

**Riverine habitats under changing land-use: A resource selection study of
Smooth-coated otter (*Lutrogale perspicillata*, Geoffroy Saint-Hilaire, 1826)
in Kabini River and tributaries**

**Thesis submitted for the partial fulfillment of
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CERTIFICATE

This is to certify that Mr. Aneesh C.R. has carried out original research titled "Riverine habitats under changing land-use: A resource selection study of Smooth-coated otter (*Lutrogale perspicillata*, Geoffroy, 1826) in Kabini River and tributaries" for partial fulfilment of Master of Science in Wildlife Science from Saurashtra University, Rajkot. The study was carried out under our supervision from December 2014 to May 2015. We hereby certify that this work has not been submitted for any other degree to any other university.

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SUMMARY

Habitat selection is an important part of the ecology of semi-aquatic mammals since they are highly specialized animals. River otters are especially vulnerable animals in the present situation due to increasing human disturbance, altering riparian vegetation, damming and channelization in river basins. This study looked at the effect of land-use pattern on the habitat selection by otters with special reference to smooth-coated otter (*Lutrogale perspicillata*) in Kabini river, South India. The study showed fewer presence sites of smooth-coated otter inside the protected areas, due to naturally unsuitable habitats for the species, with shallower stream habitats in hilly terrains. These sites were occupied by Asian small-clawed otters (*Aonyx cinerea*). However the sign intensity was more in presence locations inside protected area and least in urbanized area. The detailed study in presence only sites revealed that anthropogenic disturbance, primarily increasing human presence, fishing and grazing is the most important factor affecting selection of habitat by smooth-coated otter. The intensity of usage of habitat is also governed by disturbance factors. Other environmental factors are only secondary to disturbance factors affecting habitat selection which includes a set of factors pertaining to land and water summarized as slow, deep waters with intact bank cover and/or grassy banks with close escape cover distance. Prey fish species of medium size class (21-40cm) affects the habitat selection. Although Asian small-clawed otter and smooth-coated otter occur in same river system, there is a clear niche partitioning between these two species. The study also looked at the effect of dams on otters which revealed that altered flow is the primary factor negatively affecting otter habitats. Yet flow regimes are mostly compensated due to more streams joining the main river channel. Increasing degree of habitat disturbance in different land-uses seems to negatively influence the fluvial functionality which is positively associated with otter habitat. The combined effect of isolation due to reservoir and increasing disturbances in downstream area pushes smooth-coated otters to select habitats upstream that are marginal to them and more suitable for small-clawed otters.

1.1 INTRODUCTION

Everything about river otters melts down to one word- 'semiaquatic'. 25 million years ago a weasel that went down to fish from a river never came back, settling down the bank he became the first river otter (van Zyll, 1972). Though being an otter wasn't easy; neither being 'water-born' nor being as smart as its Mustelid cousins on land anymore, its life was tied to a river and the close neighborhood. Although the first ancestral otter might have been just a good swimmer, it became obligatory to 'swim' later. This obligatory aquatic living in otters and other eutherian mammals such as insectivores, rodents, cetaceans, pinnipeds, and sirenians has independent origin in evolution (Gittleman, 1989). There is 'unevenness' even in being called as aquatic since all these animals have a varying degree of 'interest' in water. The otter falls somewhere in the middle, and not with the easiest of the strategies for life.

Semi-aquatic mammals are essentially adapted for a life in water, and we expect the otter (and a carnivore) to be up to par. But a river otters' body seems to be in perpetual fight with its own niche. Nature rarely invents new structures of adaptation, and in case of otter it seems that there has just been modification on its basic 'carnivore design' to suit an aquatic life (Chanin, 1985). The biggest taxing on them is thermoregulation. The average normal body temperature of a mammal is 37-39°C. Otters face the biggest challenge to maintain this body temperature. Other semi-aquatic mammal like the Platypus, with a body temperature of just 32°C, we expect that this thermoregulatory burden would be lightened on otters, which is not the case (Kruuk, 2006; Dunstone, 2007). They appear to be stuck somewhere in evolution, between being a carnivore and a fish-eater, between land and water, between a niche and needs.

If an animal is more or less defined by its habitat, then an otter habitat is a curious thing to look at. The habitat of an otter ranges from lakes and bogs to rivers to forested streams to reservoirs to estuaries, and from sea level up into mountain peaks (Kruuk, 2006, Mason & McDonald, 1986). But for a fact, they are always around a watercourse. In case of river otters, in a habitat that is more or less linear and not so great in extent (Melquist & Hornocker, 1983) one won't expect them to be very choosy. In fact, these specialized carnivores are one of the choosiest when it comes to habitat (Mason & McDonald, 1986; Foster-Turley, 1992; Hussain, 1993; Kruuk, 1994), probably because of the same reason that the available physical space is less

when compared to land. But selecting a habitat, can be extra tricky for otters, for a number of reasons, but basically because they have constantly been shuttling between terrestrial and aquatic environments (Dunston, 2007).

An issue that is innate or lies within an otter habitat is the striking difference between the two medium that an otter lives in. Interestingly, half of the otter habitat is moving and half of it is static (though the use of the term 'half is debatable). The aquatic part of its habitat is highly dynamic while the other is more or less stable. The activity of an otter, may it be daily or seasonal vary to large extent (Mason & McDonald, 1986, Hussain, 1993, Erlinge, 1967). But, the pattern remains the same-land to water and vice versa. And the activity itself is divided into two-those in water and that on land. Otters are aquatic predators (piscivorous or invertebrate feeders) while for thermoregulatory needs they depend on the land (except sea otter) (Estes, 1974 & Gittleman, 1989). So the critical activities of their life are split while they are closely related. The problem arises when one tries to think which of the two (land or water) is more critical for otter survival.

Energetic studies, under experimental condition has given some light on how the otter manages to be 'semiaquatic' (Kruuk, 2006). But how exactly this happens in the field through the process of habitat selection? What is there in the structure of a riverine system that an otter is looking for to handle its own 'semiaquatic' nature? There has been a lot of work done on habitat selection of otters around the world of which most information available from the European countries (Kruuk, 2006; Mason & McDonald, 1986, Foster-Turley, 1992) while a few other studies are from India (Hussain, 1993; Durbin, 1998; Anoop& Hussain, 2004; Shenoy *et.al*, 2006). But few of them addressed the split in otter habitat and interpreted how an otter deals with it. It might be difficult to unwind every thread of a habitat and put them in two groups. But for an otter, a certain level choice must be existing between two mediums of its life.

The dynamicity of water and land are not the same, creating two different physical, chemical and biological spaces. Any extant amphibious creature has adapted to such dynamic environments. But how did they accomplish this remarkable feat? The question need not necessarily be towards evolution or the phylogeny. The clues might be lying left and right in their habitat. Despite that fact, the purpose and the scope of the current study is on a slightly

bigger scale, since the current study site and the species that is chosen doesn't occur under ideal conditions.

Among the three extant species of otters in India, smooth-coated otter (*Lutrogale perspicillata*) is chosen as the species to study. It's primarily a piscivorous otter that lives in diverse habitats including mangroves, rice fields, tidal stretches of rivers, estuaries, reservoirs, lakes and canals (Pocock, 1985; Prater, 1971, Sivasothi & Burhanuddhin, 1994, Hussain, 2013). Reports of occurrence of this species in Kabini River of South India were collected mostly through personal contacts since no scientific study has been conducted on them in the Kabini river before. The study was intended to document habitat use of otter on a different landscape scales. The primary objective is to 'understanding the habitat selection of smooth-coated otters under varying land uses'. The landscape under the present study is a riverine landscape; it can be translated into an area composed of interacting terrestrial and aquatic units that are directly influenced by the river such as aquatic habitats, floodplain surface, and riparian zone (Ward, 2002). In recent past there has been an increased level of land-use changes happening along Kabini river basin, mostly due to altered agricultural practices; altered riparian forests, damming and channelization pose another threat to the riverine habitats of Kabini basin (Javeed, 2009).

Clearly the two entities of the otter's life both land and water are being modified in the study site and the animal has to keep a balance between two 'sub-sets' of habitat by being a wisely choosy one. The river Kabini actually offers a different set of environmental conditions under which the otter might select the habitat or not. Rather than testing otters under laboratory conditions to understand the effect of adverse environmental conditions (Mason & McDonald, 1986) where we actually loose most of the ecological information about how the species might adapt, studying the animal under field conditions (a lot less than ideal) will yield ecological information about how the animal is doing under sub-optimal habitats (Krebs, 1994). To support otter distribution with overall environmental quality, an index called Fluvial Functionality Index (Carranza, 2012) has been used in the present study. The intention is to combine otter habitat selection with 'health' of the river to give more conservation implication for the outcome of the study.

1.2 REVIEW OF LITERATURE

Otters are members of the sub-family Lutrinae of the family Mustelidae; one of the largest family of the mammalian order Carnivora (Mason & Macdonald, 2009; Sivasothi, 1995). Other sub-families include Mustelinae (martens, stoats and weasels), Melinae (European badgers and mink), Mellivorinae (Honey badgers), Taxidiinae (American badger) and Mephitinae (skunks) (Foster-Turley, 1992; Ottino & Giller 2004; Pocock, 1941; Koepfli & Wayne, 1998). Modified for an amphibious life, otters are believed to be originated from an ancient cursorial predatory stock of Mustelinae (Pocock, 1941). The oldest fossil record is represented by the genus *Mionictis* about 20 million years ago and the closest living relative of the otter is American mink (*Mustela vison*).

Otters being inseparably tied to aquatic environments (Dunston *et.al.*, 2007; Eisenberg, 1981) are transitional forms between truly aquatic and strictly terrestrial mammals and their sustenance is dependent on this land-water continuum (Fish, 2000). This in turn has an effect on their shape, metabolism, locomotion, food and other fundamental aspects of their biology, such as foraging behaviour, social organization, survival and mortality (Kruuk, 2006; Fish, 2000). The adaptations that Lutrinae have because of the semiaquatic nature are mostly just modifications on their carnivore design (Chanin, 1985)

There are 7 genera and 13 extant species of otters worldwide, of which five are found in Asia including the sea otter (*Enhydra lutris*). Out of the 13 species most of them are freshwater dwelling, except Sea otter (*Enhydra lutris*) and Marine Otter (*Lontra felina*). Though, many species have adapted to coastal habitats and mangroves. Phylogenetic relationships based on evaluation of morphological characters from extant and extinct otter taxa, identified three principal clades - *Lutrini*, *Aonychini* and *Enhydrini*, with *Lontra*, *Lutra* and *Lutrogale* in the first, *Aonyx* and *Amblonyx* in the second, and *Enhyra* in the third clades, respectively (Willemsen, 1992; Koepfli and Wayne's, 1998).

In India, three species – *Lutra lutra* (Eurasian Otter), *Aonyx cinerea* (Small-clawed Otter) and *Lutrogale perspicillata* (Smooth-coated otter) are found (Schipper & Hoffman, 2008; Hussain *et. al.* 2011; Foster- Turley 1992).

The Eurasian Otter (*Lutra lutra*) can be identified by its coarse, dusky brown coat that looks bedraggled when wet. The total length of Eurasian otter including tail measures about 92 cm- 120 cm and weight ranges from 4 kg- 12 kg. Its underside is light grey and often has spots on its lips and nose (Menon, 2003). The Eurasian Otter has the widest distribution of all otters. It extends from Europe through Northern Africa to Asia as far as Korea Taiwan and Philippines (Mason and McDonald, 1986). Seven subspecies are recorded by Pocock (1941). In India *L.l.monticola* is found in Himachal Pradesh, Sikkim, and Assam, *L.l.kutab* in Kashmir, *L.l.aurobrunnea* in Garhwal Himalayas and *L.l.nair* in Southern India.

The Asian small-clawed otter (*Aonyx cinereus*) is the smallest among the 13 extant species of otters in the world (Schipper & Hoffman 2008; Hussain *et. al.* 2011; Foster- Turley 1992). Two subspecies were reported in India *A. c. concolor* in northeast India, Myanmar extending up to Sumatra *A. c. nirnai* in the hill ranges of Southern India (Pocock, 1941). The total length of Asian small-clawed otter including tail measures about 65.2 cm- 93.9 cm and weight ranges from 2.7 kg- 5.4 kg (Foster- Turley 1992). Its claws are very much reduced (Sivasothi 1995). The South Indian (*A.c.nirnai*) animals are distinctive in their darker colouring (Prater 1971).

Among the three species, Smooth-coated otter (*Lutrogale perspicillata*) is the species under current study. The smooth coated otter (*Lutrogale perspicillata* Geoffroy Saint-Hilaire, 1826) is easily identified by its large size and well-groomed chocolate-brown coat. Its underside is light and its paws are dark brown but lighter than the body. The total length of smooth-coated otter including tail measures about 106 cm- 130 cm and weight ranges from 7 kg- 11.4 kg (Harris, 1968). The tail is considerably long and flattened with a thick base (Menon, 2003; Pocock, 1985; Prater, 1971). It is distributed throughout south and south-east Asia. In India they have the widest distribution from Himalayas southwards and in most of their ranges they are sympatric with the Asian small-clawed otter (*Aonyx cinerea*) and sometimes Eurasian Otter (*Lutra lutra*) (Kruuket.al., 1994). Two subspecies are reported by Pocock (1941). (1) *L. l. perspicillata* from North-east and Southern India, Myanmar and Sumatra. (2) *L.l.sindica* from North and north-west India and Pakistan. An isolated race *L. l. maxwelli* is reported from the marshes of Iran (Hussain, 1996). In Southern India, they have been reported from many major

river systems including Kabini, Kaveri and Periyar (Anoop & Hussain, 2004; Menon, 2014, Shenoy *et.al.*, 2006).

Smooth-coated otters are listed under schedule I of Wildlife Protection Act, 1972 and they are listed under vulnerable category of IUCN Redlist.

In West Java, smooth-coated otters preferred mangroves and tidal stretches of rivers (Melisch *et.al.*, 1996). Sharif (1984, 1985) reported smooth-coated otters in Malaysia, in the mangroves of Kuala Gula, the Tembeling River in Taman Langkawi nearby Anak and Negara. Smooth-coated otters inhabit marshes, canals, rivers and flooded fields at low elevations (Lekagul and McNeely 1977). In Periyar Tiger Reserve, smooth-coated otters selected less rocky areas of the shallower part of Periyar lake, which are narrower and slanting. Deep waters are avoided by smooth-coated otters (Anoop & Hussain, 2004). In Kaveri Wildlife Sanctuary, Karnataka, its habitat consisted largely of loosely packed sand and small amount of rock, but lacked canopy cover, dense vegetation and stony or gravelly substrates. They also avoid areas with high level of anthropogenic disturbances (Shenoy *et.al.*, 2006). The availability of habitat features such as rocky and sandy stretches with gentle bank slopes, river bank vegetation, slow water current and prey availability govern the distribution of smooth-coated otters in Corbett Tiger Reserve (Nawab and Hussain, 2006). Elsewhere in the world smooth-coated otters occurs in mangroves, rice fields, tidal stretches of rivers, estuaries, reservoirs, lakes and canals (Pocock, 1985; Prater, 1971, Sivasothi & Burhanuddhin, 1994, Hussain, 2013).

Although, Smooth-coated otter is primarily a piscivorous animal (Cameron, 1908; Anoop & Hussain, 2005, Hussain & Choudhury, 1997, Kruuk *et.al.*, 1994), they do diversify their diet with molluscs, crayfish, crab, insects, frogs and occasionally birds and small mammals (Foster-Turley, 1992). Yet, fish constitute around 75-100 percent diet of the otter (Anoop & Hussain, 2005; Nawab & Hussain, 2012; Foster-Turley, 1992; Hussain & Choudhury, 1997) which makes them ideal candidates for aquatic conservation. Foster-Turley (1992) has described the variation in the diet of smooth-coated otter which indicates the flexibility in prey utilization.

Smooth-coated otter are social carnivores (Kruuk, 2006). In south-East Asia, smooth-coated otters are found in larger groups (Foster-Turley, 1992), yet the basic family group consists

of an adult female with her offspring, sometimes their father and older siblings join the group (Hussain, 1996). Also two or more families may combine while fishing (Prater, 1971). The home ranges of otters vary to large extent. In Chambal river the home range size varied from 5- 17 km, which also depended on the age of the individuals (Hussain, 1996). Though, among Carnivores there is little correlation between the size of a social group and the area it occupies; individuals of the same species may live in groups of variable size, and they may be in small territories or in relatively huge ones (Kruuk, 2006). Smooth-coated otters have conspicuous scent post toilets or communal spraint sites on dry grounds which are essential markers for other otters. This is essentially a strategy to defend their resources (Rostain, 2004; Sivasothi & Burhanuddhin, 1994; Kruuk, 2006; Kruuk, 1992). Otter dens or 'holts' are essentially associated with such kind of 'communal latrines'.

Although, otters are adapted to a wide range of habitats, their existence at a particular site depends on the quality of the habitat on a micro-scale, where they live, swim, hunt and rear their offspring along the waters' edges. Disturbances may not affect otter populations directly, but rather more indirectly. Kloskowski *et.al.* (2013) has shown that in largely modified landscapes otters couldn't survive since water level instability and the poor structure of the habitat, resulting from the concrete lining in canals and regular vegetation removal, apparently adversely affected the abundance of prey fish. Since otter populations are mostly food-limited (Kruuk, 1993), disappearance of prey means disappearance of predator. Otters cannot negotiate their way through hostile terrestrial environments away from the riverine habitat and thus recolonization is prevented (WCU, 1992). Pollutants may also affect otters indirectly by affecting the food resources or by exerting direct toxicity or poisoning of food chain (Mason & MacDonald, 1986). Now, loss of such predators from a 'simpler' system with fewer guilds (Pace *et.al.*, 1999), will have far more lethal effects, than a much more diversified terrestrial system.

Fluvial Functional Index is a protocol developed by the Italian Environmental Protection Agency to assess the ecological functionality of the river (Carranza, 2012). It consists of 14 variables (physical and biological) having four responses with a score for each, depending upon the functional levels (Carranza, 2012). These scores are then summed up to give the final score which categorize the river into a particular functional category. The fluvial functionality index

allows the collection of information about the major ecological characteristics of watercourses, and is able to describe functional aspects through the description of morphological, structural and biotic parameters of the fluvial ecosystem (Paolo *et.al.*, 2004). The variables to be collected are attached as Appendix II. Specifically for dam sites, functionality assessment would be carried out upstream and downstream of the dam at 5km stretches.

Asian otters have received little attention from scientists and conservationists for a very long time (Foster-Turley, 1992). Still very little information is available on the ecology of the otters in India. Most of the studies have looked at the feeding habits and habitat preference of the three species of otters (Anoop& Hussain, 2005, Anoop& Hussain, 2004, Nawab& Hussain, 2006; Perinchery *et.al.*, 2011; Shenoy *et.al.*, 2006; Umapathy, 2000; Khan *et.al.*, 2012). A few have looked at the ranging patterns, group size and breeding behaviour (Hussain, 1996; Hussain & Choudhury, 1997). A few studies looked at the poaching of otters (Meena, 2002). Though, very few works have been done on a landscape scale to know the distribution of otters (Prakash, 2012).

In the recent past, there have been major impacts on the geomorphology and hydrology of rivers throughout the world via damming, channelization, excessive water harvesting and pollution (Dodds, 2002; McCully, 1996). India's Rivers are in no different state, which are largely modified for human use. Wetlands are the most threatened ecosystems in India, river systems included. Rivers are categorized as *Riparian wetlands* (Mitsch & Gosselink, 2007) constituted by the river bed itself and the surrounding *riparian zone*. They are important wildlife habitats showcasing an array of organisms living in close association with it. In India, lakes, rivers and other freshwater habitats support a large diversity of biota representing diverse taxonomic groups (Prasad *et.al.*, 2002; Day, 2009). The hydrologic regimes of wetlands can be highly variable, especially in a river system like Kabini which is primarily fed by monsoonal precipitation. The water inflow and outflow determines the hydrologic regime of a river which forms the most important abiotic template that influences wetland ecology. For example, permanence (of water) controls the ability of large aquatic predators to inhabit a wetland. The presence or absence of these predators then structures the invertebrate and vertebrate community (Dodds, 2002). These apex predators will disappear once the hydrological regime is altered (by

damming, channelization etc.), this will in turn result in an ecological meltdown of the entire trophic structure (Terborgh *et.al.*, 2001; Estes & Palmisano, 1974). Such changes in predator abundance can have far-reaching consequences for ecosystem structure, functioning, and resilience (Paine 1969; Duffy 2002).

The purpose of the present study is to understand how the distribution and resource selection of smooth-coated otters happens within its natural distribution range in Kabini River and within selected habitats on a finer scale under the influence of a varying land-use pattern along the river. Another subset of data will be generated through Fluvial Functionality Index (Carranza, 2012), which looks at the variations in river functionality derived from a set of physical, morphological and biological parameters. While the habitat selection model evaluates the resource availability and usage by target species (Carranza 2012; Manly 1992), the fluvial functional index allows the collection of information about the major ecological characteristics of watercourses, and is able to describe functional aspects through the description of morphological, structural and biotic parameters of the fluvial ecosystem (Paolo *et.al.*, 2004). By combined interpretation of both, it is expected to give information on the vulnerability of riverine habitats and better insight for conservation prioritization. The current study is modified approach of Carone (2012) which looked at river systems with a multilayered approach using Common Otter (*Lutra lutra*) as a paradigmatic species.

1.3 OBJECTIVES

- I. To determine the effect of land-use pattern on habitat selection and distribution of otters with special reference to smooth-coated otter (*Lutrogale perspicillata*) in Kabini River.
- II. To determine the fluvial functional levels of Kabini River under different land-use systems.

1.4 RESEARCH QUESTIONS

- i. What is the effect land-use pattern on habitat selection by otter?
- ii. What is the effect of dams on habitat selection by otter?
- iii. What is the effect of land use pattern on Fluvial Functionality?
- iv. What is the effect of dams on fluvial functionality?

1.5 STUDY AREA

This study was conducted in Kabini River and its tributaries in Southern Western Ghats, India. The Kabini River basin lies within the geographical limits of $11^{\circ}40'N$ and $12^{\circ}10' N$ latitude; $75^{\circ}50'E$ and $76^{\circ}50'E$ longitude. The area comes under the administrative jurisdiction of Wayanad district in Kerala State and Mysore and Chamarajanagar districts in Karnataka State. The intensive study sites of 5km length in the main Kabini river as well as its major tributaries such as Panamaram, Mananthavady, Nugu, Bavali and Nagarhole Rivers. The study area lies within three protected areas namely Nagarhole National Park Officially known as (Rajiv Gandhi National Park (RGNP)), Bandipur National Park in Karnataka and Wayanad Wildlife Sanctuary in Kerala. Some portion of study area falls in North and South Wayanad Territorial Forest divisions in Kerala.

Kabini is a seventh order stream with the river basin spreading over an area of 2141 sq. km. It is a part of Kaveri middle basin. The river Kabini has two major tributaries namely Panamaram and Mananthavady which are originating from the Western Ghats in the Wayanad district of Kerala. After the confluence of these tributaries (after 2 km downstream), the river Kabini forms many islands in between left and right branches called Kuruva islands over an area of 146.01 ha.

This is the only protected stretch of the river in Kabini under South Wayanad Forest division in Kerala part. After Kuruva islands, another major tributary called Bavali river (locally known as *Kallindi*), which joins Kabini at Bavali village. About 10 km downstream of the Bavali confluence, Kabini flows between Kerala and Karnataka state and forms state border between these states for about 12 kms. Further downstream, Kabini flows through the protected areas (PA) of Rajiv Gandhi National Park and Bandipur National Park on either sides. There is one major dam situated in the main river channel at Beechanahalli, Karnataka which is also called Kabini reservoir. It is a multipurpose project having irrigation and power generation facilities. This project has 20 MW capacity. The catchment area of this reservoir is 2142 sq. km. The gross and dead storage of the reservoir is 552.74 MCM and 99.675 MCM respectively. After the reservoir, agricultural land is more predominant in this basin extending up to Tirumakudalu Narasipur (T.N. Pura) where Kabini joins with the Kaveri River.

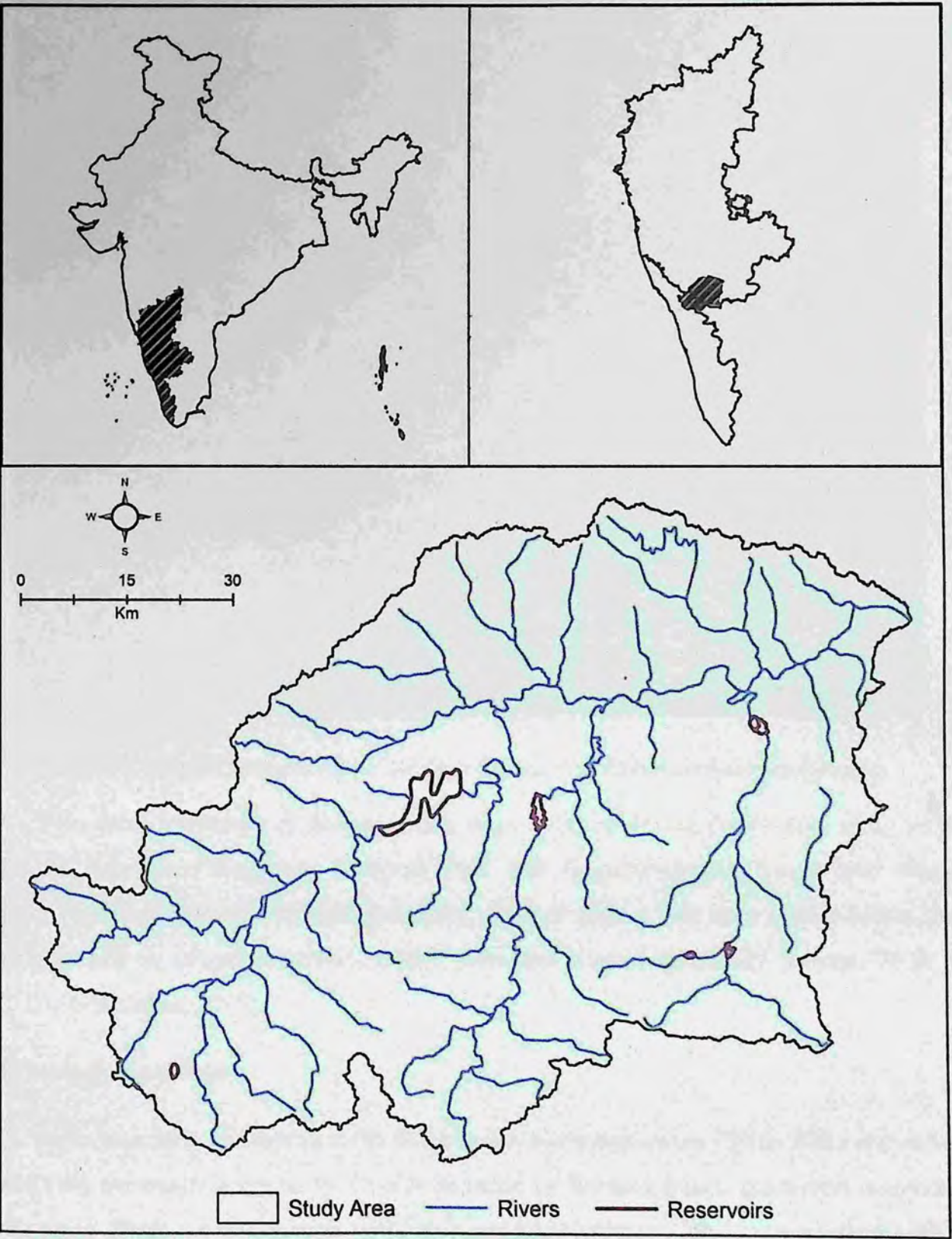


Plate 1. Map showing Kabini river basin

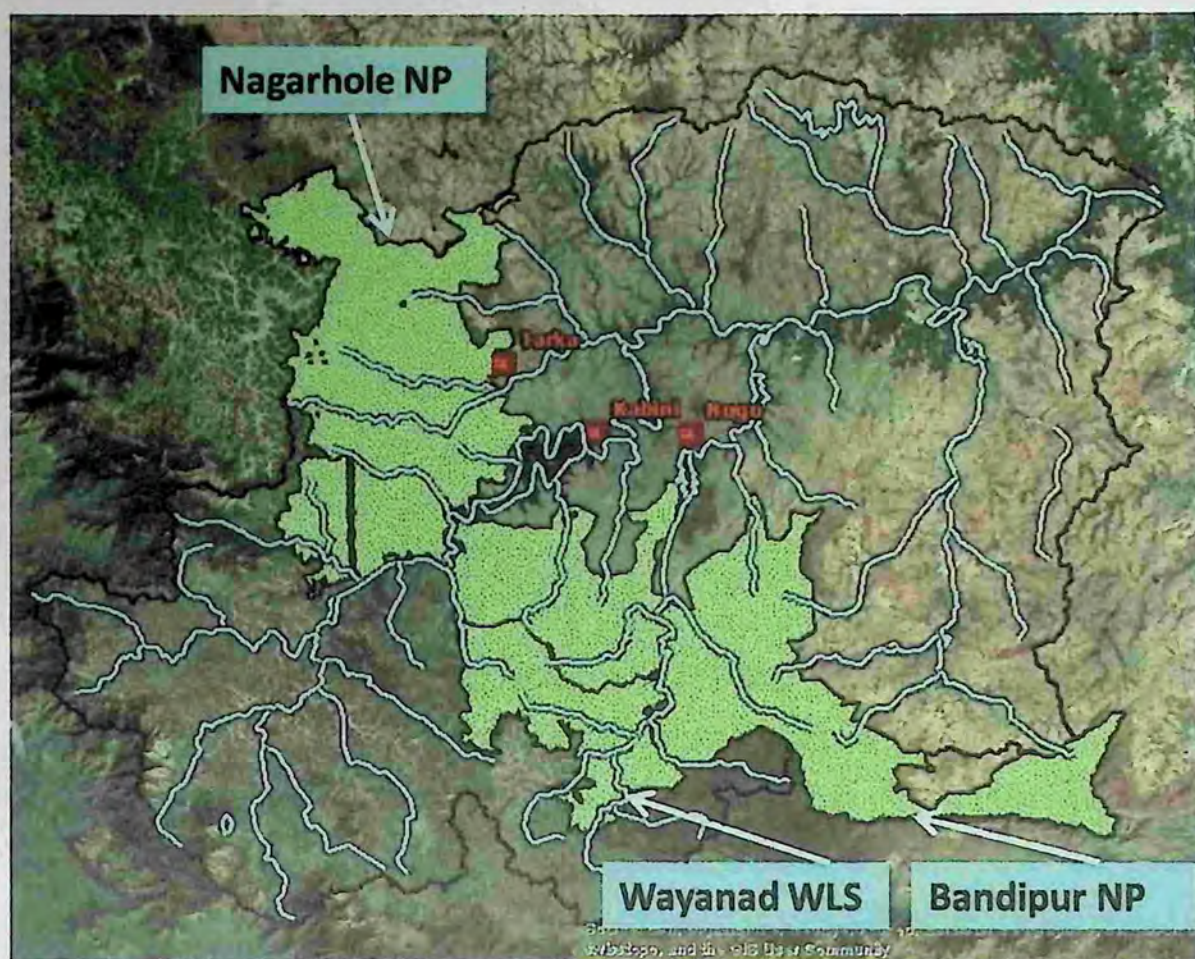


Plate. 2. Map showing the three protected areas and three reservoirs in the river

Two other tributaries of Kabini which were sampled during the present study include Nagarhole river from Nagarhole National Park and Nugu/Noolpuzha River from Banipur National Park and Wayanad Wildlife Sanctuary. Both of these rivers have a mini-hydro power projects as well as irrigation projects called Tarka and Nugu respectively (Javeed, 2009; Joji *et.al.*, 2013; Vandana, 2013).

1.5.1 Geological settings

More than 80% of the area under Kabini river basin lies within 700 to 900m above MSL. Towards the western side where the river is bounded by Western Ghats, the terrain is steeper in the Wayanad Plateau which merges with the Karnataka/ Mysore Plateau and gradually flattens towards the eastern side. The Kabini river basin encompasses the climatic and the geomorphological gradient which forms on the edge of the rifted continental passive margin of

the Karnataka Plateau in Peninsular India. This plateau is developed on the high-grade metamorphic silicate rocks of the West Dharwarcraton. The area is characterised by different physiographic zones viz., high ranges with rugged topography, high ranges with moderately rugged topography, intermontane valley and flood plains. The landform units identified in the area are alluvial plain, flood plain, valley fill, linear ridge, hillcrest, sloping terrain, rocky slope (scarp face) and hilly terrain. Flood plains and valley fills are the major fluvial landforms. The flood plains have relatively smooth valley floors formed by alleviating rivers, which are subject to overflow.

1.5.2 Climate

The Kabini basin is characterized by humid, sub-humid and semi-arid regions. The climate of the Kabini basin is tropical monsoonal with four seasons viz. cold weather/winter (December to February), hot weather/summer (March to May), south-west monsoon (June to September) and north-east monsoon (October to November). Major part of the annual rainfall is from South-West Monsoon while the semi-arid eastern landscapes benefited from the retreating North-East monsoon. There is a steep decline of the mean annual rainfall along the inland region, from 3800 mm/year (towards Western side) to 600 mm/year (Towards Eastern side). The rainfall patterns show inter-annual variability like the extreme 1990 and 2002 droughts and mild drought of 2014. The climate at the basin level generally remains dry except from monsoon months. April is generally the hottest month of the summer with mean monthly maximum temperature of 34.31° C. January is the coldest month with mean minimum temperature of 17.15° C. There is a considerable variation in the mean daily maximum and minimum temperatures across the basin. During cold season, the Western Ghat is cooler than the rest of the basin and the climate is generally pleasant. There is a complex interaction existing between ground water and surface water in Kabini River basin.

1.5.3 Land-use pattern

The land-use and landcover map for entire Kaveri basin (including Kabini) was prepared by Central Water Commission using LISS-III data of the year 2005-2006. Around 21 land use/land cover classes exist in the Kaveri river basin. Agricultural land is the dominant land-use class

in this basin (66.21%) followed by forested area (20.50%). The built up area in this river basin is quite low, which comprises of 4.01% in the land cover. Wastelands constituted 3.86% of the total basin area. Paddy is the most important crop in this basin, while Ragi, Jawar and other millets also constitute the important crops under rainfed conditions. Significant changes in the agriculture have occurred in the semi-arid zone (primarily Mysore district) of the Kabini basin, moving from rainfed crops like sorghum and millet, to intensive agriculture (with double cropping) of sugarcane and banana, highly dependent on irrigation resulting in higher water demand and consumption and altering the hydrological cycle at a local as well as landscape scale. In Chamarajanagar district groundwater forms the main source of irrigation. The canal network arising from the Kabini and Nugu dams provide irrigation in large areas in the taluks of Mysore district and crops, such as paddy and sugarcane, are grown in these commands. Demographic changes and demand on food crops have altered the land-use dramatically over the past few years.

The increasing population and population density trends are reflected in the per capita availability of forestland. Increasing food demands pushes agricultural areas beyond their limits encroaching into forest areas. The protected areas those which are surveyed under this study includes Bandipur National Park, Rajiv Gandhi National Park and Wayanad Wildlife Sanctuary. The Kuruva island of South Wayanad Forest Division is also a protected river habitat of the main Kabini river channel.

1.5.4 Description of the protected areas along Kabini River

1.5.4.1 Bandipur National Park

Bandipur National Park is spanning over an area of 874 sq. km. It was first declared as a game reserve in 1931 and later it was declared as a National Park in 1974. This Park is located in the geographical limits of $N11^{\circ}35' 34$ to $N-11^{\circ}57' 02''$ latitude, $E-76^{\circ}51' 32$ to $E-76^{\circ}12' 17$ longitude.

Geological setting

The altitude in the park ranges from 680 to 1454m. The rocky hills and valleys of the park is drained by the Rivers Kabini, Nugu, Moyar and numerous small streams. The Northern and Southern boundaries of the Park are set by Kabini and Moyar respectively. Nugu River, coming from Wayanad flows through the Park. The highest point in the Park is Himavad Gopalaswami Betta (1454m).

Climate

The park experiences typical tropical climate with dry and wet seasons. The mean annual rainfall ranges between 625 and 1250 mm and the annual temperatures range from 18 to 29°C. The rivers Moyar, Nugu and Kabini and their tributaries are the major sources of perennial water. Kabini Reservoir and Nugu reservoir are built adjoining the park.

Vegetation

The forest is largely of dry deciduous nature with trees 10-15 m height and open canopy. Scrub jungle towards the eastern limits of the Reserve consists of stunted trees, interspersed with bushes and open grassy patches. Towards its northwestern limits of the park, a gradual shift in the vegetation from open dry deciduous forest to tropical mixed deciduous forests can be seen. The major tree species include *Anogeissus latifolia*, *Terminalia alata*, *Emblica officianalis*, *Butea monosperma*, *Tectona grandis*, *Xeromphis spinosa* and *Lagerstroemia parviflora*. The park has extensive undergrowth of the exotic *Lantana camara*.

Fauna

Major mammals (large mammals) in this area includes Elephant, gaur, sambar, chital or spotted deer, muntjac, mouse deer, four horned antelope, wild boar, gray langur, bonnet macaque, slender loris, black-naped hare, porcupine, Indian giant squirrel, common giant flying squirrel, three striped palm squirrel, tiger, leopard, leopard cat, jungle cat, rusty-spotted cat, common palm civet, small Indian civet, sloth bear, dhole or Asiatic wild dog, striped hyena, golden jackal, common mongoose, striped-necked mongoose, ruddy mongoose, smooth-coated otter, Indian pangolin. Over 230 species of Birds have been identified. Reptiles include Marsh crocodile, Indian pond terrapin, starred tortoise, common Indian monitors Indian chameleon,

common rat snake, spectacled cobra, Russell's viper, common krait, Indian python, checkered keelback etc.

1.5.4.1 Nagarhole National Park

The Nagarhole National Park (officially Rajiv Gandhi National Park - RGNP) was initially constituted as a sanctuary in 1955, later it was upgraded to National Park in 1975. Subsequently, an area of 71.84 sq. km was added extending the area to 643.39 sq. km. It is located within the geographical limits of 11°45' - 12°15' N latitude and 76°5' - 76°25' E longitude. The park derived its name from the snake shaped river (Naga=snake, hole=stream) inside the park.

Geological setting

RGNP is situated at an average elevation of 800 -850 m above MSL. The highest peak is Masalabetta peak 959 m and the lowest is near Kabini backwaters (701m). The Kabini river separates Nagarhole National Park from Bandipur National Park. Nagarhole and Saravathihole inside the park and Kabini adjoining the park are the major drainage basins.

Climate

The park has tropical climate with dry and wet seasons as that of Bandipur. The temperature in summer reaches upto 30° C. During June to September (South-West monsoon) the Park receives an average annual rainfall of 1300 mm to 1800mm.

Vegetation

The primary vegetation type is moist deciduous forest. Dry deciduous forests and scrub jungle is found towards the drier eastern side. The major tree species found here are *Pterocarpus marsupium*, *Lagerstroemia lanceolata*, *Terminalia tomentosa* and *Grewia tiliifolia*. Towards the drier Eastern side tree species such as *Anogeissus latifolia*, *Cassia fistula* and *Butea monosperma* are dominating.

Fauna

Mammalian species include Elephant, gaur, sambar, tiger, leopard, leopard cat, jungle cat, rusty-spotted cat, chital or spotted deer, muntjac, mouse deer, four horned antelope, wild boar, sloth bear, dhole or Asiatic wild dog, golden jackal, gray langur, bonnet macaque, slender loris, black-naped hare, porcupine, Indian giant squirrel, common giant flying squirrel, three striped palm squirrel, common palm civet, small Indian civet, striped-necked mongoose, ruddy mongoose, brown mongoose and smooth-coated otter.

1.5.4.2 Wayanad Wildlife Sanctuary

Wayanad Wildlife Sanctuary in Kerala is located in contiguous with Nagarhole National Park, Mudumalai National Park and Bandipur National Park. It is situated within the geographical limits of N11° 35 ' and 11°51' Latitude and E 76° 02' and 76° 27' Longitude. This sanctuary was declared in the year 1973 with a total area of 344 sq. km. The North Western part of the sanctuary has only one range named Tholpetty adjoining Nagarhole National Park, the rest of the sanctuary is south of the river adjoining Bandipur National Park.

Geological setting

The northern part with an elevation of 700 to 1600 m altitude from MSL, differs from the southwestern slope of uneven peaks ranging from 1000 to 2000 m. The highest peak of the sanctuary is Karottimala.

Climate

The sanctuary has a tropical climate and receives an average annual rainfall of about 2000mm. The mean annual temperature varies from 13° (winter) to 32° (summer). Noolpuzha (known as Nugu in Karnataka) in Muthanga and Bavalipuzha in Tholpetty ranges are the two major drainage basins of the sanctuary.

Vegetation

The major vegetation types include moist mixed deciduous forests, dry mixed deciduous forests and semi-evergreen forests. Moist deciduous forests are the dominant vegetation. The entire protected area network had abundant bamboo brakes as well. But after the mass flowering of 2011 most of it had died out. The major tree species found here includes *Pterocarpus marsupium*, *Tectona grandis*, *Terminalia chebula*, *Terminali paniculata*, *Grewia tiliifolia*, *Phyllanthus emblica*, *Terminalia chebula* etc.

Fauna

Fourty five species of mammals including Elephant, Gaur, Tiger, Leopard ,Sambar, Spotted deer, Barking deer, Wild boar, Sloth bear, Nilgiri langur, Bonnet macaque, Common langur, Wild dog, Smooth-coated otter, Small-clawed otter, Malabar giant squirrel, 203 sp. of birds, 45 species of reptiles are reported from this Sanctuary.

1.5.4.3 Kuruva islands

Kuruva island is located about 2 km down after the confluence of Manathavadi and Panamaram rivers. The 146.01 ha island in the middle of the Kabini River is protected under South Wayanad Forest Division (Territorial Forest Division). This stretch of Kabini river contains 3 uninhabited islands and few submergible islands. It is the only compact protected uninhabited island in Wayanad. The islands divide the main river channel into two major channels and a few minor ones which flows through the islands. The average elevation is about 700 m above MSL.

Climate

The climate is moderately hot and humid with temperature varies from 18⁰C to 20⁰C. Average annual rainfall is about 5000 mm as the tract receives both south west and north east monsoon.

Vegetation.

The Kuruva island comprise of tropical evergreen forest. The flora is very diverse with a relatively high percentage of endemic floras. The major plant species found here include *Diospyros peregrine*, *Vateria indica*, *Hopea ponga*, *Garcinia Morella*, *Scleropyrum pentandrum*, *Hoya ovalifolia*, *Salix tetrasperma*, *Santalum album* etc.

Fauna

Ninety seven species of terrestrial mammals reported from Kerala are found here. It includes tiger, elephant, wild boar, Chital, Bonnet macaque, Malabar giant squirrel, Smooth-coated otter, Small-clawed otter, Mouse deer, Common palm civet, Small Indian civet, common mongoose, wild dog etc.. The island has a rich avian diversity including Malabar trogon, Malabar pied hornbill, Grey jungle fowl, Malabar whistling thrush, Malabar parakeet, Oriental honey buzzard etc. The major reptiles include Mugger or marsh crocodile, monitor lizard, spectacled cobra etc.

2.1 METHODS

Based on reconnaissance survey and collected literature the Kabini river basin was divided into multiple land-use categories using google-earth, since land-use at finer scales along river course are difficult to obtain from normal satellite images. Both natural (undisturbed) and human-modified areas were selected for the study. Sampling design followed in the present study is multi-stage sampling (Fuller, 2011). From each land-use type, a 5 km stretches of river were used for intensive study which is the *primary sampling unit (PSU)*. The 5 km stretch of river roughly falls within the homorange of an otter (Mason & MacDonald, 1986; Hussain, 1993). Each 5 km stretches of the river were divided into segments of 200 m for *secondary sampling unit (SSU)* for collecting information on otter habitat use (MacDonald & Mason, 1983; Mason & MacDonald, 1986; Hussain & Choudhury, 1997).

The habitat selection by otter was studied using indirect evidences through 'otter surveys'. The survey methodology was designed after referring to the method used by various authors (Melquist and Hornocker, 1979; Mason and MacDonald, 1983; Kruuk *et. al.*, 1994; Lee, 1996; Hussain & Choudhury, 1997). The distance searched for sign survey varied from 2 km to 5

km, due to logistical constraints. Within each site, a 10 m strip on either side of the bank of the river was intensively surveyed for 'otter signs' (Kruuk, 2006, Mason & MacDonald, 1983; Hussain & Choudhury, 1997). This is based on the assumption that otters rarely use banks more than 100 m away from the shoreline (Kruuk, 2006).

The banks were surveyed for indirect evidences such as presence of spraints (otter feces), pugmarks, resting and grooming sites, and holts (otter dens) along the banks and GPS locations were taken. Otter Spraints are characterized by blackish in colour with a sweet musky odour which fades with time. However the smooth-coated otter spraint has a characteristic 'fishy' smell and contains mostly fish-scales, while small-clawed otter which is also known from the same landscape has spraints containing mostly of crab remains (Perinchery *et.al.*, 2011). The colour of spraints, when they are old, gradually turns into grey and eventually white. Smooth-coated otter pugmarks are different from small-clawed otter pugmarks. The smooth-coated otter mostly dens in crevices between rocks, usually on islands in rivers, but sometimes it also digs its own holt (Kruuk, 2006, Mason & MacDonald, 1983; Anoop & Hussain, 2004; Perinchery *et.al.*, 2011; Hussain & Choudhury, 1997).

2.1.1 Habitat characterization

If no otter sign is encountered within 1 km of the sign survey, such a site is considered as 'absence site' (Shenoy *et.al.*, 2006). Since, the study area covered is quite large, it was necessary to segregate 'presence' and 'absence' sites first using a set of habitat variables (mostly on a qualitative scale) and then do detailed habitat characterization for presence only sites. Doing detailed habitat characterization for both type of site was impossible due to poor logistic support and with the resources at hand. The following site-covariates were collected (at each 200 m) to segregate/characterize presence and absence sites.

- i. Average river width
- ii. Water current – slow, medium, fast (visual estimation; roughly falls within categories of pool, run and riffle)
- iii. Water flow – natural/ altered (i.e. altered due to presence of dam, check dams, channelization etc.)

- iv. Water depth (shallow (<1m), Deep (>1m))
- v. Bank vegetation (trees, shrubs, grass or bare bank)
- vi. Bank erosion (present/absent)
- vii. Islands (present/absent)
- viii. Distance to human settlement (aerial distance)
- ix. Distance to nearest presence site (the river length separating current and the nearest presence site)
- x. Fishing (on a scale from 0-4)
- xi. Sand mining (on a scale from 0-4)
- xii. Presence of humans (on a scale from 0-4)
- xiii. Grazing (on a scale from 0-4)
- xiv. Pollution (on a scale from 0-4)
- xv. Tourism (present/absent)

Once 'absence sites' were segregated, following habitat variables are collected in 'presence' only sites for understanding habitat selection on a smaller scale at each 200m within each site.

Table.1. Variables collected from 200m stretch

Variable	Measurement
Average depth of River	Depth rod
Average width of the river	Range finder
Slope of the bank	Clinometer
Substratum of the bank (%)	Point intercept method Categorical (Rock, Cobble, Gravel, Sand, Mud, Litter, Grass)
Substratum of River	Visual estimation, collecting samples
Water Current	Float method
Canopy Cover	Densiometer

Distance of escape cover from water	Measuring tape
Average Height of escape cover	Measuring tape
Type of Disturbance	Visual estimation (Fishing, Sand mining, Water harvesting Pollution, Presence of humans/livestock, Grazing)
Disturbance Level	Visual estimation (On a scale of 0- to 4, with 0=absent, 4 = very high)
Fish abundance	Catch per unit efforts (CPUE)

For assessing fish availability catch per unit effort method was adopted using 3 mono-filamentous gill nets (mesh size 2.5mm, 3.2mm, 4.1mm) (Gulland, 1964; Harley, 2001; Johnson, 2010). Different mesh sizes were used to obtain different size classes of fishes. To check the effect of physical barriers or dams on otter distribution sign surveys were conducted above and below the dam site at a 5 km stretch. Some additional variables were also collected after preliminary sign surveys.

Table.2. Additional habitat variables collected from 200 m stretch of effective sampling unit.

Total extent of sand bars/ 100 m	Total linear measurement of the immediate substratum near the shoreline on a strip of 10 m (at a maximum distance of 1m from water) within each 200 m on left and right bank.
Total extent of mudbanks / 100 m	Total linear measurement of the immediate substratum near the shoreline on a strip of 100 m (at a maximum distance of 1m from water) within each 200 m on left and right bank.
Total extent of grassbanks / 100 m	Total linear measurement of the immediate substratum near the shoreline on a strip of 100 m (at a maximum distance of 1m from water) within each 200 m on left and right bank.

Total no. of fallen bamboos/ logs/100 m	The total no. of fallen bamboos/logs within a 5m strip across a length of 100 m within each 200 m on left and right bank.
Total no of bamboo clumps/ trees with buttresses/ exposed roots/100 m	Total no of bamboo clumps/ trees with buttresses/ within a 5m strip across a length of 100 m within each 200 m on left and right bank
Total no. of natural waterholes	Total no natural waterholes across a length of 100 m within each 200 m on left and right bank
Total no of steep rocks/100 m	Total no of emergent rocks in water within a length of 100 m (within each 200 m) which can't accommodate an otter on top of it.
Total no of percheable rocks/100m	Total no of emergent rocks in water within a length of 100 m (within each 200 m) which can accommodate an otter on top of it.
Total no of fallen woods or bamboos in water/100	Total no of fallen woods or bamboos in 100 m (within each 200 m)

Again, upon presence of otter signs additional variables were collected for fine scale habitat study. The length and breadth of each pugmark was noted and photographs were also taken of all indirect otter sings.

Table. 3. Variables collected upon otter presence

Variable	Type
Type of sign	Categorical
If spraint, Age of spraint	Categorical
Distance to water	Measuring tape
Distance to escape cover	Measuring tape

Height of holt from water surface	Measuring tape
Substratum of sign	Categorical (Rock, Cobble, Gravel, Sand, Mud, Litter, Grass)
Mid river water depth	Depth rod
River width	Range finder
Water current	Float method
Canopy cover	Densiometer
Slope of the bank	Clinometer
Major content of the spraint	Fish, Crab or Vertebrates

2.1.2. Camera trapping

Camera traps (Cuddeback Attack 1149, Cuddeback Ambush 1170 and Spypoint) were deployed along 5km intensive study areas. The intention was to confirm the identity of the species and also to find a correlation between sign survey data and the number of individuals present at a site. The camera traps were deployed at a maximum height of 30 cm from ground, mostly facing landwards from water edge (to reduce detection of camera trap by otters). However, camera trapping wasn't possible in all the sites since there was risk of traps being stolen outside PA. In such circumstances natives or local people were asked to get photographs or videos of otter groups as and when they sight them.

2.1.3 Testing detectability

Plaster of Paris (POP) molds of otter pugmarks were taken in the field. These molds were later used to test detectability of the observer. The field assistant of the researcher was asked to put 'artificial' pugmarks of otter on a 100 m stretch of river bank on different substratum without the knowledge of the researcher. The researcher later would find out the maximum number of pugmarks he can find. The ratio of 'detected' to 'total made' pugmarks gives the detectability of

the observer. The experiment was repeated five times in five different sites. Additionally the substratum and the distance of pugmark from the shore were also taken.

2.1.4 Assessing Fluvial Functionality

The ecological functionality of the river was assessed using Fluvial Functional Index which is a protocol developed by the Italian Environmental Protection Agency (Carranza, 2012). It consists of 14 variables (physical and biological) having four responses with a score for each, depending upon the functional levels. These scores are then summed up to give the final score which categorize the river into a particular functional category. The fluvial functionality index allows the collection of information about the major ecological characteristics of watercourses, and it is able to describe functional aspects through the description of morphological, structural and biotic parameters of the fluvial ecosystem (Paolo *et.al.*, 2004). The detailed information on collected variables are attached as Appendix I. In the case of dam sites, fluvial functionality index assessment were carried out in the upstream as well as in the downstream of the dam at 5 km stretches.

2.2 ANALYSIS

The habitat selection and habitat use otters were analysed using multivariate techniques and generalized linear models. For habitat selection binomial (logit) model was selected with only presence and absence data from each 200 m from each different site. Poisson model was used for assessing habitat usage. Data from all the sites were pooled in before analysis. Using a correlation matrix, variables correlated more than 0.6 were dropped from analysis. The rest of the variables were selected and Principal Component analysis was done using SPSS 20 software. The factor loadings from principal component analysis were used for linear regression using R 3.2.0-software. Fluvial functionality was assessed using Microsoft Excel 2010 software. Softwares SPSS 20, R 3.2.0 and Microsoft Excel were used for all other the analysis.

Fluvial functionality index is a method that aims to assess the most important ecological aspects of the whole course of a river such as riparian areas, morphological characteristics, and biological features.

2.3 RESULTS

During the study period 28 sites were surveyed for smooth-coated otter. Out of which 16 sites recorded the presence of smooth-coated otter. Additionally 5 sites recorded the presence of small-clawed otter. Out of 16 presence sites, only 11 sites were intensively surveyed for otter habitat study since the other sampling stretches had to be discarded due to lack of logistic support. Indirect evidences such as pugmarks, spraints, grooming sites and holts were used to ensure otter presence. The 11 intensive study sites of smooth-coated otters were distributed in different land-use categories of Kabini basin. Out of 11, three presence sites were in protected area, three in agricultural land, two in urban/human settlement area and one in river with only one side protected area and other side human settlement. To understand the influence of dams on otters river stretch below the Kabini reservoir was also surveyed of which 2 presence sites were found. A total of 136 signs of smooth-coated otter were observed during the study period from the 11 intensive study sites. A summary of the different signs encountered is given below.

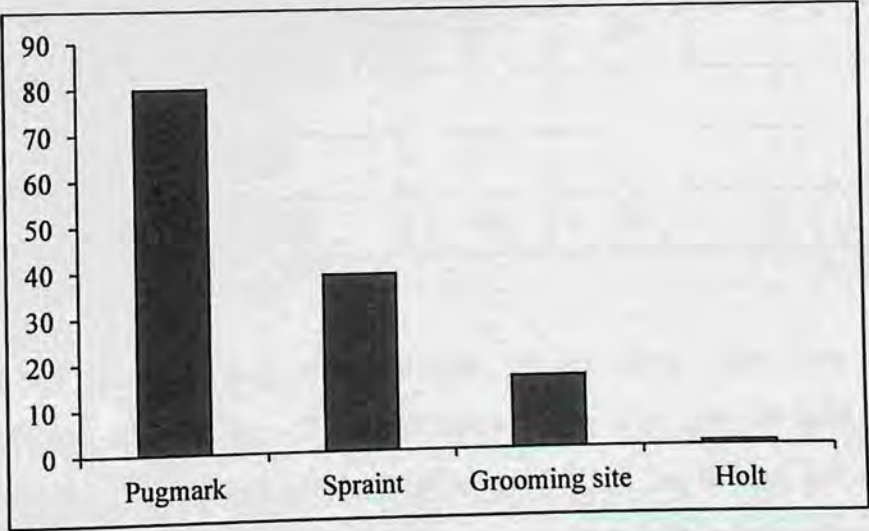


Fig.1. Summary of signs encountered during the survey

Highest number of indirect evidences was through pugmarks and spraints. Grooming is the vigorous rubbing of fur on loose sand, soil or grass on the ground. The grooming site of otters was taken into account as indirect evidence only if it's associated with pugmarks or spraints. (Anoop & Hussain, 2004). While doing sign survey, a sign was counted as separate sign only if it is 5m away from the previous sign (Kruuk, 2006).

Table.4 The 11 intensive study areas and the number of indirect evidences from each (PA- protected area, OS-One side protected area, AG- Agriculture, UR- Urban or human settlement, AD- After dam)

Category	Site	Pugmark	Spraint	Grooming site	Holt
PA	Kuruva1	12	4	1	0
OS	Kuruva2	6	0	5	0
AG	Bairekkuppe	4	2	2	0
PA	Bogeswara	17	2	0	0
AG	Beechanahalli	4	4	1	0
AD	Hulahalli	14	2	1	1
PA	Muthanga	11	5	0	0
AG	Nugu 2	5	13	2	0
AG	Nugu 1	2	5	0	0
UR	Panamaram	3	1	3	0
UR	Mananthavady	2	1	1	0

The size of the intensive study stretch varied from 2km-5km depending upon accessibility, logistical support etc. Each intensive study area was divided into segments of 200m which were searched for the presence of otter. Out of the 9 sites (of 16 presence sites) inside protected area, only 4 sites recorded the presence of smooth-coated otter. Other than main river channel, the presence of otter was confirmed in 3 tributaries including Mananthavady Puzha, Panamaram puzha and Noolpuzha.

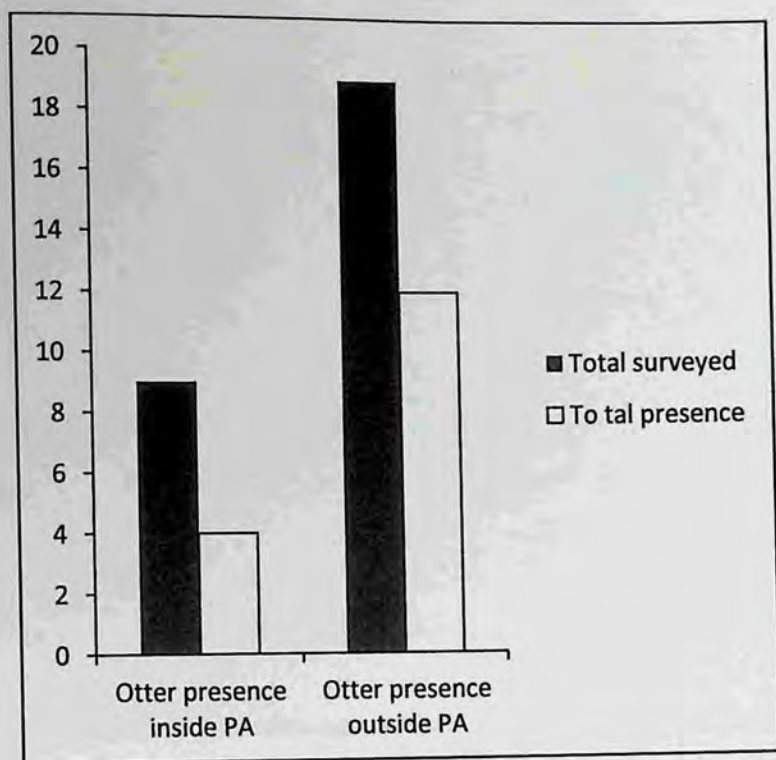


Fig 2. The presence of smooth-coated otter inside and outside protected area.

More number of presence sites for smooth-coated otters were recorded from outside protected areas than within the protected area. Out of the nine sites inside the protected area only four recorded presence of otter within two river channels only. Additionally five presence sites were recorded for small-clawed otter inside protected area.

Based upon number of signs encountered at each 200m section and the total effort (length of river transect walked) taken encounter rate of signs for each site was calculated. The encounter rate of smooth-coated otter signs per km varied from 6.154 to 0.8 (mean= 1.474, SE = 0.445). The encounter rate drastically varied between sites. Encounter rate was highest in protected areas and lowest in urban area. Downstream of the reservoir the encounter rate increased when moving farther from the dam.

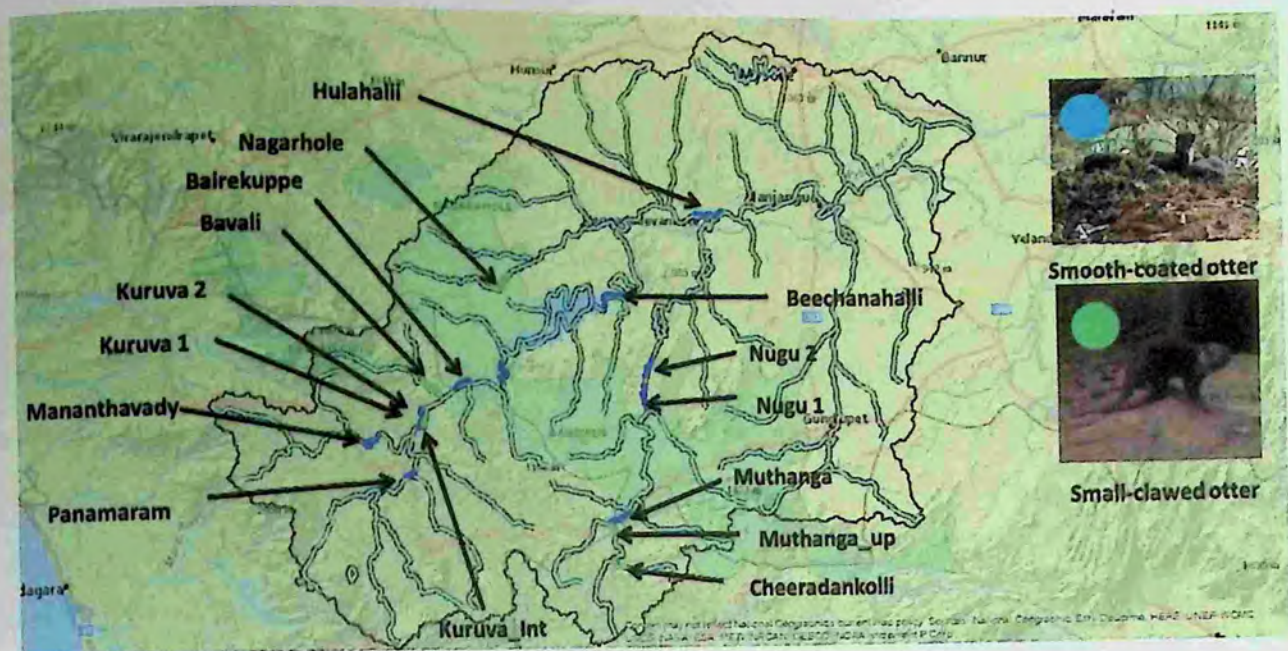


Plate 3. The 11 presence sites of smooth-coated otter (blue) and the five presence sites of small-clawed otter (green)

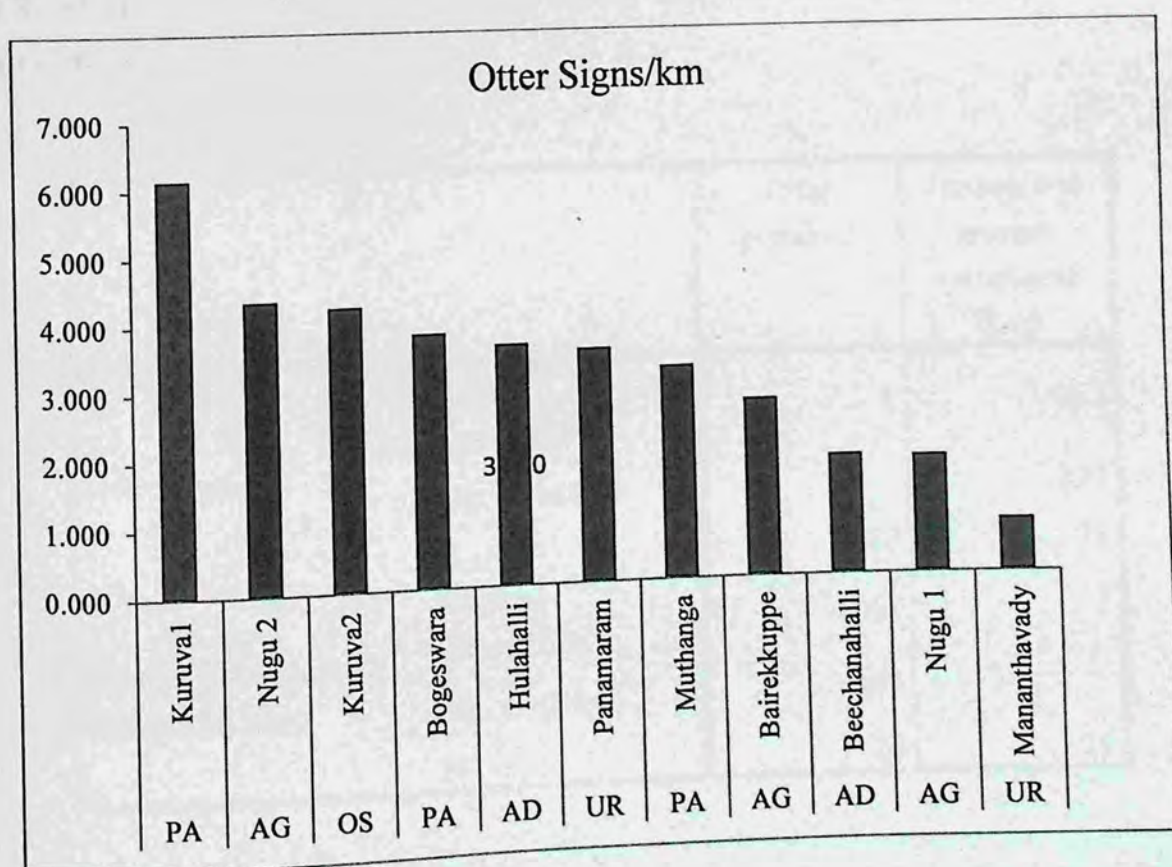


Fig 3. Encounter rate of otter signs in 11 different sites

2.3.1 Otter presence and absence sites

In case of absence, river stretches where otters signs were not encountered with 1km of the survey were considered as non-otter sites (Mason & MacDonald, 1986). 15 different variables were used to separate presence and absence sites of smooth-coated otter. The difference between otter and non-otter sites is graphically represented here (only for nominal variables). The otter prefers slow flowing water over fast, deeper water over shallow ones, rivers with islands and arboreal vegetation. The result is in confirmation with Shenoy *et.al*, 2006. Pearson's product-moment correlation was used for quantitative variables. Distance to human settlement and otter presence had no significant relationship ($r = 0.062$). The width of the river does not seems to affect the otter presence either ($r= 0.127$). The distance to presence site was just a technical information and not as a habitat variable since already 5km distance is fixed (in most cases) between sites. But this information might be useful to predict probability dispersal of otters between sites in detailed study.

Table 5. Pearson’s product-moment correlation between otter presence and distance to human settlement

		Otter presence	Distance to human settlement (km)
Otter presence	Pearson Correlation	1	-.062
	Sig. (1-tailed)		.377
	N	28	28
Distance to human settlement (km)	Pearson Correlation	-.062	1
	Sig. (1-tailed)	.377	
	N	28	28

Table 6. Pearson's product-moment correlation between otter presence and distance to human settlement

		Otter presence	Average river width
Otter presence	Pearson Correlation	1	0.127
	Sig. (2-tailed)		0.520
	N	28	28
Average river width	Pearson Correlation	0.127	1
	Sig. (2-tailed)	0.520	
	N	28	28

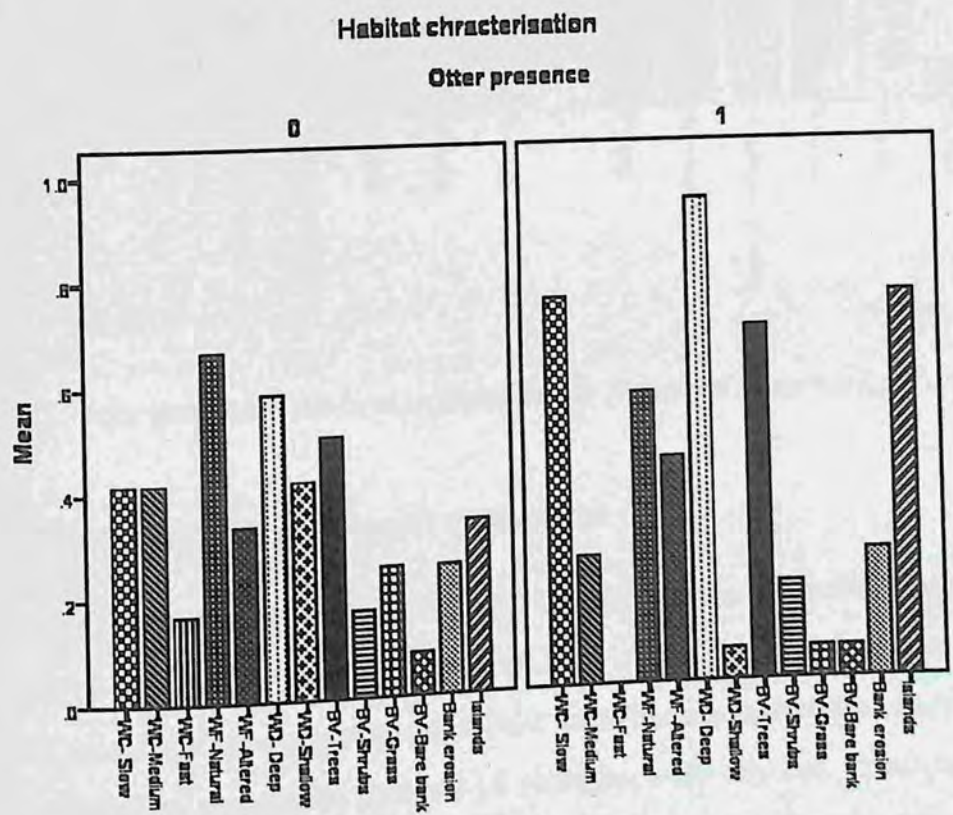


Fig 4. Otter presence v/s absence sites (0=absent, 1=present)

Other variables collected included disturbance variables (ordinal). Since the disturbance inside and outside protected area vary to a large extent (mostly 0 in PA). The otter presence was again split between inside and outside PA. Absence of otter is mostly related to presence of humans, sand mining and grazing. The absence of otter inside protected area had little relationship with disturbance, in fact otters were found slightly more disturbed areas inside PA.

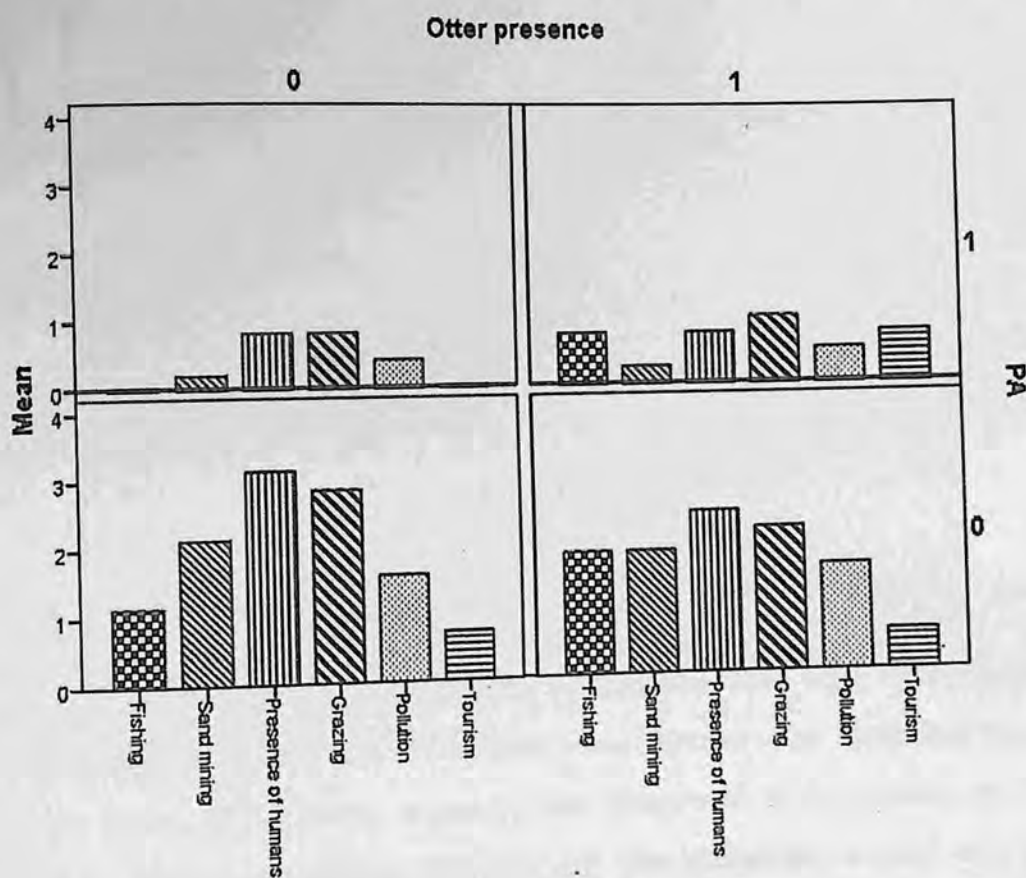


Fig 5. Otter presence and human disturbance (0=absent, 1 present; PA=Protected area)

2.3.2 Habitat selection in intensive study areas

21 habitat variables were collected to characterize the habitat in each intensive study area. Each of the variables was collected at each 200 m distance for each site. Fish abundance estimation was done once per study site. Prior to ordination correlation matrix was created for 21 variables. Based on correlation analysis 14 variables were selected. Principal component analysis (PCA) was done on these variables (except binomial variables) using varimax rotation (Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.574)

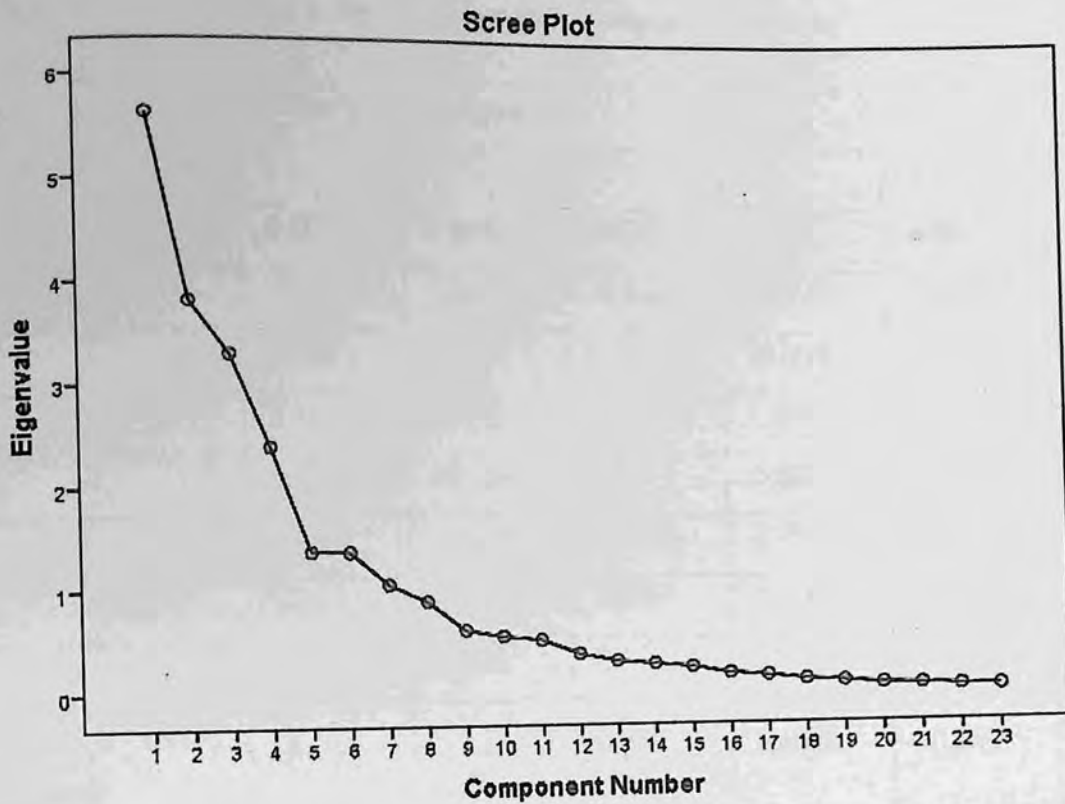


Fig 6. Scree plot showing number of principal components against Eigen value

Both magnitude and direction of the principal components were used to interpret the results (Anoop & Hussain, 2004). PC1 (18.727 variance) was interpreted as Steep and sandy banks on deep and wide rivers. PC2 (16.663 variance) was interpreted as disturbance axis with lot of human presence, fishing and grazing. PC3 (14.365) was interpreted as sand mined rivers with emergent rocks. PC4 (9.998 variance) was interpreted as well wooded rivers (good riparian vegetation) with grassy banks. PC 5 (9.107) was interpreted as rivers with far and low escape cover. PC 6 (7.558) was interpreted as water current axis.

Linear regression (Binary, logit model) was performed with otter presence or absence (0 to 1) as dependent variable and PCA **factor scores** as independent variables in SPSS version 20.

Table 7. Showing rotated component matrix

Variables	Principal Components					
	1	2	3	4	5	6
WC	0.003	0.046	0.030	0.004	0.001	0.952
AWD	-0.701	-0.226	-0.480	-0.227	0.006	0.097
WR	-0.823	-0.052	0.006	-0.018	0.103	0.153
BS	0.667	0.070	-0.467	0.000	-0.165	0.109
CC	0.194	-0.139	-0.243	0.882	0.020	0.040
ECD	0.144	0.017	-0.066	0.090	0.758	-0.157
Fishing	0.217	0.795	-0.261	0.092	0.047	0.033
Grazing	0.056	0.685	0.441	0.063	0.053	0.109
Presence of humans/livestock	-0.114	0.880	0.046	-0.086	-0.091	-0.047
AHEC	0.175	0.008	-0.083	0.027	-0.736	-0.162
TES	0.712	-0.109	0.189	-0.090	0.223	0.172
TEG	-0.517	0.299	0.153	0.707	0.099	-0.075
TNPR	0.225	-0.164	0.817	-0.153	-0.112	0.051
Sand mining	-0.177	0.498	0.707	-0.101	0.186	0.030

(WC- Water current, AWD- Average Water Depth, WR – Width of River, BS- Slope of the bank, CC- Canopy cover, ECD – Escape cover distance, AHEC – Average height of escape cover, TES – Total extent of sandbanks, TEG – Total extent of grass banks, TNPR – Total extent of perchable rocks in water).

Summary of the linear regression (binomial logit model) is given in table 1.

Coefficients:

	Axis title	Estimate	Std. Error	z value	Pr(> z)
(Intercept)		-0.4591	0.1537	-2.986	0.002824 **
PC.6	Water current	-0.5465	0.5272	-1.037	0.299912
PC.2	Disturbance	-0.5399	0.1548	-3.487	0.000488 ***
PC.5	Far escape cover with low height	-0.5299	0.1749	-3.03	0.002446 **
PC.3	Sand mined rivers with emergent rocks	0.2985	0.151	1.977	0.048092 *
PC.4	Well-wooded rivers	0.184	0.146	1.26	0.207548
PC.1	Deep and wide rivers	-0.0601	0.1508	-0.398	0.69032

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Principal components 2, 3 and 5 defined habitat selection of smooth-coated otter. The segments of river selected by smooth-coated otter were strongly influenced by disturbance (PC 2). Otters avoided areas with lot of human presence and where there are severe pressure of grazing and fishing. Rivers with emergent rocks was positively influencing otter presence with negative relation towards deeper areas (PC 3). Areas with close escape cover distance (< 2m) and high escape cover (> 0.5m) seemed to have a strong influence on otter presence (PC 5).

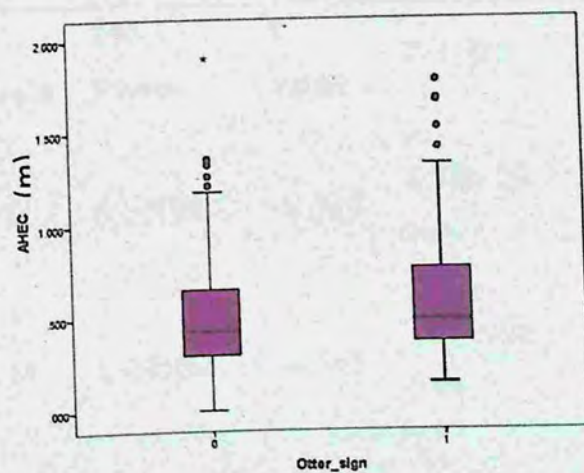
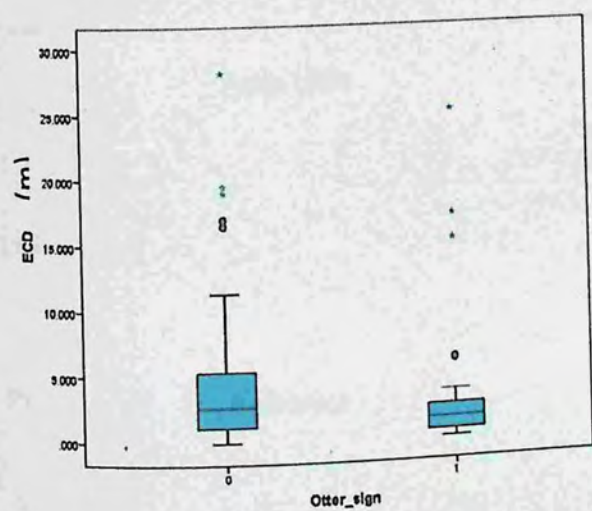
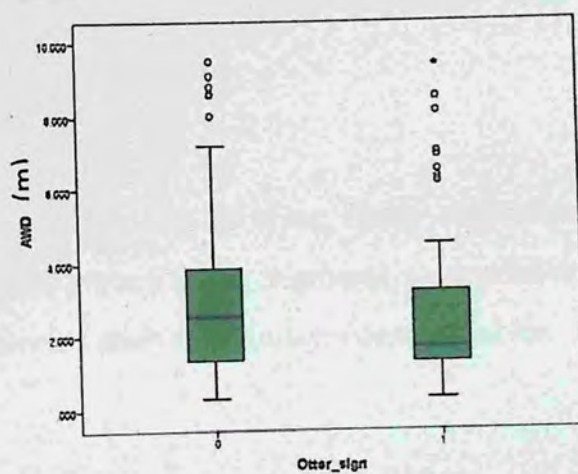
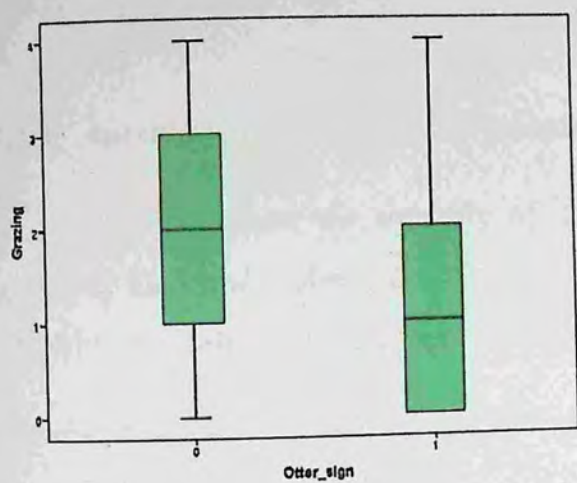
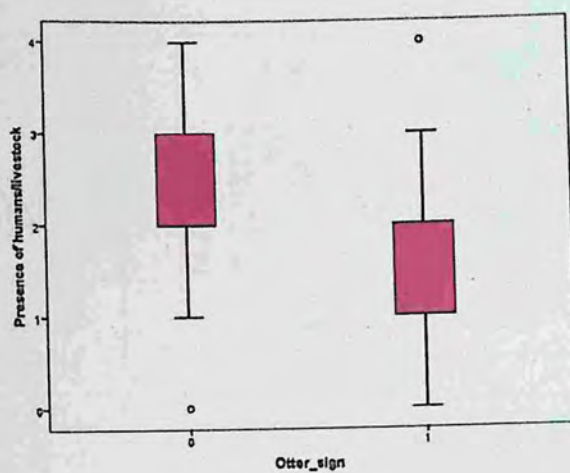
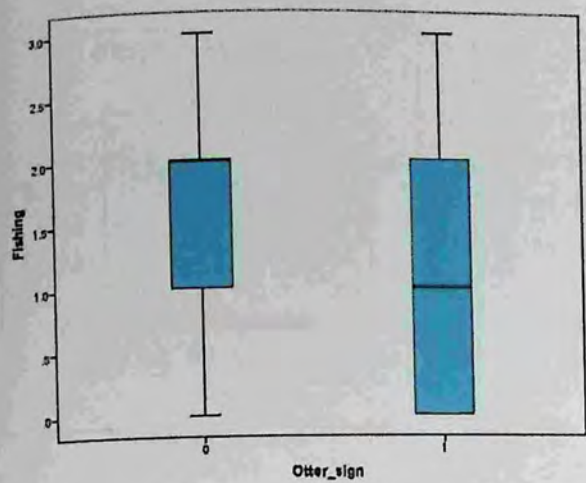


Fig 7. Boxplots showing individual variables in presence and absence sites (unitwise – 200m)

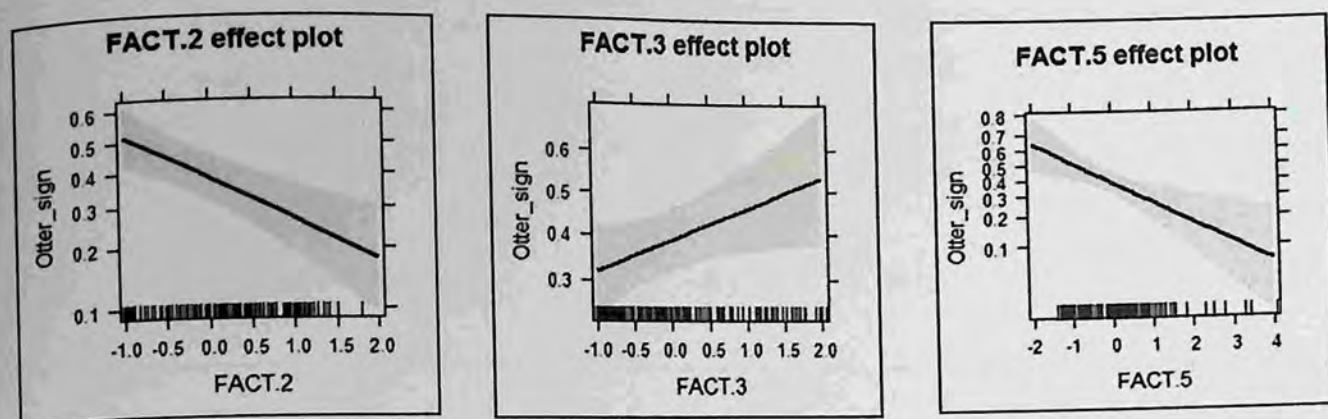


Fig 8. Effect plots showing principal components (named as FACT.) influencing habitat selection

2.3.4 Intensity of habitat use by smooth-coated otter

To understand the intensity of usage of different sections of river, linear regression (poisson, log) was performed with number of otter signs in each 200m segments as dependent variable and **factor scores** from above Principal components analysis as independent variables.

The results are summarized in the table below.

Axis title		Estimate	Std. Error	z value	Pr(> z)
(Intercept)		-0.6474	0.10199	-6.347	2.19e-10 ***
PC 2	Disturbance	-0.4129	0.09504	-4.345	1.39e-05 ***
PC 5	Far escape cover with low height	-0.3198	0.10815	-2.957	0.00311 **
PC 4	Well-wooded rivers	0.25811	0.0818	3.156	0.00160 **

PC 3	Emergent rocks in shallower water	0.15984	0.08622	1.854	0.06377 .
PC 6	Water current	-0.1452	0.22795	-0.637	0.52403
PC 1	Deep and wide rivers	-0.1301	0.09189	-1.415	0.15693

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results were in compromise with habitat selection model (binomial, logit). Disturbance showed highest negative influence on habitat use by otters (PC 2). The effect of emergent rocks in sand-mined area of rivers seemed to have a weaker positive influence on intensity of habitat use (PC 3). Canopy cover and grassy banks showed a positive effect on intensity of habitat use by otters. While escape cover distance have a negative influence and height of escape cover has a positive influence on habitat use.

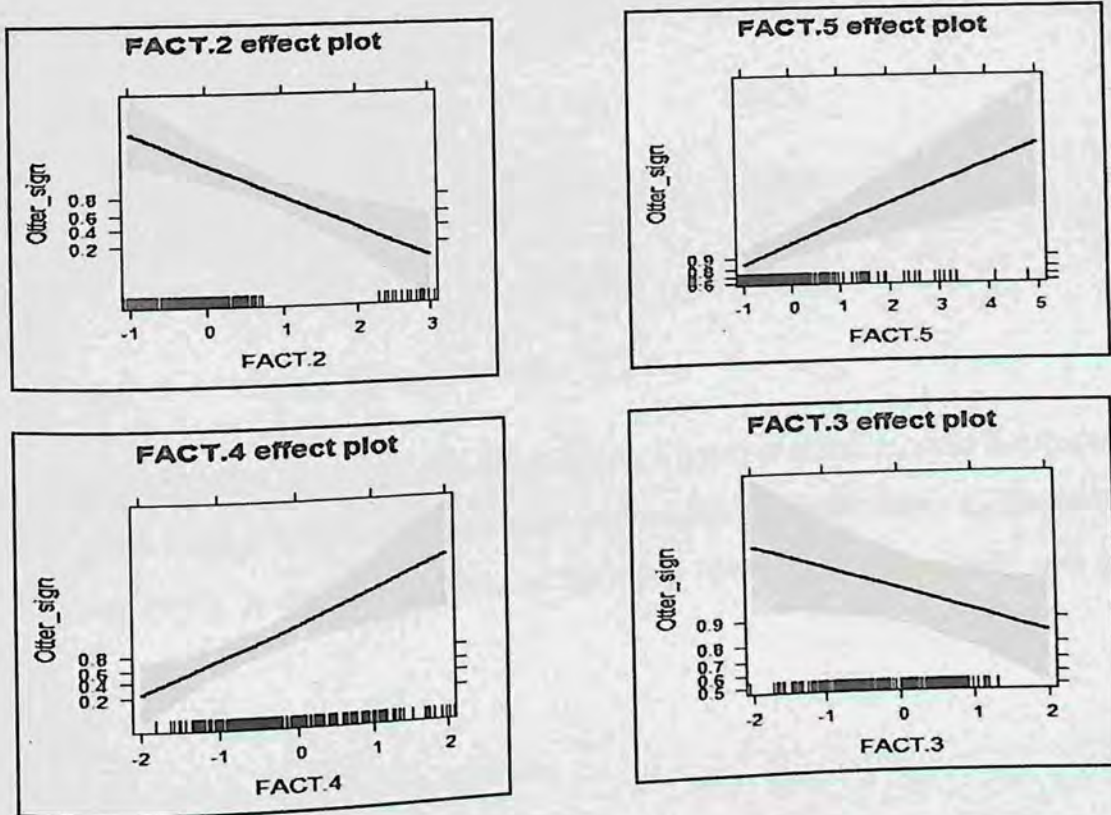


Fig 9. Effect plots showing principal components (named as FACT.) influencing habitat use

2.3.5 Habitat use and prey abundance

Although the intensity of habitat use showed a neutral trend between habitat use and relative fish abundance (Width of river was highly correlated with Prey abundance, hence it was removed from PCA. Width of river was chosen upon prey abundance because most of the other variables are pertaining towards environment and selecting width of river would enable holistic analysis of system.) Yet prey abundance has been found to be an important factor in habitat selection by otter (Mason & MacDonald, 1986, Anoop & Hussain, 2005, Nawab & Hussain, 2012; Kruuk, 2006). In order to see influence of fish prey abundance on otter habitat usage, a linear regression model was done with otter signs in each 200 m as dependent variable and Fishes classified into three size classes, 1-20 cm, 21-40 cm, 40 cm and above as independent variables. The results are summarized below.

Coefficients:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.68157	0.35041	-1.945	0.0518 .
Fish_Large	-0.97550	2.10074	-0.464	0.6424
Fish_Med	1.84506	0.89847	2.054	0.0400 *
Fish_Small	0.00471	0.91333	0.005	0.9959

---Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The fishes in the medium size class (20-40 cm) have a positive effect on otter habitat usage. The result is in confirmation with the general size class of fish taken by otters in literature (Kruuk, 2006; Hussain, 1993). A detailed checklist of the fishes obtained from the study area is given in Appendix.



Plate 4. Kuruva island- a protected habitat of smooth-coated otter



Plate 5. A typical small-clawed otter habitat in Wayanad WLS



Plate 6 Smooth-coated otters in protected river stretch (From Kuruva)



Plate 7. Small-clawed otter from Kuruva island occurring in smaller streams

2.3.6 Differentiating between signs of smooth-coated and small-clawed otter

The pugmarks of smooth-coated otter measured about 9.34 cm length and 7.20 cm breadth for forefoot and 10.6 cm length and 7.22 cm breadth for hindfoot. The forefoot of small-clawed otter measured around 4.1 cm length and 3.4 cm breadth and hind with 5.7 cm length and 3.4 cm width. The spraint of small-clawed otter contained primarily of crabs with a sweet musky odour (Perinchery, 2011) and that of smooth-coated otter contained mostly fish remains with pungent smell (Anoop & Hussain, 2005). Also it was observed that the spraint of smooth-coated otter is more loose (watery) and that of small-clawed otter is more solidified. Upon degradation both of them turns white.

2.3.7 Habitat segregation between smooth-coated and small-clawed otter

Five surveyed sites under current study holds populations of small-clawed otter (*Aonyx cinerea nirnai*). In order to understand the habitat segregation between both species a binary logit model was used with smooth-coated otter sites as presence sites and small-clawed otter sites as absence sites. 15 different habitat variables were selected for habitat characterization. Disturbance was not taken into account since all presence sites of small-clawed otter were inside protected area and that of smooth-coated otter is both inside and outside the protected area. This will eliminate bias and moreover, the intention is to know how the environmental variables segregate these two species. PCA was run on 15 variables and 5 Principal components were selected with eigen values more than 1 (Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.583). About 75.65% variation in the system was explained by 5 components. PC1 (19.612 variance) was interpreted as densely wooded rivers. PC2 (17.291 variance) was interpreted rivers with dead woody vegetation. PC3 (16.115) was interpreted as rivers with emergent rocks. PC4 (14.250 variance) was interpreted wide rivers with grassy banks. PC 5 (8.385) was interpreted as faster streams with far escape cover. Summary of the binomial regression is given below

Coefficients:

	Axis title	Estimate	Std. Error	z value	Pr(> z)
(Intercept)		3.1803	0.5843	5.443	5.25e-08 ***
PC 1	Shallow densely wooded rivers	-3.7044	0.553	-6.699	2.10e-11 ***
PC 4	Wider rivers with open canopy	2.1712	0.6999	3.102	0.001922 **
PC 2	Dead woody vegetation	-1.7905	0.5022	-3.565	0.000364 ***
PC 5	Faster streams with far escape cover	1.4345	0.4171	3.439	0.000583 ***
PC 3	Rivers with emergent rocks & mudbanks	-0.7225	0.4058	-1.78	0.075007 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The result of regression analysis shows that smooth coated otter habitats are comparatively deeper and less wooded than small-clawed otter habitats (PC 1). While Smooth-coated otters chose wide rivers with grassy banks, small clawed otter selected smaller streams (PC 4). The small clawed otter habitats are characterized by rivers with more dead woods in and around the water body (PC 2). Water current and escape cover distance seems to have a positive correlation on smooth-coated otter habitats, with small-clawed otter habitats appearing to be more stagnant (PC 5). The small-clawed otter habitat is characterized by presence of more emergent rocks.

Table 8. Rotated Component Matrix

Variables	Component				
	1	2	3	4	5
WC	-0.093	-0.126	0.256	-0.204	0.654
AWD	-0.566	0.424	-0.388	0.386	-0.092
WR	-0.451	0.272	-0.118	0.722	0.084
BS	-0.111	-0.122	-0.342	-0.596	0.274
CC	0.840	-0.152	-0.236	-0.025	-0.050
ECD	0.111	0.001	-0.087	0.111	0.755
TES	0.494	0.050	0.283	-0.487	-0.050
TEM	-0.428	-0.060	-0.525	-0.275	-0.340
TEG	0.050	-0.386	-0.187	0.811	0.068
TNFT	-0.314	0.875	-0.234	0.042	-0.081
TNTB	0.833	-0.009	0.098	0.022	0.123
TNNW	0.648	0.625	0.085	-0.239	-0.136
TNSR	0.115	-0.213	0.851	-0.164	-0.004
TNPR	-0.141	-0.216	0.882	-0.040	0.066
TNFTW	0.057	0.939	-0.209	-0.009	-0.015

(WC = Water current, AWD= Average water depth, WR= Width of river, BS= Slope of the bank, CC=Canopy cover, ECD= Escape cover distance, TES=Total extent of sandbars, TEM= Total extent of mudbanks, TEG=Total extent of grassbanks, TNFT=Total number of fallen trees, TNTB= Total number of trees with buttresses, TNNW= Total number of natural waterholes, TNSR= Total number of steep rocks, TNPR=Total number of perchable rocks, TNFTW=Total number of fallen trees in water)

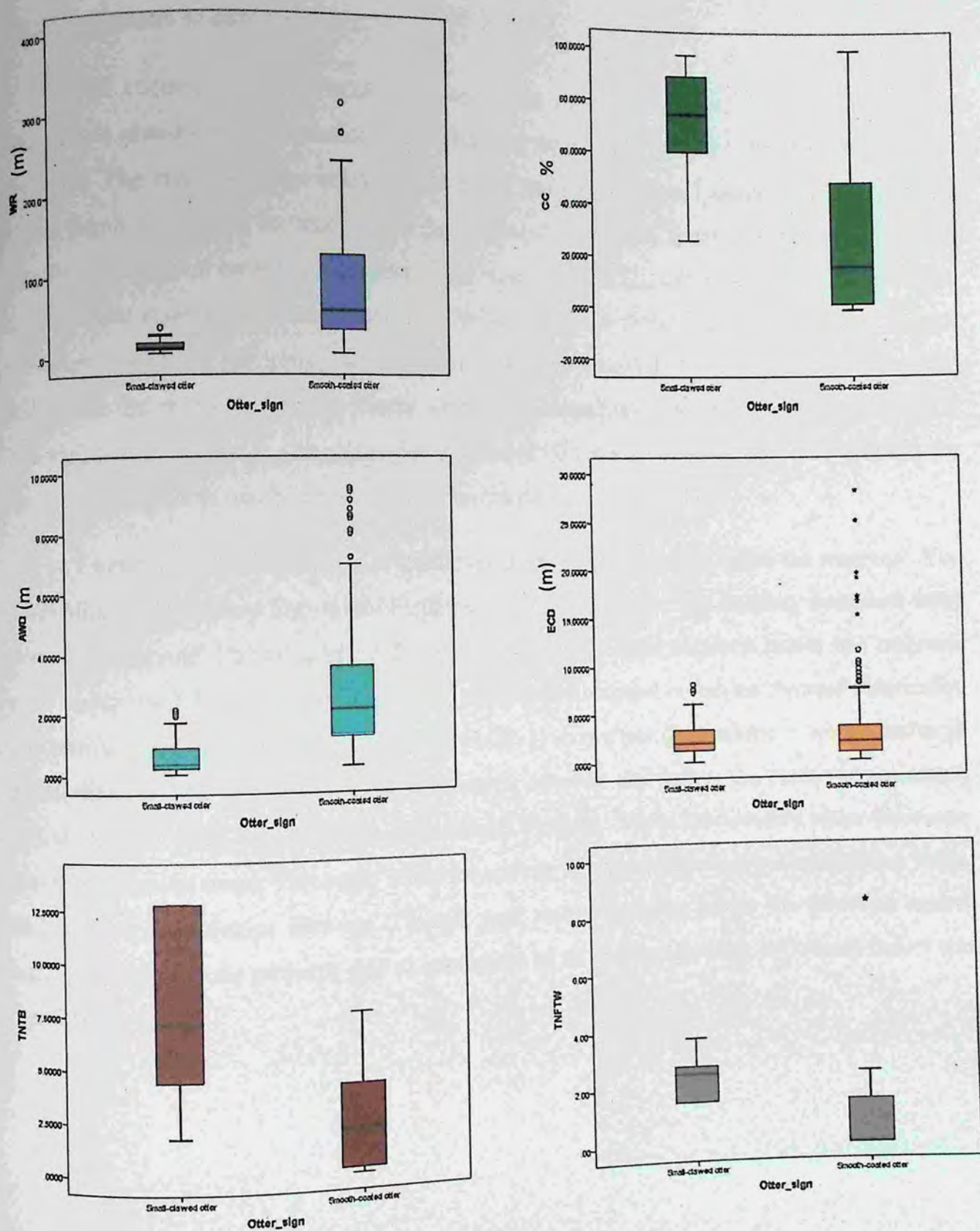


Fig 10. Boxplots showing the independent variables upon otter presence and absence (sitewise)

2.3.8 Influence of dam on otters

The encounter rate of otter signs below the reservoir was relatively low. From the presence vs absence site information, water flow and water depth seemed to be affecting the otter presence. The river stretches below the reservoir has mostly altered water flow regimes and lower depth compared to that above the reservoir. Although water current doesn't show significant effect on otter habitat selection (p value = 0.69032), there might be other possible effects of the reservoir on otters since only 76 percent of the variance was explained by current variables. The water discharge data in Kabini river was collected at two different points above and below the reservoir namely, Muthenkera and T.Narasipura, between the years 1973-2012. The variation in discharge was plotted for a period of 10 years (2002-2012) and also annually for the year 2012 (due to unavailability of more recent data).

From the field it was observed that otters occupied habitats right below the reservoir. Yet, the habitat recorded very high level of anthropogenic disturbance. Sign intensity increased away from the reservoir. Unfortunately only two sampling sites were obtained below the reservoir since unexpected dam release was happened and the environment or habitat changed drastically. The annual water discharge for 10 years (2001-2011) shows that fluctuations in water discharge below the reservoir is more irregular than above reservoir and below the reservoir prolonged periods for low water discharge is more (Anoop & Hussain, 2004). The monthly water discharge also shows similar trend. This could affect the activity of otters such as grooming, making holts, finding communal latrine sites etc. Though, peak water discharge below the reservoir seems higher than that above probably due to confluence of more than ten other tributaries below the reservoir.

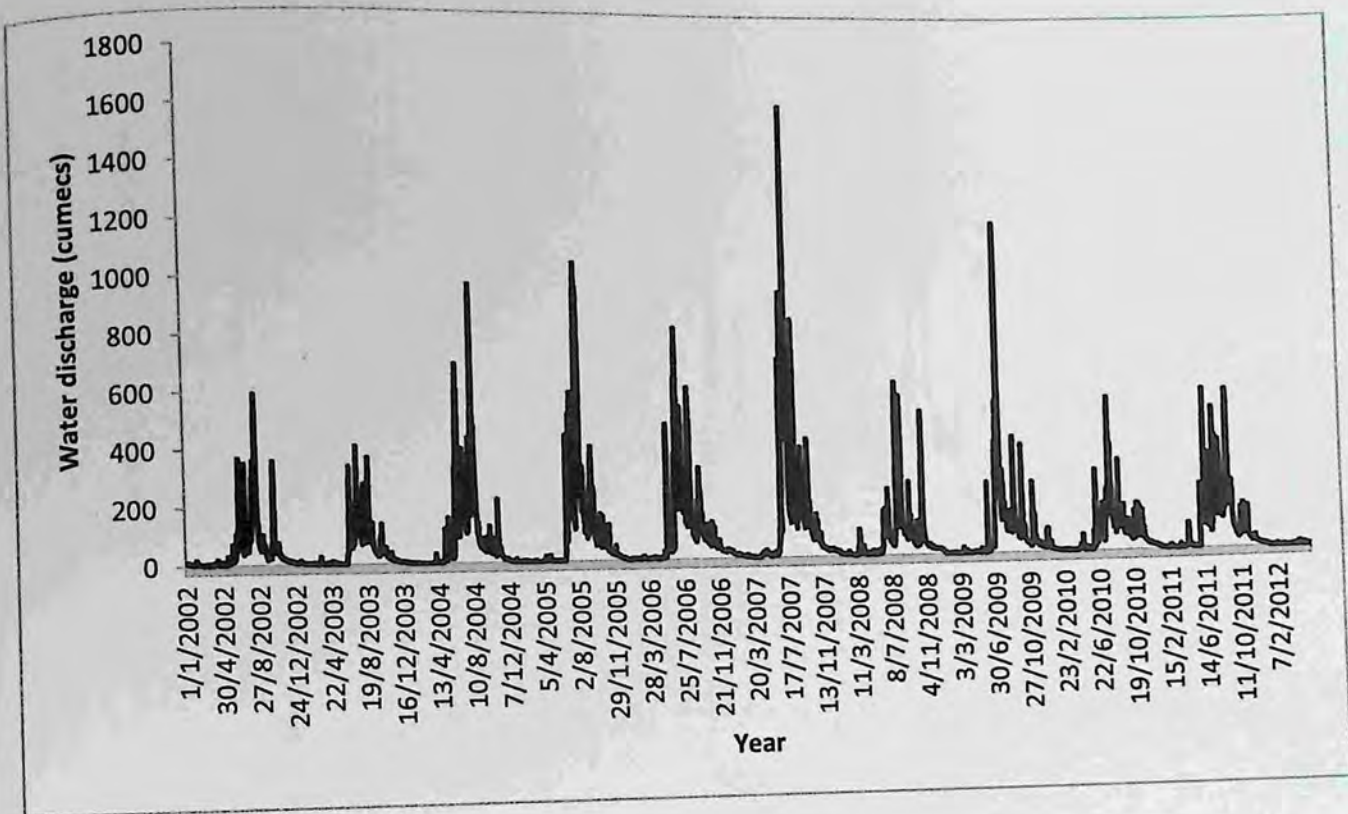


Fig 11. Annual water discharge data for Muthenkera (above reservoir)

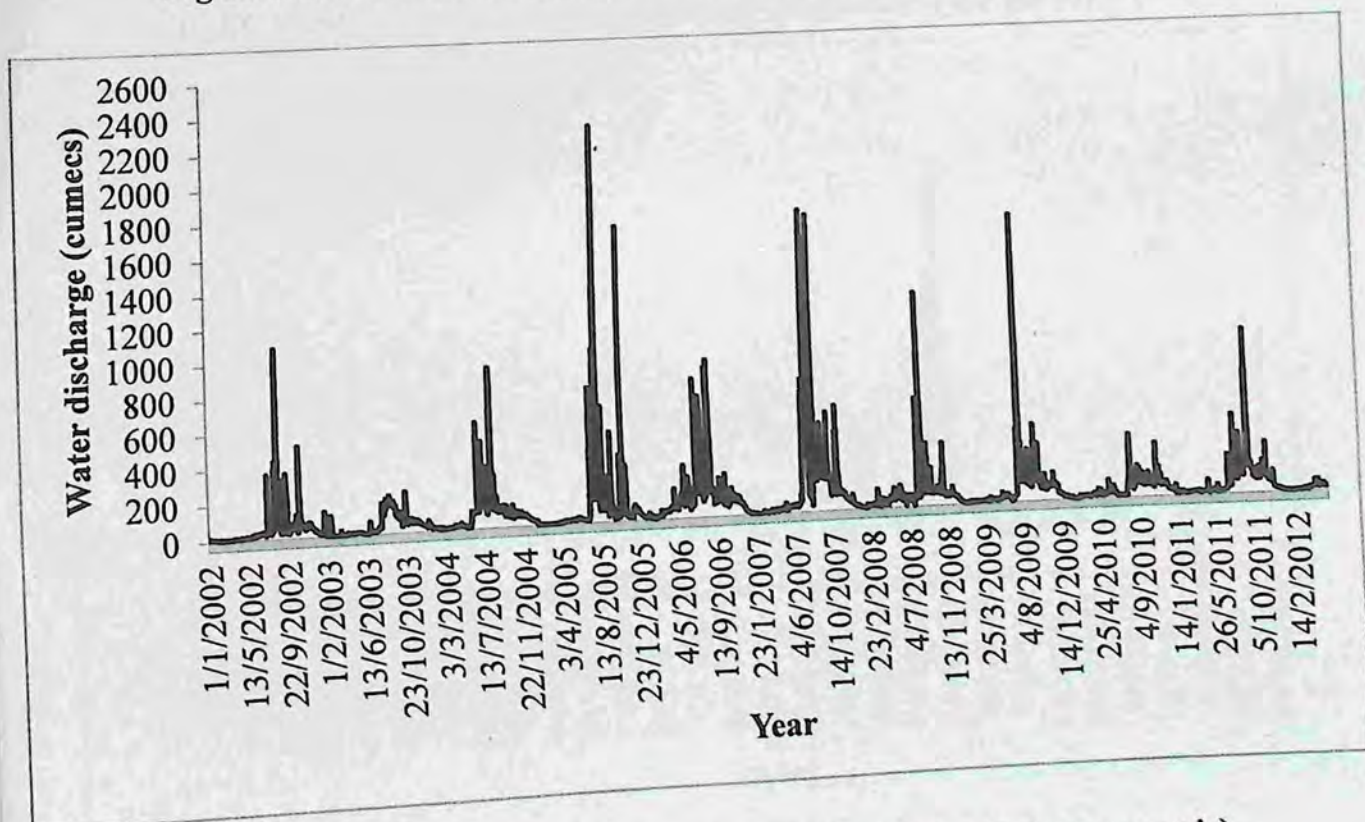


Fig 12. Annual water discharge data for T.Narasipura (below reservoir)

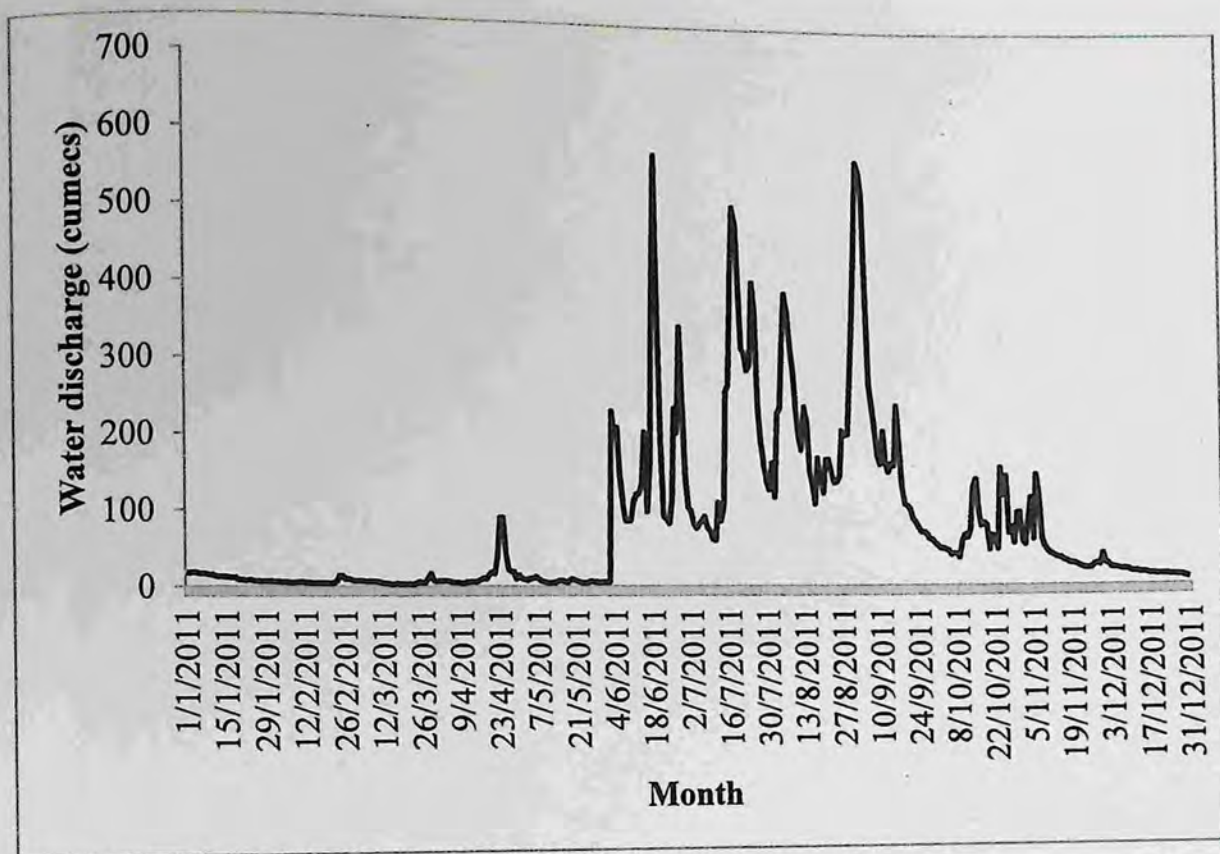


Fig 13. Monthly water discharge data for Muthenkera for the year 2011

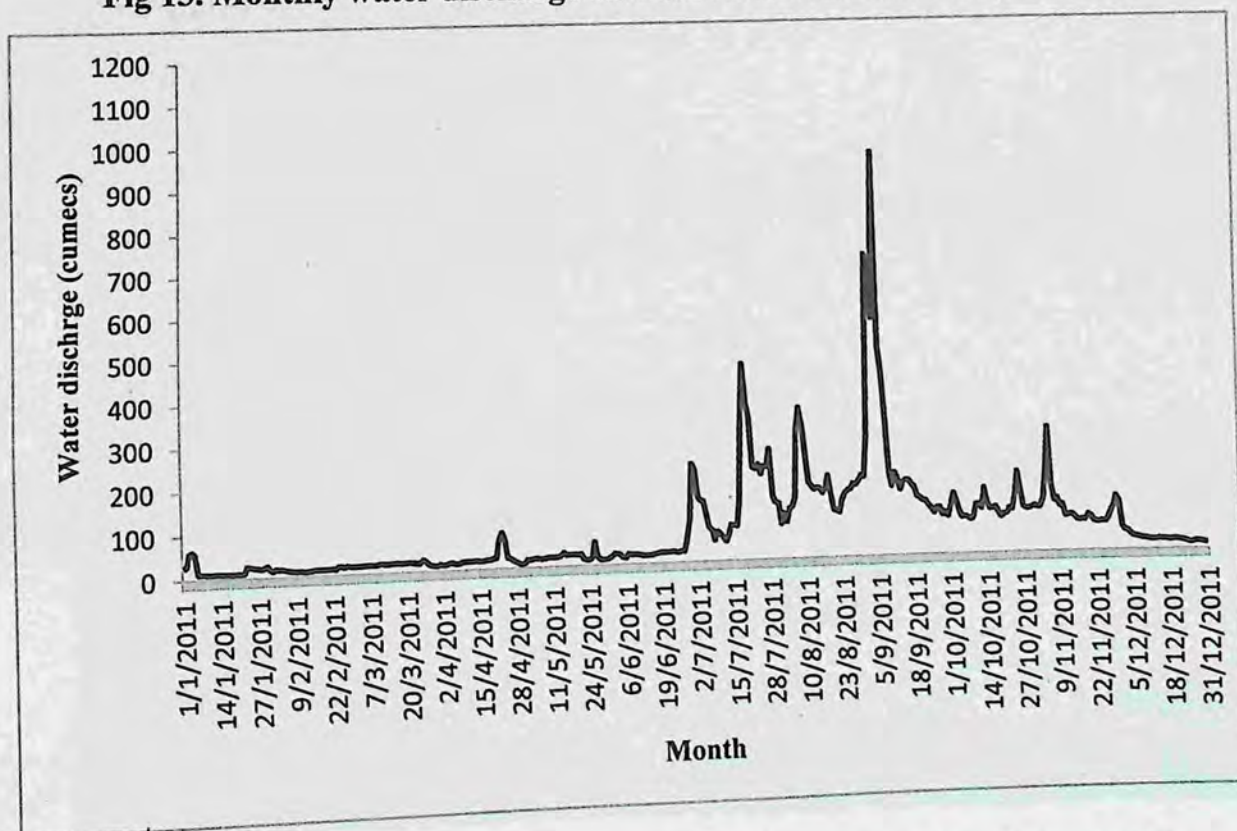


Fig 14. Monthly water discharge data for T.Narasipura for the year 2011



Plate 8. An otter holt submerged due to unexpected dam release

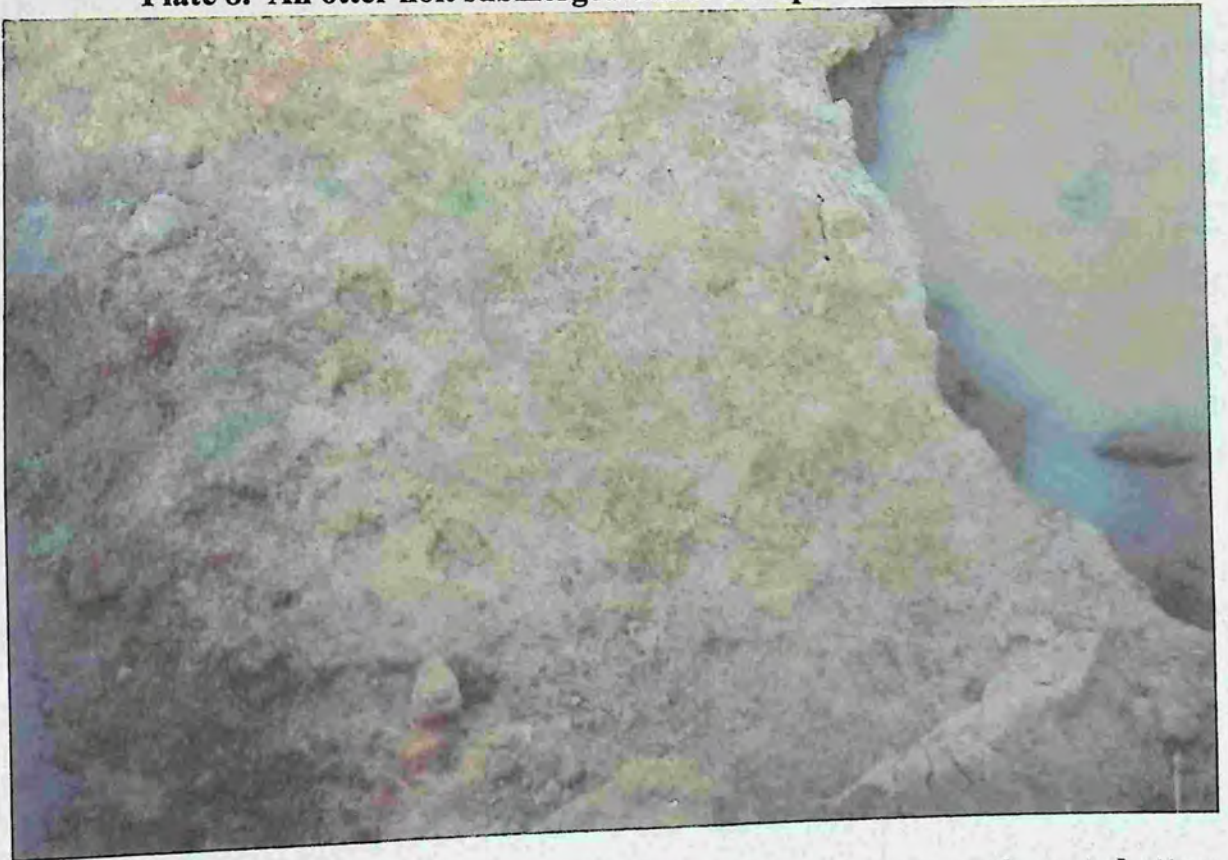


Plate 9. A heavily sand-mined area used as grooming site by smooth-coated otters

2.3.9 Camera trapping otters

The camera trap attempted for smooth coated otter did not yield successful results. The encounter rate was quite low (0.0188 per trap night-highest) to no captures at most sites. The total number of photo captures of smooth coated-otters using 5 camera traps was 8. Out of the 11 presence sites, photographic evidence of smooth-coated otters was obtained in 6 using both direct sightings and camera traps. Nine direct sightings of smooth-coated otters were recorded during the field work with a group size ranging from 1-4 in intensive study areas. Small-clawed otter was camera trapped at 3 intensive study areas all showing a pair of otters.

2.3.10 Detectability trials

A total of 289 signs (pugmarks) were made using pop molds. Out of which 139 signs were detected by observer. (Detectability = 0.481).

2.3.11 Estimation of Fluvial Functionality

The fluvial functionality was estimated from 14 response variables. The variables collected at each 200 (for 1km only) were then averaged to get final fluvial functionality value for a site. The table below shows the summary of Fluvial Functionality for 11 sites. The Fluvial functionality index shows a decreasing trend from inside to outside protected area showing sensitivity towards disturbance. The FFI was lower (mean =145.56) below the reservoir than above (mean=243.825). The trend of FFI is PA>OS>AG>AD>UR. Spearman's rank correlation was used to see any correlation between otter sign intensity and fluvial functionality. The results are summarized below. The results show that FFI and otter sign intensity are positively correlated indicating that habitat selection by smooth-coated otter shows better 'ecological health' of the river.

Table 9. Fluvial Functionality of 11 Sites

Category	Site	FFI	Judgment
PA	Kuruva1	294.5	excellent
OS	Kuruva2	269.375	excellent
PA	Muthanga	267.75	excellent
AG	Nugu2	231.5	good
PA	Bogeswara	217.5	good
AG	Nugu1	192.625	good-fair
AD	Hulahalli	183.75	good-fair
AG	Bairekkuppe	170	fair
UR	Mananthavady	143.375	fair
UR	Panamaram	139.375	fair
AD	Beechanahalli	107.375	fair-poor

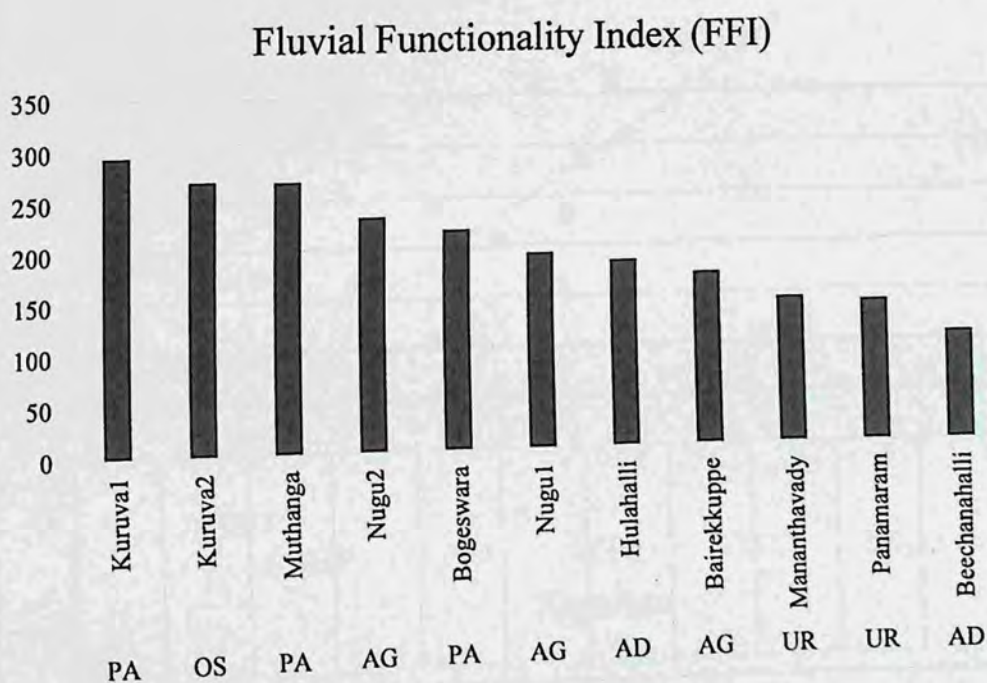


Fig. 15 . Fluvial Functionality of 11 sites in Kabini River

Table 10. Spearmann's rank correlation between FFI and Otter sign/km

Correlations			FFI	Otter sign/km
Spearman's rho	FFI	Correlation Coefficient	1.000	.656*
		Sig. (2-tailed)	.	.028
		N	11	11
	Otter sign/km	Correlation Coefficient	.656*	1.000
		Sig. (2-tailed)	.028	.
		N	11	11

*. Correlation is significant at the 0.05 level (2-tailed).

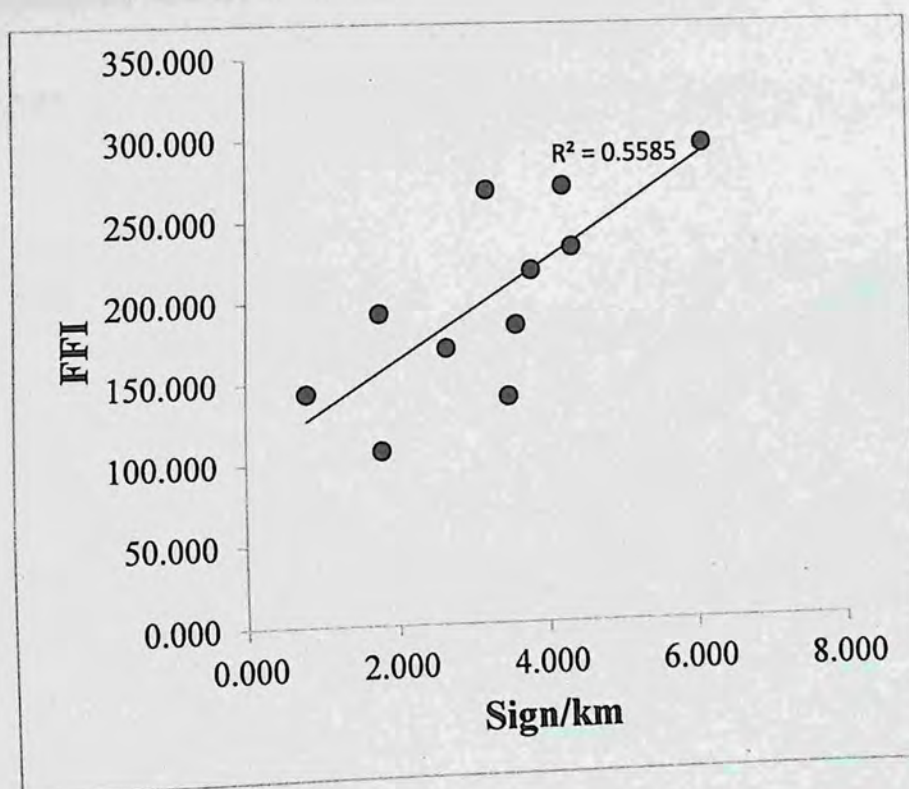


Fig 16. Trends in FFI and otter sign/km in 11 different sites



**Plate 10. An unusual habitat of Smooth-coated otter from Nugu river with shallow river
(Note spraint on rock)**



Plate 11. Heavy sand mining in smooth-coated otter habitats after Kabini reservoir

2.4 DISCUSSION

Smooth-coated are semi-aquatic predators (Kruuk, 2006). Little was known about the ecology of this species until late 1990s (Hussain, 1993, Anoop & Hussain 2004). Although occurring in a wide range of habitats (Foster-Turley, 1992), smooth-coated otters face severe threats to their habitat by being a specialized carnivore and occurring mostly outside protected areas. The results of the current study show how the species embrace the changes in the habitat, despite being highly specialized. Kabini river has largely been modified as far as it's ecology is concerned. Smooth-coated otters are apex predators in the same river system.

Not surprisingly, highest encounter rate of otter signs was from within protected areas. . But more presence sites were recorded outside protected areas, the reason being the landscape and the habitat within protected areas. Smooth-coated otters are animals of larger river systems (Kruuk, 2006). Half of the study site is located within Western Ghats landscape (Sekhar *et.al*, 2004). The undulating terrain has an average elevation above 700m. Most of the water bodies here inside protected area are smaller hill streams, with shallow water and faster current causing the absence of Smooth-coated otter inside protected area despite being least disturbed. The result is in confirmation with the study conducted in Kaveri basin by Shenoy *et.al.*, 2006. This kind of hill streams is a habitat for small-clawed otters (Perinchery, 2007). Thus 5 presence locations of small-clawed otter were recorded within the protected area. Only two protected stretches are located within main Kabini channel, Kuruva islands and Kabini river between Nagarhole and Bandipur above Kabini reservoir, where presence of smooth-coated otters were recorded. Another presence site of Smooth-coated otter is within a tributary called Noolpuzha (Muthanga) inside Wayanad Wildlife Sanctuary and Bandipur National Park, being the only tributary inside protected area with a population of Smooth-coated otters. Outside protected area the presence of smooth-coated otters was mostly governed by disturbance factors such as presence of humans, grazing etc.. Most of the presence sites were characterized by arboreal vegetation on banks, deeper waters and slower currents which are mostly the characteristic of smooth-coated otter habitat (Prater, 1971). The presence of islands in rivers positively influences otter presence. This might be primarily because of the fact that outside PA, river banks are mostly disturbed and islands are more inaccessible and secure from human disturbance.

The finer scale study of habitat selection by smooth-coated otters within presence locations provided the following insights into its ecology. As most of riverine habitat has been modified, the habitat selection by smooth-coated otter is largely determined by elements of disturbance. The presence of humans and livestock in and around the river system has a high negative impact on selection of habitats by otters. Cattle grazing is a severe threat to bank vegetation which has been identified by many authors (Taylor, 1986; Amy *et.al.*, 2001). It mostly destroys the bank vegetation which provides escape cover for the otters. The linear regression analysis shows the same that escape cover height is positively influencing otter habitats while, escape cover distance is influencing it negatively, also proven by other studies (Qureshi *et.al.*, 2009; Nawab & Hussain, 2012; Shenoy *et.al.*, 2006). Alternatively rivers with emergent rocks seem to be positively influencing habitat selection (Nawab and Hussain, 2012). There could be multiple reasons for this; emergent rocks act as an alternative for escape cover (the animal doesn't have to come to land after each hunting bout), Also they can act as 'dinner tables' without risking to come on land. But sandmining loaded on PC 2 and PC 3 showed negative and positive trends. As a disturbance factor it influences the otters habitat selection negatively. But in sand mined rivers, where the banks are heavily disturbed it pushes otters to choose emergent rocks in rivers may be as 'refuge', thus affecting habitat selection positively. But from personal observations, it was found that the smooth-coated otters use sand mined areas as grooming sites, probably because of lack of other options.

The intensity of habitat use was studied through indirect evidences (Kruuk, 1986). Habitat use was also governed by the same factors as that of habitat selection. Again, habitat use was highly influenced by human disturbance. This actually shows towards increasing gradients of disturbance, from protected area to urbanized landscape how habitat became unusable for otters. When it comes to usage sand mined areas have a less preference. Additionally canopy cover and grassy banks show positive correlation with habitat use (Anoop & Hussain, 2004). More canopy cover also indicates more number of trees on the bank, trees/ bamboos with buttresses provide sites for making holts and are also relatively undisturbed. Almost all the activities of otters are centered around the holt (Mason & MacDonald, 1986; Hussain, 1993; Kruuk, 1978). The escape cover has a stronger influence on habitat use. Kabini River has flowered in 2011 and died off. Yet the dead and decaying bamboos are providing excellent

escape cover for otters at some sites. Especially near Kabini backwater side, almost no tree cover is there after the death of bamboo, the dead and decaying bamboo may work as escape cover as well as provide holt locations. But a few years after the when the bamboos are completely degraded and no cover is left, it might pose a threat to survival of otters.

The influence of prey abundance on carnivores is studied by many authors (Karanth *et.al.*, 2004; Myers *et.al.*, 1979; Gittleman, 1989; Wise 1980) and also on otter by (Kruuk, 2006; Jacobsen; 2009; Anoop & Hussain, 2005). Preliminary analysis of otter presence and absence shows otters avoid areas with high fishing pressure. This would mean that prey is a critical factor for their survival. Otters feed on fishes of size varying size classes, although they avoid young size classes (Kruuk *et.al.*, 1987; Hussain, 1993). From analysis it's shown that fishes of medium size classes (21-40 cm) have a positive influence on habitat use. While fishing in study sites it was found that large size classes (<40 cm) are very less and medium size classes represent the most.

Since two species of co-occur in the same landscape, there is need to find which species occur where. The small clawed otters, compared to smooth-coated otter are smaller animals mostly occupying evergreen forest habitats (Kruuk, 1994). Although, the present study revealed the existence of this species in dry deciduous forests (Nagarhole) as well. The smooth-coated otter, compared to small-clawed otter chose areas with less canopy cover and less number of trees on the bank (Hussain, 1993; Perinchery, 2011; Kruuk *et.al.*, 1994). The reason is that Smooth-coated otter is not a forest animal like small-clawed otter, whereas the latter lives in well wooded hill stream areas with lot dead woody vegetation and emergent rocks on banks and in water. Also small clawed otter prefers shallow water compared to smooth-coated otter (Kruuk, 1994; Perinchery, 2011, Hussain, 2013, Foster-Turley, 1992). Smooth-coated otter chose wide rivers with grassy banks while the later occurs in streams of lower width.

An interesting case was found in the study site, where smooth-coated otters are occurring in habitats similar to that of small -clawed otter. Nugu/Noolpuzha is one of the tributaries of the Kabini river where presence of smooth-coated otter was found. Multiple sites were located in this river stretch. A mini irrigation project is present in this river which is called Nugu reservoir. The dam was built in 1947. Since then smooth-coated otters in this river might have been

isolated from the main river population. The land-use near to the reservoir and upstream is mostly dominated by agriculture. There intense pressure of grazing, sand mining and fishing from this area. But the river is coming from Wayand WLS, through Bandipur NP. The sampling site closer to the reservoir had less signs of otters (1.765/km) and low prey abundance (Total relative prey abundance = 0.2778), yet again the next sampling site upstream and along the forest fringes had more number of signs (4.348/km) and higher prey abundance (Total relative prey abundance = 0.4167), which would actually mean the usage of the river habitat has been increasing upstream. Closer to the forest the habitat is less disturbed. But while moving upstream the habitat itself had changed into shallower, stream like habitat of small-clawed otter. The third sampling stretch was located within Wayanad Wildlife Sanctuary where evidences of both species were found, though occurring *randomly* in the same river stretch (Muthanga) (Foster-Turley 1992). But the habitat is very marginal for a smooth-coated otter there with shallower depth (Mean = 1.25m, s.e = 0.0976) and with a total relative prey abundance of 0.4167, but with smaller size class fishes (mean=13.853, S.E. = 1.304). In addition to this it was observed from all the spraints checked that smooth-coated otters had their diet composed mostly of crab, rather than fish. Possibly because, it might be difficult for a large animal like smooth-coated otter to forage or catch fish in such shallow area. Hence the more sedentary prey like a crab might be an 'easy catch'. This could be an example, where smooth-coated otters are pushed upstream into small-clawed otter habitats due to increasing human pressure downstream.

An opposite trend was observed in a site called Kuruva islands in the main river channel, where small clawed otter close to smooth-coated otter habitats. The island divides the main river channel into smaller and bigger channel while the smaller channels are occupied by small-clawed otter and bigger channels are occupied by smooth-coated otter. But during summer the smaller channels dries up and this might push small-clawed otters to use smooth-coated otter habitat for which further study is required.

The dams influence the habitat selection and distribution of otters as evident from discharge datasets. There is more irregular flow downstream. The water current is altered. There is a prolonged low water discharge level downstream of the dam. Yet the peak discharges are on a higher side downstream. One incident was observed where a holt was submerged under water

due to unexpected water release indicating that the otters are still not adapted to water flow regimes which are irregular. Also evidently, the population the tributary, Nugu is separated from the population in the main river channel due to the presence of the reservoir.

The camera trapping attempted for capturing otter images weren't very successful due to following reasons

- i. Otters are elusive animals and they easily avoid camera traps
- ii. Setting camera trap at a particular point (otter usage area) along the river has the drawback that the animal would be detected only if it comes to that point, unlike trail cameras set along the side of trail (which can be assumed as a line) and any animal using the trail will be captured
- iii. The camera trap models like Spypoint, Cuddeback (attack) don't have good sensors to detect small carnivores
- iv. Setting camera traps at very low height for otters often results in over-exposed images.
- v. Usually its not easy to fix camera traps along the banks, which are sloping and trees (to tie) are slanting to water. Better to set camera traps along water edge facing landwards.
- vi. Setting camera trap outside protected area had big limitations
- vii. The otters usually select sites which are very inaccessible for humans or areas with thick undergrowth when camera traps with flash will give over-exposed images due to confined space.

The estimated fluvial functionality shows riverine habitat functioning level from excellent to poor, the protected areas have excellent river systems while that of urban or immediately after the reservoir has a lower value due to many anthropogenic interferences such as pollution, erosion, loss of riparian cover etc. obtained through the response variables (Carone et.al., 2012). The areas nearer to the reservoir has lower FFI values due to the reason that there the riverine habitat becomes more lentic in nature than lotic, altering the flow regimes and the fauna within. Also it was observed that after the reservoir the FFI values increased with

increasing distance probably due to more tributaries joining main river channel and alterations in water flow are compensated. The FFI values and sign intensity has a positive correlation, indicating that otter habitats are present in more healthy river system and otters can be considered as an indicator of better ecological functioning of the river.

Land-use pattern with increasing level of disturbance from protected area to urban sites shows a negative relation with otter presence. Though habitat selection will happen in similar manner only, the habitat quality in terms of bank vegetation, water flow, prey abundance etc. is poorer outside protected areas. Also the fluvial functionality of the river is affected in the same manner. The inferior habitats in agricultural or urban areas pushes smooth-coated otters to choose habitats in protected areas by moving upstream creating more overlap between habitat of smooth-coated and small-clawed otter.

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APPENDIX – I. Variables and scoring system for fluvial functionality index

Bank	Left		Right
1) Land use pattern of the surrounding area			
Undisturbed forests, woods and/or natural wetlands	25		25
Meadows, pasture, woods, a few areas of arable and uncultivated land	20		20
Mainly seasonal cultivation and/or mixed arable and/or permanent cultivation	5		5
Urbanised area	1		1
2) Vegetation of primary perfluvial zone (fluvial zone around watercourse)			
Arboreal riparian formations	30		30
Shrub riparian formations (shrubby willow thicket) and/or reeds	25		25
Non-riparian arboreal formations	10		10
Made up of non-riparian or herbaceous or absent shrub species	1		1
2b) Vegetation of secondary perfluvial zone			
Arboreal riparian formations	20		20
Shrub riparian formations (shrubby willow thicket) and/or reeds	15		15
Non-riparian arboreal formations	5		5
Made up of non-riparian or herbaceous or absent shrub species	1		1
3) Extention of the perfluvial vegetation zone			
Perfluvial vegetation zone >30 m	20		20
Perfluvial vegetation zone 5-30 m	10		10
Perfluvial vegetation zone 1-5 m	5		5
Perfluvial vegetation zone absent	1		1
4) Continuity of the perfluvial vegetation zone			
Continuous perfluvial vegetation without gap	20		20
Perfluvial vegetation zone with gap in vegetation	10		10
Frequent gaps or only continuous and consolidated herbaceous vegetation	5		5
Soil without or with thin herbaceous vegetation	1		1

5) Water conditions of the river bed			
Width of the annual peak flow bed less than three times than the wet river bed		20	
Annual peak flow bed more than three times than the wet river bed with		15	
Annual peak flow bed more than three times that of the wet river bed with		5	
Wet river bed non-existent or almost non-existent or presence of		1	
6) Stream bank structure			
Bank with arboreal vegetation and/or stones	25		25
Bank with grass and shrubs	15		15
Bank with a fine grassy layer	5		5
Bare banks	1		1
7) Retention structures of trophic matter			
River bed with large boulders and/or old trunks firmly embanked or presence of	25		25
Boulders, cobbles and/or branches present with depositing of sediment or scarce	15		15
Retention structures free and mobile during flooding or absence of reeds	5		5
River bed with sandy sediment without algae or smooth artificial profile with	1		1
8) Erosion			
Little evident and not important	20		20
Only at bends and/or narrow passages	15		15
Frequent with cutting of the banks and of roots	5		5
Very evident with undercutting of banks and landslips or presence of artificial	1		1
9) Cross-section			
Natural		15	
Natural with some artificial intervention		10	
Artificial with some natural elements		5	
Artificial		1	
10) Stream bottom			
Diversified and stable		25	
Movable in stretches		15	
Easily moveable		5	

Cemented		1	
11) Riffles, pools or meanders			
Clearly distinguished and recurrent		25	
Present at different distances and at irregular intervals		20	
Long pools which separate short riffles or vice versa, few meanders		5	
Meanders, riffles and pools absent, straightened path		1	
12) Vegetation in the wet river bed			
Periphyton only noticeable on touching and/or low covering of macrophytes		15	
Periphyton visible and/or small covering of macrophytes		10	
Periphyton fair, presence of filamentous algae and/or monotonous macrophytes		5	
Periphyton thick and/or macrophytes relatively unvaried		1	
13) Detritus			
Presence of leaves and woods, vegetable fragments recognisable and fibrous		15	
Leaves and woods scarce, vegetable fragments fibrous and pulpy		10	
Pulpy fragments		5	
Anaerobic detritus		1	
14) Macrobenthonic community			
Well structured and diversified, appropriate to the fluvial type		20	
Sufficiently diversified but with altered structure as compared to that expected		10	
Poorly balance and diversified with a prevalence of taxa tolerant of pollution		5	
Absence of a structured community, presence of a few taxa all relatively tolerant		1	
Total Score			
Fluvial Functioning Level			

APPENDIX II. Conversion of scores to fluvial functional levels

LEVEL	SCORE	JUDGEMENT
I	261-300	excellent
I-II	251-260	excellent-good
II	201-250	good
II-III	181-200	good-fair
III	121-180	fair
III-IV	101-120	fair-poor
IV	61-100	poor
IV-V	51-60	poor-very poor
V	14-50	very poor

APPENDIX III – Checklist of fishes

Sl. No.	Species
1	<i>Barbodes sp 1</i>
2	<i>Bangana dero</i>
3	<i>Barbodes carnaticus</i>
4	<i>Barbodes sp 2</i>
5	<i>Channa marulius</i>
6	<i>Channa punctatus</i>
7	<i>Channa striatus</i>
8	<i>Cirrhinus reba</i>
9	<i>Garra mullya</i>
10	<i>Garra stenorrhincos</i>
12	<i>Hemibagrus punctatus</i>
13	<i>Heteropeniestis fossilis</i>
14	<i>Hypsalarbarbus micropogan</i>
15	<i>Hypselobarbus dubius</i>

16	<i>Hypselobarbus spl</i>
17	<i>Labeo ariza</i>
18	<i>Labeo calbasu</i>
19	<i>Labeo gonius</i>
20	<i>Labeo sp 1</i>
21	<i>Mastacembalus armatus</i>
22	<i>Mystus cavassius</i>
23	<i>Mystus montanus</i>
24	<i>Notopterus notopterus</i>
25	<i>Ompok bimaculatus</i>
26	<i>Parambassius ranga</i>
27	<i>Parambassius thomassi</i>
28	<i>Pristolepis marginatus</i>
29	<i>Puntius chola</i>
30	<i>Puntius chonchonius</i>
31	<i>Puntius sarana</i>
32	<i>Salmophysia boobis</i>
33	<i>Tilapia mossambicus</i>
34	<i>Tor khudri</i>
35	<i>Unidentified 1</i>
36	<i>Unidentified 2</i>