there was no single method by which the fish population of the lake could be sampled correctly. Probably 'electro fishing' which takes samples of fish by killing them might give a better sampling accuracy. As it was a destructive method of sampling no effort was made to use electro fishing.

During this study only 12 species of fish were recorded while sampling, as against 27 species reported from the Periyar Tiger Reserve by Arun (1999). The information such as size of fish catch, behavior and trapability of fish species were collected by interacting with the local fishermen and by consulting literature.

The details of the fish species present and the body size classes of the various species recorded from Periyar and the biggest one caught during the study are given in Appendix I. The number of species in different size classes of fish seen in the study area is given in Figure (12). The maximum number of species is found in the size class of 6-10 cm. Only one species of fish is less than 5cm (Kerala loach-*Nemacheilus keralensis*). The biggest ones are European carp (*Cyprinus caprio*) and Mahseer (*Tor khudree*).

The frogs that are commonly encountered in the lakeside are *Rana curtipes*, *Hoplobatrachus tigerinus* and *Rana cyanophlyctis*. During the early months of the study, large groups of tadpoles used to be encountered all over the lake. They were jet black in

colour and some of them were having orange colored spots. By the end of this five months study almost all of them metamorphosed to the adult frogs and were *Rana curtipis*. In the month of April, the number of frogs that were encountered on the lakeside was infinite.

The lake has thousands of dead trees standing within the water. These dead trees had been there for the last 106 years (The dam was built in the year 1896). Since then many species of water birds especially cormorants and darters have been using these trees for nesting. Almost throughout the year there will be nests of some bird or the other on the dead trees.

In order to assess the population of the *Phalacrocoracids* of the lake, 1/4 portion of the lake was taken and a total count of the nests was done in which 30 cormorant nests were counted on the stumps standing in the lake. Taking the average number of chicks hatched out from a nest as 2, plus the parents, the large cormorant population of the Periyar lake can be estimated to be around 500 birds including chicks, Oriental darters will be around 40 individuals, and around 20 little cormorants. There is a resident population of about 20-30 Woolly necked storks and equal number of Grey herons.

4.4 Representative weight for detailed scat analysis

The cumulative percentages of size classes of fish when plotted against different weight classes of spraint showed a flattening trend at 3.5 gm (Figure.3) and this was decided to be the standard weight for detailed analysis.

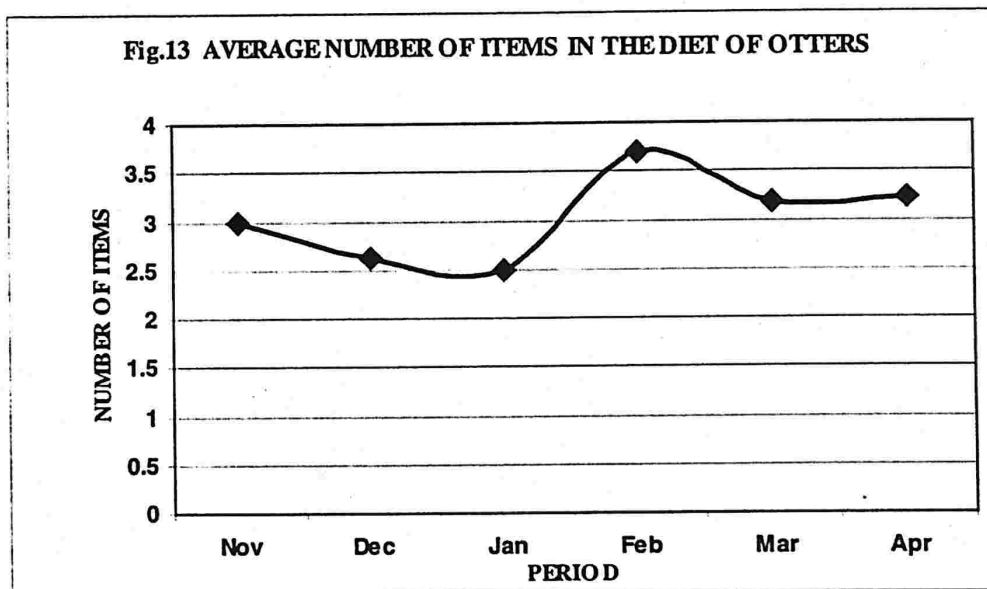
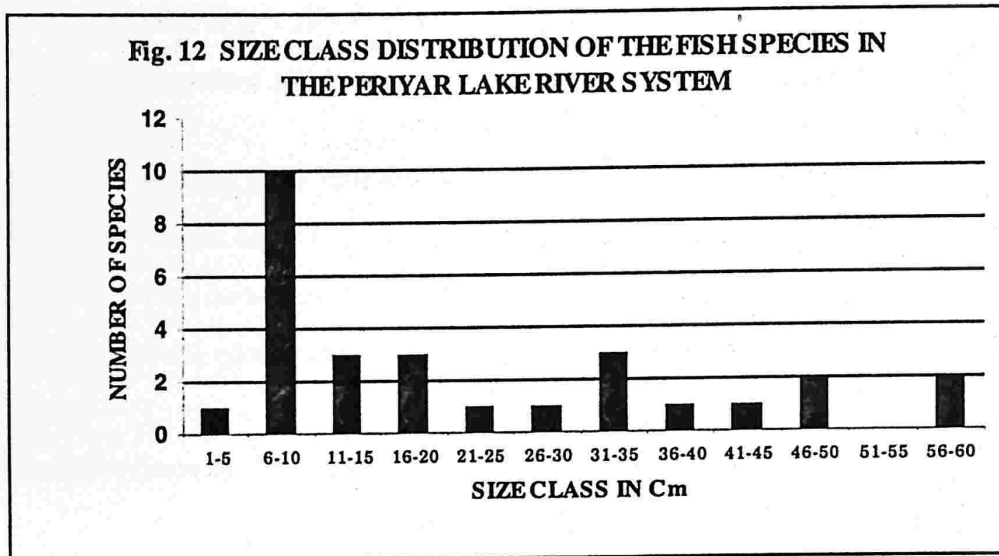


Table. 8 Proportions of different prey categories in otter scats

Prey Item	No. of occurrences	Frequency of occurrence	Score Bulk estimate
Fish	96	82.75	96.02
Frog	12	10.34	1.08
Crab	5	4.31	1.07
Bird	2	1.72	1.07
Insect	1	0.86	0.76

4.5 DIET COMPOSITION OF OTTER

4.5.1 The average number of prey items encountered in the otter scats.

The total number of prey items encountered in the scats varied from 1 to 7 in the study area. But most of the scats contained 3 to 4 items on average (Figure 13). There was no significant difference between different months. This could not be tested statistically as the assumptions of chi-square (values should be above 5) were not met by the data set.

4.5.2 The proportions of different prey categories encountered in the otter scats

The fish contributed maximum to the otter diet 82.75 % in frequency of occurrence (FO) and 96.02% through score bulk estimate (SB) (Table.8). Followed by frog (10.34% (FO) and 1.08% (SB)), crab (4.31 (FO) and 1.07 (SB), bird (1.72(FO) and 1.07 (SB)) and Insects (Table 10).

4.5.3 Proportions of different prey items as estimated by the 'score-bulk' estimate and the 'frequency of occurrence' methods.

Tilapia (*Oreochromis mossambicus*) constituted the major portion of the otters' diet in Periyar (51.4(SB) and 32 (FO), followed by catfish (*Heteropneustes fossilis*) (21.27(SB)and 26.33 (FO), Curmuca barb (*Gonoproktopetrus curmuca*) (12.37(SB) and 16.33(FO), European carp (*Cyprinus caprio*) (9.16 (SB) and 15.00(FO) and frogs (1.08 (SB) and 4.00 (FO))(Table 9). The rest of the items were represented in very few scats. From the results it is clear that the major items are under represented and minor items are over represented in the frequency of occurrence method.

4.6 Relating the vertebrae length and eyeball diameter to body size of the fish

A total of 43 individuals belonging to different species were caught for the purpose of establishing a linear relationship between various body parts and the total length of the fish. A total of 72 eyeballs and 215 vertebrae were measured for the dimensions. This data was subjected to liner regression using SPSS Software.

Table. 9 Relative proportions of individual prey species in otter scats calculated using two different techniques.

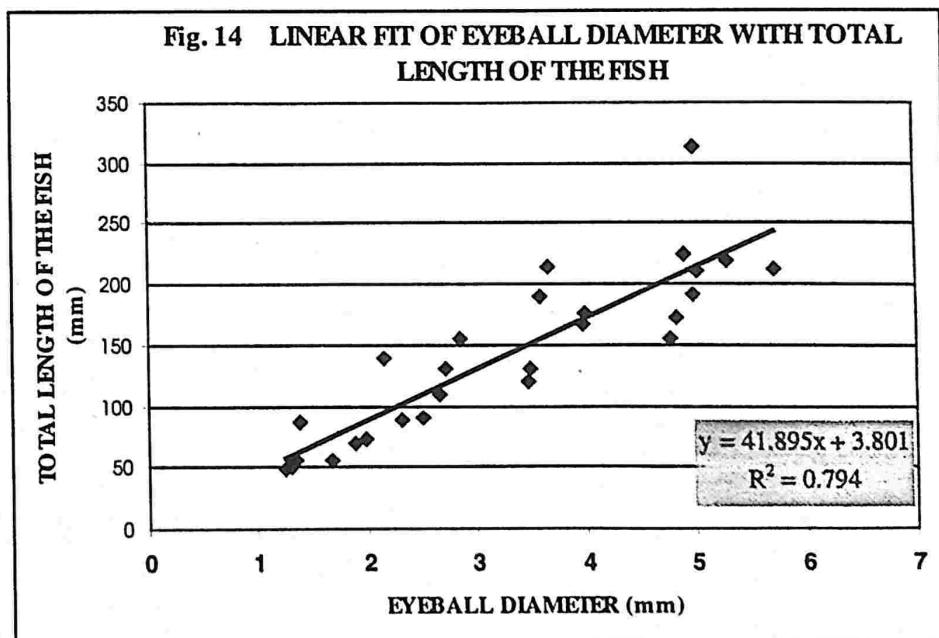
Sl. No	Prey item	Frequency of Occurrence (%)	Score Bulk Estimate (%)
1	Tilapia, <i>Oreochromis mossambicus</i>	32.00	51.54
2	Catfish, <i>Heteropneustes fossilis</i>	26.33	21.27
3	Curmuca barb, <i>Gonoproktopterus curmuca</i>	16.33	12.37
4	European carp, <i>Cyprinus caprio communis</i>	15.00	9.16
5	Periyar barb, <i>Barbus micropogon periyarensis</i>	1.00	0.36
6	Mahseer, <i>Tor khudree</i>	3.00	1.27
7	Frogs	4.00	1.08
8	Crabs	1.66	1.07
9	Birds	0.66	1.84
10	Insects	0.02	0.04

Table.10 LINEAR RELATION BETWEEN EYEBALL DIAMETER AND FISH LENGTH IN PERIYAR LAKE

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.891 ^a	.794	.786	3.1318	.794	104.145	1	27	.000

a. Predictors: (Constant), EYEBALL DIAMETER

b. Dependent Variable: TOTAL LENGTH OF THE FISH



4.6.1 Eyeball diameter against total length of the fish

The eyeball diameter is related to fish length by means of a linear relationship (Table 10 and Figure 14)

$$\text{Total length of the fish} = 41.895 \times \text{Eyeball diameter} + 3.801$$

4.6.2 Vertebrae length against total length of the fish

The vertebrae length is related to fish length by means of a linear relationship (Table 11 and Figure 15)

$$\text{Total length of the fish} = 62.407 \times \text{Vertebrae length} - 6.3327$$

4.7 Size classes of fish consumed by the otters

The scat analysis shows a higher degree of occurrence of the fish size corresponding to the vertebrae lengths 0.5-1 mm, 1-1.5 mm and 1.5-2 mm (Figure 13). 1 to 1.5 mm and 1.5 to 2mm length class which corresponds to fishes of length 8 cm to 12 cm respectively, constituted 29 % of the total vertebrae extracted from the scats. 0.5-1 mm (fishes of length 5 to 8 cm) class constituted 23.7% followed by 2.0 to 2.5 mm (14.4%) (fishes of 12 to 15 cm) of total vertebrae from the scats. All other size classes were not consistent in the scats and thus indicating that bigger size fishes are taken only occasionally.

4.8 Seasonal variation in the diet (at high and low water levels)

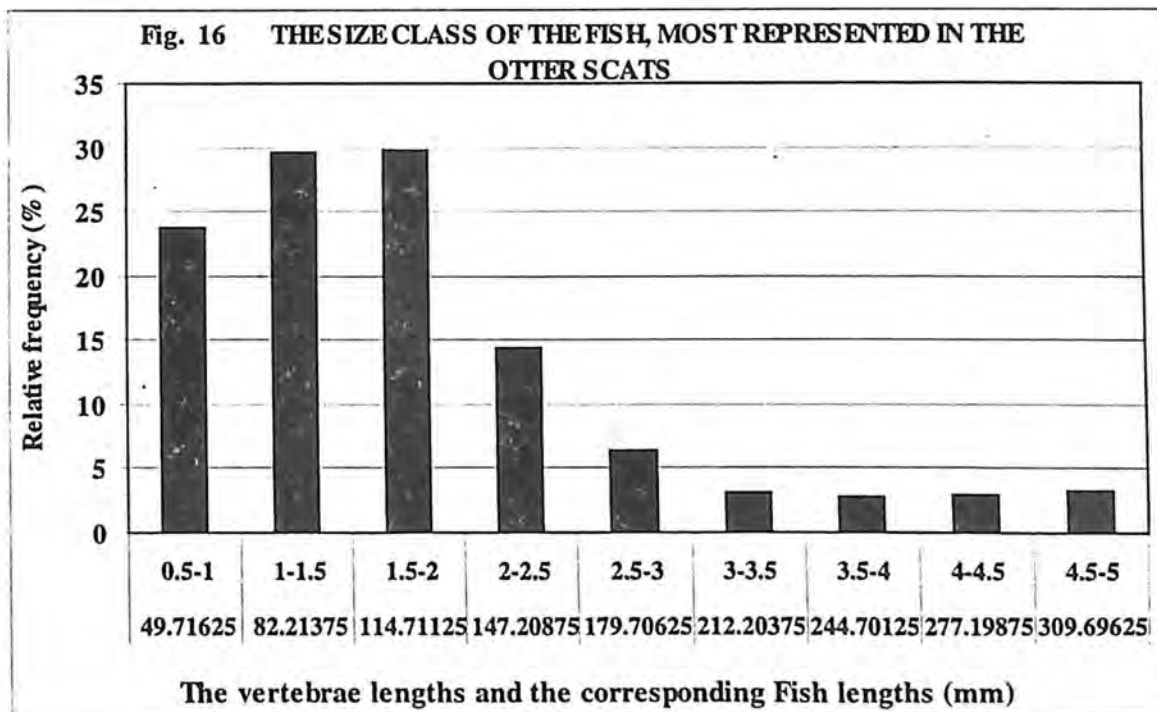
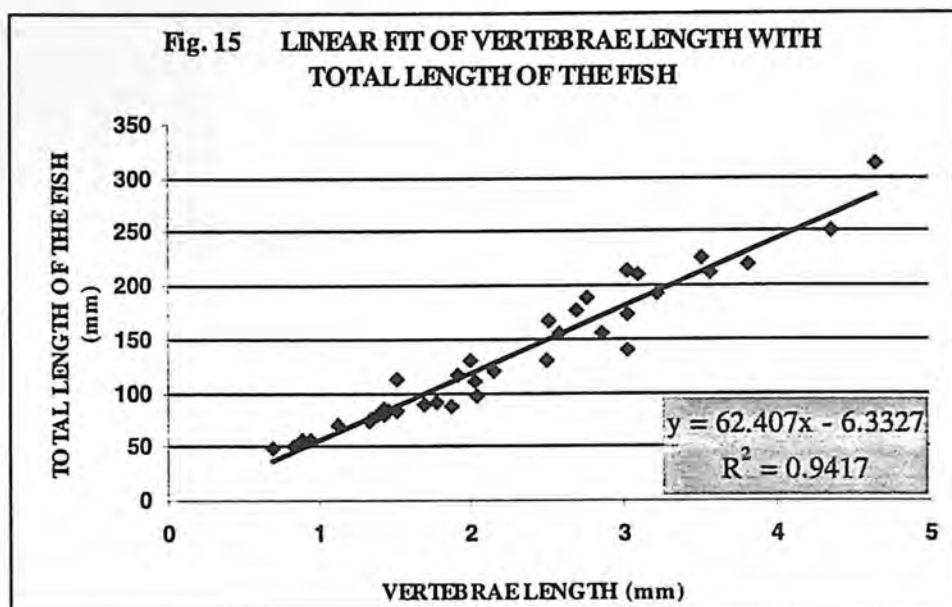
The average number of species in the otter diet during higher water levels (*i.e.* during the months of November, December and January) was 2.73 (varied between 1 to 7). During lower water levels when more and more areas were available for the otters for foraging, the average species number in the otter diet showed a rise and reached 3.21 (varied between 1 to 5). However at both higher and lower water levels, Tilapia was the major food item (73%) for the otters (Figure 16). But during the lower water levels, a higher intake of cat fish, carp and curmuca barb was seen. As the catfishes are bottom dwelling fishes (Arun, 1999) at low water levels the otters are able to catch them more effectively. A comparison between the diets of the otters of the river and that of the lake could not be done because of a low sample size of scats from the rivers.

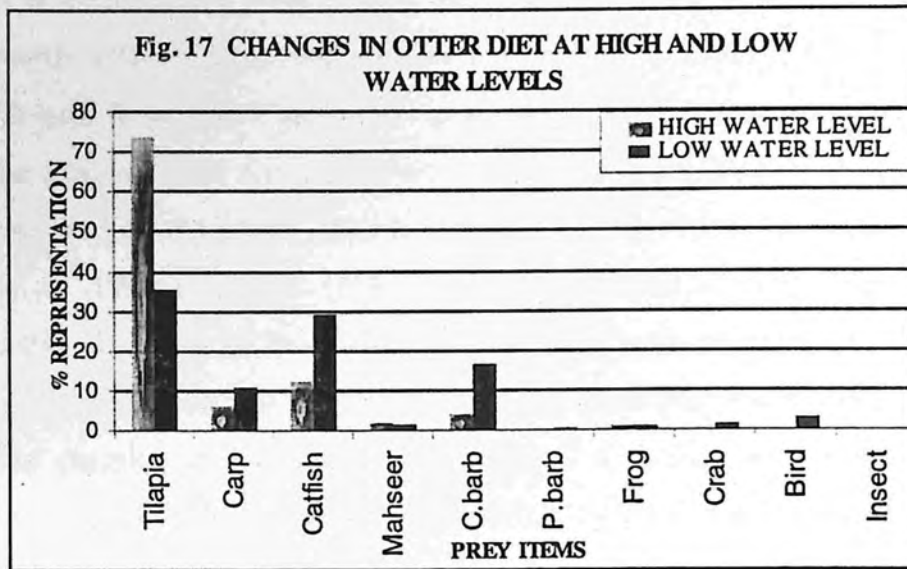
Table.11 LINEAR RELATIONSHIP BETWEEN VERTEBRAE LENGTH AND TOTAL LENGTH OF THE FISH

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.970 ^a	.942	.940	1.5991	.942	581.398	1	36	.000

a. Predictors: (Constant), VERTEBRAE LENGTH

b. Dependent Variable: TOTAL LENGTH OF THE FISH





5.0 DISCUSSION

As its broad geographic distribution (Pocock, 1943) suggests the smooth-coated otter is able to adapt to diverse aquatic habitats. In the Indian subcontinent the smooth-coated otter is essentially a plain's otter. They are adapted to live even in the semiarid region of north-western India and the Deccan plateau (Prater 1971; Hussain 1993). Generally, it uses large rivers and lakes, peat swamp forests, mangroves and estuaries, and even the rice fields for foraging (Foster-Turly 1992). In South-east Asia rice fields appear to be one of the most suitable habitats in supporting its viable populations (Melisch *et al.* 1996a). Shariff (1984) found that smooth-coated otters were more abundant in the mangroves of Kuala Gula, Malaysia as compared to the rain forest rivers.

The availability of certain key components (including food, shelter and water) determine the duration and intensity of selection of a habitat (Melquist and Dronkert, 1987). In this study the habitat of otter is visualized in a landscape level as a host of many features, which influence each other. These parameters in turns influence the occurrence of a species in the landscape. During the study effort was made to understand which of the factors for sure is essential for the survival of otters in the Periyar Tiger Reserve.

5.1 Features critically important for the survival of otters

The first and foremost necessity is of course distribution of dependable food resources. For a carnivore like otter, food availability is an inherently complex concept, which is influenced by the degree of familiarity of the animal with distribution of food items within its foraging area (Schoener, 1971), the abundance of the prey (Griffith, 1975), and possibly, the ability of the prey to escape from being caught (Pardini, 1998). Shelter (holt) comes next, which in the case of otter is used for resting, littering as well as to protect themselves from inclement conditions or disturbances. Otters selected such areas for making holts that are very well inside its foraging range. If otherwise, *i.e.* making holts outside the foraging range, would be very expensive in terms of the enormous amount of energy that is required in foraging trips. Next to shelter, sites for grooming and basking are important to otter for survival.

The two major problems that diving mammals have to deal with are increased loss of body temperature caused due to greater thermal conductance of the water and the state of apnoea (Nolet and Kruuk, 1998) Most of the aquatic mammals rely on the subcutaneous fat for insulation but the semi-aquatic otters, which are remarkably lean

(Pond, 1985), have a different means to reduce the rate of the temperature loss when in water. They have air trapped in the fur, which prevents water coming in direct contact with body of the animal and while swimming, the air continuously escape as bubbles forming a white line along the swim course (Nolet and Kruuk, 1998). The function of basking and grooming is to rearrange the fur to facilitate the entrance of the fresh air (Nolet and Kruuk, 1988). It might also stimulate the blood flow, thereby recovering from the temperature loss.

5.2 Situation in Periyar lake

Otters in Periyar selected shallower and narrower regions of the lake, where the bank has gentle slope and are less rocky and, where more number of streams joined the lake. They seemed to avoid deeper parts of the lake, which have steeper and rocky banks, with very few streams joining the lake. The number of streams joining the lake, which indirectly influence the congregation of fish and the vegetation density (refer section 4.2.2), was interpreted to be the most important factor in determining presence of otters in Periyar lake. These areas were characterized by a slope of less than 5 degrees and low water depth and extend over a few meters, and offered an excellent foraging ground for otters. Dark humus rich substratum is another peculiarity of these areas. As Kruuk (1995) had pointed out otters will be able to sustain themselves only if they are able to consume their food with least foraging expenses. So the areas, which offer most dependable food resource are the ones, which the otters appear to prefer.

Otters avoided the stretches of the reservoir, which were deep and wide where the physical constraints of the animal to take deeper dives, hindered their hunting ability. The animals equally avoided areas with sparse vegetation, which offered no shelter to them. The importance of vegetation cover has been suggested previously for smooth coated otters by Melisch *et al.* (1996), Hussain and Choudhury (1995, 1997) for spotted-necked otters and cape clawless otters by Rowe-Rowe (1992) and Procter (1963). The virtual absence of otters from a section of the river where the bank side vegetation was very poor, was described by Kruuk and Goudswaard (1990), while investigating the reasons for decline of otters in parts of Europe.

Human disturbance did not seem to affect the distribution of the otters, instead a positive association of otters and human presence was observed in Periyar Tiger Reserve. As the fishermen folk are concentrated around areas of high fish density, it is natural that otters have no other choice other than to exist in the same area. Often they raid fishing

nets. Even though the otters damage the nets and steal fish from the fishermen's catch, the conflict is negligible because of the increased awareness of the people towards conservation after the implementation of the ecodevelopment project.

5.3 General conclusions about habitat selection from this study

At first glance, otter habitat appears to be extremely variable. Detailed studies suggest that otters are very catholic for their taste with regards to where they live, swim, hunt and rear their offspring (Kruuk, 1995). However the large variability is deceptive; within this range of landscape inhabited by otters, actual living space is much more confined. Many of the landscape features are only non-essential tapestry behind the stage where everything happens. The success of a study relies on understanding the living space of otters in its true sense.

Narrowing down from the landscape level to living space, habitat of otters could be characterized as a narrow strip on either side of the interface between water and land, where food is acquired in the cold, watery environment of one side, and recovery from the costs borne from this exposure takes place on the other *i.e.* land (Kruuk, 1995).

The preference of shallow strip of water for foraging by otters may be because of two reasons. Firstly fishing at depth extracts its energetic toll from otters. Second reason could be that ability of the prey to escape is more in deep waters. In mouths of streams, too many factors favor the otters. The low depth and high congregations of fish populations in such areas because of rich food availability provide otters with easy food with minimum energy input.

Otter is fairly clumsy on land and therefore it is highly vulnerable to predators whereas in water it can move fast but loses body temperature very rapidly (Kruuk, 1995). These inherent limitations are countered by high intake of food to replenish the greater energy burnt to keep itself warm and by frequent grooming on land to dry the fur and heating up of the body. So otters will be able to sustain themselves only when food is available in plenty and it could be extracted with least effort. The other essentials of the life of otters like shelter and grooming places are only selected from what is available.

Further more the probability of otter occurrence in a stretch could be predicted using number of streams and rockiness of an area with an accuracy of 95.71% using logistic regression model strongly supporting the findings discussed above (refer section 4.2.3)

5.4 Holts of otters

During the reconnaissance conducted around the Periyar reservoir in June, 2000, otters were found using a holt, which was dug under a fallen tree. Five months later when the study was taken up in mid November, it was found that the previous den was not in use. Besides, one more abandoned holt was also found a few hundred meters from the first one. The second one was not there during the reconnaissance survey. During the commencement of this study in November it was found that the otters were using a third holt, which was near the first two. In a study along the Chambal river Hussain (1993) found that a group of otters used six to seven holts, shifting from one holt to others, to avoid prey depletion in an area.

The water level in the lake fluctuates from about 110 feet to above 130 feet in a year (Dr.Veeramani Pers comm.). The fluctuating water has caused development of a zone without any tall vegetation and this zone has developed as meadow. In areas of lower slopes, the distance from the water level to the vegetation often extends up to a few hundred meters. In such areas the threat to otter is high as otters are not that agile on land and they seemed to be very cautious, while moving through these areas. They seemed to feel secure in areas where, the distance between the water and vegetation is smaller so that they can immediately enter the thick undergrowth of either *lantana* or elephant grass, where it is virtually impossible for any animal other than elephants to venture through. The mean distance to the escape cover from the water was found to be 18 meters with a minimum of 1 meter and a maximum of 30 meters in the denning areas.

Some times the otters spend whole night in areas where there is no holt. This stray behavior has been observed three times. This was observed in the noon time also when the temperature was a little higher than usual. All these temporary areas were explored after the otters had left, and there was no digging or removal of soil, instead there was just a cleared area in between the tall grasses. This clearly proves the importance of thick under growth for otters.

5.5 Grooming and spraint sites of otters

Otters showed site fidelity for grooming and sprainting sites. In every foraging area they visited the same grooming site in all the foraging events and deposited the spraint in the same spraint site. Some times such sites will be submerged following the

rains. Surprisingly they started using the same site once the water receded. Similar site fidelity sites by Eurasian otter have been noted by Kruuk (1995) in Scotland.

The selection of sandy substratum for grooming may be because it is more dry and thus absorbs moisture very fast. The physical comfort also matters here. The reason why the otters selected grooming places around some solid objects may be that it would offer them some protection by not getting noticed easily as against basking in open areas.

5.6 Food habits of otters

The present study reveals that fish constitutes 96% of the diet and the otters go mostly for small and medium sized fish (5-15 cm). Since the larger fish are more difficult to catch than smaller ones (Erlinge 1968, Rowe- Rowe, 1997) they were targeted or eaten opportunistically. In Periyar, the otters have enough opportunity for an intentional opportunistic predation on bigger fish. They used to steal fish from the nets of fishermen. Spraints, which showed remains of bigger fish, were all collected from the areas where the local fishermen were active.

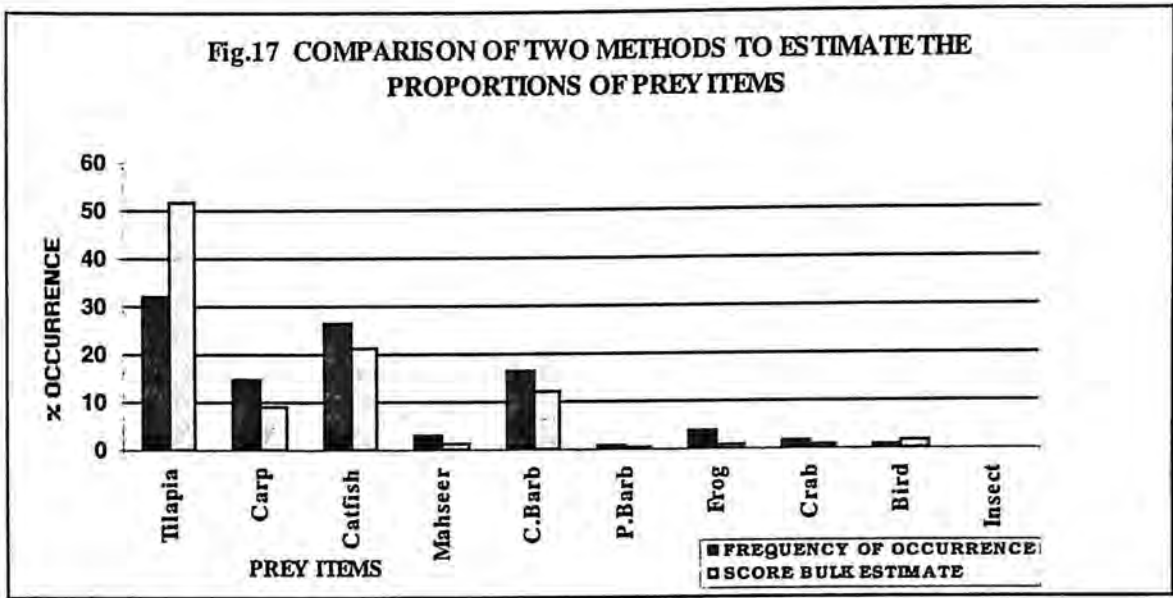
The bigger fish like Mahseer and European carp would be making a much greater contribution to the otters' food than appears at first sight. This phenomenon would be easily overlooked if we assessed the diet from the spraints alone because with the large fish, disproportionately few bones are consumed (Kruuk, 1995).

On two occasions the remains of a large beetle (Coleoptera), possibly Rhinoceros beetle was recorded in the otter scat. This is insignificant in terms of the food eaten and it is omitted from consideration as it has most likely been ingested by accident, possibly from the stomach of the major prey.

Birds formed an important secondary item in the diet of the European otter and water birds were usually the most common prey (Perrin and Carrugati, 2000). In Periyar, the cormorants, which nest on the dead trees standing in the water, make nests on really unstable branches. The chicks sometimes fall into the water (Personal observation) and otters, whenever they encounter such birds, would kill and feed on them. On two occasions remains of feathers and bones and feet of some *Phalacrocoracid* was recovered from the otter scat.

Otters are not sufficiently agile to regularly catch prey on land and predation on mammals and birds likely reflects opportunism rather than focused hunting (Perrin and Carugati, 2000). During this study, no predation of mammals by otters was noted.

Looking at the diet composition of otters in Periyar, two out of the first five major food items, are exotic fish (Tilapia and European carp), which got introduced into the lake about 10-15 years ago (Local fishermen Pers. comm). This points fingers to the fact that the multiplication rate of these exotic fish is much faster and they are replacing the indigenous fish. The seasonal differences in overall proportions of fish in diet and the proportions of the major fish species may be due to either availability and/or to the preference of otters. The observed higher intake of catfish during lower water levels in Periyar may be due to the increased ability of otters to exploit more areas, which became shallow during periods of low levels of water. At lower water levels, the otters engaged in patch fishing mostly, wherein they hunted in a relatively small patch of water and did not range widely for foraging. The most frequently used method for estimating the proportions of different prey items, the 'frequency of occurrence method' has been criticised widely for its inherent problems (Jacobson and Hanson, 1996). Here, the presence of a single item, for example a single lateral spine of catfish will be weighted the same as the presence of a number of catfish spines in the spraint. This would lead to under-estimation of major prey items and over-estimation of minor items (Mason and MacDonald, 1986; Wise *et al.*, 1981). From Figure (17) it is clear how the major prey items are under-estimated and the minor ones are over-estimated. The feeding trials conducted elsewhere (Jacobson and Hansen, 1995) recommend that the 'score bulk estimate' give a better estimate than any other method.



Ideally, the linear relationship between vertebrae length/ eyeball diameter should be separately calculated for different species. But as it was beyond the scope of this study, and because of the difficulties in differentiating the species based on the characteristics of the vertebrae alone, all the size classes of different species were pooled together for modeling. The species, which have an exceptional length to breadth ratio, for example eels (*Mastacembelus* spp.) might present some problems to the model. But this species is not an abundant fish in Periyar.

In the assessment of fish body size from the remains of body parts in the scat, the vertebrae length was preferred over eyeball diameter in this study. The vertebrae are invariably present in the scat however small or big the fish is but eyeball gets crushed up most of the times. Also the vertebrae suffer less damage in passage through the intestine, they are identifiable to a particular region of the fish, and are often identifiable to species or genus of the fish (Wise, 1980). The length of the vertebrae does not vary considerably along the vertebral column. Vertebrae 'length' was preferred over 'width' since projections from the lateral surface of the centra caused considerable variation in length measurements (Wise, 1980).

The estimated fish lengths were tested for accuracy with the actual fish lengths and there was no significant difference between both. The size class of fish that is most represented in otter scats of this study is 5 to 15 cm. Studies conducted elsewhere (Jacobson and Hansen, 1996; Wise, 1980) show that Eurasian otters go for Cyprinids of 9

to 18 cm class, Persids of 6 to 12 cm trouts of 6 to 9 cm and eels of 24 to 30 cm class mostly, which is quite similar to this study.

The habitat of otters is widely varied and they have been successful in exploiting various kinds of prey in each system. This may be is the reason why the changes in the proportions of prey items of otters have often attributed to changes in prey availability, even when this variable was not actually measured (Pardini, 1998). But certainly, availability decides the choice of the prey. In the case of Periyar, a crab was never encountered in the lake, subsequently there were hardly any crab remains in the scats that were collected from the lake. But in the case of river where there are numerous rocks and the water is shallow, the crab density is very high and that is very well reflected in the scat.

In the presence of a competitor there should be a kind of partitioning for both species to co-exist. In the case of Periyar the cormorants and darters can be viewed as potential competitors for the otter. The size classes of the fishes that the otters and cormorants, especially the large cormorants feed on, overlaps. When the otters were seen to feed on 5-15 cm long fish, the large cormorants were seen to feed on below 15 cm long Tilapia fishes (measured from the regurgitated fish by the cormorants). But if you look at the low population of the cormorants and the amount of fish in the lake, there seems to be no threat to the otters.

The accidental introduction of exotic species like Tilapia (*Oreochromis mossambicus*) and European carp (*Cyprinus caprio*) have likely caused a decline in the exploitation of the native fish species by the otters but they have replaced the native fishes by means of their rigorous growth capacity. This could be one of the strongest reasons for the untimely extermination of many of the indigenous fish species. Through the years Periyar lake stream system has lost as many as 16 species of fishes which includes 3 *Anguillids*, 2 *Bargids*, 8 *Cyprinids*, 1 *Gobiid*, 1 *Mastecembalid*, 1 *Notopterid* and 1 *Schillbeid* members (Arun, 1999). Out of the 27 species of fish reported from Periyar, otter used only six species. Periyar barb (*Barbus micropogon periyarensis*) which is reported only from Periyar Tiger Reserve, was found to be used by otters very rarely (1%).

Among the fish present in Periyar lake river system (Appendix-I), all loaches, except the Malabar loach (*Lepidocephalus thermalis*) are endemic to Western Ghats and one among them is threatened (*Travancoria jonesi*). Two snake heads present in the system are threatened and very seldom found in the catches. Among the 13 *Cyprinids*, 8

were endemic to Western Ghats, of which three are exclusively endemic to Periyar lake and streams (*Lepidopygopsis typus*, *Crossochelius periyarensis*, and *Barbus micropogon periyarensis*). Other threatened fishes in the system are *Glyptothorax madraspatanam* and *Mastacembelus armatus* (Arun, 1999).

Out of these threatened fish only one, *Barbus micropogon periyarensis* was found in otter diet in minute quantity (1%). This can be because of the low abundance of these fish in the lake.

5.7 Constraints during the study

5.7.1 Quantification of the fish abundance in the lake

Despite the efforts made using all possible methods the quantification of the relative abundance of the different species and size classes of fish did not yield good result. The hidden tree stumps in the lake hinder the use of nets and very often the net got damaged whenever it was thrown. What is understood from the fish sampling efforts is that the fish from a water body can be sampled by using a combination of many methods making use of the knowledge of local communities. The local fishermen know that in which area and at what time of the day to put their nets for which fish. The next day following the rain all the fishermen use the 2 x 2-inch gill nets because the bigger carps come to the shallow waters just after the rains.

5.7.2 Relationship between eyeball diameter and the stratum that the fish species occupies

The relative eye diameter of the bottom living fishes like catfish (*Heteropneustes fossilis*), spiny eel (*Mastacembelus armatus*) are very low and others like giant danio (*Danio aequipinnatus*), Black line Rasbora (*Parluciosoma daniconius*), Malabar Baril (*Barilius bakeri*), European carp (*Cyprinus caprio communis*), mahseer (*Tor khudree*) etc. have relatively larger eyes. This is an indication that the fish of the bottom strata use other sense organs than eye for locating food whereas the fish of the upper strata use eyesight. The problem of confusing the eyeball of smallest individual of the upper strata fish with that of the largest individual of lower strata fish could be avoided by proper and precise identification of the species from the characteristics of the eyeball.

3. Problems of unexpected rains

Rains washed out many of the evidence of otter from the lake banks making it difficult to ascertain whether otters used those stretches. This probably affected the sampling in this study by giving no evidence of otter in stretches where they were expected to be present. So ideally the average time lag between two successive visits to the same area by otters should have been looked for and this gap should have been given before starting the sampling again.

5.8 Conservation implications of the study

The ability of otters to adapt to a wide range of habitats is well established (Kruuk, 1995). But it is also a fact that they will not survive in water bodies in which the prey population is depleted because of excessive exploitation and contamination by agricultural pesticides (Mason and Macdonald, 1986; Melisch *et al.*, 1996; Hussain, 2000). Periyar Tiger Reserve is a unique area where this threat of pollution does not exist as the entire Mullayar and Periyar catchments are well inside the Tiger Reserve. Not many such areas are left in India, which has no immediate threat. So the otter population in Periyar Tiger reserve should be considered as the precious possession of the park.

In the coming millennium, demands on water resources will continue to increase as will the level of pollutants. This will put additional pressures on existing wetlands. One possible threat to Periyar that is looming in the horizon is the issue of raising of the water level of the dam. If the water level is increased, almost all the holts far located will be submerged. As November to March is the littering time of otters a sudden rise in water level during this period might kill all the pups of the year.

The Otters are consuming large proportion (60%) of exotic fishes in the Periyar lake (tilapia and golden carp) fishes. These exotic fish species have the potential to replace all the indigenous species. The Otters are in a way controlling the population size of this species by consuming them. In a condition where there are no otters in the lake Periyar might fast loose out many of the native fish species at much faster rate.

6.0 REFERENCES

- ADRIAN, M.I., WILDEN, W. & DELIBES, M. (1985). Otter distribution and agriculture in south-western Spain. In XVIIth congress of international union of game biologists. Brussels. September 17-21: 519-526.
- ARUN, L.K. (1999). Fish Community Assemblages of Periyar Tiger Reserve. Report submitted to Kerala Forest department.
- BAS, N., JENKINS, D. & ROTHERY, P. (1984). Ecology of otters in Northern Scotland. V. The distribution of otter (*Lutra lutra*) faeces in relation to bankside vegetation on the river Dee in summer 1981. *J. Appl. Ecol.* 21: 507-513
- BLANDFORD, (1889). *Mamm. Brit. Ind.* (Appendix) p. 601
- CHAMPION, H.G. & SETH, S.K. (1968). A revised survey of the forest types of India. Manager of Publications, Delhi.
- DAVIS, J.A. (1978). A classification of otters. In *Otters*: 14-33. Duplaix, N. (Ed). Switzerland; IUCN Publ. New Ser.
- DESAI, J.H. (1974) Observations on the breeding habits of the Indian smooth otter (*Lutrogale perspicillata*) in captivity. *Int. Zoo Yearbook.* 14: 123-124.
- DE SILVA, P.K. (1997). Seasonal variation of the food and feeding habits of the Eurasian otter (*Lutra lutra*) (Carnivora: Mustelidae) in Sri Lanka. *Journal of South Asian natural History.* 2 (2): 205-216.
- DUPLAIX, N. & DAVIS, J.A. (1981) *Lutra perspicillata*. In. CITES identification manual. Volume I, Mammalia. Secretariat of Convention, IUCN, Gland, Switzerland.
- DURBIN, L.S. (1993), *Food and habitat utilization of otters (Lutra lutra) in a riparian habitat*. PhD thesis. University of Aberdeen.
- DURBIN, L.S. (1996) Some changes in the habitat use of a free-ranging female otter *Lutra lutra* during breeding. *J. Zool. (Lond.)*. 240(4): 761-764.
- DURBIN, L.S. (1998). Habitat selection by five otters *Lutra lutra* in rivers of northern Scotland. *J. Zool. Lond.* 245: 85-92.
- ERLINGE, S. (1968). Food studies on captive otters (*Lutra lutra* L.). *Oikos*, 19, 81-98.
- ESTES, J.A., JAMESON, R.J. and RHODE, E.B. (1982). Activity and prey selection in the sea otter: Influence of population status on community structure. *American Naturalist*, 120: 242-58.
- FAIRLEY, J.S. (1972). Food of otters (*Lutra lutra*) Co. Galway, Ireland and notes on other aspects of their biology. *J. Zool. Lond.* 166: 469-473.
- FERNANDO, ROSAS, C. W., JANSEN, ZUANON, A. S. & SARAH, K. CARTER, (1999). Feeding ecology of the Giant otter, (*Pteroneura brasiliensis*)
- FOSTER-TURLEY, P.; MACDONALD, S. & MASON, C. (Eds) (1990) *Otters. An Action Plan for their Conservation*. IUCN/SSC Otter Specialist Group, 126p.

- FOSTER, TURLEY P. (1992) Conservation aspects of the ecology of Asian small-clawed and smooth otters on the Malay Peninsula. *IUCN Otter Specialist Group Bulletin*. 7: 26-29.
- GASTON, A.T.(1975). Methods for estimating bird population. *J. Bombay. Nat. Hist. Soc.* 15 (2);273-283.
- GRIFFITHS, D.(1975) Prey availability and food of predators; *Ecology* 56: 1209-1214
- GRIMMET, R., INSKIPP CAROL & INSKIPP TIM (1999). Pocket guide to the birds of the Indian subcontinent. Oxford university press.
- HAQUE, N. & VIJAYAN, V.S. (1995) Food habits of the Smooth Indian Otter (*Lutra perspicillata*) in Keoladeo National Park, Bharatpur, Rajasthan (India). *Mammalia*. 59(3): 345-348.
- HARRIS, C. J., 1968. *Otters: A Study of the Recent Lutrinae*. Weidenfeld & Nicolson, Lond., 397pp.
- HODGSON.(1839).*Journ. As. Soc. Beng.vii*, p.320,1839
- HUSSAIN, S.A. (In press) Otters. In Mammals of South Asia.
- HUSSAIN, S.A. (1999); Otter conservation in India *In: ENVIS Bulletin - Wildlife and Protected Areas*. 2(2) : 92-97
- HUSSAIN, S.A. (1998) Conservation status of otters in the Tarai and lower Himalayas of Uttar Pradesh, India. *Proceedings of the VII International Otter Symposium*, March 13-19, 1998, Trebon, Czech Republic.
- HUSSAIN, S.A. (1996) Group size, group structure and breeding in smooth-coated otter *Lutra perspicillata* Geoffroy (Carnivora, Mustelidae) in National Chambal Sanctuary, India. *Mammalia*. 60(2): 289-297.
- HUSSAIN, S.A. (1993). Aspects of the ecology of Smooth-coated Indian Otter *Lutra perspicillata* in National Chambal Sanctuary. *Ph. D. Thesis, Aligarh Muslim University, Aligarh*, 206 pp.
- HUSSAIN, S.A. & CHOUDHURY, B.C.(1995) Seasonal movement, home range, and habitat use by smooth coated otters in National Chambal Sanctuary, India. *In: Proceedings VI. International Otter Colloquium, Pietermaritzburg 1993 (Reuther C & Rowe-Rowe D, eds); Aktion Fischotterschutz Hankensbuettel, Habitat*. 11: 45-55.
- HUSSAIN, S.A. & , CHOUDHURY, B.C. (1997) Status and distribution of smooth-coated otter *Lutra perspicillata* in National Chambal Sanctuary. *Biological Conservation*. 80:199-206.
- HUSSAIN, S.A & CHOUDHURY, B.C.(1997a) Feeding ecology of smooth-coated otter *Lutra perspicillata* in National Chambal Sanctuary. *Proceedings of the Symposia of the Zoological Society of London, Behaviour and ecology of riparian mammals*, No.71.
- JACOBSON, L. & HANSEN, H.M. (1996) Analysis of otter (*Lutra lutra*) spraints: Part 1: comparison of methods to estimate prey proportions; Part 2: estimation of the size of prey fish. *J. Zool. (Lond.)*. 238(1): 167-180.

- JENKINS, D. & HARPER, R.J. (1980). Ecology of otters in Northern Scotland II . Analyses of otter (*Lutra lutra*) and mink (*Mustela vison*) faeces from Deeside, N.E. Scotland. *J. Zool. Lond.*, 187, 235-244.
- JENKINS, D. & BURROWS, G.O. (1980) Ecology of otters in Northern Scotland III. The use of faeces as indicators of otters (*Lutra lutra*) density and distribution. *J. Anim. Ecol.* 49:755-774
- KOEPFLI, K.P. & WAYNE (1998). Phylogenetic relationships of otters (Carnivora: Mustelidae) based on mitochondrial cytochrome *b* sequences.
- KRUUK, H., CONROY, J.W.H., GLIMMERVEEN, U. & OUWERKERK, E.J. (1986). The use of spraints to survey populations of otters *Lutra lutra*, *Biol. Conserv.* 35: 187- 194.
- JACOBSON, L. & HANSEN, H.M. (1996) Analysis of otter (*Lutra lutra*) spraints: Part 1: comparison of methods to estimate prey proportions; Part 2: estimation of the size of prey fish. *J. Zool. (Lond.)*. 238(1): 167-180.
- KRUUK, H & CONROY, J.W.H. (1987) Surveying otter *Lutra lutra* populations: A discussion of problems with spraints. *Biol. Conserv.* 41(3): 179-183.
- KRUUK, H.; MOORHOUSE, A. (1990) Seasonal and spatial differences in food selection by otters (*Lutra lutra*) in Shetland. *J. Zool. (Lond.)*. 221: 61-637
- KRUUK, H., and GOUDSWAARD, P.C. 1990. Effects of changes in fish populations in Lake Victoria on the food of otters (*Lutra maculicollis* and *Aonyx capensis*). *Afric. J. Ecol.*, 28: 322-329.
- KRUUK, HANS. KANTSANASAKA, B., WANGHONGSA, S. & O' SULLIVAN, S. (1993). Identification of tracks and other sign of three species of otter *Lutra lutra*, *L. perspicillata* and *Aonyx cineria* In Thailand. *Nat. Hist. Bull. Siam. Soc.*, 41, 23-30.
- KRUUK, H. & CARSS, D.N. , CONROY, J.W.H. & DURBIN, L. (1993a). Otter (*Lutra lutra*) numbers and fish productivity in rivers in north-east Scotland. *Symp. Zool. Soc. Lond.* No. 65: 171-191.
- KRUUK H; KANCHANASAKA B.; O'SULLIVAN, S. & WANGHONGSA, S. (1994) Niche separation in three sympatric otters *Lutra perspicillata*, *L. lutra* and *Aonyx cinerea* in Huai Kha Khaeng, Thailand. *Biological Conservation.* 69(1): 115-120.
- KRUUK, H. (1995) *Wild otters - Predation and populations*. Oxford University Press. 287pp
- MACDONALD, S.M. & MASON, C.F. (1983) Some factors influencing the distribution of otters (*Lutra lutra*). *Mammal Rev.* 13(1): 1-10.
- MACDONALD, D.W. 1983. The ecology of carnivore social behavior. *Nature.* 301: 379-
- MACDONALD, S.M. & MASON, C.F. (1980) Observation on the marking behaviour of a coastal population of otters. *Acta Theriol.* 25(19): 245-253.
- MARTHA, L CRUMP N. & J. SCOTT in Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians Edited by HEYER, W. RONALD, DONNELLY,

- A. MAUREEN, McDIARMID, W. ROY, HAYEK, C. LEE and FOSTER, S. MERCEEDS; Smithsonian Inst. Press. page 84-92.
- MASON, C.F. & MACDONALD, S.M. (1986) *Otters - Ecology and Conservation*. Cambridge University Press, Cambridge, 236 pp.
- MELISCH, R. & FOSTER-TURLEY, P. (1996) First record of hybridisation in otters (Lutrinae: Mammalia), between smooth-coated otter, *Lutrogale perspicillata* (Geoffroy, 1826) and Asian small-clawed otter, *Aonyx cinerea* (Illiger, 1815). *Der Zoologische Garten*. 66(5): 284-288.
- MELISCH, R., KUSUMAWARDHANI, L. ASMORO, P.B. AND LUBIS, I.R. (1996a). The otters of west Java – a survey of their distribution and habitat use and a strategy towards a species conservation programme. PHPA/Wetlands International – Indonesia Programme, Bogor
- MELQUIST, W.E. & HORNOCKER, M.G.(1983). Ecology of otters in west central Idaho. *Wildlife Monographs*. 83. 60pp.
- MELQUIST, W.E. & DRONKERT, A.E.(1987). River otter. In *Wild Furbearer Management and Conservation in North America* (ed. M. Novak, J.A. Baker, M.E.Obbard, and B. Malloch), pp. 627-41, Ministry of Natural Resources, Ontario.
- MORRISON, MARCOT, M.L. B.G.& MANNAN, R.W. (1992). Wildlife-habitat relationships : concepts and applications. pp. 227-335.
- NOLET, B.A. & KRUIK, H. (1998). Grooming and resting of otters *Lutra lutra* in a marine habitat. *J. Zool. Lond.* 18: 441-460.
- PARDINI,R. (1998) Feeding ecology of the neotropical river otter (*Lontra longicaudis*)in an Atlantic forest stream, South-Eastern Brazil. *J. Zool. (Lond.)* 245: 385-391
- PERRIN, M.R. & CARRANZA D'INZILLO ILARIA, 2000. Habitat use by spotted necked otters in KwaZulu-Natal Drakensberg, South Africa. *S. Afr. J. Wildl. Res.* 30(1).
- PERRIN, M.R. & CARUGATI, C. (2000) Food habits of co-existing Cape clawless otter and spotted necked otter in the KwaZulu- Natal Drakensberg, South Africa. *S. Afr. J. Wildl. Res.* 30 (2):85-92.
- POCOCK, R.I. (1921) On the external characters of some species of Lutrinae (otters). *Proc. Zool. Soc Lond.*, 1921:535-546
- POCOCK, R.I. (1941) *The Fauna of British India including Ceylon and Burma. Vol. II*. Taylor & Francis, London, 503 pp.
- POHLE, H., 1919. Die Unterfamilie der Lutrinae. (Eine systematisch-tiergeographische Studie an dem Material der Berliner Museen.). *Archiv for Naturgeschichte*, 85A: 1-259.
- PRATER, S.H. (1971) *The Book of Indian Animals*. Eleventh Impression. Bombay Natural History Society. Oxford University Press, Calcutta, Chennai, Delhi, Mumbai. pp 96-105.
- PROCTER, J.1963. A contribution to the natural history of the spotted necked otter (*lutra maculicollis*) in Tanganyika. *E. Afr. Wildl. J.* 1: 93-113.

- POND, C (1985). Body mass and natural diet as determinants of the number and volume of adipocytes in Eutherian mammals. *Journal of Morphology*, 185: 183-93
- REUTHER, CLAUS (1991) Otters in captivity - a review with special reference to *Lutra lutra*. *Proceedings V. International Otter Colloquium, Hankensbuettel, 1989. Claus Reuther and Ralf Rochert, editors. Habitat (Aktion Fischotterschutz). No. 6. p. 269-307.*
- ROWE-ROWE, D.T. (1977) Food ecology of otters in Natal, South Africa. *Oikos*, 28:210-219.
- SANDELL, M. (1989) Ecological energetics, optimal body size and sexual size dimorphism: A model applied to the stoat, *Mustela erminea* L. *Funct. Ecol.* 3(3): 315-324.
- SATYANARAYANA, D. (1997) Studies on smooth-coated otter (*Lutra perspicillata* {I. Geoffroy}) in two ecologically different habitats in south India with special emphasis on its conservation. *Ph.D. thesis, Osmania University.*
- SCHOENER, W.T. (1971) Theory of feeding strategies. *Annual review of Ecology and systematics* 2: 369-405
- SIMPSON, G.G. (1945) The principles of classification and a classification of mammals. *Bull. Am. Mus. Nat. Hist.* 85: 1-350.
- SIVASOTHI, N.L & BURHANUDDIN, H.M.N. (1994). A review of otters (*Carnivora: Lutrinae*) in Malaysia and Singapore. *Hydrobiologia* 285: 151-170.
- SHANUBHOGUE, A. & A.P. GORE (1987) using logistic regression in ecology. *Current Science.* 56 (18): 933-935
- SHARIFF, S.M. (1984). Some observations on otters at Kuala Gula, Perak and National Park, Pahang. *The J. of Wildlife and Parks (Malaysia)* 4:20-24
- SOKOLOV, I.I. (1973). Evolutionary trends and the natural classification of otters (*Lutrinae, Mustelidae, Fissipedia*) *Bull. Mosc. Nat, Soc.* 9: 204-215.
- TILER, C.; EVANS, M.; HEARDMAN, C. & HOUGHTON, S. (1989) Diet of the smooth Indian otter (*Lutra perspicillata*) and of fish eating birds; a field survey. *J. Bombay Nat. Hist. Soc.* 86(1): 65-70.
- UMAPATHY, G. (2000). Food habits and activity pattern of the common otter (*Lutra lutra*) at Pichavaram, Tamil Nadu, South India.
- WALKER, E.P. (1975). *Mammals of the world*. Third edition. Baltimore, Johns Hopkins Press.
- WAYRE, P. (1978) The status of otters in Malaysia, Sri Lanka and Italy. *In: OTTERS (N. Duplaix Ed.), Proc. 1st Working Meeting Otter Spec. Group 1977, IUCN Publ. New Ser.* 152-155.
- WEBB, J.B. (1975) Food of the otter (*Lutra lutra*) on the Somerset levels. *Journal of zoology, London*, 177, 486-91.
- WHITE, G.C. & GARROT, R.A. (1990). *Analysis of wildlife radio tracking data.* Academic Press Inc.

- WILLEMSEN, G. F., (1980). Comparative study of the functional morphology of some Lutrinae, especially *Lutra lutra*, *Lutrogale perspicillata* and the Pleistocene *Isolalutra cretensis*. II. *Proc. Koninklijke Nederlandse Akad. Wetenschappen*, B 83(3): 310-326.
- WISE, M.H. (1980) The use of fish vertebrae in scats for estimating prey size of otters and mink. *J. Zool. (Lond.)*. 192(1): 25-31.
- WISE, M.H.; LINN, I.J. & KENNEDY, C.R. (1981) A comparison of the feeding biology of mink *Mustela vison* and otter *Lutra lutra*. *Journal Of Zoology (London)*. 195(2): 181-213.
- WOZENCRAFT, W.C. (1993) Order Carnivora. In Wilson and Reeder, D.M. (Eds). *Mammal species of the world-A taxonomic and geographic reference*. II edition. Smithsonian Institution Press, 279-344pp.
- VAN NIEKERK, C.H., SOMERS, M.J. & NEL, J.A.J. (1998). Freshwater availability and distribution of cape clawless otters spraints and resting places along the south-west coast of South Africa. *S. Afr. J. Wildl. Res.* 28 (3): 68-72.
- VAN ZYLL DE JONG, C. G. (1991) A brief review of the systematics and a classification of the Lutrinae. In *Proc V Inter Otter Colloquium (C. Reuther and R. R chert, eds.)*. *Habitat 6, Hankensbuttel*. pp. 79-83.
- VAN ZYLL DE JONG, C. G.(1987) A phylogenetic study of the Lutrinae (Carnivora; Mustelidae) using morphological data. *Can. J. Zool.* 65: 2536-2544.
- VAN ZYLL DE JONG, C. G., 1972). A systematic review of the Nearctic and Neotropical river otters (Genus *Lutra*, Mustelidae, Carnivora). *R. Ont. Mus. Life Sci. Contrib.No*, 80: 1-104.
- ZAR, J.H. (1984). *Biostatistical analysis*. II edn. Prentice-Hall Inc., New Jersey. 718pp.

Appendix I. The fish species recorded from the Periyar lake and stream system

No	Scientific name	Common name	Local Name	Body size (Cm)	Scale Size
Aplocheilidae					
1.	<i>Aplocheilus lineatus</i> Bloch	Top minnow	Manathukanni	7	Fairly large
Balitoridae					
2.	<i>Bhavana australis</i>	Western Ghat loach	Kalnakki	9	Small
3.	<i>Nemacheilus denisonii</i>	Denison's loach	Koitha	5	Small
4.	<i>Nemacheilus guentheri</i>	Guenther's loach	Koitha	5	Small
5.	<i>Nemacheilus keralensis</i>	Kerala loach	Koitha	3.5	Small
6.	<i>Travancoria jonesi</i>	Travancore loach	Kalsravu	8	Small
Channidae					
7.	<i>Channa gachua</i>	Brown snake head	Vatton	35	Large on head
8.	<i>Channa striatus</i>	Striped snake head	Varal	35	Large on head
Cilichlidae					
9.	<i>Oreochromis mossambicus</i>	Tilapia	Tilapia	15	Large Cycloid
Cobitidae					
10	<i>Lepidocephalus thermalis</i>	Malabar loach	Manalaron	8	small
Cyprinidae					
11	<i>Barilius bakeri</i>	Malabar baril	Pavukan	5	Small
12	<i>Crossochilus periyarensis</i> ♣	Periyar latia	Karimbachi	10	Small
13	<i>Cyprinus caprio communis</i>	European carp	Gold fish	50	Large
14	<i>Danio aequipinnatus</i>	Giant danio	Pavukan	15	Medium
15	<i>Garra maclellandi</i> Jerdon	Cauvery garra	Kallotti	17.5	Medium
16	<i>Garra mullya</i> Sykes	Common sucker	Kallotti	17	Medium
17	<i>Lepidopygopsis typus</i> Raj ♣	Periyar trout	Brahmanakanda	25	Medium
18	<i>Gonoproktopterus curmuca</i>	Curmuca barb	Kooral	35	Large
19	<i>Puntius ophicephalus</i> Raj	Channa barb	Eettilakanda	16	Small
20	<i>Barbus micropogon periyarensis</i>	Periyar barb ♣	Kariyan	60	Large
21	<i>Puntius fasciatus</i> Jerdon	Tiger barb	Karutha kanda	5	Small
22	<i>Parluciosoma daniconius</i>	Blackline rasbora	Kananjan	10	Small
23	<i>Tor khudree</i> Sykes	Mahseer	Kuyil	50	Large
Mastacembalidae					
24	<i>Mastacembelus armatus</i>	Spiny eel	Arakan	60	Smallest
Heteropneustidae					
25	<i>Heteropneustes fossilis</i>	Stinging catfish	Kari	30	Smallest
26	<i>Ompok bimaculatus</i>	Butter catfish	Chottavala	40	Smallest
Sisoridae					
27	<i>Glyptothorax madraspatnm</i>	Travancore sucker	Kalsravu	45	Smallest

♣ Endemic to Periyar,