

**RESOURCE USE AND DISTRIBUTION OF
SMOOTH-COATED OTTER (*Lutrogale perspicillata*) IN THE SUB-
HIMALAYAN FOOTHILL RIVERS OF UTTARAKHAND**

**DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT, IN PARTIAL
FULFILLMENT OF THE MASTER'S DEGREE IN
WILDLIFE SCIENCE**

Submitted by

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CERTIFICATE

This is to certify that Ms. Sayanti Basak of the Wildlife Institute of India has carried out a piece of original research work entitled “**Resource use and distribution of Smooth-coated Otter (*Lutrogale perspicillata*) in the sub-Himalayan foothill rivers of Uttarakhand**”, in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot. These investigations were carried out under our supervision at the Wildlife Institute of India from November 2018 to June 2019. We also certify that this work has not been submitted for any other degree of any university.

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DECLARATION

I, **Sayanti Basak**, hereby declare that the research work entitled “**Resource use and distribution of Smooth-coated Otter (*Lutrogale perspicillata*) in the sub-Himalayan foothill rivers of Uttarakhand**”, carried out in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot is an original piece of research work. This research work was carried out under the supervision of **Dr. S.A. Hussain, Dr. Bivash Pandav** and **Dr. J.A. Johnson** at the Wildlife Institute of India from November 2018 to June 2019. I hereby declare that this work has not been submitted for any other degree of any university.

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SUMMARY

Otters are the apex predators of the wetland ecosystems they inhabit. Being sensitive to both pollution and habitat destruction, the presence of otters in a wetland ecosystem, be it rivers, lakes, swamps, mangroves or estuaries, indicates the occurrence of a viable prey base, thus indicating an ecologically healthy condition of such ecosystems. Coupled with habitat, prey is one of the major factors that limit species populations. Many species, including otters, are often seen to cope up with disturbed surroundings only for the easy accessibility or abundance of prey in those areas. The aim of this study was to understand the ecology of Smooth-coated Otter (*Lutrogale perspicillata*) in terms of their habitat requirements, food habits, and distribution across the landscape.

The study was conducted in select rivers of Rajaji National Park and Tiger Reserve, Lansdowne Forest Division, and Corbett National Park and Tiger Reserve. These protected areas fall in sub-Himalayan region, a region of high biodiversity value threatened by immense anthropogenic pressure.

Habitat parameters were measured at every 250 m along a river bank and also in locations where there were otter evidences. The importance of different habitat parameters influencing otter occurrence were analysed using Generalised Linear Models (GLMs) and non-mapping technique using Bonferroni confidence interval approach. Smooth-coated Otter significantly preferred deep pools with moderate to sparse bank-side vegetation during the mid-winter and late-winter season. Moderate width water bodies are preferred over narrow water bodies. Muddy and sandy bank substrate types were preferred. Rocky stretches were largely avoided. Water body type i.e. pools and bank substrate type, i.e. rocky substrate, are the significantly influencing factors on otter distribution.

Feeding habit of otters were studied by analysing 120 spraints collected throughout the study area. Fishes contributed maximum to the diet of Smooth-

coated Otter having frequency of occurrence (FOC) of 95 % and score-bulk estimate (SBE) of 96.48 %. Frequency of occurrence and Score-bulk estimate methods were used to estimate the proportions of different prey items consumed. While the former method is used more often in studies, it results in the under-representation of major items and over-representation of minor items. Thus, the latter method is used for minimising the discrepancy. In the study, a total of 15 species of fishes could be identified in the otter spraints. *Tor putitora* formed the maximum contribution (FOC = 21.93, SBE = 25.87), followed by *Barilius vagra* (FOC = 12.96%, SBE = 22.44%), while *Channa gachua* (FOC = 0.99, SBE = 0.35), *Labeo calbasu* (FOC = 0.33, SBE = 0.14) and *Puntius spp.* (FOC = 0.33, SBE = 0.22) formed the least.

To estimate fish size from the remains in spraints, a linear regression was drawn between fish length (dependent variable) and vertebrae length (independent variable). For this, a total of 202 vertebrae belonging to 30 individuals of different fish species were measured for the vertebrae dimensions. The data was then subjected to linear regression using SPSS Software. Vertebrae length classes 1.5 – 2 mm (fish length = 110.98 mm), 2 – 2.5 mm (fish length = 136.54 mm) and 2.5 – 3 mm (fish length = 168.69 mm) constituted 25 %, 21 % and 17 % of the vertebrae extracted from spraints. All other size classes were represented inconsistently in the spraints, which means that very small and bigger preys are taken only occasionally.

In this study, we also explored how the habitat suitability modelling could predict the percentage of area and a gradient of environmental conditions suitable for the occurrence of Smooth-coated Otter across the study area. MaxEnt modelling was used to predict habitat suitability of Smooth-coated Otter across the landscape. The most important variables affecting otter distribution were compound topographic index, Euclidean distance from the river, and slope position index. With increasing distance from water, and increasing slope, the suitability of an area to sustain otter populations decreased. It was analysed that, out of the total 3716.18 km², 4.9 % (181.7 km²)

was found to be potential habitat for Smooth-coated Otter, while 95.1 % (3534.4 km²) was unsuitable.

As concluded from this study, habitat use by otters is governed by the availability of certain habitat features such as pools, moderate vegetation, and muddy or sandy bank substrate. This is governed by the necessary requirements of otters such as sufficient prey base, resting, denning and grooming sites, and escape cover. Such features may seem general at first glance, but when observed closely, the habitat features necessary for otter survival are very patchy in distribution. Since otters can move long distances in search of foraging and denning sites, it is necessary that the connectivity of such patches is maintained. With the increasing human population, pressure on the biotic resources is inevitable. The growing demand for water resources especially jeopardizes the resource requirements for otters. Rivers, although falling under the network of protected areas, usually form the boundaries of protected areas, thus making them susceptible to illegal anthropogenic activities. Creation and maintenance of protected area networks with additional legal protection given to rivers and wetlands can be effective in the long-term survival of otters.

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Abstract

1. This study entails the understanding of patterns of distribution, habitat use and diet of Smooth-coated Otter (*Lutrogale perspicillata*) in areas subjected to different disturbance regimes in the sub-Himalayan river systems of Uttarakhand.
2. Indirect signs such as spraints, tracks, holts, and grooming sites, with associated habitat covariates were used to assess factors influencing otter habitat use.
3. Generalised Linear Models and non-mapping technique using Bonferroni confidence interval indicated a preference of deep (3 – 6 m) pools, with muddy and sandy bank substrate and moderate to sparse bank side vegetation by otters. Pools with muddy substrate show a significant positive association with otters, while riffles with boulders as bank substrate negatively influence otter distribution.
4. Otter spraints (n=120) were used to analyse otter diet. Fishes of small and medium-sized lengths were the predominant prey of otters. Habitat suitability was predicted using MaxEnt, which revealed that only 4.9 % of the available area in the region was suitable for the species.
5. With the increasing human population, the growing demand for water resources jeopardizes the resource requirements for otters in the region. Rivers, although falling under the network of protected areas, usually form the boundaries of protected areas, thus making them susceptible to illegal activities. Creation and maintenance of protected area networks with additional legal protection given to rivers and wetlands can be effective in the long-term conservation of otters.
6. *Synthesis and applications:* This study highlights that the presence of otters in a region is governed by habitat heterogeneity, diversity of prey species and relatively low disturbance regime. The overarching principle of the study involving resource use for understanding the distribution of *L. perspicillata* in the landscape will aid in a multi-faceted conservation approach for the species.

1. INTRODUCTION

*Underwater eyes, an eel's
Oil of water body, neither fish nor beast is the otter:
Four-legged yet water-gifted, to outfish fish;
With webbed feet and long ruddering tail
And a round head like an old tomcat.
Brings the legend of himself
From before wars or burials, in spite of hounds and vermin-poles;
Does not take root like the badger. Wanders, cries;
Gallops along land he no longer belongs to;
Re-enters the water by melting.*

Ted Hughes

An Otter

1.1 Otters – a general introduction

Otters are semi-aquatic mammals, belonging to the family Mustelidae, the most speciose family of the order Carnivora (Wozencraft 2005; Larivière and Jennings 2009). They are piscivorous, obligate wetland species occupying the littoral areas of both marine and freshwater habitats (Estes 1989; Pardini 1998). Cosmopolitan in distribution, otters are present in all continents except Antarctica and Australia. The first aquatic otter lived around 30 million years ago, according to recognizable fossil records (Chanin 1985). Today, there are 13 species of otters around the world, of which Asia has five species, viz. the Sea Otter (*Enhydra lutris*), the Hairy-nosed Otter (*Lutra sumatrana*) the Smooth-coated Otter (*Lutrogale perspicillata*), the Eurasian Otter (*Lutra lutra*) and the Oriental Small-clawed Otter (*Aonyx cinerea*) (Pocock 1941; Mason and Macdonald 1986; Foster-Turley, Macdonald and Mason 1990; Hussain 1993).

They have streamlined body, webbed feet, dense layer of hair that interlock among themselves trapping air, providing thermoregulation, as otters lack blubber, unlike other aquatic mammals. The long vibrissae located on the sides of the mouth assist in foraging even in murky waters (Mason and Macdonald 1983; Chanin 1985). These adaptations make otters excellent swimmers and hunters in the aquatic environment that they live in.

Most otter species have a narrow niche, found living at low population densities, because of the wide dispersion of food resources in their natural habitats. Consequently, anthropogenic threats such as habitat degradation and fragmentation, over-exploitation of prey base, which is concentrated mostly along water bodies, pose a direct threat to such species, as they become unable to manoeuvre their way through hostile environments (Hussain 1997).

1.2 Otter Species of India – A profile

India is home to three species of otters, viz. the Smooth-coated Otter (*Lutrogale perspicillata*), the Eurasian otter (*Lutra lutra*) and the Oriental small-clawed otter (*Aonyx cinerea*) (Pocock 1941; Mason and Macdonald 1986; Hussain 1993). The three species have been reported to occur in sympatric association in north-east

India and Western Ghats (Pocock 1941). The similarity of the species in their external characters and field signs makes it difficult to distinguish them from each other, especially in areas where they occur sympatrically. Thus, during field studies, if the signs are not carefully segregated from each other and other related species; the results might be erroneous and misleading (Kruuk *et al.* 1993; Kruuk *et al.* 1994).

1.2.1 Smooth-coated Otter (*Lutrogale perspicillata*, Geoffroy, 1826)

The Smooth-coated Otter is distributed from Indonesia through Southeast Asia, and westwards from south China to India and Pakistan, with an isolated population in Iraq (Pocock 1941; Medway 1969). In India, it is distributed throughout the country, southward from the Himalaya, except the arid regions of western India (Prater 1971; Hussain 1993; Hussain 1997) (Fig 1).

Pocock (1941) reported two subspecies – (1) *L. p. perspicillata* from north-eastern and southern India, (2) *L. p. sindica* from northern and north-western India and Pakistan (Sindh Province). Another subspecies, *L. p. maxwelli*, has been described from the marshes of southern Iraq (Hayman 1956; Hatt 1959; Maxwell 1960). This rare subspecies has been recently reported from Al-Edheam Marsh at the northern edge of Hawizeh Marsh in southern Iraq (Al-Sheikhly, Haba and Barbanera 2015).

Smooth-coated Otters are the largest otters in India, and second largest in Asia, after sea otters, with a total length of 1067-1300 mm, head to body 655-790 mm, and tail length 406-505 mm (Duplaix and Davis 1981). They are quite distinctive in their external features, having flattened tails, exceptionally large and heavily webbed front paws, smooth, velvety coat and a peaked upper border of the rhinarium (Pocock 1941; Prater 1971). Sub-adults weigh around 6.5 kg and adults weigh between 7.00-11.4 kg (Harris 1968). The pelage colour on the dorsal side varies from dark, nearly blackish-brown to light brown, with a rufous tinge to pale sandy or tawny brown. The ventral side is lighter compared to the dorsal side. The cheek to the eye and ear, the upper lip to the edge of the rhinarium, the sides of the neck, chin and throat is whitish (Pocock 1941). The rhinarium is hairless, and the

upper margin is inverted “V” shaped. All the paws are large, well-webbed, but the third phalanges are free of webbing (Hussain 2013).

The species attains sexual maturity at 22 months in captivity (Desai 1974). The gestation period ranges from 60-62 days with a mean litter size of 1-5 (Yadav 1967; Desai 1974; Naidu and Malhotra 1989).

The habitat of the *L. perspicillata* ranges from large rivers and lakes to peat swamp forests, mangroves and estuaries. It is essentially a species of lowlands and floodplains (Foster-Turley 1992; Hussain and Choudhury 1997). They are social carnivores, living in large groups of 1-9 individuals, varying between seasons (Hussain 1996). The activity patterns also change seasonally, being diurnal in winters and nocturnal or crepuscular during summer and monsoon (Hussain 1993). The average home range is approximately 5 km (Hussain and Choudhury 1995).

Predominantly a piscivore, the Smooth-coated Otter also supplements its diet with invertebrates such as crabs, shrimps, insects and vertebrates such as frogs, birds, small mammals, and also snakes (Prater 1971; Foster-Turley 1992; Hussain and Choudhury 1998). Smooth-coated Otters concur to the feeding habits of the members of the genus *Lutra*, in using visual sense to locate prey and catching them with their mouths (Sivasothi and Nor 1994).

Threats to the species include loss of wetland habitats, prey base depletion, pollution, and poaching for pelt and meat. In the last decade loss of mangrove habitats, reclamation of wetlands and construction of multipurpose dams have increased, leading to loss of habitats for the otters (Hussain *et al.* 2018). The species is listed as Vulnerable by the IUCN (de Silva *et al.* 2015) and in Schedule II (Part I) of the Wild Life (Protection) Act, 1972.

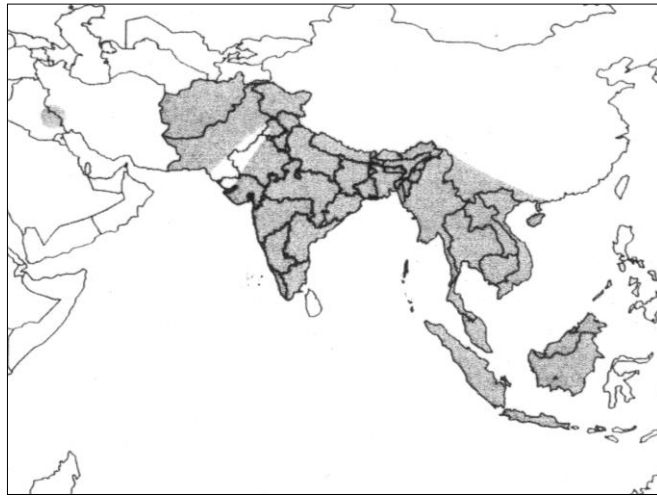


Figure 1: Range map of Smooth-coated Otter

Source: Hussain 1999

1.2.2 Eurasian Otter (*Lutra lutra*, Linnaeus 1758)

The Eurasian Otter is the most widely distributed of all the Palearctic mammalian species, spanning across Northern Africa to Europe and Asia (Fig 2) (Mason and Macdonald 1986, Ando and Corbet 1966). In India, the species occurs across the Himalaya, to the north of the Ganges and in the south (Hussain 2000; Roos *et al.* 2015). The species has been recently reported from the Central Indian Landscape (Jena *et al.* 2016).

Pocock (1941) reported seven sub-species – (1) *L. l. lutra* in Europe and northern Africa (2) *L. l. nair* in southern India and Sri Lanka (3) *L. l. monticola* in northern India (Himachal Pradesh, Sikkim and Assam) Nepal, Bhutan and Myanmar (4) *L. l. kutab* in northern India – Kashmir (5) *L. l. aurobrunnea* in the Garhwal Himalayas of northern India and higher altitudes in Nepal (6) *L. l. barang* in southeast Asia (Thailand, Indonesia and Malaysia) and (7) *L. l. chinensis* in southern China and Formosa.

The Eurasian Otter is similar to the Smooth-coated Otter in body size. The total length ranges between 920-1200 mm, head to body 550-570 mm, tail length 35-375 mm (Foster-Turley 1992). The weight ranges from 4-12 kg in females and 7-12 kg in male (Reuther 1991). The pelage colour on the dorsal part varies from rusty to dark

brown, whereas, the ventral side is lighter in shade, sometimes, being grey or whitish in colour. Individual yellow, grey, or white spots are present on the lips and throat. The tail is entirely hairy and is flattened at the terminal half and tapered at the end. The rhinarium is hairless, black in colour, occasionally with light spots. The upper margin of the rhinarium is “W” shaped. All four paws bear five digits with strong claws and webbings between the digits, which extend at least to the last bone of each digit (Pocock 1941).

Eurasian Otters attain sexual maturity at 18 months, in males and 24 months in females, which in captivity is three to four years (Reuther 1991). The gestation period is approximately 60-65 days, with a litter size of one to five (Acharjyo and Mishra 1983).

The habitat of the Eurasian Otter ranges from lakes (both highland and lowland), rivers, streams, marshes, swamp forests and coastal areas (Mason and Macdonald 1986). Mostly solitary and nocturnal, most portions of the activities of the Eurasian otter is confined up to a narrow extent on either side of the land-water interface (Green, Green and Jefferies 1984; Kruuk 1995). The home ranges of males, which are generally larger than that of females, is driven by hierarchy and territoriality, influenced by sexual factors, while the home ranges of females are influenced by the availability and dispersal of resources (Erlinge 1969).

Fish forms the major prey of the Eurasian Otter, sometimes exceeding more than 80% of the diet, similar to other *Lutra* species (Erlinge 1969; Webb 1975; Ruiz-Olmo and Palazon 1997). Prey items other than fish include crustaceans, aquatic insects, birds, small mammals, reptiles and amphibians, in variable proportions (Jenkins and Burrows 1980; Adrian and Delibes 1987; Skaren 1993).

Major threats to the species across its range countries include habitat degradation and destruction, pollution, over-exploitation of prey biomass, and conflicts with fisherfolk (Reuther and Hilton-Taylor 2004, Roos *et al.* 2015). The species is listed as Near Threatened by the IUCN (Roos *et al.* 2015) and in Schedule II (Part I) of the Wild Life (Protection) Act, 1972.

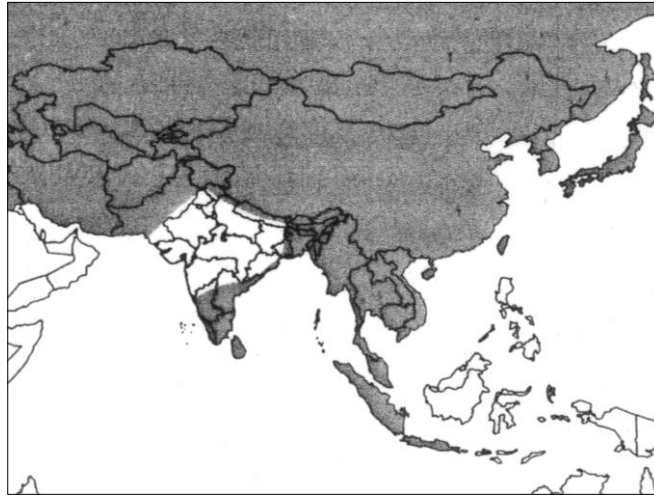


Figure 2: Range map of Eurasian Otter across Asia

Source: Hussain 1999

1.2.3 Oriental Small-clawed Otter (*Aonyx cinerea*, Illiger 1815)

The Oriental Small-clawed Otter or Asian clawless Otter, has a large distribution range, extending from India in the west to Philippines and Taiwan in the east, across Indonesia in southeast Asia and southern China in the north (Pocock 1941) (Fig 3). In India, the species occurs from Arunachal Pradesh in the northeast, across Assam, and up to West Bengal. In southern India, it occurs in the hill ranges of Coorg (Karnataka), Ashambu, Nilgiri and Palni hills (Tamil Nadu) and some places in Kerala (Pocock 1941; Prater 1971; Hussain 2000; Hussain, Gupta and de Silva 2011). It has recently been reported from Odisha in eastern India (Mohapatra, Palei and Hussain 2014).

Pocock (1941) reported two sub-species – (1) *A. c. concolor* found in northeast India and Myanmar, extending up to Sumatra, (2) *A. c. nirnai* found in the hill ranges of southern India.

The Oriental Small-clawed Otter is the smallest otter species, with the total length being 652-939 mm, head and body measuring 406-635mm, tail length 246-304 mm and weight ranging between 2.7-5.4 kg (Walker 1975). Females are generally smaller than males. The pelage colour on the dorsal part is dark brown, sometimes with a tawny or rufous tinge with the tip of the contour hair often paler, with a greyish or ashy tint. The ventral side is pale brown to grey, lighter than the

dorsal side. The upper lip, chin, cheeks, sides of the neck and throat are contoured by lighter fur, which is contrasted with the darker fur of the head and neck (Pocock 1941). The rhinarium is similar to that of smooth-coated otter, with its anterior surface directed forward and a straight posterior margin (Pocock 1941). The distinctively webbed paws are particularly adapted for capturing invertebrates and small vertebrates in shallow, murky waters (Foster-Turley and Markowitz 1982). The third and fourth digits in each paw is markedly longer than the second and fifth digit, and the claws are reduced to small rudiments which do not project beyond the tips of the digital pads (Foster-Turley 1992).

Oriental Small-clawed Otters attain sexual maturity at 15-18 months (Foster-Turley and Engfer 1988). Gestation period is of approximately 60 days, with a litter size of 2-7 (Lancaster 1975; Sobel 1996; Crandall 1964).

The habitat of the species includes freshwater swamps, streams, tidal pools and mangroves, characterized by pools and stagnant water, narrow streams with less than 1 m depth (Wright *et al.* 2015). It often exists in sympatric association with Smooth-coated Otters and Eurasian Otters in the mangrove forests of Sundarbans, and in north-eastern and southern India (Sanyal 1991). Near human settlements, the species is nocturnal or crepuscular, foraging for invertebrates such as crabs in rice fields (Melisch *et al.* 1996).

The diet of Small-clawed Otters comprises mostly of invertebrates such as crabs, molluscs, insects, and small fishes such as gouramis and catfish (Pocock 1941; Wayre 1978).

The species is threatened by habitat destruction caused by anthropogenic activities, pollution and illegal pet trade (Gonzalez 2010; Aadrean 2013; Gomez and Bouhuys 2018). The species is listed as Vulnerable by the IUCN (Wright *et al.* 2015) and in Schedule I (Part I) of the Wild Life (Protection) Act, 1972.

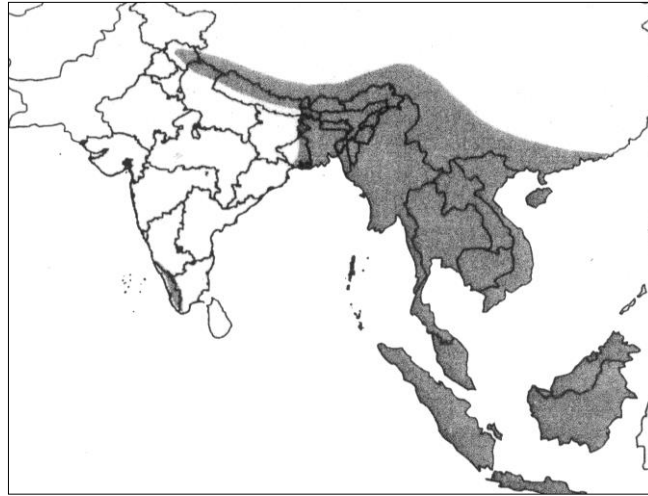


Figure 3: Range map of Oriental Small-clawed Otter

Source: Hussain 1999

1.3 Importance of otters

Otters, the apex predators of the wetland ecosystems they inhabit, can be considered as indicators of such ecosystems (Mason and Macdonald 1986; Foster-Turley *et al.* 1990). Being sensitive to both pollution and habitat destruction, the presence of otters in a wetland ecosystem, be it rivers, lakes, swamps, mangroves or estuaries, indicates the occurrence of a viable prey base, thus indicating an ecologically healthy condition of such ecosystems. Moreover, the charismatic and playful nature of otters, has gained it the status of a flagship species for conservation at an international level, hence it can be used as an emblem to promote conservation of wildlife and its habitat at local, regional and international levels (Mason and Macdonald 1986).

1.4 Rationale of the study

Global extinction of species, as a consequence of the upsurge in anthropogenic pressure on natural ecosystems, is occurring at an exponential pace. All the four Asian river otter species listed in the IUCN Red List of Threatened Species are showing declining population trends. In India, otters rarely occur outside protected areas because of the widespread destruction of their habitats owing to increasing anthropogenic pressure, reduction in prey biomass, and poaching (Das *et al.* 2007; Choudhury 2006). Thus, proper plans based on scientific knowledge need to be devised to counter the deteriorating trends.

Populations of species are limited by the variability in resources such as habitat and prey. Otters being apex carnivores of the ecosystems they inhabit, manifest dynamism in the usage of such resources subject to the variability. In light of the current changes in land use pattern and increase in anthropogenic pressure in India, it is important to study the ecology of such a vulnerable and narrow-niche species such as the Smooth-coated Otter (*L. perspicillata*) for designing better policies and management plans for the protection of the species and its habitat.

The wide distribution range of the Smooth-coated Otter makes it an ideal species for a short-term study focusing on the patterns of distribution, concerning habitat use, prey availability and diet across different water bodies (rivers and streams), subjected to various levels of disturbance and protection. It has been declared as Vulnerable by the IUCN Red List of Threatened Species since 1996, owing to extensive population decline because of habitat loss and exploitation (de Silva *et al.* 2015). While most studies concerning the ecology of Smooth-coated Otter considered habitat use and diet in a particular area, be it a protected or a human-modified area (Hussain and Choudhury 1997; Anoop and Hussain 2004; Perinchery, Jathana and Kumar 2011; Prakash *et al.* 2012), very few studies actually delved into the patterns of such aspects in context of a larger landscape.

The sub-Himalayan foothill forests, a subset of the Terai Arc Landscape (TAL) are one of the most threatened ecosystems of the country. Owing to the burgeoning human population and its ever-increasing pressure on natural resources, these ecosystems are faced with fragmentation and degradation. In this study, we shall focus on how resources such as habitat and prey, shape the distribution of Smooth-coated Otter in the region concerning seven rivers: Kolhu, Palain, Mandal, Khoh, Rawasan, Malin and Ganga. Apart from direct observation, which is difficult in case of this elusive species, indirect signs such as spraints (otter faeces), tracks, holts, and resting and grooming areas are important indices to infer the usage of an area by otters (Mason and Macdonald 1986; Foster-Turley and Santiapillai 1990; Kruuk 2006). The habitats of Smooth-coated Otter are not homogenous across the landscape (Nawab and Hussain 2012), hence the species' response to different habitat features shall also differ. Also, there is a dearth of extensive information of the species' biology with respect to

different habitat types and land-use changes. Hence, an inductive approach for predictive habitat suitability modelling using presence-only data will provide an insight into sensitive otter habitats and streamline conservation measures for the species and its habitat.

Coupled with habitat, prey is one of the major factors that limit species populations. Many species are often seen to cope up with disturbed surroundings only for the easy accessibility or abundance of prey in those areas. Carnivore dietary diversity often varies inversely with prey abundance (Tinker, Bentall and Estes 2008). This indicates the vulnerability of carnivore populations as a consequence of any perturbations in the environment affecting the existence of prey populations (Carbone *et al.* 2007). Therefore, in this study, the diet of Smooth-coated Otter has also been examined.

This study will be instrumental in contributing to the basic ecological knowledge pertaining to otters in the important sub-Himalayan forests of India. This can in turn aid in the conservation of imperilled otter habitats such as rivers and streams.

1.5 Objectives of the study

In view of the previously mentioned discussions, following objectives had been proposed for the study:

1. Assess factors affecting habitat use by Smooth-coated Otter in the sub-Himalayan foothill rivers of Uttarakhand
2. Examine the feeding habits of Smooth-coated Otter in the landscape
3. Predict habitat suitability of Smooth-coated Otter using MaxEnt

1.6 Research Questions

The key research questions that have been addressed through this work are:

1. What are the factors that govern habitat use of otters in the study landscape?
2. What are the patterns of prey consumption by otters in the region?
3. How much area is suitable otter habitat in the landscape?

2. STUDY AREA

2.1 The sub-Himalayan region

The Himalayan mountain range, the youngest extends from the Indus in the northwest to the Brahmaputra in the east, forming a broad continuous range of 2575 km along the northern boundary of the Indian subcontinent (Karan 1966). The mountain system, rising abruptly at the Indo-Gangetic Plain, can be physically divided into three parallel zones – (1) the Great Himalaya, (2) the Inner Himalaya, also called the middle or lesser Himalaya, and (3) the sub-Himalayan foothills and adjacent Terai and Duar plains. The sub-Himalayan range, along with the Shiwalik hills, that lie parallel to the main Himalayan arc, forms the southernmost part of the Himalayan mountain range, extending from Punjab in the northwest to Assam in the northeast. Characteristic features of the sub-Himalayan region are the presence of conspicuous flat-bottomed valleys, known as “duns”, filled with loose gravelly alluvium soil, sub-tropical climate and seasonal streams called “*Rau*” (Karan 1966; Agrawal *et al.* 2002; Rawat and Mukherjee 2005; Jerath, Pujar and Chadha 2006). The Shiwalik hills run along the southern periphery of Uttarakhand, occupying a large tract of the State. Towards the south, the hills merge with the Gangetic Plains (Negi 1990). The major vegetation of the region from west to east, along an increasing rainfall gradient include – Dodonea scrub forests, Sub-tropical dry evergreen forests, Sub-tropical pine forests, Northern Dry Mixed deciduous forest, Dry Shiwalik Sal forest, and Moist Mixed Deciduous forest (Champion and Seth 1968; Rawat and Bhainsora 1999; Jerath, Pujar and Chadha 2006). The Shiwalik hills encompass two protected areas – Rajaji National Park and Corbett National Park, and the Forest Divisions of Shiwalik, Dehra Dun and Lansdowne (Fig 4).

The present study was conducted in Rajaji National Park, Corbett National Park, and Lansdowne Forest Division, falling in the sub-Himalayan region of Uttarakhand.

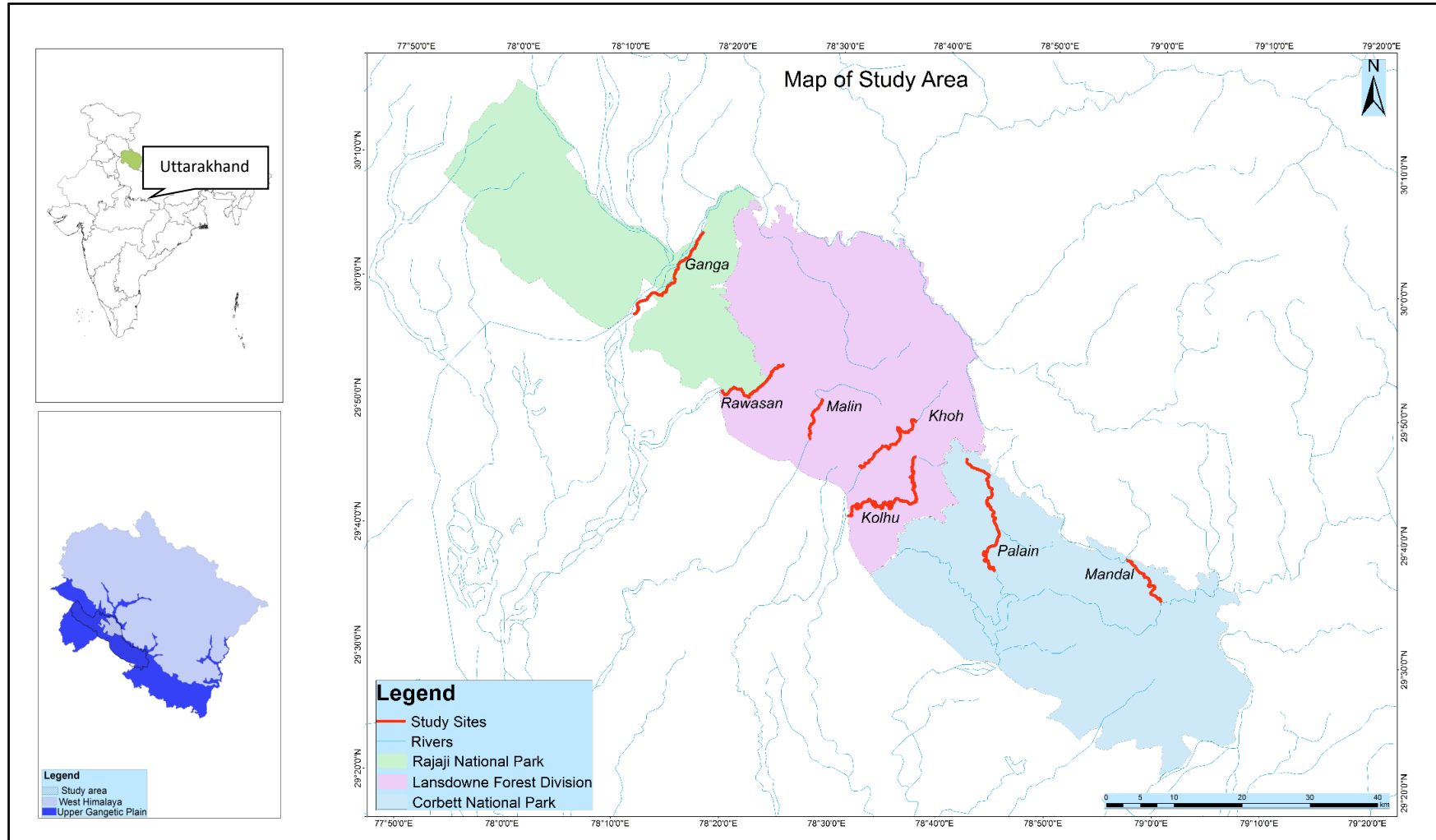


Figure 4. Study Area

2.2 Study sites and description

2.2.1 Rajaji National Park and Tiger Reserve

The Rajaji National Park and Tiger Reserve is located at 77° 57' 7" to 78° 23' 36" E and 29° 51' 7" N to 30° 15' 50" N, in the *bhabar* tract of northern India. It is divided by the River Ganga into two parts. The eastern part comprises of Chilla and Gohri ranges, and the western part comprises of Motichur, Haridwar, Dholkhand (East and West), Kansrao and Chillawali ranges (Datta 2009). The altitude ranges from 400 m – 1300 m. The narrow Chilla – Motichur corridor, a highly fragmented but ecologically important corridor, connects the Eastern and Western parts of the Park (Johnsingh, Prasad and Goyal 1990). The river Ganga also forms a part of this valuable corridor.

The intensive study area selected for the present study is the stretch of River Ganga, of approximately 20km, from the Rishikesh Barrage (30° 04'27.13" N, 78° 17' 18.93"E) in Rishikesh to Bhimgoda Barrage (29° 57' 23.44"N, 78° 10' 49.51"E) in Haridwar.

2.2.1.2 Climate

The climate in the region is characterized by extreme variations in temperature and humidity during different seasons of the year. The region experiences three distinct seasons – winter, summer and monsoon. The winter season ranges from November – February, characterised by a minimum temperature of 3-5°C. Summer begins at mid-March, extending up to mid-June, with the maximum temperature rising up to 44°C. Monsoon begins during mid-June, continuing till September, characterised by heavy rains, occasional flash floods and minimum variations in temperature.

2.2.1.3 Flora

The vegetation of the region is composed of heterogeneous deciduous species of tropical and sub-tropical origin. Champion & Seth (1962), recognized the following forest types in Rajaji National Park –

- (1) Sub-type 3C/C2a. Moist Shivalik sal forest
- (2) Sub-type 5B/C1a. Dry Shivalik sal forest
- (3) Sub-type 5B/C1b. Dry plain sal forest
- (4) Type 5B/C2. Northern dry mixed deciduous forest
- (5) Sub-type 5/E9. Dry bamboo brakes
- (6) Type 5/1S2. Khair-Sissoo forest
- (7) Sub-type 9/C1a. Lower or Shivalik chir pine forest

The riverine tracts consist mostly of *Ziziphus mauritiana*, *Z. xylopyrus*, *Syzigium cumini*, *Dalbergia sisso*, and *Trewia nudiflora*. The major grass species consist of *Saccharum spp.*, *Vetiveria zizanioides*, *Heteropogon contortus*, *Themada spp.*, *Eulaliopsis binata*, *Chrysopogon spp.*, and *Cymbopogon spp.*

2.2.1.4 Fauna

The rich and diverse faunal assemblage of the Park, consist of some globally threatened species such as the Bengal tiger (*Panthera tigris*), leopard (*P. pardus*), and Asiatic elephant (*Elephas maximus*). Other species of fauna include – sambar (*Cervus unicolor*), chital (*Axis axis*), Nilgai (*Bosephalus tragocamelus*), barking deer (*Muntiacus muntjak*), wild pig (*Sus scrofa*), and goral (*Nemorhaedus goral*), Asiatic black bear (*Ursus thibetanus*), sloth bear (*Melursus ursinus*), striped hyena (*Hyena hyena*), Indian pangolin (*Manis crassicaudata*), yellow-throated marten (*Martes flavigula*) and Smooth-coated Otter (*L.*

perspicillta). The region also supports a diverse avifauna consisting of around 350 species of birds (Ravi 2008). The endangered Golden Mahseer (*Tor putitora*) is found in the river Ganges, section of which passes through Rajaji National Park.

2.2.2 Lansdowne Forest Division

Lansdowne Forest Division (LFD), located at 29°50'26.96"N and 78°32'39.16"E, covers an area of approximately 430 km² with its peripheries touching the boundaries of Corbett National park and Tiger Reserve to the east and Rajaji National park and Tiger Reserve to the west. Owing to its geographical placement, LFD is a quintessential wildlife corridor supporting the dispersal of umbrella species like the Bengal tiger (*Panthera tigris*) and the Asiatic Elephant (*Elephas maximus*) between Corbett and Rajaji National Parks. LFD has five ranges- Laldhang Range, Dugadda Range, Kotdwar Range, Kotdi Range and Lansdowne Range.

The intensive study area in the LFD selected for the current study consisted of the rivers Khoh (Fatehpur to Saneh), Kolhu (Dugadda to Saneh), Rawasan (Dharkot to Laldhang) and Malin (Kanwasharm). The rivers Khoh and Kolhu are important tributaries of the River Ramganga. Rawasan is an important tributary of River Ganga.

2.2.2.1 Climate

The climate is sub-tropical to temperate, with three distinct seasons – summer, monsoon and winter. The mean monthly temperature ranges from 25°C - 35°C.

2.2.2.2 Flora

The vegetation is composed of tropical moist deciduous, tropical dry deciduous, tropical semi-evergreen, Himalayan moist temperate and Himalayan dry temperate forest types (Champion and Seth 1962). The major flora includes Sal (*Shorea robusta*), *Mallotus*

philippensis, *Dalbergia sisoo*, *Acacia catechu*, *Ziziphus spp.*, *Terminalia tomentosa*, *Butea monosperma*, *Adina cordifolia*, and *Schleichera oleosa*. *Eulaliopsis binata*, commonly known as *bhabar* grass lines the bare rock cliffs. Riparian species mostly include *Syzigium cumini*, *Ficus saemocarpa*, *Syzigium heyneanum*. The extensive grassy plains known as *Chaur*s have a significant ecological role in the area. Species of grasses such as *Apluda mutica*, *Saccharum spp.*, *Vetiveria zizanioides*, and *Chrysopogon spp.* are common. Teak (*Tectona grandis*) plantations are dispersed throughout the region. Other rare species of flora are - *Wallichia densiflora*, *Schefflera venulosa*, and the snow orchid (*Diplomeris hirsuta*).

2.2.2.3 Fauna

The region supports important species of fauna such as the Smooth-coated Otter (*Lutrogale perspicillata*) Bengal tiger (*Panthera tigris*), leopard (*P. pardus*) and the Asiatic Elephant (*Elephas maximus*). Other important species include sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), and common giant flying squirrel (*Petaurista petaurista*). Reptilian fauna includes the Bengal monitor lizard (*Varanus bengalensis*), brown-roofed turtle (*Pangshura smithii*), and the Indian Black Turtle (*Melanochelys trijuga*). The region also harbours important avian species such as the Great hornbill (*Buceros bicornis*), Himalayan Griffon (*Gyps himalayensis*) and the migratory Merganser (*Mergus merganser*). The rivers Kolhu and Khoh serve as important breeding grounds for the endangered Golden Mahseer (*Tor putitora*) (Atkore and Kuppuswamy 2011).

2.2.3 Corbett National Park and Tiger Reserve

Corbett National Park and Tiger Reserve, situated at the foothills of the Himalaya lies between 29°25'N to 29°40'N and 78°5'E to 79°5'E, in the *bhabar* tracts of Shiwalik. The altitude ranges from 350 – 1210 m, with a varied topography of marshy depressions, ravines and

plateau land. The drainage system comprises of the River Ramganga and its many tributaries – Rivers Sonanadi, Mandal and Palain; along with many smaller streams (*sots*) that remain dry for most parts of the year.

The intensive study areas in the Park were the Palain and Mandal rivers, falling in the Kalagarh Tiger Reserve Division of Corbett National Park.

2.2.3.1 Climate

The climate is tropical with three distinct seasons – winter (November to February), summer (March to June) and monsoon (mid-June to October) (Bhartari 1999). The annual temperature ranges from 3°C in winter to 42°C in summer.

2.2.3.2 Flora

Champion & Seth (1962), recognized the following forest types in area –

- (1) Sub-type 3C/C2a. Moist Shivalik sal forest
- (2) Sub-type 5B/C1a. Dry Shivalik sal forest
- (3) Sub-type 3C/C2b (1). Moist Bhabar Dun sal
- (4) Type 5B/C2. Northern dry mixed deciduous forest
- (5) Sub-Group 5B. Northern Tropical Dry Deciduous
- (6) Type 5/1S2. Khair-Sissoo forest
- (7) Sub-Group 9. Himalayan Sub-Tropical Pine Forest
- (8) Sub-type 9/C1a. Lower Siwalik Chir Pine Forest

Around 617 species of flora have been reported from the area (Pant 1986). Major tree species include – Sal (*Shorea robusta*), *Terminalia*

tomentosa, *Anogeissus latifolia*, *Bauhinia spp.*, and *Adina cordifolia*. *Wallichia densiflora*, and *Diplomeris hirsuta* are also observed in rare patches in the area.

2.2.3.3 Fauna

Around 50 species of mammalian fauna, 29 species of fishes, and 549 species of birds (migratory and resident) and 23 species of herpetofauna have been reported from the area (Lamba 1987; Hussain 1995; Sinha 2001; Sharma *et al.* 2003). The gharial (*Gavialis gangeticus*), a critically endangered reptile belonging to the Order Crocodylia has been the subject of the Crocodile Project in 1976. During 1987, 27 hatchlings were released in the Park (Derek 1989).

Table 1: List of Study Rivers

Protected Area/ Forest Division	Rivers	Location	Type
Rajaji National Park and Tiger Reserve	Ganga	30° 04'27.13"N, 78° 17' 18.93"E and 29° 57' 23.44"N, 78° 10' 49.51"E	Perennial
Lansdowne Forest Division	Khoh	29°49'13.56"N, 78°37'24.99"E and 29°45'27.89"N, 78°32'13.64"E	Perennial
Lansdowne Forest Division	Kolhu	29°46'20.55"N, 78°37'18.65"E and 29°41'27.97"N, 78°31'20.23"E	Perennial
Lansdowne Forest Division	Rawasan	29°53'31.20"N, 78°24'55.21"E and 29°51'20.23"N, 78°19'19.68"E	Perennial
Lansdowne Forest Division	Malin	29°50'50.58"N, 78°28'43.39"E and 29°47'42.09"N, 78°27'33.76"E	Non-perennial
Corbett National Park and Tiger Reserve (Kalagarh Tiger Reserve)	Palain	29°46'22.09"N, 78°42'15.05"E and 29°37'18.30"N, 78°45'1.65"E	Perennial
Corbett National Park and Tiger Reserve (Kalagarh Tiger Reserve)	Mandal	29°38'24.36"N, 78°57'13.60"E and 29°35'4.38"N, 79° 0'31.02"E	Perennial

3. METHODS

3.1 Reconnaissance survey

The first few days in the study area were spent to gain an understanding of the different habitat types such as pools, riffles, runs, and cascades present in a stream or riverine ecosystem. Looking for otters during their activity period, i.e. at dawn and dusk for species identification, and indirect signs, such as tracks, grooming signs, spraints, denning sites and feeding signs were observed and thoroughly examined.

3.2 Habitat use by Smooth-coated Otter

3.2.1 Measuring habitat parameters

During the reconnaissance survey, it was found that habitat characteristics varied considerably at small stretches of the rivers. Random plots at every 250 m along the bank were taken and the following habitat variables were measured:

1. Water body type (pool/ riffle/ run/ river)
2. Mean width (m)
3. Mean depth (cm)
4. Velocity (m/s)
5. Bank substrate type (sand/rocks/mud bars/grass/gravels/ cobbles)
6. Bank vegetation (dense/ moderate/ sparse)
7. Bank vegetation height (m)
8. Distance from bank to escape cover (distance from the edge of the water to the point where undergrowth starts) (m)
9. Disturbance (disturbed/ undisturbed) (presence of *gujjar deras*, lopping, fishing, sand and stone collection, proximity to roads or human settlements were considered as disturbance).

Apart from the 250 m random plots, the above parameters were measured at sites where otter signs (tracks, spraints, feeding signs, holts, and also direct sightings) were encountered. Signs survey was conducted along both banks of the water body, extending 25 m away from the edge of the water. The width was selected based on available literature and also on the basis of reconnaissance survey, as no otter signs were recorded more than 15 m away from the bank.

The measurements of distance and height were taken with a laser range finder; depth was measured using a depth gauge, velocity was measured using a flow probe, and remaining parameters were estimated visually. Sampling was performed during mid-winter and late-winter season.

3.2.2 Data analysis

3.2.2.1 Non-mapping technique for studying habitat preferences

For analysing habitat availability and utilisation, the confidence interval technique in conjunction with the Chi-square goodness of fit test as suggested by Marcum and Loftsgaarden (1980) was used. This method is suitable for random point locations used to assess habitat use and availability of a species. The hypothesis (H_0) being tested is that Smooth-coated Otter uses every habitat category in proportion to its availability. This was done by comparing the proportion of points falling in each habitat category with the proportion of otter occurrences in each habitat, then tested using Chi-square test of homogeneity (Mendenhall 1971). Then, to determine which habitat categories are preferred, simultaneous confidence intervals with $\alpha = 0.05$, 95 % confidence intervals for each category were constructed using Bonferroni approach (Miller 1966), with the formula:

$$(P_a - P_u) \pm Z_{1-\alpha/2k} [P_a (1-P_a)/n_1 + P_u (1-P_u)/n_2]^{1/2}$$

where, P_a = proportion of points falling in each category
(proportion available)

P_u = proportion of otter locations that fall in that
category (proportion used)

k = total number of categories in each habitat parameter

n_1 = number of random points distributed

n_2 = total number of otter locations

While studying habitat preference for otters, usual emphasis is given on surveys based on spraints (Mason and Macdonald 1986), which have often been unreliable indicators of places where otters might spend most of their time (habitat preference) (Green, Green and Jefferies 1984; Kruuk, Glimmerveen and Ouwkerk 1986). Thus, in this study all types of indirect signs (tracks, grooming sites, spraints, holts, and feeding signs) were taken into account for inferring otter presence in an area and habitat preference was interpreted accordingly.

3.2.2.2 Generalized Linear Models (GLMs) for assessing factors affecting otter occurrence

Generalized Linear Models (GLMs) with binomial error distribution and logit-link function were used to evaluate habitat variables such as water body type, depth, velocity, water body width, vegetation, vegetation height, substrate type, distance from bank to escape cover, and disturbance, that best explain otter occurrence in an area. All the above-mentioned environmental variables were used as explanatory variables, including both categorical and continuous variables. The Akaike Information Criteria corrected for small sample sizes (AICc) and Δ AIC was used to rank the models, comparing the null model with models with an increasing number of predictor variables. The best ranked

model was selected on the basis of lowest AICc value and $\Delta AIC < 2$. The continuous variables were Z standardized before the analysis. The categorical variables were assigned as factors using the 'as.factor' code. The analysis was performed in package MuMIn of RStudio ver. 1.2.1335 (RStudio Team 2018).

3.3 Food habits of Smooth-coated Otter

3.3.1 Preparation of standard reference collection of fish for spraint analysis

Standard reference material of fishes was prepared by first making a catalogue of available fish species in the landscape by studying available literature (Atkore and Kuppuswamy 2011; Nawab and Hussain 2012). Preliminary fishing was also conducted in three sites, along upper, middle and lower courses of each river. Equipment such as cast nets, gills nets and drag nets were used and a checklist of fish species was prepared (Plate 1). Fishes caught were released back. For preparation of standard reference material, dead fish found during the surveys and available specimens in the WII repository were used. The scale shape and patterns (circuli, radii, and foci) differ from species to species (Webb 1975; Bräger and Moritz 2016).

Scales were pulled out from different regions of the fish specimen, such as the base of the head, near the tail, above the lateral line and below the lateral line. The mucous layer was removed carefully using a scalpel and the scales were washed thoroughly in distilled water. Staining was done using methylene blue stain, and DPX was used as a mounting agent. The slide was sealed using a cover slip and labelled for use latter during spraint analysis.

The total body length of each specimen was measured and then each specimen was separately boiled until the digestible parts were removed. The hard parts were retrieved and dried at room temperature.

At least five vertebrae from the upper (towards the skull), middle and lower (towards the tail) portions of the vertebral column were taken and measured using Vernier calliper, with an accuracy of 0.01 mm. Unique features found in the skeletal system of fishes, such the dorsal spine in catfish, skull of tire-track eel (*Mastacembelus armatus*), dorsal fin spines, fin rays were dried and preserved (Plate 2).

PLATE-1



Tor putitora



Barilius bendelisis



Chagunius chagunio



Garra gotyla



Barilius vagra

PLATE-2



Mastacembelus armatus: remains of skull, spines



Chagunius chagunio (male): dorsal fin spine

3.3.2 Collection of spraints

Spraints around 1 – 2 weeks old were collected during the sign surveys, labelled and kept in ethanol. Fresh spraints were identified by the characteristic dark grey colour, smell, and sliminess, and cannot be picked up intact. Spraints lying in the sun become intact and stiff and the smell reduces too. Very old spraints become bleached and scattered. Rains usually wash off most of the spraints, leaving behind only a few scattered bits along the course of the flowing water.

Since otters defecate in communal latrine sites, spraints more than 1 m apart were considered distinct and stored separately (Hussain and Choudhury 1995). 182 spraint samples were collected from field.

3.3.3 Cleaning of spraints

The spraints were soaked in 0.1 % sodium carbonate (Na_2CO_3) solution overnight prior to washing in order to remove slime, mucous and dirt. Spraints were then washed in running tap water using a 1 mm sieve, placed in petri-dishes, dried in hot air oven at 50°C , and the dry weights were taken of each spraint using a weighing balance ($d=0.01$ g, $e=0.01$ g). 182 spraint samples were prepared for analysis.

3.3.4 Sorting and identification of prey items

After drying, non-digested prey remains (scales, bones and exoskeletal remains) were identified and categorized as fish, crab and bird. Since examining the all scales or other skeletal remains of fishes up to species level would be very time-consuming, so an alternative sub-sampling method was chosen. Ten scales were examined at random from all portions of the petri-dish. If all the scales indicate that they were from the same species, the spraint was assumed to have only one species. If different species were identified from the first ten scales, another ten scales were picked randomly and examined. More the

species found, the greater number of times this was repeated (Hermsen and Maarseveen 2011).

Scales were stained and examined under 4 X magnification of compound microscope. Effort was made to identify prey up to species level, but whenever not possible, prey was identified up to genus level only.

3.3.5 Determination of sample size

Out of the 182 samples, random samples were analysed to examine the representatives of samples. The cumulative number of prey species found in the spraints and the number of samples analysed were plotted following Mason and Macdonald (1981), Hussain (1993). An asymptote was reached at 22 samples (Fig 5). Thus, for each river, at least 28 samples (25 %) were analysed and wherever the sample size was less, all the samples were considered. A total of 120 samples have been analysed for this study.

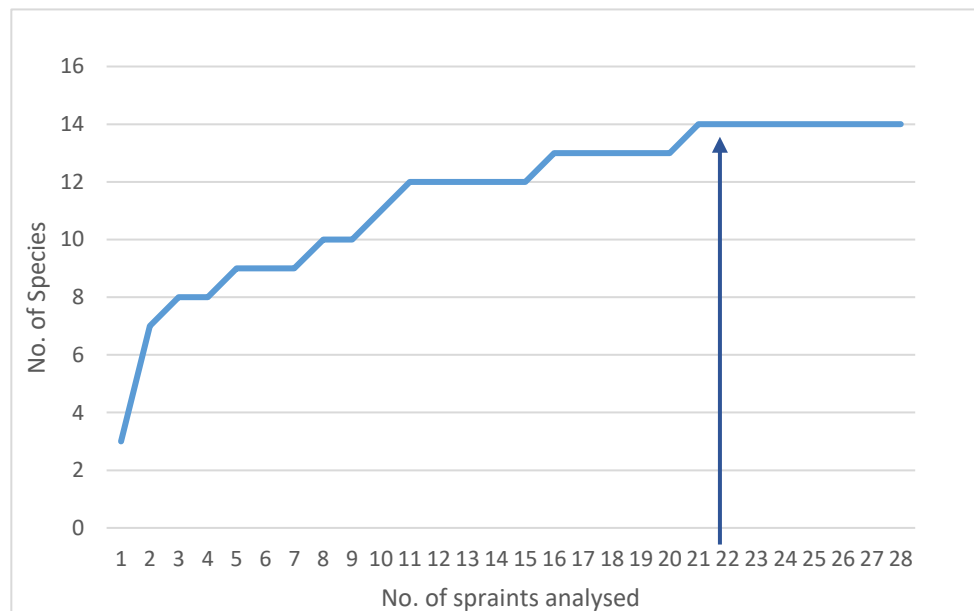


Figure 5. Plot of number of spraints analysed and the cumulative number of species found

3.3.6 Estimation of fish size from the remains

The premise of this exercise was that there is a positive correlation between vertebral length, eyeball diameter and fish length (Wise *et al.* 1980). A linear regression was used to determine the relationship between the vertebrae length and fish length, to examine the length of fish consumed. Eyeball diameter was not used to determine fish length because the chances of finding eyeballs of smaller fish in spraints are minimal. Also, eyeballs of fishes of upper strata are larger as compared to the body size, while eyeballs of fishes of lower strata are smaller as compared to the body size. Since this method has inherent restrictions, in that it is not possible to determine that all the vertebrae occurring in the spraint have originated from the same individual of fish or from several individuals, following assumptions were applied following Anoop and Hussain (2005):

1. The total number of vertebrae is almost constant in all species of fish.
2. The chance of a single vertebra of fish passing undigested through the digestive system is the same for all the vertebrae of all the fish.
3. If several fishes belonging to a particular size class are consumed by an otter, the vertebrae length corresponding to that size class will be proportionately represented in the otter spraint.

A maximum of ten vertebrae were randomly selected from each spraint were measured using Vernier calliper and segregated into different size classes of 0.5 to 1mm, 1-1.5mm, 1.5-2mm, 2-2.5mm, 2.5-3mm, 3-3.5mm, 3.5-4mm, 4-4.5mm, 4.5-5mm, 5-5.5mm, and 5.5-6mm. The proportions of these size classes will be a representation of the corresponding size classes of fish eaten. This was calculated using linear regression.

3.3.7 Estimation of proportions of prey items consumed

There are numerous methods of spraint analysis and none of them can accurately reflect the relative importance of a wide variety of prey species to the predator (Wise, Linn and Kennedy 1981). In this study the data was analysed in the following two ways:

1. **Frequency of occurrence:** The prey categories (fish species and major prey items) were noted for each spraint. The numbers of occurrences of a prey category were expressed as the percentage of samples having that category, in relation to the total number of samples. This method has been extensively used to study the diet of otters (Mason and Macdonald 1986 for Eurasian otter; Melquist and Hornocker 1983 for Canadian river otter; Hussain and Choudhury 1998 for Smooth-coated Otter; Fernando *et al.* 1999 for Giant otter; and Perrin and Carrugati 2000 for spotted-necked otter and Cape clawless otter).

2. **Score-bulk estimate:** This method allows minimizing the discrepancy of over-representation of minor items and under-representation of major items consumed. The proportion of each prey category was estimated visually, and each prey item was given a score from 1 – 10, so that the total for one spraint was 10. The score for each category was then multiplied by the dry weight of the spraint and the resulting figures were summed up and expressed as a percentage for each prey category (Wise, Linn and Kennedy 1981; Hussain and Choudhury 1998).

3.4 Habitat Suitability Modelling

The presence locations of Smooth-coated Otter collected during the sign survey, which included both direct and indirect evidences (spraints, tracks, dens and feeding signs) were used for modelling habitat suitability. A total of 302 presence locations of Smooth-coated Otter were recorded

across the landscape of Rajaji and Corbett National Parks and Lansdowne Forest Division, including some areas outside the protected area boundary (Fig 6 a). In order to reduce the effects of sampling bias and auto-correlation between the Bioclimatic layers, the presence locations were filtered to obtain the maximum number of locations that were 0.5 km apart (Fig 6 b).

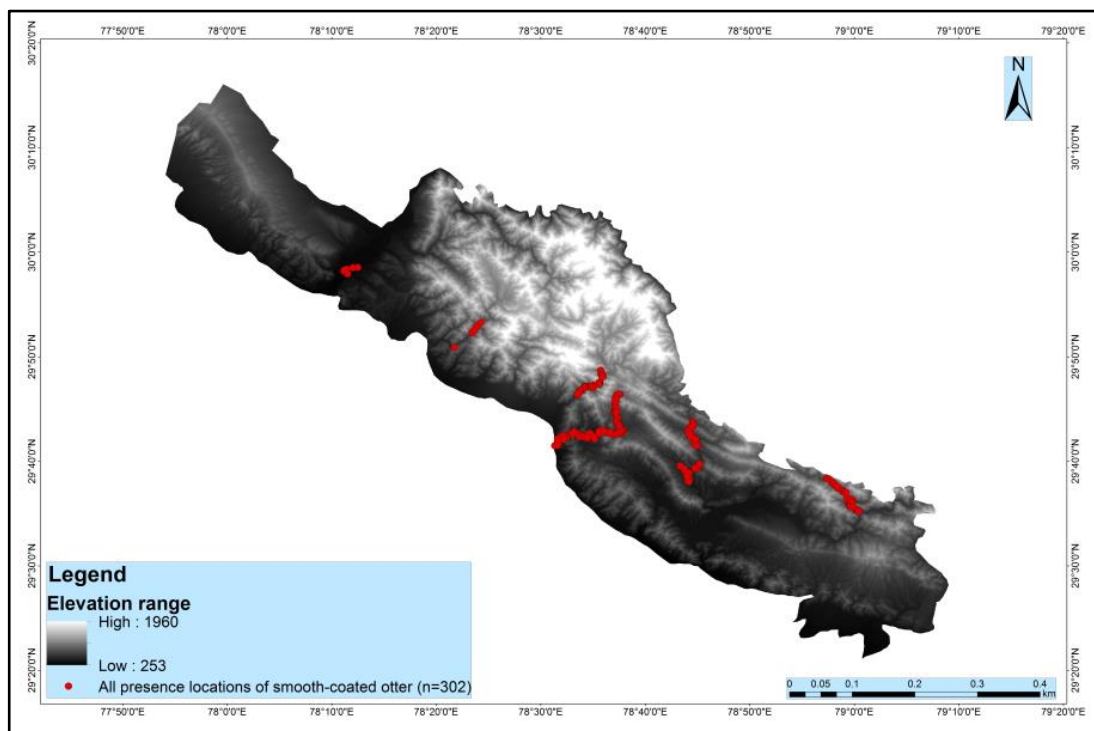


Figure 6 a. Representation of all Smooth-coated Otter presence locations (n = 302)

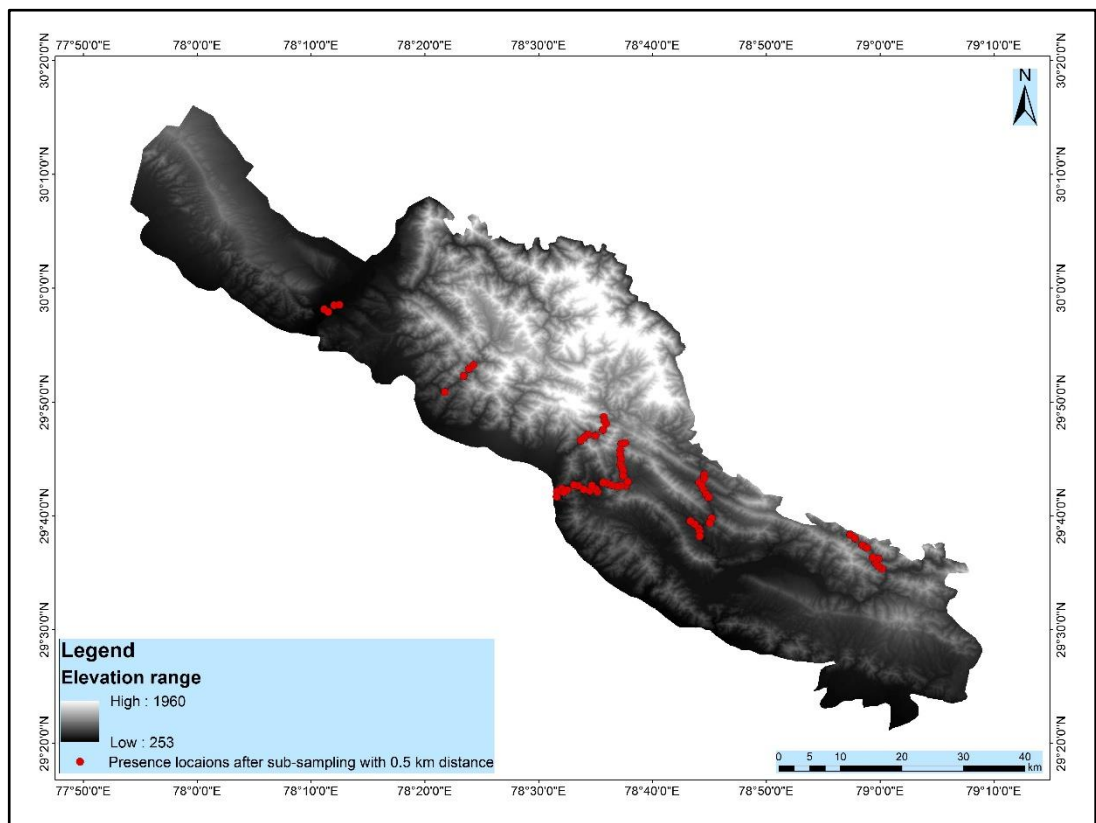


Figure 6 b. Representation of sub-sampled locations, with a minimum distance of 0.5km (n = 67)

3.4.1 Variables

The variables chosen to assess the potential habitat for Smooth-coated Otter in the study area were decided based on literature and ecological understanding of the species. All variables were prepared in ArcGIS 10.3. Files were modified to have the same extent and snapped to the same base raster, and converted to .asc files by using Circuitscape tool in ArcGIS 10.3 for use in MaxEnt. As fine scale data of the habitat variables deemed useful for assessing the potential habitat of such a narrow-niche species were not available, already available data were used as proxies for the ecological requirement of otters.

3.4.1.1 Vegetation

Globe cover was used as a proxy for vegetation. The globe cover was obtained from MODIS.

3.4.1.2 Topography

Hydrology is the crucial parameter influencing the distribution of otters. A digital elevation model (DEM) layer was obtained from the Shuttle Radar Topography Mission (SRTM) version 4 (Jarvis *et al.* 2008). Compound Topographic Index (CTI) and Euclidean distance to drainage with 2 km radius were calculated from the DEM and used as proxies to model aspects of hydrological system (Carlston 1963; Moore, Grayson and Ladson 1991). The degree of steepness influences otter distribution, in that otters prefer gentle slopes while steep slopes are usually avoided (Anoop and Hussain 2004), hence a slope position index was also derived from DEM. The Digital Elevation Model (DEM) of 90 m resolution was obtained from the Shuttle Radar Topography Mission (SRTM) version 4 (Jarvis *et al.* 2008).

3.4.1.3 Anthropogenic disturbance

The distribution of otters is negatively influenced by human disturbance. As a proxy for anthropogenic disturbance, Human Influence Index (HII) was used from Socioeconomic Data and Applications Centre (SEDAC). HII was created from nine global data layers - population density, human land use and infrastructure (built-up areas, night time lights, land use/land cover), and human access (coastlines, roads, railroads, navigable rivers) based on 2004 data. Index values range from zero, indicating no impact to 64, indicating maximum human influence.

3.4.1.4 Climate

The prevailing climate of a region has a direct influence on shaping its hydrological conditions (Xu 1999; Su, Jiang and Jin 2006). The climate data were obtained from World Climate (<http://www.worldclim.org>). The set of nineteen bioclimatic variables with 1 km resolution, include annual, seasonal and extreme temperature and precipitation (Hijmans *et al.* 2005; Graham and Hijmans 2006). In order to avoid the correlation between the 19 climatic layers PCA were performed using Principal Components (Spatial Analyst) tool in ArcGIS 10.3. Then three PCA components were used to assess the potential distribution of Smooth-coated Otter based on Accumulative of EigenValues. The environmental variables used are given in (Table 2).

3.4.2 Building the Predictive Models

MaxEnt algorithm, predictive algorithm based on the principle of maximum entropy was used to determine the potential habitat of Smooth-coated Otter across the landscape of Rajaji-Corbett National Parks (Phillips Anderson and Schapire 2006). Five models were developed and each model was run using 80% presence records as training and remaining 20% for testing, and 5000 iterations with a

bootstrap strategy. The best model was selected based on AUC value and the model with highest AUC value was selected as the final model. 10% percentile training presence logistic threshold was used to convert the probability map to binary map for area suitability-unsuitability calculation.

Table 2. List of environmental variables used in the study

Climatic Variables	Accumulative of EigenValues	Type
PCA Component 1	70.82	Continuous
PCA Component 2	99.19	Continuous
PCA Component 3	99.58	Continuous
Topographic variables		
Compound topographic index (CTI)		Continuous
Slope position index (SPI)		Continuous
Euclidean distance (Drainage)		Continuous
Vegetation variables		
Globe cover		Categorical
Anthropogenic variables		
Human Influence Index (HII)		Continuous

4. RESULTS

4.1 Identification of otters – a taxonomic account

The species of otter found across the study area was identified as *Lutrogale perspicillata* (Plate 3). This was confirmed by two ways – direct observation of the species and indirect signs (Plate 4). During direct observations, the shape of the rhinarium (Foster-Turley 1990, Hussain 2013), smooth, velvety coat, and the terminally flattened tail (Pocock 1941). Indirect evidences such as measurements of the footprints (mean length = 9 cm, mean width = 7.5 cm (n = 45) (Kruuk *et al.* 1993). No signs or direct sightings were recorded of the Eurasian otter (*Lutra lutra*) and the Oriental small-clawed otter (*Aonyx cinerea*). Indirect signs were observed in Ganga, Khoh, Kolhu, Rawasan, Palain and Mandal. Direct sightings occurred in Khoh, Kolhu, Palain and Mandal. The river Malin had no signs of otters.

4.2 Habitat use by Smooth-coated Otter

4.2.3 Habitat preference using non-mapping technique

The results following Marcum and Loftsgaarden (1980) technique showed that Smooth-coated Otter significantly preferred deep pools with moderate bank-side vegetation during the mid-winter and late-winter season. Medium width water bodies were preferred over very wide water bodies. Sandy and muddy bank substrate type was preferred while grassy banks were used in proportion to their availability. Rocky stretches were largely avoided. The critical Chi-square value, with significance level 5% and degrees of freedom (*df*) 16, was 26.30, and the test statistic was 28.59, based on which the null hypothesis (H_0) of otters using all habitat categories in proportion to availability was rejected (Table 3).

4.2.4 Factors affecting otter occurrence using Generalised Linear Models (GLM)

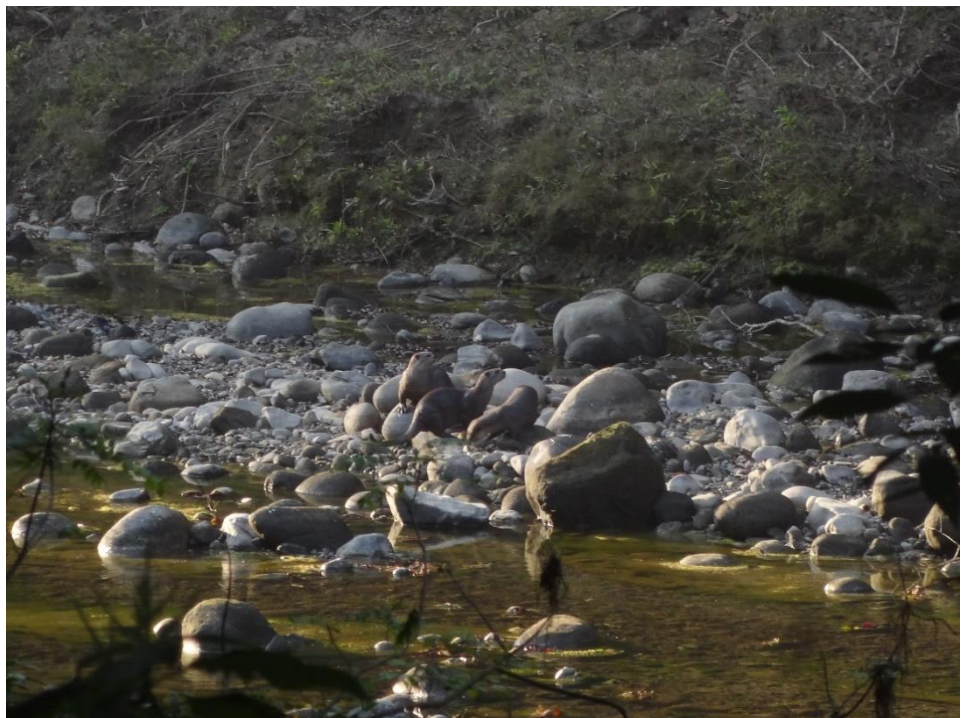
Habitat characteristics in a total of 716 points, with otter occurrences in

132 points were utilized for this analysis. A total of 11 models explaining otter occurrence in an area were generated containing and increasing number of parameters with each model. The ranking of models according to AICc and Δ AIC is shown in Table 4. A summary of the best ranked model (Model 6) is shown in Table 5. Table 6 shows the predictor variables as given in Model 6. Pools (wbt 2) show a significant positive association with otters, while riffles (wbt 1) negatively influence otter distribution, with more than 99% significance level. Bank substrate type (Sub_1, Sub_2), i.e., cobbles and bedrock show significantly negative association (more than 99% significance level) with otters. Thus, water body type and bank substrate type are the significantly influencing factors on otter distribution.

PLATE-3



A pod of Smooth-coated Otters in Kalagarh Tiger Reserve



A pod of Smooth-coated Otters in Lansdowne Forest Division

PLATE-4



Holt dug in dry soil substrate



Otter tracks on muddy substrate



Otter spraint with anal jelly



Grooming site



Rock holt at Khoh river

Table 3: Summary of the availability and use of different habitat types by otters during winter and late winter season

Habitat categories		Availability (pa)	Use (pu)	Exp. Prop.	(O-E) ² /E	Confidence Intervals at 5 % significance level	Inference
Water body type	Riffle	0.64	0.08	0.02	0.30	0.49, 0.63	NP
	Pool	0.28	0.43	0.08	1.58	-1.26, -0.04	P
	River	0.08	0.09	0.07	0.34	-0.08, 0.05	UIA
Waterbody width	Narrow (1-10 m)	0.66	0.57	0.02	14.15	-0.01, 0.18	UIA
	Medium (10 – 40 m)	0.27	0.39	0.04	3.65	-0.22, -0.03	P
	Wide (> 40 m)	0.07	0.03	0.01	0.04	0.004, 0.08	NP
Waterbody depth	Shallow (<1 m)	0.75	0.11	0.02	0.40	0.57, 0.70	NP
	Moderate (1 – 3 m)	0.21	0.26	0.05	0.97	-0.13, 0.04	UIA
	Deep (> 6 m)	0.05	0.14	0.02	0.52	-0.15, 0.03	P
Bank substrate type	Sandy	0.09	0.19	0.03	1.05	-0.19, -0.02	P
	Cobbles	0.26	0.06	0.01	0.32	0.14, 0.26	NP
	Grass	0.11	0.12	0.02	0.65	-0.08, 0.06	UIA
	Rocky	0.49	0.12	0.02	0.61	0.31, 0.46	NP
	Mud bars	0.03	0.17	0.02	0.89	-0.22, -0.06	P
Vegetation	Dense	0.79	0.22	0.03	1.08	0.47, 0.69	NP
	Moderate	0.09	0.21	0.03	1.01	-0.22, -0.01	P
	Sparse	0.11	0.21	0.03	1.01	-0.20, 0.01	UIA
Test Statistic Chi-square = 28.59 , Critical Chi-square value at $df=16$ is 26.30 ; H₀ is Rejected.							

P = Preferred; used more than available

NP = Not Preferred; used less than available

UIA = Used in proportion to availability

Table 4: Models ranked by Akaike Information Criterion corrected for small sample sizes (AICc) and ΔAIC

Response variable	Model	Variables	AICc	ΔAIC	Weight
Otter occurrence	6	Waterbody type + Width + Depth + Velocity + Substrate type	597.1	0.00	0.958
	8	Waterbody type + Width + Depth + Velocity + Substrate type + Vegetation + Vegetation height	604.8	7.75	0.020
	7	Waterbody type + Width + Depth + Velocity + Substrate type + Vegetation	604.9	7.82	0.019
	9	Waterbody type + Width + Depth + Velocity + Substrate type + Vegetation + Vegetation height + Escape cover left bank	608.6	11.50	0.003
	2	Water body type	615.1	18.06	0.000
	3	Water body type + width	615.7	18.62	0.000
	10	Waterbody type + Width + Depth + Velocity + Substrate type + Vegetation + Vegetation height + Escape cover left bank + Escape cover right bank	617.1	20.04	0.000
	11	Waterbody type + Width + Depth + Velocity + Substrate type + Vegetation + Vegetation height + Escape cover left bank + Escape cover right bank + Disturbance	617.3	20.21	0.000
	4	Waterbody type + Width + Depth	617.5	20.45	0.000
	5	Waterbody type + Width + Depth + Velocity	619.0	21.89	0.000
	1	Null (Otter)	686.4	89.34	0.000

Table 5: Summary of best model (Model 6) generated by Generalized Linear Modelling (GLM)

Parameters	Estimate	Standard Error	z-value	Pr(> z)
wbt 1	-0.837	0.299	-2.801	0.005 **
wbt 2	1.005	0.298	3.365	0.001 ***
wbt 3	-0.406	1.168	-0.348	0.727
wbt 4	-1.545	1.193	-1.295	0.195
wbt 5	-1.105	1.373	-0.805	0.421
wid	0.168	0.251	0.667	0.504
dep	0.014	0.136	0.100	0.920
vel	-0.103	0.135	-0.765	0.444
Sub_1	-1.479	0.351	-4.210	0.000 ***
Sub_2	-1.776	0.536	-3.312	0.001 ***
Sub_3	-16.146	1243.045	-0.013	0.989
Sub_4	-16.706	821.002	-0.020	0.983
Sub_5	-0.666	0.342	-1.946	0.051
Sub_6	-0.469	0.329	-1.426	0.153
Sub_7	-16.086	3956.180	-0.004	0.996
Sub_8	-0.679	0.421	-1.610	0.107
Sub_9	-16.245	1931.767	-0.008	0.993
Sub_10	0.618	0.574	1.076	0.281
Sub_11	-1.982	1.086	-1.824	0.068
Sub_12	-0.104	0.627	-0.166	0.868
Significance codes: 0 '***' 0.001 '**'				

Table 6: Predictor variables in Model 6

Variable	Measure	Type of Variable
Water body type	1 – Riffle 2 – Pool 3 – Run 4 – River 5 – Cascade	Categorical
Width	m	Continuous
Depth	cm	Continuous
Velocity	m/s	Continuous
Substrate type	1 – Cobbles 2 – Bedrock 3 – Boulders 4 – Cobbles, Bedrock 5 – Bedrock, leaf litter 6 – Bedrock, boulders 7 – Leaf litter 8 – Clay 9 – Mixed 10 – Sand 11 – Gravel 12 – Mud	Categorical

4.3 Food habits of Smooth-coated Otter

4.3.1 An account of fish species in the study rivers

Efforts were made to catch and identify all species of fishes in the study rivers, except Malin, as no otter signs of otters were observed in this river; but this was not possible due to time constraint and inefficacy of the fishing techniques.

During the study, 24 fish species, belonging to five families, in total were recorded from the study rivers (Appendix I). Members of the family Cyprinidae were the most commonly caught species.

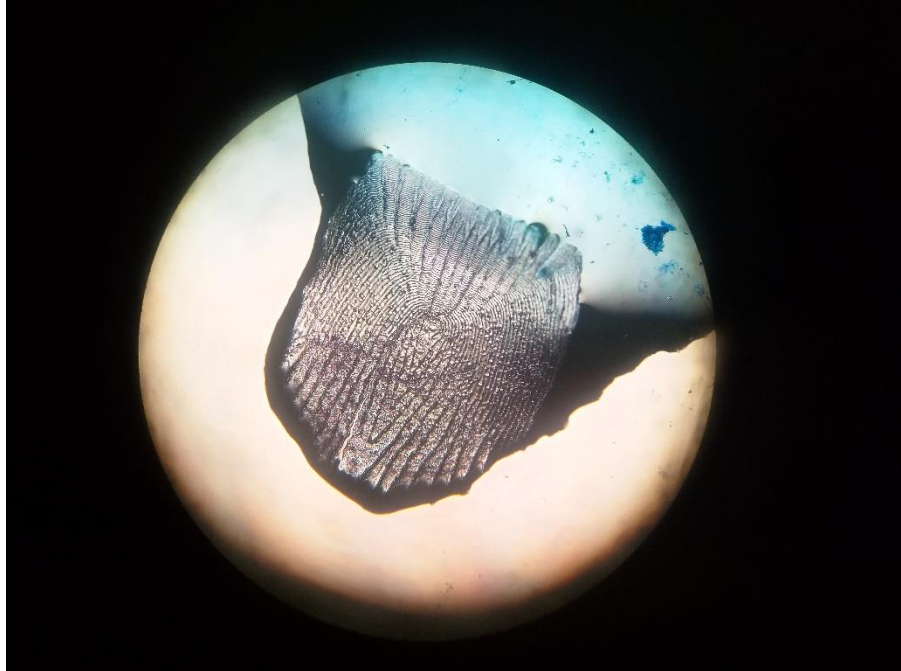
4.3.2 Diet composition of Smooth-coated Otter

4.3.2.1 Proportions of different prey categories encountered in otter spraints as estimated by ‘frequency of occurrence’ and ‘score-bulk estimate’ methods

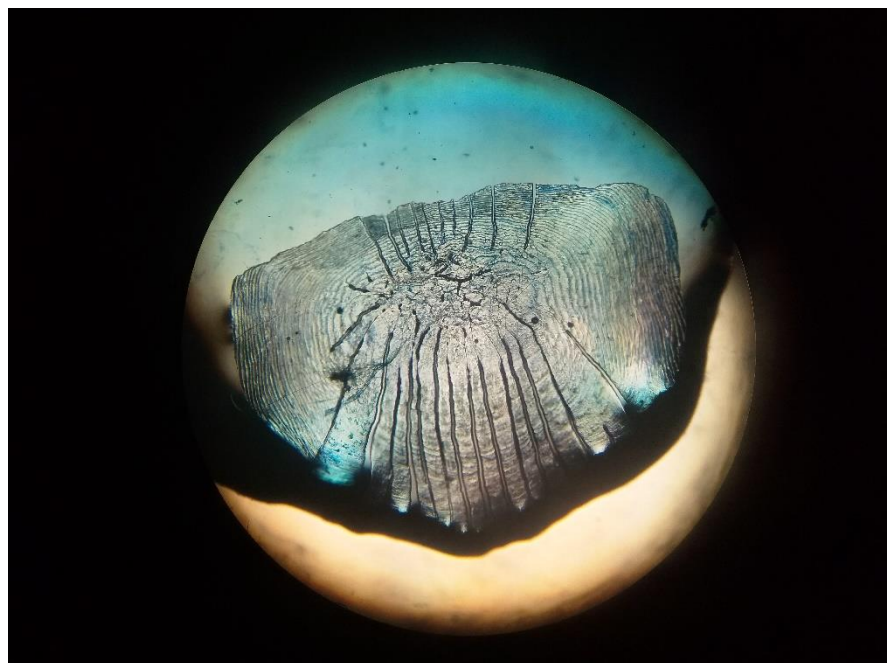
Fishes contributed maximum to the diet of Smooth-coated Otter having frequency of occurrence (FOC) of 95 % and score-bulk estimate (SBE) of 96.48 % (Table 7). This was followed by crabs (FOC = 4.17% and SBE = 3.14 %) and birds (FOC= 0.83% and SBE = 0.39%).

A total of 15 species of fishes could be identified in the otter spraints. *Tor putitora* formed the maximum contribution (FOC = 21.93, SBE = 25.87), followed by *Barilius vagra* (FOC = 12.96%, SBE = 22.44%), while *Channa gachua* (FOC = 0.99, SBE = 0.35), *Labeo calbasu* (FOC = 0.33, SBE = 0.14) and *Pethia conchoniis* (FOC = 0.33, SBE = 0.22) formed the least (Table 8) (Plate 5).

PLATE-5



Scale of *Channa gachua* observed under 4 X magnification



Scale of *Barilius bendelisis* observed under 4 X magnification

Fish scales observed in Smooth-coated Otter Spraints

4.3.2.2 Estimating prey size: relating vertebrae length to body size of fish

A total of 202 vertebrae belonging to 30 individuals of different fish species were measured for the vertebrae dimensions. The data was then subjected to linear regression using SPSS Software.

The vertebrae length is related to the total fish length by means of a linear relationship (Table 9 and Fig 7).

$$\text{Total length of fish} = 61.56 \times \text{Vertebrae length} - 0.325$$

The spraint analysis reveals a high occurrence of fish sizes corresponding to the vertebrae length classes 1 – 1.5 mm, 1.5 – 2 mm, 2 – 2.5 mm, 2.5 – 3 mm, and 3 – 3.5 mm corresponding to fish lengths 79.05 mm, 110.98 mm, 136.54 mm, 168.69 mm, and 192.92 mm respectively (Fig 8). Vertebrae length classes 1.5 – 2 mm (fish length = 110.98 mm), 2 – 2.5 mm (fish length = 136.54 mm) and 2.5 – 3 mm (fish length = 168.69 mm) constituted 25 %, 21 % and 17 % of the vertebrae extracted from spraints. All other size classes were represented inconsistently in the spraints, which means that very small and bigger preys are taken only occasionally.

Table 7: Relative proportions of major prey categories represented in the diet of Smooth-coated Otter (n=120)

Prey items	Occurrences	Frequency of Occurrence (%)	Score-bulk estimate (%)
Fish	114	95	96.48
Bird	1	0.83	0.39
Crab	5	4.17	3.14
	Sum = 120		

Table 8: Relative percentage of major prey species represented in the diet of Smooth-coated Otter (n=120)

Species	Occurrences	Frequency of Occurrence (%)	Score-bulk estimate (%)
<i>Tor putitora</i>	66	21.93	25.87
<i>Tariqilabeo latius</i>	47	15.61	8.41
<i>Barilius vagra</i>	39	12.96	22.44
<i>Labeo pangusia</i>	34	11.29	14.33
<i>Labeo dyocheilus</i>	26	8.64	7.08
<i>Garra gotyla</i>	22	7.31	4.53
<i>Barilius bendelisis</i>	22	7.31	8.58
<i>Chagunius chagunio</i>	9	2.99	3.00
Unidentified	9	2.99	1.47
Catfish	7	2.33	0.48
<i>Barilius barna</i>	6	1.99	2.33
<i>Mastacembelus armatus</i>	5	1.66	0.32
<i>Raiamas bola</i>	4	1.33	0.46
<i>Channa gachua</i>	3	0.99	0.35
<i>Labeo calbasu</i>	1	0.33	0.14
<i>Pethia conchonius</i>	1	0.33	0.22
	Sum = 301		

Table 9. Linear relationship between vertebrae length and fish length

Model Summary ^b									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.750 ^a	.563	.543	27.48237	.563	28.342	1	22	.000

a. Predictors: (Constant), VertebraeLength
b. Dependent Variable: FishLength

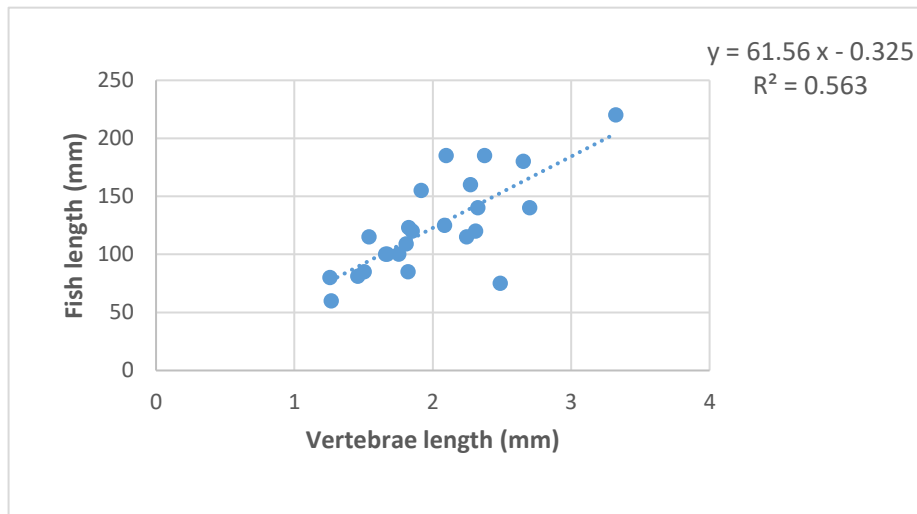


Figure 7. Linear fit of vertebrae length with the total length of fish

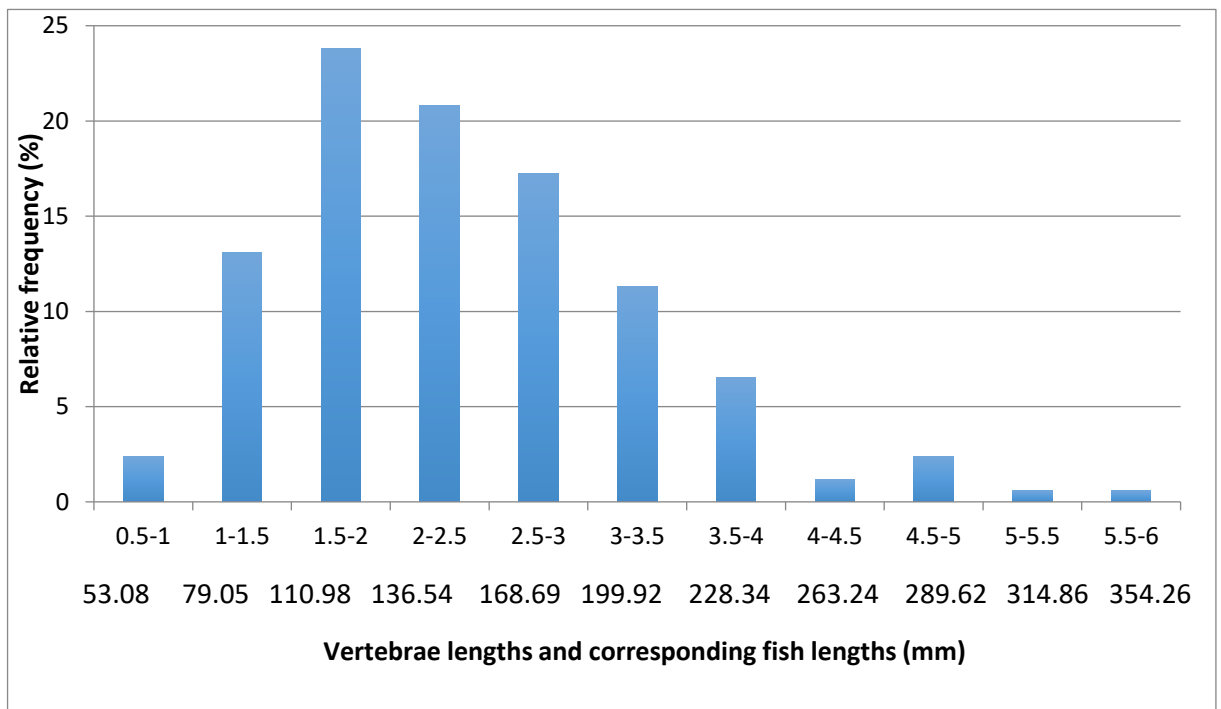


Figure 8. Size classes of fishes represented in otter spraints

4.4 Habitat suitability modelling of Smooth-coated Otter

The potential habitat suitability (MaxEnt model) of Smooth-coated Otter is shown in Fig 9. In this study, we explored how the habitat suitability modelling could predict a gradient of environmental conditions suitable for the occurrence of Smooth-coated Otter across the study area. Potential habitat of Smooth-coated Otter is shown in a colour scale that represents the suitable habitat for the species, where increased suitability was indicated by values close to 1, and decreased suitability was indicated by values close to 0. The AUC value of the model was 0.957 ± 0.006 (Fig 10).

MaxEnt modelling identified PCA 1 as the most important variable influencing Smooth-coated Otter habitat suitability, followed by PCA 2, Human Influence Index, PCA 3, Euclidean distance to drainage and Slope Position Index (Table 10). The potential habitat of Smooth-coated Otter across the study area is shown in Fig 11. From this model, out of the total 3716.18 km^2 , 4.9 % (181.7 km^2) is found to be potential habitat for Smooth-coated Otter, while 95.1 % (3534.4 km^2) is unsuitable (Table 11). Response curves show how each environmental variable affects the MaxEnt prediction. The most important variables affecting otter distribution were compound topographic index, Euclidean distance from drainage, and slope position index (Fig 11 a, b and c).

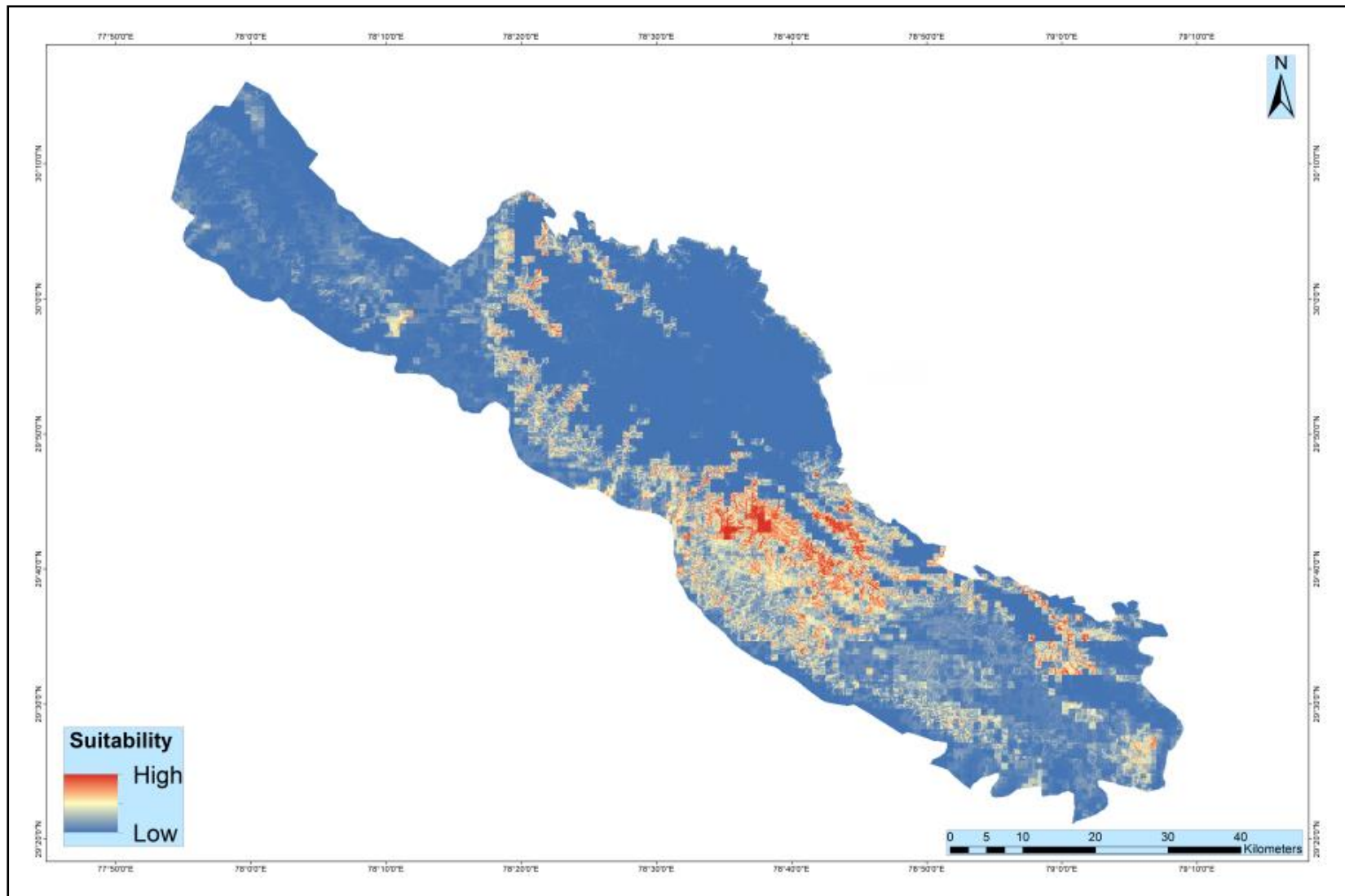


Figure 9. Habitat Suitability Map of Smooth-coated Otter based on MaxEnt model.

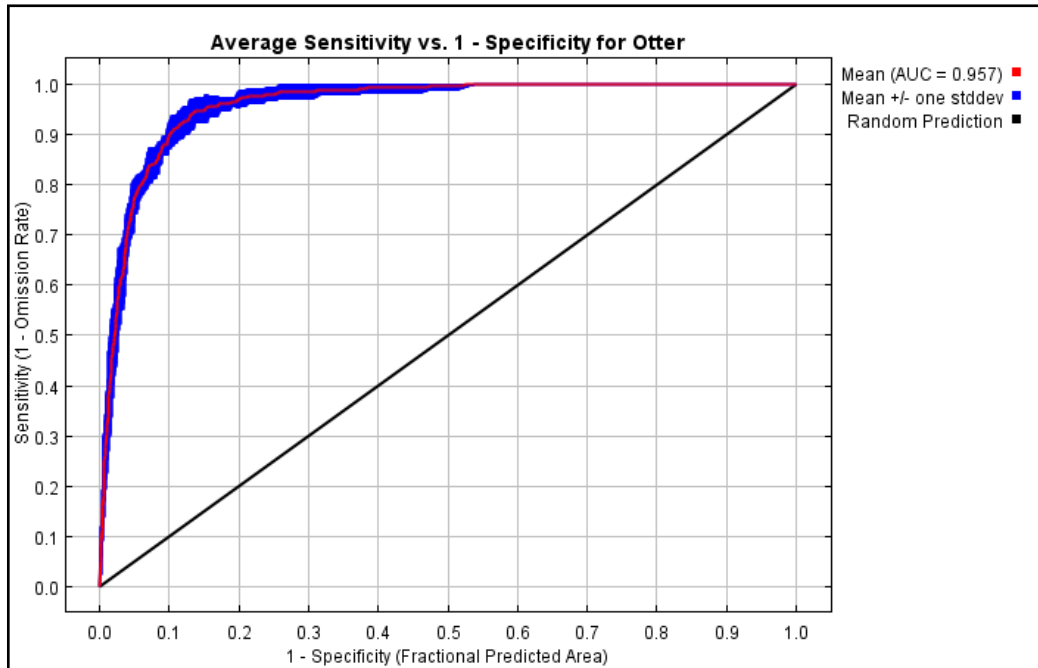


Figure 10. The Receiver Operating Characteristic (ROC) curve for the data

Table 10. Percent contributions of variables used in the MaxEnt model

Variable	Percent contribution
PCA 1	33.2
PCA 2	21.6
Human Influence Index	10.6
PCA 3	9.2
Euclidean distance	7.6
Slope Position Index	7.2
Compound Topographic Index	5.5
Globe Cover	5

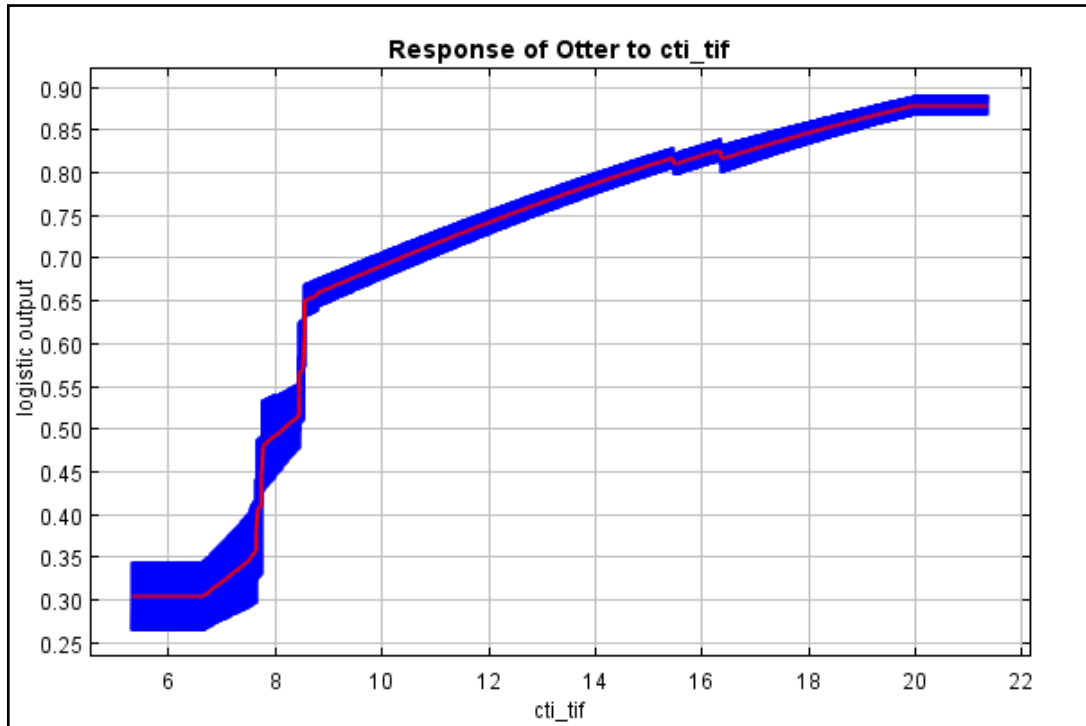


Figure 11 a. Response of Smooth-coated Otter distribution to Compound Topographic Index (CTI)

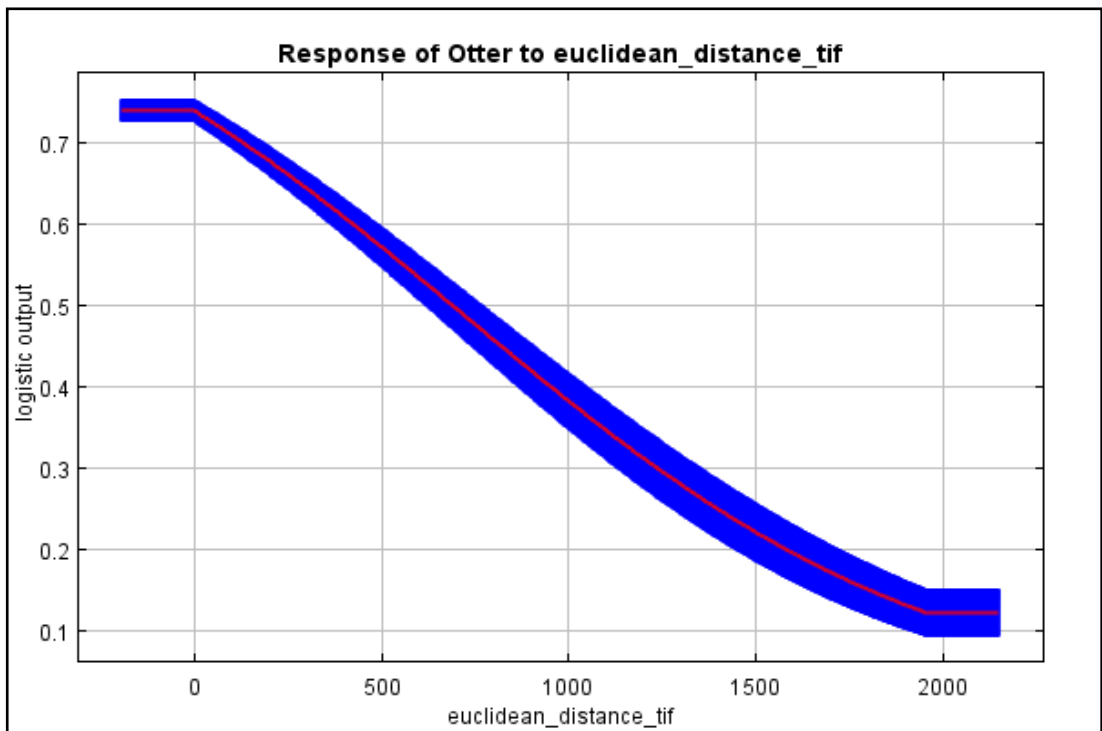


Figure 11 b. Response of Smooth-coated Otter distribution to Euclidean distance from water

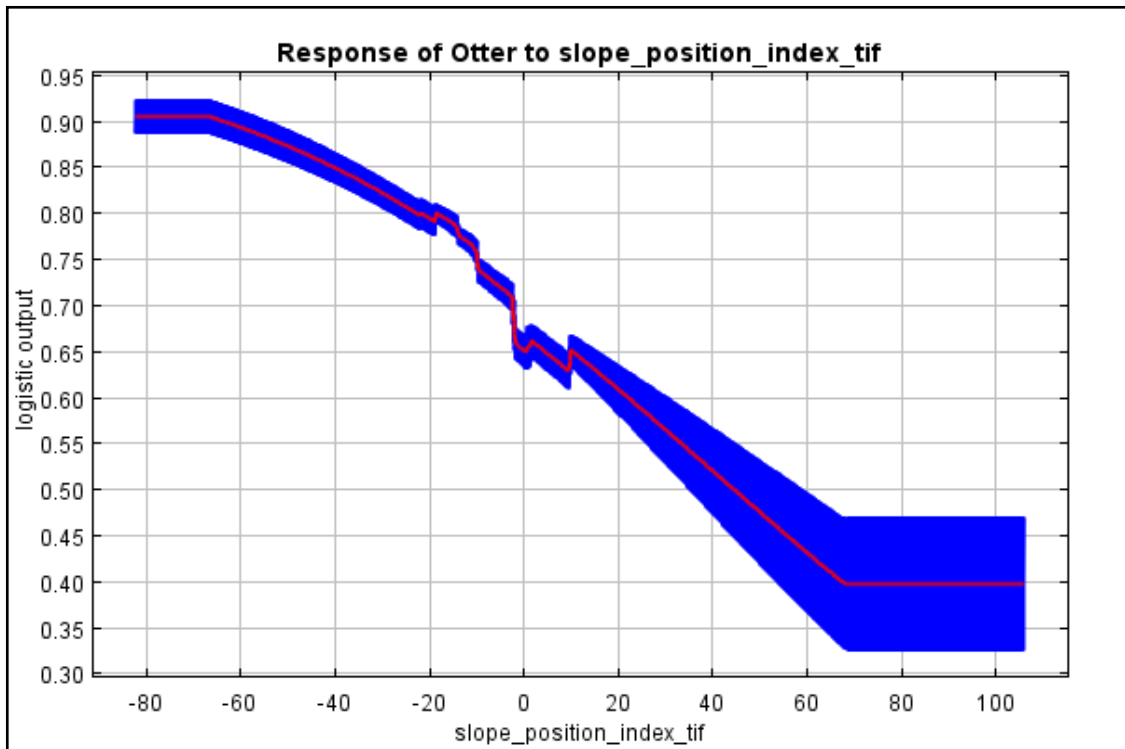


Figure 11 c. Response of Smooth-coated Otter distribution to Slope Position Index

Table 11. Total estimated suitable and unsuitable habitat for Smooth-coated Otter in the study area

Category	Area (km ²)
Unsuitable	3534.443
Suitable	181.7401
Total area	3716.183

5. DISCUSSION

Understanding the ecology of species pertaining to the resources it is dependent upon, is the first step towards conservation. The broad-geographic range of the Smooth-coated Otter (*Lutrogale perspicillata*) suggests that it is well adapted to survive in diverse aquatic habitats (Pocock 1941). Essentially a plains' otter in India, the Smooth-coated Otter is adapted to survive even in the semi-arid regions of northwestern India and the Deccan Plateau (Prater 1971; Hussain 1993). In the sub-Himalayan foothill forests, which have high biodiversity value but are also the hot seat for developmental activities, the probability of adverse effects on wildlife and its habitat is ever increasing. Otters, being apex predators of the aquatic ecosystems, they inhabit, play important ecological roles in maintaining the proper functioning of these systems. During the study, efforts were made to understand the factors essential for the survival of otters across the landscape.

The duration and intensity of selection of a habitat by an otter is determined by the certain key components – food, shelter, and water (Melquist and Dronkert 1987). Prey, the most prominent factor that governs the presence of otters in a habitat, in spite of the presence of some degree of disturbance (Theng and Sivasothi 2016). In this study the resources essential for the survival of Smooth-coated Otter was visualised at a landscape level.

5.1 Habitat features critical for the survival of Smooth-coated Otter

Habitat selection by otters largely depends on the requirements of otters, such as prey, denning sites, and grooming sites. While habitat features may seem extremely variable, the preferences of certain habitat feature by otters for their survival are very catholic (Kruuk 1995). This study indicated a preference of deep (3 - 6 m) pools, with sandy and muddy substrate and moderate bank side vegetation by otters. The preference of deep pools can be attributed to the availability of prey, a major factor for

the survival of otters. The velocity of water in deep pools is minimum, thus making it energetically feasible for otters to forage for prey. This study shows that water bodies with moderate width (10 – 40 m) over very wide (> 40 m) or narrow widths (1 – 10 m), were preferred by otters. The findings were in congruence with the study conducted on Eurasian otter (*Lutra lutra*) in Bzura catchment of Central Poland, by Romanowski, Brzeziński and Zmihorski (2013), wherein the colonization sites of Eurasian otter were characterised by lesser river width and lower percentage of tree cover.

In the study area, pools usually had sandy or muddy bank, with gentle slope and moderate bank vegetation. The sandy banks were used as grooming sites, while the mud bars adjacent to the pools, were sites for otters to rest in between feeding bouts and haul their prey and feed. However, otters were also seen foraging in riffles, but such encounters were very rare (Personal observation). Grooming is an important behaviour of otters to maintain social bonds and also for fur maintenance, which is required for thermoregulation. All species of otters are known to spend most of their time foraging in cold waters, thus a well-functioning fur achieved by grooming, is of utmost importance to maintain body temperature (Kruuk 2006). The preference for moderate bank side vegetation may be an artefact of the sampling season that was winter and sunlight was a necessary requirement for foraging and basking of otters. Moreover, in areas with less vegetation, temperature of the water body was also likely to be higher than the shaded areas, making it suitable for fishes to become active, enabling otters to prey on them easily. Fish eagles and crested kingfishers were often seen in association with foraging otters, trying to snatch a meal that slipped from the otters' mouth (Personal observation). Thus, moderate bankside vegetation provided otters with a wide visibility range to avoid such aerial predators.

Anoop and Hussain (2004) showed that otters in Periyar Lake preferred shallower regions of the lake. Nawab and Hussain (2012) in

Corbett Tiger Reserve suggested that otters preferred sandy or rocky banks with moderate bank slope. In this study, the significant negative association of bedrock and cobbles (rocky substrate type) with otter occurrence indicate that substrate type plays a major role in habitat selection by otters. While otters may use sections of river stretches strewn with boulders and cobbles for travelling, and also at times for denning, signs especially spraints were found only occasionally on rocks. Rocky areas cannot be used by otters for grooming, which is an important behaviour of otters. Spraints were invariably deposited on sand or grass even in areas where rock dens were used. The significantly positive association of otter occurrence with pools, indicates the importance of this water body type in influencing otter occurrence in an area. Rivers and streams provide a multitude of habitat features for otters to exploit, but all habitat features do not provide the same habitat quality for otters. Influence of bank substrate type and water body type on otter occurrence in a habitat signifies the dependence on otters on these factors for performing various life history functions. Being a narrow niche species, otters remain restricted to a narrow stretch of the river-land continuum and both are equally essential for the survival of the species. For foraging, otters require water as the major component of their diet is composed of fish. For grooming, denning and breeding, a dry land surface is quintessential. Slow moving waterbodies (pools) are often preferred because of the increased hunting efficiency and also for teaching the pups to catch fish during their initial days out of the holts. The influence of different habitat characteristics thus has a significant bearing on the species' behaviour and populations.

In the study area, otters were found to make holts in rock crevices, and in clayey bank sheltered with shrub cover. The river Khoh, which runs adjacent to the National Highway 119, was the most prone to disturbance, but Smooth-coated Otter population in this river were considerable tolerable and denning sites were concentrated in a stretch least accessible to humans. In Mandal river, a pod of Smooth-coated Otters was seen

foraging under a footbridge. This indicates that Smooth-coated Otter is a considerably tolerant species to human disturbance.

In congruence with other studies, otters showed a high degree of fidelity in denning sites (Kruuk, Glimmerveen and Ouwerkerk 1986; Conroy and Jenkins 1986; Mason and Macdonald 1986; Hussain and Choudhury 1997; Anoop and Hussain 2004). It was observed that during receded water levels, otters shifted their denning sites to places where prey was in abundance. After rains, when the water levels became higher, otters returned to their original den site.

5.2 Food habits of Smooth-coated Otter

In congruence with previous studies, this study reveals that fish constituted the major prey item (95 %) in the diet of Smooth-coated Otter (Hussain 2013; Anoop and Hussain 2005; Nawab and Hussain 2012). Small to medium sized fishes are most represented in otter spraints, indicating that it is energetically more feasible for otters to catch medium-sized prey, since prey is captured by mouth, and larger sized prey is taken opportunistically (Erlinge 1968; Rowe-Rowe 1977). Spraints that showed remains of bigger fish were found near deeper and bigger pools, especially in river Ganga, where bigger sized prey was available. The relatively less proportion of remains of birds and crabs indicate that these prey categories are of secondary importance and are taken opportunistically.

The overall results indicate that Smooth-coated Otter is predominantly piscivorous. The consumption of secondary prey such as crabs and birds, is a strategy of this opportunistic species to meet additional energy requirements, especially during the winter season and in area where fish population is not sufficient. Such secondary prey categories have also been reported for other otter species (e.g. Wise, Linn and Kennedy 1981; Weber 1990 for *Lutra lutra*; Melquist and Hornocker 1983 for *Lutra canandensis*). Mammals and terrestrial birds do not usually form a

significant part of an otter's diet as otters are not particularly dexterous to capture prey on land and predation on them reflects opportunism rather than focused hunting (Perrin and Carugati 2000). Prey taken by otters varies according to the otter species, the seasonality and landscape features (Hussain and Choudhury 1997).

In the landscape, six species of fishes formed a major portion of the diet of Smooth-coated Otter and members of the family Cyprinidae were taken more frequently.

The frequency of occurrence and the score-bulk estimate methods used in the study gives a fairly accurate rank-order of prey categories and species (Wise, Linn and Kennedy 1981; Jacobsen and Hansen 1996; Carss and Parkinson 1996). However, the 'frequency of occurrence' method has been widely criticised for its inherent problems (Jacobsen and Hansen 1996). In this method, the presence of one mahseer dorsal fin spine will be weighted the same as the presence of a number of mahseer dorsal fin spines in a spraint. This leads to under-estimation of major items and over-estimation of minor items (Mason and Macdonald 1986; Wise, Linn and Kennedy 1981). Thus, the 'score-bulk estimate' method gives a better representation of the prey categories consumed. Feeding trials conducted by Jacobsen and Hansen (1996), also recommends 'score-bulk estimate' better than any other method.

In the estimation of fish length in this study, vertebrae length was preferred over eyeball diameter as suggested by Wise 1980. This was so because vertebrae of bigger or smaller fish are invariably present in the spraints, although vertebrae of bigger fishes were usually found broken, but intact ones were also present in fair amounts. These are congruent with the conclusion drawn by Wise 1980; Anoop and Hussain 2005.

Prey availability plays a major role in the occurrence of otters across the landscape (personal observation). In winter, when the water level went drastically down, fishes were seen to migrate upstream towards larger

pools of water. Along with the movement of prey otters shifted their denning sites too, indicating the importance of prey in otter occurrence.

5.3 Habitat suitability of Smooth-coated Otter

The habitat suitability model created using MaxEnt modelling gave a fairly good idea of the potential habitat of Smooth-coated Otters across the landscape, although there was scarcity of fine-scale data. There have been several studies for modelling species distribution of otters at different scales, using various approaches (Prenda and Granado-Lorencio 1996; Boitani *et al.* 2002; Loy *et al.* 2009; Ottaviani *et al.* 2009; Ali *et al.* 2010; Cianfrani *et al.* 2010, 2011, 2013). Our study was the first to analyse otter habitat suitability modelling in India.

Smooth-coated Otter presence probability increased with the reduced distance from water, which is congruent with the ecological understanding of the species (Hussain 1993; Anoop and Hussain 2004; Nawab and Hussain 2012; Kruuk 2006). Compound Topographic Index (CTI) is also known as steady state wetness index. It is a function of the slope and the upstream contributing area per unit width orthogonal to the flow direction; lower values of CTI indicate steep slopes with small streams, whereas higher values of CTI indicate gentle slopes, plains and rivers (Moore, Grayson and Ladson 1991). Thus, with increasing CTI values, an area can be predicted as suitable for Smooth-coated Otter. With increasing slope, i.e. steepness of a terrain, probability of otter presence decreases. This is similar to the findings of Anoop and Hussain 2004 in Periyar Tiger Reserve, where otters prefer gently sloping ($<5^\circ$) terrain. Human disturbance affects the survival of otters which is reflected in this study too (Verwored 1987; Butler and Du Toit 1994; Hussain and Choudhury 1997).

The absence of the representation of potential habitat in certain areas with sufficient drainage may be because of the increased Slope Position Index, i.e. steepness of the terrain or also may be an artefact of

absence of sampling points from those areas. Of the available area, only 4.9 % is suitable for sustaining Smooth-coated Otter, which is very less. While interpreting the results, it needs to be borne in mind that otters occupy narrow stretches along the land-water continuum, and not all rivers provide for the requirements of otters. In this study the river Malin was otter-negative, i.e. no otter signs were recorded from this river. The non-perrineal, gorge-like nature of the river does not seem suitable for inhabitation by otters. Moreover, disturbance along some river banks, deters otters. This asserts the importance of conserving the available habitats that sustain otter populations and maintaining their connectivity.

There are a multitude of factors affecting the distribution of animals (Rosenzweig 1985). Several hierarchical levels of spatial scale are included in species-habitat relationships and different habitat features may affect species at different scales, temporally or spatially (Bissonette 1997). Thus, the potential impact of scales must be considered while doing habitat suitability modelling of a species.

5.4 Limitations of the study

Because of time constraints and lack of resources for fishing, only the inventory of fish species found in the study area was prepared. Proper fish sampling at different times of the day and across the entire river stretches could not be carried out. The lack of fine-scale data of important ecological variables for otters such as prey abundance, vegetation cover, and depth profile of rivers were some limitations in the habitat suitability modelling of Smooth-coated Otter.

5.5 Conservation implications

The sub-Himalayan foothill forests are a biodiversity rich region, facing immense anthropogenic pressure due to increasing human population. Several protected areas fall in this landscape including Rajaji National Park, Lansdowne Forest Division and Corbett National Park, which were surveyed in this study. Although the otter is an apex predator of aquatic ecosystems, there is not much information is available on the ecology of the species from the landscape (Nawab and Hussain 2012). Otter populations in the landscape are restricted to the rivers and streams of the protected area network, thus strict ban on the illegal activities such as sand mining, boulder collection and garbage dumping needs to be executed. Fishes constitute a major portion of the diet of Smooth-coated Otter; thus, conservation of native fish species is crucial for the long-term survival of otters in the landscape

6. CONCLUSIONS

As evident from this study, habitat use by otters is governed by the availability of certain habitat features such as pools, moderate vegetation, muddy or sandy bank substrate. This is influenced by the necessary requirements of otters such as sufficient prey base, resting, denning and grooming sites, and escape cover. Such features may seem general at first glance, but when observed closely, the habitat features necessary for otter survival are very patchy in distribution. Since otters can move long distances in search of foraging and denning sites, it is necessary that the connectivity of such patches is maintained. Availability of prey is an important limiting factor for species distribution. However, not all river stretches are used by otters, although prey might be available there. Thus, understanding the interactions of various habitat parameters with the species is important. With the increasing human population, pressure on the biotic resources is inevitable. The growing demand for water resources especially jeopardizes the resource requirements for otters. Rivers, although falling under the network of protected areas, usually form the boundaries of protected areas, thus making them susceptible to illegal anthropogenic activities. Creation and maintenance of protected area networks with additional legal protection given to rivers and wetlands can be effective in the long-term survival of otters.

Suggestions for future work

This study will be further extended to cover most of the Terai-Arc landscape. Emphasis will be given to seasonal data to understand the variations in resource use of otters according to seasons. Intensive habitat survey along with fish sampling needs to be carried out at a landscape level. To understand the perception of people towards otter conservation as well as wetland conservation in general, questionnaire surveys need to be conducted. Further research with better refined methodologies will help to elucidate otter population trends, distribution and conservation requirements. Priority should be given to understanding species ecology at a landscape level, with prey populations, riverine connectivity and anthropogenic disturbance as the limiting factors of otter distribution.

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Appendix I

Fish species recorded from the study rivers

Family	Order	Species
Balitoridae	Cypriniformes	<i>Acanthogobius botia</i>
	Gobiiformes	<i>Glossogobius giurus</i>
Cyprinidae	Cypriniformes	<i>Barilius vagra</i>
		<i>Barilius barna</i>
		<i>Barilius bendelisis</i>
		<i>Chagunius chagunio</i>
		<i>Cirrhinus mrigala</i>
		<i>Tariqilabeo latius</i>
		<i>Garra gotyla</i>
		<i>Labeo bata</i>
		<i>Bangana dero</i>
		<i>Labeo calbasu</i>
		<i>Labeo dyochelius</i>
		<i>Labeo pangusia</i>
		<i>Pethia conchonius</i>
		<i>Schizothorax richardsonii</i>
		<i>Schizothorax progastus</i>
		<i>Tor putitora</i>
<i>Raiamas bola</i>		
Channidae	Anabantiformes	<i>Channa gachua</i>
Mastacembelidae	Synbranchiformes	<i>Mastacembelus armatus</i>
Sisoridae	Siluriformes	<i>Glyptothorax spp</i>