DEPARTMENT OF ZOOLOGY

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Habitat use and abundance of fishing cats (Prionailurus viverrinus) from camera-trap surveys used for monitoring tigers in the Terai region of India

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A report submitted in partial fulfilment of the
Post-graduate Diploma in Wildlife Management

University of Otago

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Contents

List of tables

List of Figures

Summary

The fishing cat, distributed in South and South-East Asia has been classified as endangered by the IUCN. Even though there has been an emphasis in research and conservation of wild felids, there is a great paucity of information on this species. There is little information on the abundance of fishing cats across the species range, and its biology is poorly understood – particularly with respect to its foraging and breeding biology, and its social ecology. Information on the occurrence and abundance of species constitute primary information that is integral to develop an understanding of its biology. Likewise, such information is integral for the conservation and management of species, particularly when their status is precarious.

This study uses camera trap data to model habitat use and abundance for fishing cats in the terai region of North India. Specifically, species occurrence is modeled using a site occupancy framework wherein the proportion of area used by the species has been estimated for two prominent protected areas in the terai – Dudhwa National Park and Kishanpur Wildlife Sanctuary. The determinants of habitat use were investigated using predictor variables (environmental covariates), which were modelled as effects for the parameters psi and p. Abundance was estimated using closed population mark recapture models, wherein individual fishing cats were identified by unique pelage patterns. In addition to the estimates of species occurrence and density, this study has also generated information on activity patterns of fishing cats.

The estimates of fishing cat abundance reported here appear to be the first for the species across its range. This study demonstrates that camera trap data for fishing cats can be used to reliably estimate abundance. The models of habitat use indicated relationships between fishing cat occurrence at a site and proximity to water sources and the forest edges as postulated. It appears that the ample availability of water within the study area and the fact that fishing cats makes it difficult to predict the drivers of species occurrence in this forest-grassland mosaic eco system. Fine scale studies of foraging habitats and home range from radio telemetry will be very useful in developing our understanding of fishing cats. This study aptly demonstrates that auxiliary data from camera trap studies focused on large carnivores may be useful and allow parameter estimation for species such as fishing cats. Moreover, it contributes useful information for conservation practitioners and managers who seek to protect and promote diversity.

1. Introduction

1.1 Background to Fishing cat

Fishing cat was named Felis viverrinus by the English zoologist Edward T. Bennet in 1833 for its viverrine or civet–shaped appearance, resembling particularly the large Indian civet (Viverra zibetha; Sunquist and Sunquist 2002). In 1858, the Russian explorer Nikolai Severtzov separated the fishing cats along with some other cat species under the umbrella term Prionailurus- members of this family are characterized by conspicuous stripes and spot patterns on the head, face and body.

Fishing cat (Prionailurus viverrinus) is distinguished from the leopard cat by its much larger size (male=660mm, n=1; female=648-743mm, n=2) and shorter tail (Prater 1997, Macdonald and Loveridge 2010). The front feet in fishing cats are partially webbed like the flat headed cats, and its claw tips protrude even when retracted into their sheaths, giving a distinct track imprint (Sunquist and Sunquist 2002). They are relatively small cats with adult female weights ranging from 5-9 kg and males ranging from about 8 to 14 kg (Sunquist and Sunquist 2002). Telemetry studies conducted in the Khao Sam Roi Yod area in Thailand estimated the home range size of a male fishing cat to be 7.3 km^2 whereas the average female home range was found to be 2.8 km^2 (n=3). The average home range overlap of the male over female home ranges was 7.28% and 2.94% among females.

1.1.1 Habitat and Ecology

Fishing cats are strongly associated with wetlands. They are typically found in swamps and marshy areas, oxbow lakes, reed beds, tidal creeks and mangrove areas and are scarcer around smaller, fast-moving watercourses (Macdonald and Loveridge 2010). Although fishing cats are widely distributed through a variety of habitat types (including both evergreen and tropical dry forests (Rabinowitz and Walker 1991), their occurrence tends to be highly localized (Nowell and Jackson 1996).

Fishing cats are good swimmers, and unlike most other small cats, they prey primarily on fish rather than small mammals. A one-year study of food habits based on analysis of prey items in scat in India's Keoladeo National Park revealed that fish comprised 76% of the diet, followed by birds (27%), insects (13%) and small rodents (9%) (Haque and Vijayan 1993). Molluscs, reptiles and amphibians are also taken (Haque and Vijayan 1993, Mukherjee 1989). However, they are capable of taking large mammal prey including small chital fawns (Nowell and Jackson 1996, Sunquist and Sunquist 2002), and have been seen scavenging livestock carcasses and tiger kills (Nowell and

Jackson 1996). Predation on small domestic livestock and dogs has also been reported (Nowell and Jackson 1996, Mukherjee et al., 2010).

1.1.2 Distribution

Figure 1 Distribution of fishing cats in the world (Seidensticker 2003).

Distribution outside India: Fishing cats occur patchily across South Asia and South East Asia, including some prominent islands of the archipelago. In Pakistan, the only known population was in the Indus river valley (Roberts 1977), but there have been no recent records. On the island of Sri Lanka, fishing cats are widely distributed and have been found on waterways near the capital city of Colombo in degraded habitats (Seidensticker 2003).

In Southeast Asia, its distribution appears very patchy, with few recent records (Mukherjee et al., 2010). There are no confirmed records of the fishing cat from Peninsular Malaysia, but an incomplete 1999 camera trap image from Taman Negara National Park suggests it occurrence (Kawanishi and Sunquist 2003). On the island of Java, it has become scarce and apparently restricted to a few coastal wetlands (Melisch et al., 1996). Although commonly believed to occur on the island of Sumatra, there are no definite historic records. Moreover, recent records have been shown to be erroneous, and its presence there remains to be confirmed (Duckworth et al., 2009, Sanderson 2009).

Camera trap studies and sign surveys have confirmed the presence of fishing cats in two coastal areas of Thailand: the Thale Noi Non-Hunting Area and the Khao Sam Roi Yot National Park. However, no evidence of the species was found at Klong Saeng and Maenam Pachi Wildlife Sanctuaries (Cutter & Cutter 2009, Jutzeler et al., 2010). The presence of fishing cats has been confirmed in northern and south-western Cambodia (Duckworth et al., 2005, Royan 2009, Rainey and Kong 2010, Jutzeler et al., 2010).

Distribution in India: The fishing cat has been extirpated in recent years from various sites and regions of India, including the Bharatpur (Keoladeo Sanctuary) of western India (Mukherjee et al.,, 2010). It has possibly also disappeared from the southern Western Ghats (Nowell and Jackson 1996, Mukherjee et al.,, 2010). However, there is also a new record from Umred, near Nagpur in central India, an area well outside of the fishing cat's known range, where a Fishing Cat that had been killed by a vehicle was found (Mukherjee et al., 2010). Fishing cats are primarily found in the terai flood-plains of North India along the Himalayan foothills, and in eastern India where few high- quality habitats still remain (Kolipaka 2006). In addition to being prevalent in wilderness areas, fishing cats are also known to occur in human dominated marsh-land habitat and aquaculture ponds of the Howrah and Hooghly regions in the state of West Bengal (Adhya 2011). Interestingly, this species is widely distributed and locally common in the mangrove dominated swamp lands of the Sunderbans region of Bangladesh (Khan 2004).

1.1.3 Threatened Status of fishing cat

The fishing cat is a nocturnal, rare and elusive cat with an apparently broad but discontinuous distribution in Asia (Mukherjee et al., 2010). IUCN Cats Red List Workshop 2007 suspected a decline of at least 50% over the past 18 years (three generations), and a similar decline is anticipated over the next 18 years in the absence of intensive habitat protection of fishing cats (Mukherjee et al., 2010).

In 2008 the status of the Fishing cat was elevated from vulnerable to endangered due to severe population decline over its range (Mukherjee et al., 2010). In India, it is accorded the highest protection status by being placed in Schedule I of the Indian Wildlife Protection Act 1972. The species is listed in Appendix 2 of CITES.

Major threats to Fishing cat include range contraction due to destruction of wetland or mangrove habitat for settlement and conversion for agriculture and aquaculture (Cutter and Cutter 2009, Royan 2009, Adhya 2011, Aziz 2012). Pollution of rivers caused by agricultural waste water also threatens fishing cats. Fishing cats are also known to be hunted or poisoned occasionally when they are believed to raid livestock (Adhya 2011, Cutter 2009, Jutzeler et al., 2010, Aziz 2012). In some areas, fishing cats are also hunted by tribals for their meat while their skins are illegally sold. (Adhya 2011, Royan 2009, Aziz 2012)

1.2 The Terai Region

1.2.1 Geography

The Shivalik- Gangetic flood plains corresponds to three regions – (i) Upper Gangetic Plains- moist deciduous forest, (ii) Terai-Duar savanna and grasslands and (iii) Himalayan subtropical broadleaf forest (Wikramanayake et al., 1999) Of these, the Terai-Duar savanna is listed among the 200 globally important areas, due to its intact large mammal assemblage, even though it scores low on plant species richness and endemism (Jhala et al., 2008). The Terai-Duar Savanna region is spread along the lowlands that abut the southern slopes of the Himalayas in India, Nepal, Bhutan and Bangladesh.

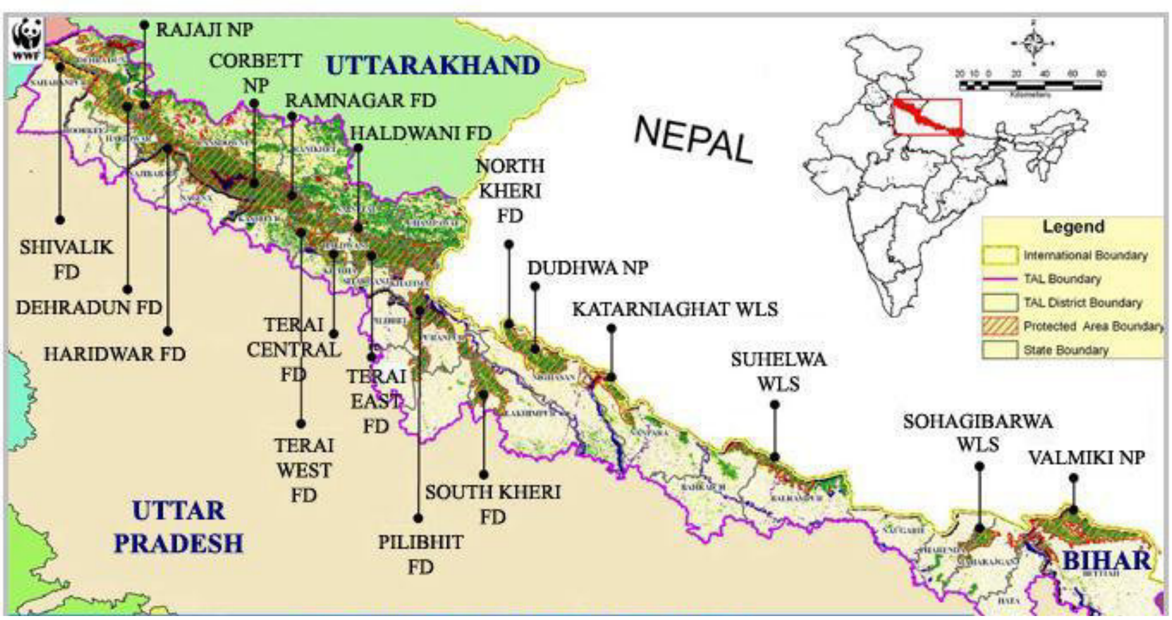

Figure 2 Map of Terai Arc Landscape. Courtesy WWF India

The Terai Arc Landscape (TAL, Figure 2) lies within this region covering an area of approximately 49,500 sq km in India and Nepal stretching from the Bagmati River in the East to the Yamuna River in the west (Semwal 2005). There are 13 existing Protected Areas (PAs) that fall within this landscape and the TAL is the best surviving remnant of the once extensive alluvial grassland and forest ecosystems of this region.

1.2.2 Current status of TAL

Less than 50 years ago, the TAL was a contiguous expanse of dense forests and tall grasses. In the past some forests within this region were set aside as hunting reserves by colonial administrators and Indian maharajas while, some were used intensively for logging. Over the past 150 years, the forests of the TAL have been subject to intensive logging operations, land clearing for agriculture and a sharp rise in the regions human population as a consequence of improved infrastructure and productive land with ample ground water for irrigation. Moreover the near eradication of malaria from the region following decades of insecticide spraying has been conducive for the regions human inhabitants (Strathorn 2009). A significant proportion of the region's inhabitants are the descendants of Sikh and Bengali refugees from Pakistan and Bangladesh who were settled and allotted land in the Terai following their exodus from these countries. Today, the TAL comprises of 23% closed forest, 7% open forest and 0.4% scrubland. There are 17 forest patches of size more than 100 sq. km; forming 90% of the landscape, most of the patches are less than 5 sq. km in extent particularly in the eastern portion of the landscape (Johnsingh et. al., 2004) (Figure 2). It is noteworthy to mention that most terai forests in the State of Uttar Pradesh are fragments, with limited or no connectivity to other forested areas in India and nearby Nepal. The region's PAs are mainly just isolated refuges and do not currently provide connectivity. This may have deleterious impacts on the populations and behaviour of several large mammals, and on ecosystem processes (Semwal 2005).

The land cover now comprises of forest patches (in various states of preservation or degradation), extensive areas under cultivation (primarily wheat, sugarcane and rice) and many thousand villages and a smaller number of towns that support a predominantly agrarian community. Growing logging and urban settlements and infrastructure networks pose challenges to conservation in this region.

1.2.3 Biodiversity

Prominent species of charismatic large mammals inhabiting the TAL forests are tigers, Asian elephants (Elephas maximus), one-horned rhinoceros (Rhinoceros unicornis) and swamp deer. (Cervus duvacelli) Sixteen other endemic and obligate species found in this landscape include hog deer (Axis porcinus), hispid hare (Caprolagus hispidus), Bengal florican (Houbaropsis bengalensis) and swamp francolin (Francolinus gularis), which are well adapted to the unique grassland - swampland - forest mosaics of the region. The terai landscape is the last home for a number of these species (Johnsingh et al., 2004, Jhala et al., 2008)

In the west the Shivalik-Bhabar portion of the landscape - which is more hilly and has fewer low lying swamps, is composed of sal (Shorea robusta) mixed and miscellaneous vegetation while the terai plains (in the central and eastern parts of the landscape) are dominated by a variety of tall grasslands and sal forest vegetation communities Overall, sal dominated and mixed forests account for majority of the overall forest cover. The other prominent tree species in this region are Mallotus philippensis, Syzygium cumini, Butea monosperma, Bombax ceiba, Sterculia urens, Aegle marmelos, Terminalia alata, Terminalia arjuna, Adina cordifolia, Azadirachta indica, and Lagerstroemia parviflora. Plantations of economically important trees like Teak, Shishoo, Eucalyptus, and Acacia cover a sizeable area of the region's forests. Tall grasses like Themeda, Saccharum, Phragmites, Vetiveria and several others also characterize the terai portion of the landscape. Once famed for its extensive tall grasslands, the landscape now boasts of less than 500 sq. km of tall grass habitats many of which are in a highly fragmented state (Johnsingh et. al., 2004).

1.3 Review of Methods

Estimating population parameters like abundance or density has long been the focus of many animal population studies.

1.3.1 Single Season Occupancy (Habitat use) models

The goal of site occupancy modelling is to account for the difference between occupancy and detection; for example, following multiple surveys in a location, a target species may not be detected even though it does occupy that site. This deals with false absences which would otherwise grossly underestimate the "true" occupancy of the site (MacKenzie et al., 2006).

When a detection probability is not incorporated into the modelling of detection- non-detection information, the reliability of the inference breaks down because the relationship between the count (the number of locations where the species was detected) and the parameter of interest (occupancy) is not known (O'Conell et al., 2011).Site occupancy modelling recognizes that in some cases the probability of detecting a species is less than one, so a replication of survey efforts (either geographically or temporally) is used to estimate a species - level detection probability (p), the probability that at least one individual of a species will be detected given that the species does inhabit the area of interest. Detection probability is then used to estimate occupancy (ψ) the probability that a randomly selected site or sampling unit in an area of interest is actually occupied by the species.

In single species - single season occupancy models, there are two stochastic processes that are occurring at a site that could affect whether or not a species is detected. The first is that a site is either occupied (with probability ψ) or unoccupied (with probability 1-ψ). Then if the site is indeed occupied, for each survey (j) there will be some probability of detecting the species (p_j). Repeated surveys of a site leads to a detection history composed of 0s (for non-detection of species) and 1s (for detections), such that a detection history of H_i = 10101 means that the site is occupied at site i and that the species was detected in survey 1, not detected in survey 2, detected in survey 3, not detected in survey 4, and detected in survey 5.

This verbal translation of the detection history can be expressed in the following probability statement:

$Pr(H_i = 10101) = \psi\, p_1\, (1 - p_2)\, p_3\, (1 - p_4)\, p_5$........................ (1)

At sites where the species was never detected, there are two possibilities for why the species was never detected at the site: either (1) the site was occupied by the species and the species was not detected in any of the five surveys or (2) the site was unoccupied by the species. Both of these possibilities must be incorporated into the probability statement, which becomes

$Pr(X3=00000) = \psi 3 \prod 5(1-p3,j)+ (1- \psi 3)$

There are five assumptions of the model, which are: (1) occupancy in the sites does not change during the survey period; (2) probability of occupancy is equal across all sites; (3) the probability of detecting the species in a survey, given that the species is present, is equal across all sites; (4) the detection of the species in each survey of a site is independent of detections in the other surveys of the site; and (5) each detection history is independent (MacKenzie et al., 2006).

Species occupancy (ψ) and detection probability (p) can also be modelled as functions of covariates such as habitat type, elevation, or distance to nearest road. The modelling of these relationships can be interpreted as a kind of generalized linear regression technique, in which there is some uncertainty as to whether an observed absence is a "true" absence. Using a logit link function that transforms the linear combination of covariate values (which range between +/- ∞) to values between 0 and 1 (a scale of probability), the probability of site i being occupied is

$logit(\psi_i) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_u x_{iu}$, (3)

which is a function of U covariates associated with site i (x_{i1}, $x_{i2 \ldots}$ x_{iU}) and the U+ 1 coefficients that are to be estimated: U regression coefficients for U covariates and the intercept (β_0). Thus, the probability of occupancy can now vary among sites, but the parameters being estimated (the βs) are assumed to be constant across all sites. Therefore, appropriate covariates for modeling ψ are those that remain constant over time, such as distance metrics, elevation, or land cover type (MacKenzie et al., 2002). Thus, the detection histories are used to create probability statements for n sites which are then incorporated into a likelihood function and maximum likelihood estimation methods are used to derive estimates of parameters of interest such as ψ, p their associated errors and β values from regression models.

When the size of sampled sites is small relative to the home range of a species, the parameter ψ is interpreted as the probability of use (for a given cell or unit) rather than the occupancy probability (MacKenzie et al., 2006). Given that camera traps represent a point in space (rather than a discrete polygonal sample unit), inferences made in this study allude to habitat use by fishing cats only.

The use of camera traps to estimate site occupancy (or habitat use at finer scales) presents a relatively nuanced means of gathering species occurrence data. Traditionally, a site is surveyed on multiple occasions (or by multiple independent observers) over a short span of time. Surveys involve exhaustively searching for a species (or indirect evidence of its presence in an area). Camera traps on the contrary are fixed at a certain point in space for a fixed duration of time. The assumption here, while gathering occupancy data, is that for mobile species (such as territorial mammals) there is a non-zero probability that the some individuals of a species will encounter camera traps over the survey period. The frequency with which such detections will be obtained will ultimately be an artifact of camera density, site selection, and species behavior in addition to other factors. Although there are many different ways in which data from camera traps can feed into occupancy studies (particularly with regard to how occasions are defined, and whether a site is represented by a single pair of cameras or several cameras in a sample unit), for this study, every 24 hour period is denoted as an occasion (as is common in mark-recapture camera trap studies), and regarded every separate camera location to be representative of a site. This has been the modelling approach of some other studies (Linkie et al., 2007). We think it is justified because fishing cats were encountered at 37.67% in Kishanpur WLS and 44.44% of our camera sites in DNP. Furthermore, identifiable recaptures for 75.5% of fishing cats in KWLS and 84.4% in DNP suggests that the scale at which sampling was carried out (camera trap spacing) is adequate (if not ideal) to make inference about the occurrence and abundance of this species.

1.3.2Abundance

Abundance or population size (often expressed as density or number of individual animals per unit area) is another state variable that provides critical information about the status of any animal population.

Most commonly used methods to reliably estimate abundance are line or point transects – which are based on "distance sampling" (Buckland et al., 2001) and "capture-recapture sampling" (Williams et al., 2002). However, distance sampling cannot be used when studying secretive, nocturnal or rare species. Instead biologists employ 'capture-recapture' methods which is invasive, difficult and expensive. Although, non-invasive capture-recapture sampling based on 'photographic captures' from camera traps can be used, (Karanth and Nichols 2002; Trolle & Kery 2003; Karanth et al., 2004; Soisalo & Cavalcanti 2006, Sunarto 2011), its application is restricted largely to species that are naturally marked and therefore individually identifiable from photographs.

The nocturnal and elusive traits of fishing cats make it difficult to use distance sampling to estimate abundance. However, they have distinct and permanent markings on their coat which can be used for capture-recapture sampling. The simplest method to estimate abundance involves two capture sessions (K=2). In the first capture session, n_1 animals are photographed and identified. The population is then re-sampled on one subsequent occasion and n_2 animals are photographed and identified of which m were captured on the first occasion. In population of N individuals the proportion of marked animals after first capture occasion is n_1 / N. Assuming all animals have equal capture probabilities proportion of marked animals in the population should be equal to the proportion of marked animals in second sample and is given by

$n_1 / N = m / n_2$

which can be re arranged to the Lincoln-Petersen estimator

$\widehat{N} = n_1 n_2 / m$

This method was developed independently by Peterson in the 1890s to estimate the size of fish populations and by Lincoln in the 1920s to estimate wildlife populations.

Otis et al (1978) listed the assumptions for capture recapture estimators. They are: (1) Population is geographically and demographically closed during the study period (2) Animals do not lose their marks (3) All the marks are recorded correctly at each trapping occasion (4) The assumption of equal catchability of animals. Otis et al (1978) considered the three main factors that can produce variations in capture probabilities viz. (i) time effect, where capture probabilities may vary due to factors such as temperature, time of the day, rainfall etc, (ii) behavioural response to capture i.e. trap shyness or trap happiness and (iii) individual heterogeneity due to factors like sex, age or bodyweight or unobservable inherent characteristics. On identifying these sources of variations, Otis et al (1978) formulated models based on all possible combinations of these variables and a starting null model for K- sample models.

They are M_o (constant p), M_t (temporal variation in p), M_b (p varies between first capture and subsequent captures), M_h models (p varies by individuals). The other complex combinations of these models have not been used widely in camera tap literature.

1.4 Significance of Study

Although fishing cats have been recognized as an endangered species, there is a great paucity of information on the species with respect to it its foraging and breeding biology, and its social ecology (Inskip and Zimmerman 2009, Mukerjee 1989, Haque and Vijayan 1993, Cutter and Cutter 2009, Adhya 2011). Likewise, its current distribution is poorly documented and reliable information on its occurrence is very limited. There is even less information on abundance, and a literature review did not yield any estimates of abundance derived from statistically sound analysis. Interestingly, other imperiled species that co-occur with fishing cats, most notably large, more charismatic species such as tigers and leopards that garner more attention are the focus of many studies today, and huge sums are spent for their conservation. There is a severe bias in funding and conservation of majority of conservation organizations who wholly focus on birds and large mammals (Clark and May 2002). Ecologically, a smaller carnivore like the fishing cat may well play a role as important as that of a tiger, as a predator that regulates populations of others species that contribute to the structure and functioning of complex and diverse eco-systems. The progress in technology and applied ecology, tightening budgets, time and expertise is increasingly turning conservation from a single species approach towards ecosystem level monitoring and management (Lindenmayer et al., 2007, Leech et al., 2008).

This study is an attempt to fill in such gaps for a region within the fishing cat's range. In addition to providing reliable estimates of abundance and occurrence for the species, I have attempted to identify key determinants for the occurrence of the species within forest-grassland- wetland mosaic habitats of the terai. Moreover, this study presents an approach to estimate the abundance of or this species, and I anticipate that this will be of value to other biologists working within the species range, given the recent spurt in camera trapping in South and South East Asia. Finally, I anticipate that these results will be of interest to managers given the paucity of available information on this species.

1.5 Objectives:

1. To estimate the occurrence of fishing cats in Dudhwa National Park (DNP) and Kishanpur Wildlife Sanctuary (KWLS) using the site occupancy framework.
2. To study macro-scale factors that influence habitat use by fishing cats.
   a. Testing the relation between site occupancy and distance to water source
   b. To determine if site specific characters like type of vegetation and distance to forest edge influence habitat use.
   c. To determine if there are any patterns in the co-occurrence of tigers, leopards and fishing cats.
3. To estimate the abundance of fishing cats in DNP and KWLS using closed population Mark-Recapture models.

2. Methods

2.1 Study Area

Dudhwa National Park and the Kishanpur Wildlife Sanctuary were brought under the Project Tiger Scheme in 1987-88. DNP, the KWLS and the Katarniaghat WLS together constitute the Dudhwa Tiger Reserve (DTR) in the central part of the TAL. DNP has a reintroduced population of Rhinoceros unicornis. DTR supports the single largest viable population of swamp deer on the Indian side of the Terai (Semwal 2005).

KWLS (Figure 3) lies between latitudes 28^{o} 14’ to 28^{o} 30’ N and longitudes 80^{o} 18’ and 80^{o} 30’ E in Shahjehanpur district covering 203.41 square kilometer. DNP (Figure 3) is located on the Indo-Nepal border in the district of Lakhimpur-Kheri between 28^{o} 18’ N and 28^{o} 42’ E and 80^{o} 57’ E longitude. The total area of the park is 490.22 sq km excluding the buffer forest (De 2001). DNP and KWLS are separated by a complex of sugarcane fields, swamps, the township of Paliya and 12 other villages. The two protected areas constituting the Tiger Reserve, though separated physically, are composed of moasic forests of sal, riverine tree communities and grassland patches (phantas).

Since its inception, tourism has played an important role in the running of the park. A limited section of DNP is open to tourists as compared to KWLS which does not have a defined tourism zone. DNP and KWLS are the finest remnant patches of the of highly diverse and productive terai ecoregion that once spanned the length of the Gangetic floodplains. The primary difference between the terai and the plains to the south is water. In Strahorn 2009, Geographer L.R. Singh explains

The geography of terai is more of hydrography than topography. Water is the key not in time and space relationships. Surface water in swamps and morasses, lakes and sluggish streams, underground water *in*.... springs and [a] high water-table give it a veritable character of a "half sol*id*" and "half fluid" passive surface.

This statement is supported by the fact that the reserve is bestowed with a number of perennial water resources. The Suheli and Mohana rivers, Joraha, Nagrol, and Newra streams are the major rivers and streams of the park. There are also a large number of perennial taals or lakes in the park, and many natural or artificial water holes and drainages that are seasonal.

The major rivers of Kishanpur sanctuary are Sharda and Ull. Sharda forms a part of the eastern boundary of the sanctuary whereas the Ull bisects the sanctuary into an eastern and western half. Jhadi Taal, the most important wetland in the sanctuary and provides habitat for a population of nearly 400 swamp deer. These rivers, streams and lakes together harbour 79 species of fishes (De 2001). All water bodies, stagnant or flowing, large or small, are prone to flooding in the monsoon period (July - September) which results in the creation of wetlands. Some of these wetlands endure through the summer months whereas others progressively dry up and are replenished in the succeeding rainy season.

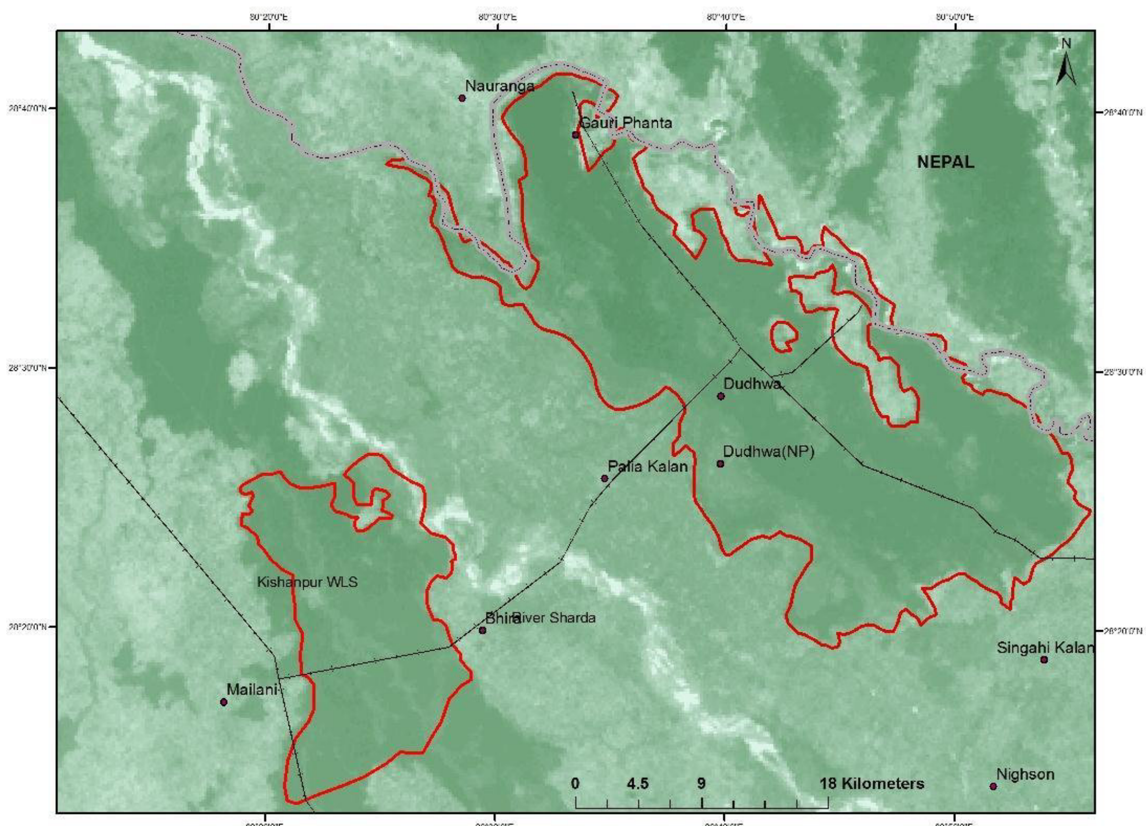

Figure 3 Map of DNP and KWLS.

Grasslands are prominent features of both, KWLS a DNP. They constitute 21% of KWLS habitat and 19% of DNP excluding the buffer forests. These grasslands are categorised as upland- Narenga Savannah type and low lying- wet Savannah. The upland areas are characterized by extremes of wet and dry condition whereas; the low lying grasslands have typically marshy conditions. The wetlands constitute the third major habitat type in in the national park (De 2001).

As fishing cats are predicted to have a strong relationship to wetlands, marshy areas and swamps, DNP and KWLS appear to be ideal habitats for the fishing cat.

2.2 Field Methods

The study involved four spatially-distinct camera trap surveys from December 2011 to May 2012. A combination of Moultrie game spy D50, Spypoint FL-A and Cuddeback Attack 1149 cameras with motion sensors were used.

KWLS was surveyed in its entirety (~200 sq km.). Constrained by the number of available cameras, and logistical factors such as vehicle and manpower resources, DNP (~600 sq km- including buffer forest) was surveyed in three trapping blocks within a period of 60 days (Table 1). The cameras were deployed in a phased manner in order to systematically sample the area (design 4, Karanth and Nichols, 2002). Each camera was programmed to take photographs 24 hours/day with a 15-second interval between consecutive photos. Cameras would be tripped by motion (passing animal) before them. No baits were used. Once deployed, cameras in each block ran for a minimum 15 nights before they were relocated to the next block in DNP. Once the cameras were deployed, they were checked every 3-6 days to download data and check battery status. The number of trap nights is defined as the product of total number of camera traps operating in a given area and the total number of nights over which they were operating. Trap success rate is defined as the number of independent pictures divided by the level of sampling effort (every 100 trap nights).

Table 1 Summary information for camera-trap, capture-recapture data in DNP and KWLS (* right flanks used to identify individuals, # area excluding buffer forests).

	Forest Range	Area (km^2)	Period	No. of camera sites	No of occasions	No. of trap nights	Individuals caught	No of captures
	KWLS	203.41	25th Dec-13th Feb	63	2647	39,468	13*	76
DNP-1	Bellraien	134.97#	21st Feb-9th Mar	52	759	37,632	7	49
DNP-2	N. Sonaripur and S. Sonaripur	194.64#	12th Mar-1st Apr	49	768	50,827	8	22
DNP-3	Dudhwa, Sathiana and Bankatti	163.38#	3rd Apr-4th May	53	959	382,844	5	28

The cameras were placed at a distance of 0.8-2 km from each other on forest roads, animal trails and along rivers as per protocol described by Karanth and Nichols (1998). Cameras were placed at lower densities in areas known to be at risk to vandalism (when we were fore-warned by forest staff and near the boundaries of DNP and KWLS).

Cameras were mounted on poles or attached to trees 40 - 50 cm above the ground. Cameras were always placed in pairs to obtain photographs of both flanks for identification of individuals that are naturally marked. At every camera site, geographic locations were recorded using a Global Positioning System (Garmin Map 60), and the camera settings were adjusted so that date and time of capture would be printed on the picture. Every fishing cat captured was given a unique identification number (e.g., DFC_1) after examining the stripe and spot pattern on the flanks, limbs, forequarters, face and neck (Figure 3). Photographs with distorted perspectives, or lacking clarity were not used for identification purposes. Given that a large number of captures comprised of identifiable pictures of only one flank (the other being blurred, or missing), for each site, the flank with the most recorded pictures was used to identify individuals. Only left flanks were used to identify individuals in DNP, while right flanks were used to identify individuals in KWLS

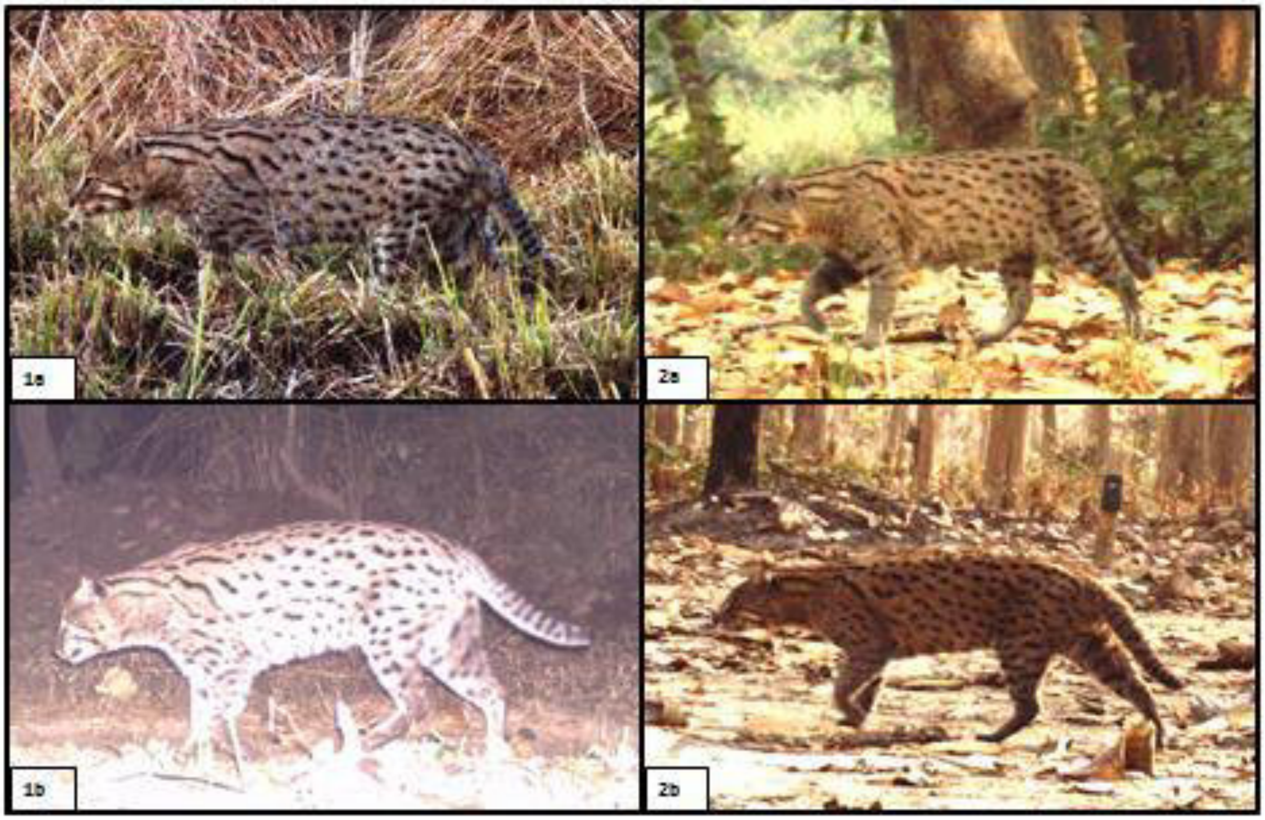

Figure 4 Identifying fishing cat individuals 1 and 2 using pelage pattern

2.3 Analytical methods

2.3.1 Fishing cat habitat use

At both study sites fishing cat occupancy (ψ) was estimated using a likelihood based method which is used foe estimating proportion of area occupied when species detection probability is less than 1 (Mackenzie et al., 2002). Following the identification of fishing cats, individual captures at each trapping site were noted and detection histories (H) in the X matrix format were developed (Otis et al., 1978)

Detection histories were produced for both DNP and KWLS were entered together into software MARK ver 6.0 (White and Burnham 1999).

2.3.2 Habitat use and modelling Covariates

Species occurrence was modelled using the following covariates (Table 2).

Table 2 Covariates for the parameter psi and a priori predictions about their influence on habitat use by fishing cat in DNP and KWLS.

Covariate	Description	Prediction for habitat use
Site	Kishanpur Wildlife sanctuary (connected with other forests) and Dudhwa National Park (large isolated patch)	Given that stream densities are about equal at both sites (DNP-1.34m/km^2;KWLS-1.21m/km^2), the expectation is that fishing cats may occur more widely in Kishanpur (with greater connectivity).
Distance to water	Distance of camera trap sites to water source (calculated as Euclidian distances).	Fishing cats are known to favour wetlands, stream courses etc.
Distance to forest edge	Effect of human disturbance. The distance of camera trap site from the forest edge.	Greater use / occurrence in core habitat where there is lesser human influence.
Vegetation	Proportions of key forest types (Sal, Mixed, Acacia, Grassland) within 1x1 km^2 grids.	Higher use of grasslands and scrub forests (Sunquist and Sunquist 2002).
Overlap with tiger	Presence of tiger at the camera site	Fishing cats may avoid tigers, even though the two species are not likely to compete for the same food resources.
ıp with leopard	Presence of leopard at the camera site	Fishing cats may avoid leopards, even though the two species are not likely to compete for the same food resources.

Habitat use modelling was carried out in two separate analyses that differed in their delineation of sites. In the initial analysis, each camera trap station (forest location where a pair of cameras was deployed) served as a site. Following detection histories of fishing cat captures from each trapping station were entered into the likelihood model. In a second analysis, sites comprised of gird (cell size 1 km x 1km) within which there was a camera site. This allowed us to use habitat covariates for which site-level delineation was not very useful, most notably vegetation covariates. These covariates were incorporated into the site occupancy model using the logit link function which can be represented as

logit $(\psi_i) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots \beta_n x_{in},$

where there are n covariates identified with site i. A similar modeling approach was used to model covariates while estimating the detection parameter p (MacKenzie et al., 2006).

Covariates were identified a-priori based on our knowledge of fishing cats. Each of these covariates represents a hypothesis. For instance, fishing cat occurrence will decrease with increasing distance from a water source. Covariates were modelled singly and in additive combinations. The two scales used were 1) at the camera site and 2) at the level of a 1000m x 1000m grid. Standard Arc GIS functions and Geospatial analysis tools (Downloaded from http://www.spatialecology.com/gme/index.htm) in Arc GIS ver 9.0 (ESRI) was used to extract habitat variables.

At the level of camera site, psi (occurrence probability) was modelled using habitat variables which included distance of each camera site from the nearest water source, distance of each camera site from the forest edge and proportion of leopard and tiger frequency by the number of occasions at that point. The detection probability was modelled using covariate "site". We postulated that there may be heterogeneity in detection probabilities for the two sites owing to a variety of reasons, including differences in vegetation types and connectivity

For analysis at the scale of 1km x 1km grids, we extracted information on proportions of forest type (Sal, Mixed, Acacia and Grassland) for every grid within the study area. The vegetation data was derived from a classified vegetation map, derived from field data and Johnsingh et al. (2004). Analysis of habitat use at this scale is relevant for two reasons: first because at the finer scale, covariates represent conditions or values pertinent for a particularly point in space (the camera trap site). Vegetation covariates collected at the larger scale are more representative of fishing cat habitat and capture environmental heterogeneity over a larger area. Secondly, resource selection by animals has been demonstrated to occur at multiple spatial scales (Johnson 1980) - incorporating this into analysis will allow me to make more meaningful inferences about fishing cat occurrence within the study area.

For each set of covariates, I first developed global (fully parameterized) models. Covariates for occupancy were modelled base on a priori hypotheses. The potential covariates were also univariately modelled, psi(covariate),p(.). Covariates that improved the model fit were then combined to develop models with multiple variables keeping in mind the a priori hypotheses. The detection probability was modelled on "site" as covariate which was binary coded (Kishanpur-1; Dudhwa-0).

Akaike Information Criterion (AIC) values for small sample sizes were used to rank candidate models and calculate their Akaike weights (Burnham and Anderson, 2002). As there were a number of models with fairly similar AIC scores and roughly equal model weights, a model averaging technique (implemented in Program MARK) was applied to estimate occupancy from these multiple models (Burnham and Anderson, 2002).

2.3.3 Abundance and Density

Individual capture histories for the identified fishing cats were constructed using a standard 'X-matrix' format (Otis et al., 1978), where rows represented the capture histories of each captured individual and columns represented captures on each occasion and were entered in software MARK. Population closure was formally tested using software CAPTURE. Akaike information criterion was used to for determining the best-fit model for the data between the null (M_0), heterogeneity (M_h), behavior (M_b) and combination of these models (Karanth and Nichols 1998).

I also developed capture history and trap activity input files for Program DENSITY ver 4.4 (Efford et al., 2004). For analysis, data from the three blocks in DNP were pooled together to form one session. Density was estimated using conventional mark-recapture models, coupled with the calculation of an effective trapping area using the half MMDM method (Wilson and Anderson 1985).non- spatially explicit capture recapture models. Density estimates for DNP and KWLS were calculated separately.

2.3.4 Activity pattern

The relation between large predators and fishing cats in terms of activity patterns was also investigated. The time stamp on the photograph when the camera was triggered was used. Photographs of the same species taken within one hour at the same trap were excluded from the analysis to avoid duplication of capture of same individual. The activity level for fishing cat, tiger and leopard were plotted as a scatter plot separately for KWLS and DNP.

3. Results

The total trapping effort in KWLS and DNP was 166761 and 382844 trap nights respectively. The trapping exercise yielded 76 and 99 fishing cat photographs from KWLS and DNP. Besides fishing cats five other species from the cat family (Panthera tigris, Panthera pardua, Prionailurus bengalensis, Felis chaus and Prionailurus rubiginosus) were recorded during the survey.

3.1Occupancy

3.1.1 Fine scale habitat use by fishing cats

Naïve estimates of proportion of area used by fishing cats for KWLS and DNP are 0.444 and 0.377 and the combined estimate for two sites together is 0.396.

The parameter 'psi' was modelled as a function of relevant covariates to generate predictive models to test a priori hypothesis about fishing cat habitat use. The top ranked model contained additive effects of distance to water and distance to forest edge (Table 3).while the global model was the least supported, last ranked model. Model averaging was carried out since no single model emerged as the top ranked model, i.e. AICc weights > 0.90 (Table 3). The model averaged estimates of 'psi' and 'p' is 0.5378(S.E. 0.0532) and 0.0643(S.E. 0.0066) respectively

Table 3 Top ranked models estimating fishing cat occupancy ($\hat{\psi}$) and detection probability ($\hat{p}$) for 223 sites for study areas DNP and KWLS computed in MARK

ID	Model	Delta AICc	AICc Weights	K	$\hat{\psi}$ ($\pm$1S.E.)	$\hat{p}$($\pm$1S.E.)
1	{psi(Dist_water+Dist_edge),p(.)}	0	0.137	4	0.54(0.05)	0.06(0.006)
2	{psi(Dist_water+Dist_edge),p(site)}	0.098	0.130	5	0.52(0.05)	0.06(0.006)
3	{psi(.),p(.)}	0.510	0.106	2	0.53(0.04)	0.06(0.006)
4	{psi(site),p(.)}	0.793	0.092	3	0.55(0.05)	0.06(0.006)
5	{psi(Dist_water+site),p(.)}	0.986	0.083	4	0.55(0.05)	0.06(0.006)
6	{psi(site),p(site)}	1.229	0.074	4	0.52(0.05)	0.06(0.007)
7	{psi(tiger),p(.)}	1.651	0.060	3	0.52(0.04)	0.06(0.006)
8	{psi(Dist_water+Dist_edge+site),p(.)}	1.773	0.056	5	0.55(0.05)	0.06(0.006)
9	{psi(leopard),p(.)}	1.889	0.053	3	0.52(0.04)	0.06(0.006)
10	{psi(Dist_edge+site),p(.)}	1.890	0.053	4	0.55(0.05)	0.062(0.006)
11	{psi(Dist_water+Dist_edge+site),p(site)}	2.214	0.045	6	0.52(0.05)	0.06(0.007)
12	{psi(.),p(Dist_water)}	2.535	0.038	3	0.53(0.04)	0.06(0.006)
13	{psi(leopard+tiger),p(.)}	3.009	0.030	4	0.52(0.04)	0.06(0.006)
14	{psi(leopard+tiger+site),p(.)}	3.361	0.025	5	0.54(0.05)	0.06(0.006)
15	Global model	4.6625	0.013	12	0.53(0.05)	0.06(0.007)
16	Model averaged				0.53(0.05)	0.06(0.006)

Covariate effects

Based on beta estimates of the global model, none of the covariates are significant predictors of fishing cat habitat use as their confidence intervals overlap zero (Table 4). However, the relationship the covariates share with predicting occupancy of fishing cats is as hypothesized except for the covariates-leopard presence and tiger (Appendix 1). Contrary to my a priori hypothesis, fishing cat habitat use is expected to increase with an increase in the presence of large predators like leopards [1.713(S.E. 2.255)] and tigers [2.898(S.E. 2.476)]. Distance to water [-0.15(S.E. 0.186)] and distance to forest edge [-0.032(S.E. 0.225)] are weak predictors of fishing cat habitat use. Modelling "site" as a covariate on ψ predicted KWLS to have lower fishing cat occupancy compared to DNP [-0.27(0.48)] supporting the a priori hypotheses.

Table 4 Summary of beta estimates of global model for fine scale.

Covariate	Estimate	SE	LCI	UCI
p(site)	0.031	0.237	-0.434	0.495
p(Dist_water)	0.337	0.113	0.115	0.559
p(Dist_edge)	-0.073	0.097	-0.264	0.118
p(Tiger)	-1.106	1.07	-3.204	0.991
p(Leopard)	0.195	0.787	-1.347	1.737
P	-2.642	0.18	-2.995	-2.29
Psi	0.042	0.333	-0.61	0.695
psi(Leopard)	1.713	2.255	-2.706	6.132
psi(Tiger)	2.898	2.476	-1.956	7.752
psi(Dist_water)	-0.15	0.186	-0.515	0.215
psi(Dist_edge)	-0.032	0.225	-0.472	0.409
psi(site)	-0.27	0.48	-1.211	0.671

3.1.2 Grid scale

The top ranked model for grid level habitat use was the model with "proportion of acacia" modelled on occupancy probability and "site" on detection probability. Model averaging was carried out since no single model emerged as top ranked model, i.e. AICc weights > 0.90 (Table 5). The model averaged estimates of ψ and p is 0.06 (S.E. 0.006) and 0.55 (S.E. 0.05) respectively.

Table 5 Top ranked models estimating fishing cat occupancy ($\hat{\Psi}$) and detection probability ($\hat{p}$) for 215 grids for study areas DNP and KWLS computed in MARK.

ID	Model	Delta AICc	AICc weights	K	$\hat{\psi}$ $(\pm 1S.E.)$	$\hat{p}(\pm 1\text{S. E.})$
1	{psi(Aacia),p(site)}	0	0.284	4	0.06(0.006)	0.55(0.05)
2	{psi(Acacia+Grassland),p(Site)}	0.930	0.178	5	0.06(0.006)	0.56(0.05)
3	{psi(Grassland),p(site)}	1.619	0.126	4	0.06(0.006)	0.54(0.05)
4	{psi(.),p(.)}	2.154	0.097	2	0.06(0.006)	0.55(0.04)
5	{psi(Sal),p(site)}	2.596	0.077	4	0.06(0.006)	0.53(0.04)
6	{psi(Mixed),p(site)}	2.778	0.071	4	0.06(0.006)	0.53(0.04)
7	{psi(Sal+Mixed+Acacia+Grassland),p(site)}	2.974	0.064	7	0.06(0.006)	0.56(0.05)
8	{psi(Sal+Mixed+Acacia+Grassland+Site),p(site)}	2.974	0.064	7	0.06(0.006)	0.56(0.05)
9	{psi(Sal+Mixed),p(site)}	4.201	0.034	5	0.06(0.006)	0.53(0.04)
10	Model average				0.06(0.006)	0.55(0.05)

Covariate effects

Based on beta estimates of the global model, none of the covariates are significant predictors of fishing cat habitat use as their confidence intervals overlap zero (Table 6). However, the relationship the covariates share with predicting occupancy of fishing cats is as hypothesized. Supporting my a priori hypothesis, fishing cat habitat use is expected to increase with an increase in the proportion of Acacia or scrub forest [1.424(S.E. 2.295)] and grassland [(0.256(S.E. 1.972)]. Modelling "site" as a covariate on 'p' (KWLS coded "1" and DNP coded "0") predicted KWLS to have lower fishing cat detection probability compared to DNP (Table 6).

Table 6 Summary of beta estimates for global model at grid scale.

Index	**Label**	Estimate	**SE**	**LCI**	**UCI**
1	pint	-3.5926391	0.638917	-4.84492	-2.34036
2	psiint	-0.9025269	1.766473	-4.36481	2.559759
3	psi(Sal)	1.3233248	1.778992	-2.1635	4.810149
4	psi(Mixed)	2.0348337	1.919082	-1.72657	5.796234
5	psi(Acacia)	1.4241493	2.294994	-3.07404	5.922338
6	psi(Grassland)	0.256031	1.971686	-3.60847	4.120536
7	psi(site)	-0.2283018	0.522861	-1.25311	0.796505

8	p(sal)	0.9258628	0.615271	-0.28007	2.131795
9	p(mixed)	0.4594593	0.604175	-0.72472	1.643642
10	p(acacia)	3.0835746	0.859467	1.399019	4.768131
11	p(grassland)	1.3446438	0.849346	-0.32008	3.009363
12	p(site)	-0.2807591	0.248686	-0.76818	0.206666

3.2 Fishing cat abundance and density

Model M_h is selected as the best model for KWLS and model M_0 for DNP based on AIC values. The estimated probabilities that a fishing cat was captured on a single sampling occasion for KWLS 0.0208(S.E. 0.0057) was much lower compared to the estimate for DNP 0.08(S.E. 0.017). The estimated probabilities that a fishing cat was captured at least once over the sampling period is higher at KWLS (0.93) compared to DNP (0.83). Estimates of fishing cat population sizes at KWLS and DNP were 14(0.06) and 24(3.24) respectively (Table 4).

Capture- recapture analysis was carried out to estimate density of fishing cat using software DENSITY. The effective trapping areas for KWLS and DNP in this study were 431.466 sq. km. and 764.287 sq. km respectively. The estimated density of fishing cats in Kishanpur is 0.0348 (S.E. 0.0069) fishing cats/km whereas the estimated value for Dudhwa National Park is and 0.0314(S.E. 0.0045) fishing cats/km respectively.

Table 7 Estimates of abundance, density and other relevant capture- recapture statistics of fishing cats at KWLS and DNP between December 2011 and May 2012. Estimates are based on capture-recapture analysis of camera-trap data computed in MARK and DENSITY.

		KWLS	**DNP**
No. of occasion		42	18
Selection criteria	M_0	89.07	0
	M_h	0	2.03
No. of animals captured	M_{t+1}	13	20
Estimated average capture probability per sampling occasion	$\hat{p}(\widehat{SE})$	0.0208(0.0057)	0.08(0.017)

Estimated capture probability over all sampling occasion	$M_{t+1}/\widehat{N}$	0.93	0.83
Population estimate and standard error	$\widehat{N}(\widehat{SE}[\widehat{N}])$	14(0.06)	24(3.24)
95% confidence interval of estimate	95% CI	14-15	21-36

3.3 Additional results

3.3.1 Activity pattern

Sample sizes for fishing cat, tiger and leopard in KWLS were 82, 109, 41 and DNP were 109, 139, 62 captures respectively. In KWLS, fishing cats are most active at night between1800-0400hrs, with activity peaking at 2400 hrs. and 0400 hrs. No fishing cat activity was recorded between 1600-1800hrs in KWLS. Tigers and leopard have bimodal peaks in their activity pattern in DNP (Figure 5) as compared to fishing cats that are consistently active during daytime in DNP. In contrast, in KWLS, fishing cat peak in activity at 1000hrs and 14000hrs. Fishing cat appear to be less active from 6000-1000hrs. Tigers and leopards were more nocturnal than diurnal and there was considerable overlap between species (Figure 5). 26.83% and 46.79% of photographs were recorded between 6000hrs and 1800hrs in KWLS and DNP respectively.

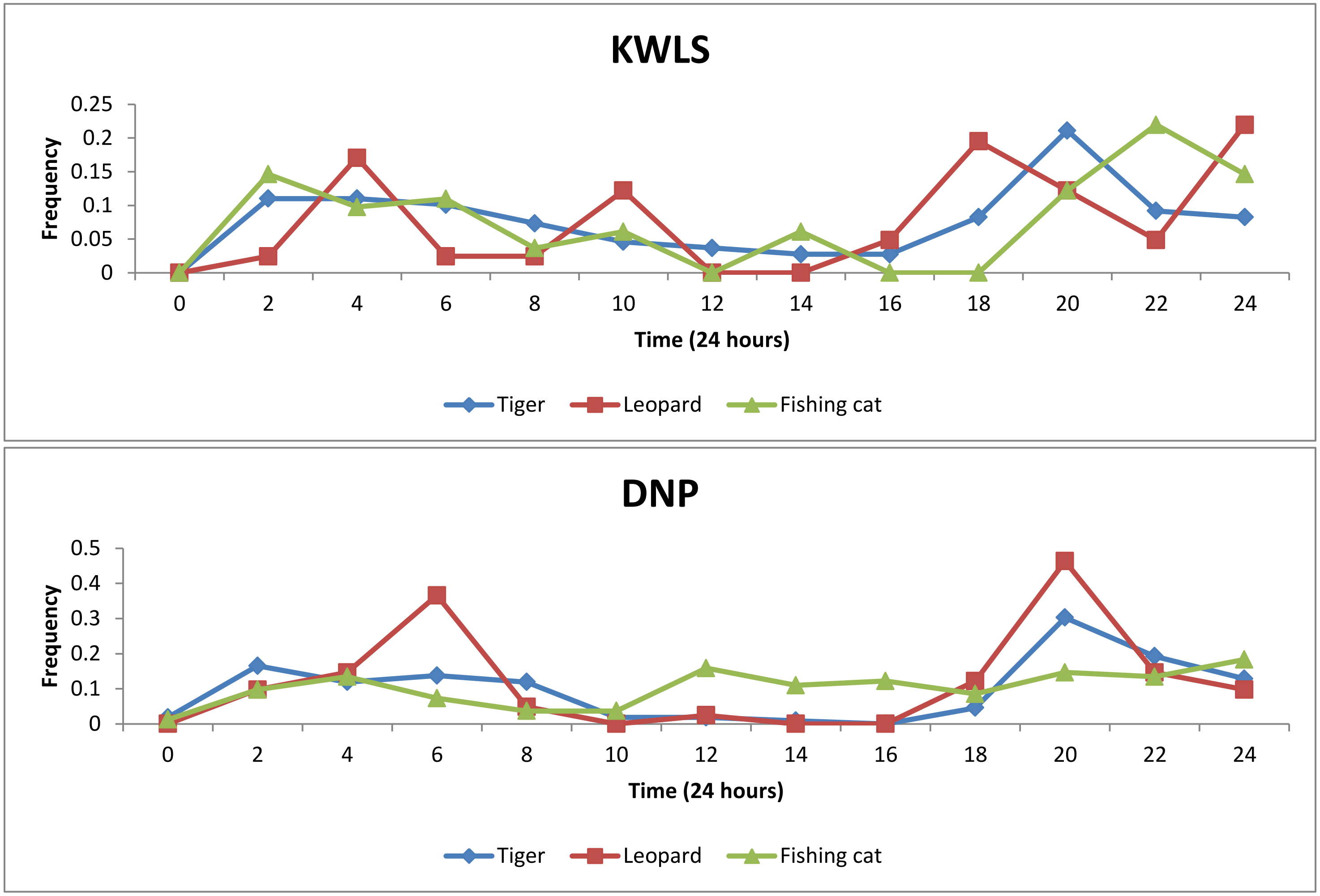

Figure 5 Daily activity patterns of fishing cat, tiger and leopard in KWLS and DNP.

3.3.2 Home range size

There were sufficient recaptures for one fishing cat individual FC07 (male) in KWLS to attempt the calculation of fishing cat home range using the minimum convex polygon method. Home range size for this individual was estimated to be 18.46 sq km.

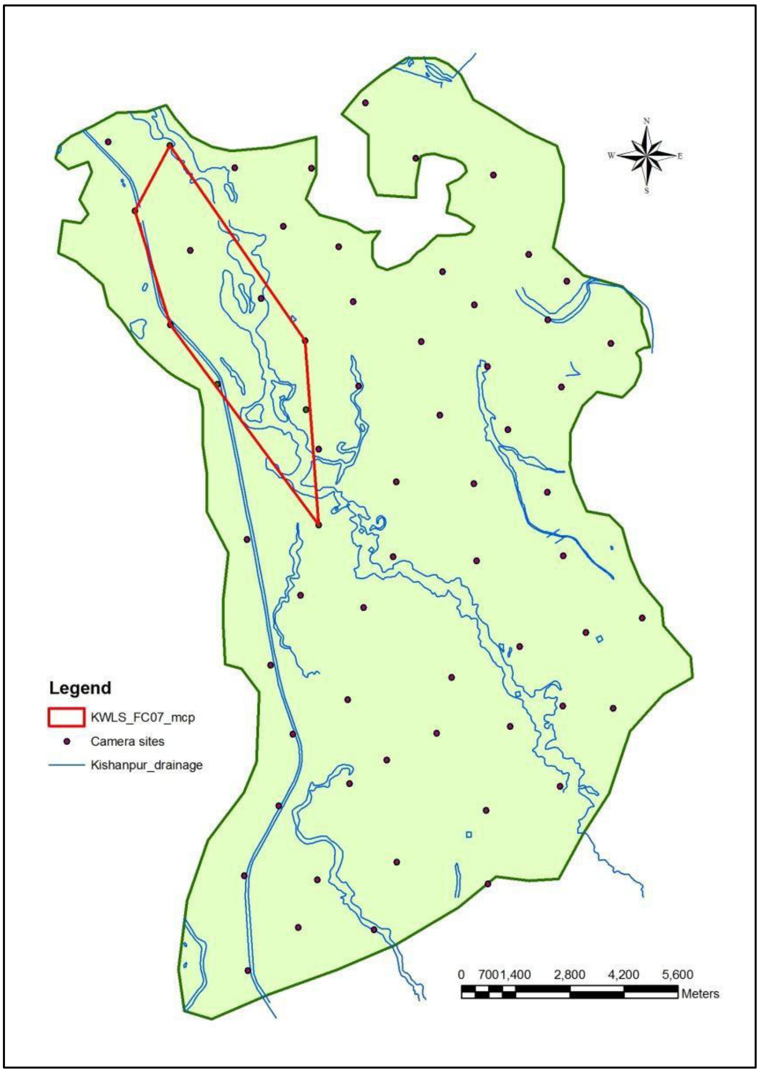

Figure 6 Map showing home range size of individual KWLS_FC07 in KWLS using minimum convex polygon.

4. Discussion

Results from camera trapping data in Dudhwa National Park and Kishanpur Sanctuary have revealed that fishing cats are relatively common in the terai's lowland forests. Like other felids in these forests, fishing cats appear to be predisposed to using forest roads and trails. The camera trap exercise carried out in these protected areas are the most exhaustive surveys of their kind in the region thus far, both in terms of their coverage of area, and the density of camera traps in each site. Camera trap data from this study (designed to sample the region's tiger population) yielded an adequate number of pictures of fishing cats for use in formal mark recapture and site occupancy analysis. For a data deficient species, it appears that these may be the first estimates of abundance across the globe derived from robust analytical methods. For a species that is rare and occurs at low densities, camera traps also provided an ideal means of determining the proportion of habitat used by the species. Surveys based on visual searches would have been more cumbersome and resulted in sparse, incomplete data. In addition, these data, when modelled with covariates provides useful information on other aspects of the ecology of fishing cats, including broad-scale habitat use and activity patterns.

4.1 Habitat use and the influence of covariates

As expected, my estimates for the probability of habitat used by fishing cats from site- occupancy data were higher than the naive estimates. These results also provide information about the relative importance of various predictors on the occurrence of fishing cats.

Although analysis revealed that fishing cat use of a site (presence at a camera station) was influenced by proximity to water (with more proximate sites having higher probability of use), this relationship was found not to be significant. These results appear to be somewhat counter intuitive given that fishing cats are described to rely greatly on fish to sustain themselves. One possible explanation for the weak association between locations of fishing cat captures and proximity to water may lie is the fact that on an average, camera stations were within 2.75 kilometers of a water source. Given that fishing cats have fairly large home ranges (~ 7 kilometers and larger), it appears that although fishing cats may use water body edges extensively, in water-rich areas, they are almost as likely to be photographed at distances two or more kilometers away from water as they are closer to the water. Territorial behaviour in these cats or the utilization of more than one water feature by individual cats may lead them to wander extensively within their home ranges. Based on these results and literature on the ecology and behaviour of fishing cats, it seems reasonable to conjecture that the association between water presence and fishing cat occurrence may be stronger at other sites in the species range where water availability is more restricted than it is in the Uttar Pradesh terai.

These models also revealed a weak relationship between distance to forest edge (more disturbed areas), and habitat use by fishing cats, wherein the occupancy (habitat use) probability was higher at sites within the forest core, than it was in the buffer. In general, it seems reasonable to conclude that unless fishing cats face direct persecution along the forest edge, their likelihood to use forest interiors and edges may be determined more by where preferred habitats and water bodies are selected than by day-time disturbance such as human and cattle presence in forests. In DNP and KWLS, prominent rivers and wetlands are located along the forest edges, and their presence may in part account for the lack of a stronger relationship for this covariate (Figure 7). The relationship

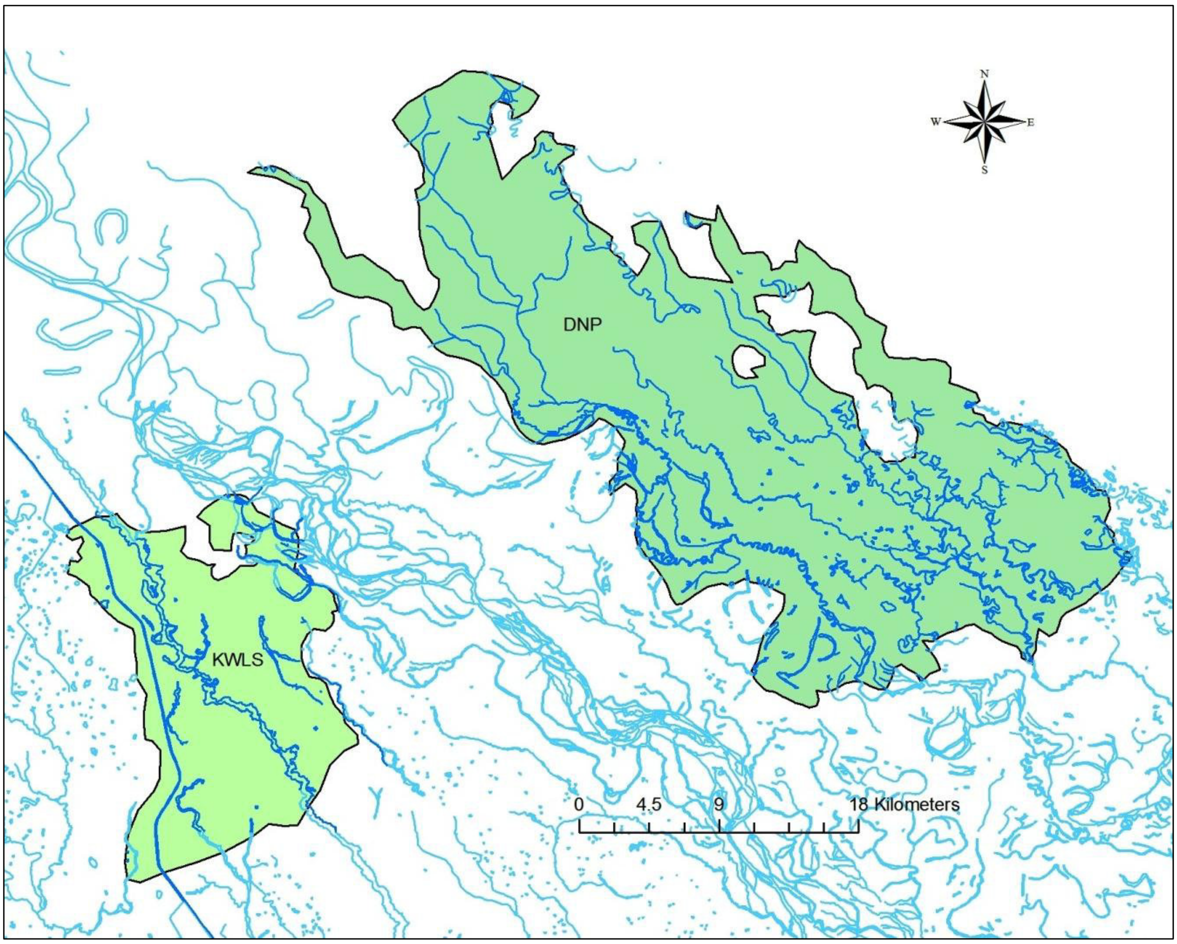

Figure 7 Map showing extensive water drainage in KWLS and DNP.

between the frequency of occurrence of tigers and leopards habitat use by fishing cats indicates that these sympatric species co-occur in the same areas. Given the significant ways in which these species differ in body size and diets, this result is not altogether surprising. Fundamentally, niche separation can be achieved in multiple ways - even where species overlap in their use of habitats, they may be temporally segregated. At the scale of 1km x 1 km grid cells where we modelled fishing cat occurrence as a function of vegetation types, there were no significant associations. As predators, fishing cats may well track food resources - and habitat (measured at the level of vegetation communities) may have weak influence on their presence at sites in contrast to food availability.

Overall, more specific information on fishing cat - habitat relationships can be derived from future studies that involve dietary analysis, fine scale data collection from feeding areas including the quantification of prey availability and radio telemetry studies.

4.2 Fishing cat abundance and density estimates

Estimates of abundance (and their associated precision) from mark recapture studies are sensitive to sample size, ie. numbers of captures and recaptures. The estimates of abundance and density have relatively small associated errors, and are therefore reliable. Studies (Soicalo and Cavalcanti 2006, Royle and Gardner 2010, Foster and Harmsen 2012) have demonstrated that estimates are also affected by trap density and trap spacing. Given that the home ranges of fishing cats are significantly smaller than those of tigers and leopards, traps with less distance between them and increased emphasis in areas near water may have resulted in a more substantial data set and more robust estimates.

There being no other estimates of abundance for fishing cats in the published literature, I cannot comment on the status of the populations in DNP and KWLS vis-a-vis populations at other sites across the species range. DNP has a higher abundance in fishing cats as compared to KWLS. However the density of fishing cats is higher in KWLS than in DNP. Contrary to the expectation, the densities of fishing cats in this study for DNP and KWLS are comparable with reported densities of tigers at these sites (Jhala et al., 2010). I had assumed that a smaller carnivore which occupies smaller territories and consumes a variety of small bodied animals would occur in higher densities than the larger predators (which are under greater hunting pressure). Further investigations are needed to identify factors that may constrain fishing cat populations in areas such as KWLS and DNP. Also density estimates calculated for DNP and KWLS are likely to be overestimated as the half MMDM method was used for density estimation. The MMDM method uses the mean maximum distances moved by individual fishing cat between photo-captures at each site to estimate buffer strip width. This buffer strip width is added to the sampled area to compute the effective sampled area. Density estimation is thus critically influenced by the buffer strip width. The half MMDM method has been criticized for its over estimation of density (Soisalo and Cavalcanti 2006, Royle and Gardner 2010, Forster and Harmsen 2012) but been commonly used in camera-trap studies to estimate density (Wallace et al., 2003, Maffei et al., 2004, Silver yet al., 2004, Soisalo and

Cavalcanti 2006, Sharma 2010). MMDM method has been justified to be used when home range estimates is not available (O'Conell et al., 2011) Also, the number of camera occasions used for this study (50) is more than the minimum recommended trapping occasions (10).

4.3Activity patterns

As per a priori hypotheses fishing cat were expected to avoid larger predators like tigers and leopards. Analysis of activity patterns suggested that in contrast to the observations of the studies of (Cutter and Cutter 2009, MacDonald and Loveridge 2010) opinion, fishing cats are fairly active during the day. One hypothesis for this observed diurnal behaviour is that fishing cats may be active during the day to reduce their contact with tigers and leopards which are predominantly nocturnal. This behaviour of avoiding large predators by fishing cat was also noted by Smith when he radio collared a fishing cat in Chitwan National park (Seidensticker 2003). Day time activity was noted in KWLS and DNP. A visual scrutiny of activity patterns for these three felids suggests that there is little temporal overlap.

4.4 Home range size

The data set I used for home range analysis had 22 locations for individual FC07 (male) at KWLS. However, a literature review on minimum convex polygons (MCP) showed that sample sizes requirements are a critical consideration when computing home ranges (Marzluff et al., 2001) and concluded that 100-300 locations are necessary to reach asymptotic levels for the MCP (Seamen et al., 1999). As a result the home range size calculated is biased for MCP.

The MCP estimated for FC07 of 18.46 sq. km. is supported by the radiotelemetry study done on fishing cats in Chitwan National park estimated a male fishing cat (n=1) to have a home range of 16-22 sq. km (Mukherjee et al., 2010). Cutter estimated fishing cat home ranges in Thailand to be 7.3 sq. km for males (n=1, Fishing cat research and conservation project). This difference in home range estimates of males could be attributed to habitat differences. Chitwan National Park, situated at the eastern end of the terai, resembles KWLS in terms of its floristic composition and faunal assemblage. Khao Sam Roi Yod National Park (KSRYNP) in Thailand, on the other hand, is a coastal national park. KSRYNP consists of scrubby mixed deciduous forest on the karst formations, limited areas of mangrove and swamp forest, and active and fallow agricultural areas. Shrimp propagation ponds and rice paddies are tightly packed against the park's highly interdigitated boundary.

Home range size and density are known to be negatively correlated in within-species comparisons of territorial carnivores (e.g. Karanth & Chundawat, 2002), and both are correlated to prey density (e.g. tiger densities, Karanth & Nichols, 1998; carnivore densities, Carbone & Gittleman, 2002;

home range size, Herfindal et al.,, 2005, ocelot density Di bitetti et al., 2006). KSRYNP has a higher proportion of wetlands, marshes, shrimp, and aquaculture and paddy farms would sustain a higher as compared to Chitwan. As a result the fish availability would also be higher in KSRYNP than in Chitwan. Thus intuitively density of fishing cats would be higher in KSRYNP without any external effects like predation.

Also the sample sizes for both the estimates is n=1 which increases the level of uncertainty of the estimates.

4.5 Study Limitations

I identify the following as limitations in this study: Due to logistic reasons and fear of theft and vandalism, cameras were placed somewhat sporadically along forest edges, and the extreme forest periphery (village edge) being avoided entirely. This sampling bias may result in incomplete information on fishing cat occurrence pattern.

As this study uses ancillary data from tiger monitoring, it lacks a species specific study design. The camera placement was based on the ecology of larger carnivore (tiger) with a large home range as compared to fishing cats. As a result fishing cat habitat; the streams and wetlands were not extensively sampled. This will ultimately number of captures of fishing cat influencing density, abundance and habitat use results.

No covariates influencing diet of fishing cats or prey choice was included while modelling occupancy which is essential to predict habitat use of an animal. A large proportion of covariates like distance to water, distance to forest edge, vegetation classification were extracted using GIS. Even an index as simple as distance to edge boundary includes some level of uncertainty due to inconsistent demarcation of boundary. The strength of the inferences made using these covariates is dependent on the accuracy of these GIS layers.

While GIS has great potential for improving ecological understanding across large spatial and temporal scales they are not a substitute for detailed field based assessments which are lacking in this study (such as a measurement of understory, or water-body characteristics). This study did not account for spatial autocorrelation which can potentially bias estimate since site occupancy models with covariates.

Camera trap monitoring is emerging as the central method in studying large mammals over India. The analysis of this ancillary data helps establish the role ancillary data can play in studying lesser known mammals. This study has helped further our knowledge on fishing cats and can be used as pilot study to help design future studies on fishing cat.

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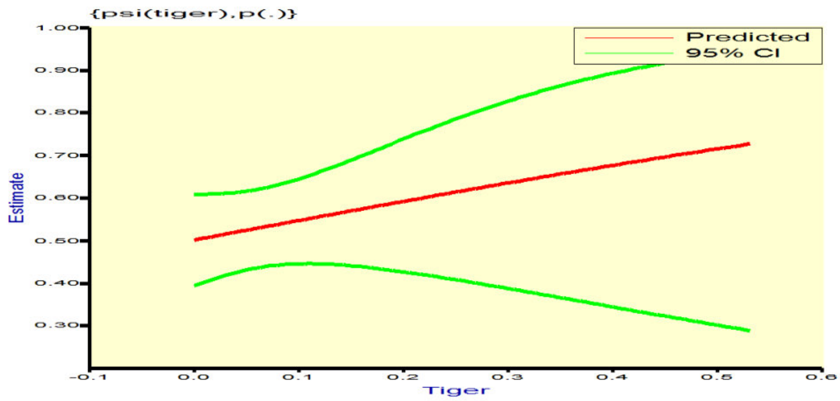
Appendix



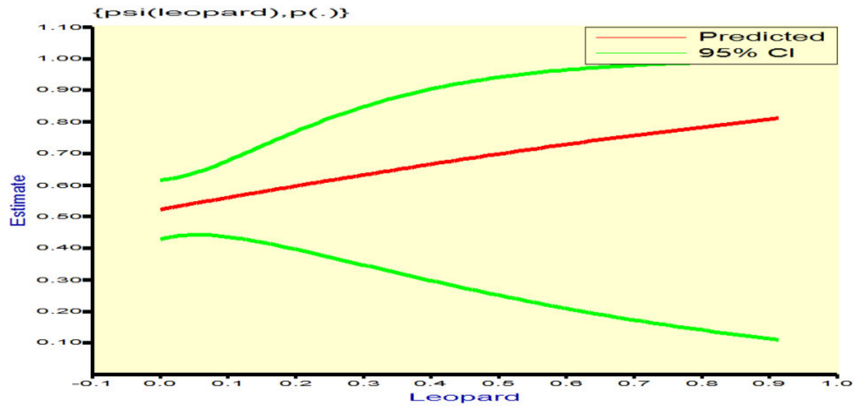


Figure: Plots showing relationship between occupancy estimate and covariates "tiger frequency" and "leopard frequency".