MAMMAL BIODIVERSITY IN THE NORTHEAST FORESTS, AND THE DISTRIBUTION OF FISHING CATS IN BANGLADESH

by

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MAMMAL BIODIVERSITY IN THE NORTHEAST FORESTS, AND THE DISTRIBUTION OF FISHING CATS THROUGHOUT BANGLADESH

by

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ABSTRACT

Although Bangladesh is densely populated by humans, it also hosts a vast array of mammal diversity. I used camera-traps in the northeast of Bangladesh to quantify local mammal species richness and community composition. My study confirmed presence of high mammal diversity in the Northeast Bangladesh. I have recorded 23 wild mammal species in four different forested areas in the region, however the forest patches differ in species richness and composition. The areas with better protection have higher species richness, however, no large ranging mammals occur in the protected area, likely due to the lack of connectivity, and smaller size. My findings suggest that the local people generally have antagonistic attitudes toward small felids and wildlife in general. Although my original focal species were five sympatric felids, I captured few in my camera traps, with zero fishing cat captures in the hilly, forested region of the Northeast. This led me to explore potential fishing cat distributions using records of fishing cat occurrence collected from various parts of the country. I used Maxent to predict their distribution, and my findings suggest that the mangrove forest of the Sundarbans and the wetlands in the northeast Bangladesh are key suitable habitats for fishing cats. My study provides the baseline for mammal species richness, community composition in the northeast forest patches, and potential fishing cat distribution throughout Bangladesh. Based on my findings I recommend that public-private partnerships, targeted protected areas, and awareness among the local people may shift the scenario toward an improved future with a win-win situation for both the humans and the wild mammals that live across northeast Bangladesh and the fishing cats throughout Bangladesh.

Chapter 1

MAMMAL DIVERSITY IN THE NORTHEAST BANGLADESH

Abstract

Although Bangladesh is one of the most human dominated countries on earth with 1033 persons/km2, it also harbors a vast array of mammal diversity. Here I assess the presence and community composition of mammal species in northeast Bangladesh. Between May 2014 and January 2015, for varying date ranges, I operated camera trap stations in four of those patches, i.e. Atora hill reserve forest (Atora hill), Patharia hill reserve forest (Patharia hill), Rajkandi reserve forest (Rajkandi forest), and Tarap hill reserve forest (Tarap hill), where at each station I deployed a single Bushnell Trophy Cam HD™ camera, which resulted into a total of 128, 311, 399, and 496 trap nights respectively. I constructed species accumulation curves, and I computed species richness estimates using three methods: Chao's method, jackknife, and bootstrapping. I recorded 27 mammal species of these 23 were wild mammal species, consisting of 6 orders and 15 taxonomic families. I also conducted interview survey to learn about the human-felid conflict in the region and public attitude toward general acceptance about felids and desired conservation level. In total, I have surveyed 260 households throughout the study areas, 170 households claimed to loss their livestock to the felids, and public attitude toward conservation in general negative, though numbers of people expressed their

positive feelings toward cats, especially toward those are absent in the study areas. My study provides the baseline for mammal species richness and community composition in the northeast forest patches of Bangladesh. Based on my findings I recommend that public-private partnerships, targeted protected areas, and awareness among the local people may shift the scenario toward an improved future with a win-win situation for both the humans and the wild mammals that live across northeast Bangladesh.

Introduction

High biodiversity and high human population densities often co-occur in tropical developing countries and protected areas in these human dominated landscapes tend to be small and fragmented (Quazi and Ticktin 2016). Effective conservation strategies must address the role of these smaller protected areas and any surrounding forested landscapes (Quazi and Ticktin 2016), but a lack of scientific information presents an obstacle to conservation planning (Muzaffar et al. 2011; Bernard et al. 2013, 2014). This is especially true in Asia, where conservation practices often lack the scientific knowledgebase needed to inform official policy (Sunderland et al. 2013). Although Bangladesh is one of the most human dominated countries on earth with 1033 persons/km^2 (BBS 2011), it also harbors a vast array of mammal diversity (Khan 2004; Chakma 2015; IUCN Bangladesh 2015). Recent economic growth, unplanned development, and increasing demand for agricultural crops have coupled with our lack of knowledge on existing wildlife distributions to hinder the conservation measures needed for biodiversity conservation (Muzaffar et al. 2011).

Mammals are an important component of faunal diversity in forest ecosystems as they fulfill a number of ecological roles, e.g., predation, herbivory and seed dispersal, some of which can potentially influence forest regeneration and recovery (Nakashima et al. 2010). Many mammals are also charismatic and/or flagship species, while others are important as game animals, all of which makes them of particular conservation and management concern (Mohd. Azlan, J., and Lading 2006; Kitamura et al. 2010; Bernard et al. 2013). A recent meta-analysis found that mammals are also the most sensitive group to habitat disturbance in Southeast Asia (Sodhi et al. 2010); thus mammals are often considered as an index for monitoring of forest management systems (Bernard et al. 2013, 2014). However, in Bangladesh, mammal species richness and community composition is often overlooked in terms of use as an indicator of conservation success or failure (DeCose et al. 2012).

Mammal diversity in Bangladesh is primarily confined to three different sections of Bangladesh (Figure 1), the Sundarbans (the largest mangrove forest in the world), the Northeast (Habigonj and Moulovibazar district of Sylhet division), and the Southeast (Chittagong Hill Tracts (CHT), and some other pockets in the greater Chittagong area). Mammal diversity consists of one species of proboscidea, 10 species of primates, 26 species of carnivora, six species of artiodactyls, one pholidotan, 35 species of chiroptera, two lagomorphs, 11 species of cetacea, and so far 27 recorded species or rodentia (Khan 2004; Muzaffar et al. 2011; Islam et al. 2013; Chakma 2015; IUCN Bangladesh 2015)

Although there have been several wildlife studies completed in the Bangladesh Sundarbans (Khan 2004; Smith et al. 2006; Barlow et al. 2008; Barlow 2009), there is little in the way of rigorous research in either Southeast or Northeast Bangladesh. In Southeast Bangladesh Chakma (2015) carried out a systematic survey over the 3600 km^2 landscape, focusing mostly on track based survey methods to evaluate the occurrence of large mammals. Chakma (2015) did use camera traps as well, but his results were limited to 387 trap nights. There is also an ongoing camera trapping study in the Chittagong Hill Tracts assessing the carnivore presence in the region, but results are preliminary (Rahman et al. *in preparation*). In Northeast Bangladesh, past studies have focused on particular taxa of mammal, e.g., Hoolock gibbon (Muzaffar et al. 2007), Asiatic black bear (Islam et al. 2013), and fishing cat (Giordono et al. *in preparation*). The only comprehensive study of all terrestrial mammals was concentrated on one small forest patch in the Northeast Bangladesh (Feeroz et al. 2013), however, again, this research had a limited number of camera trap nights (n = 60) and relied more on interview surveys of forest department staff and collecting information from the forest department's animal sighting and capture record. The limited scope of research in Northeast Bangladesh has hindered our ability to formulate effective policy measures based on valid scientific data.

Effective conservation in Northeast Bangladesh is important as the region is contiguous with the Manas-Namdhapa tiger conservation landscape of India (Sanderson et al.2006), and once harbored a diverse array of forest types from tropical evergreen, to mixed and or semi-evergreen forest. Over the last two decades, since the reestablishment of democracy, much of the forest has been cut down to make way for roads and highways; tea, rubber, and betel leaf (*Piper betel*) plantations, natural gas mining; and for other agricultural uses (Islam et al. 2013; Quazi & Ticktin 2016). Currently the landscape is heavily fragmented, and the remaining forest is almost completely confined to a few small patches that are either isolated or connected to a greater forested landscape of India and Bhutan (Quazi & Ticktin 2016).

In this chapter I assess the presence, community composition, and species richness of mammal species in Northeast Bangladesh. In addition, I have evaluated the role that human-felid conflict plays in the both the opinion and actions of local villagers. Finally, I have recommended a series of management recommendations designed to improve felid and general wildlife conservation in the region.

Study Area

Northeast Bangladesh is contiguous with the Manas-Namdhapa tiger conservation landscape of India (Sanderson et al. 2006) (Figure 3), and once harbored a diverse array of forest types, from tropical evergreen, to mixed and or semi-evergreen forest. The landscape is heavily fragmented, and the remaining forest is mostly confined to a few small patches (n = 10) varying in size from 10 to 100 km^2 (Bangladesh Forest Department of 2012). There is one wildlife sanctuary (IUCN category IB), and two national parks (IUCN category II) among those forest patches, i.e. Rema-Kalenga wildlife sanctuary (17.5 km^2), Satchari and Lawachara national parks (3 and 12.5 km^2 respectively). The remainder of these patches (n = 7) are classified “reserve forest” as declared under the Forest Act 1927. This act defined reserve forest as protected areas of forest, where certain extraction activities are allowed. The areas within the border of Bangladesh that surround the 10 forest fragments are mostly under industrial plantation such as tea and rubber, or they are agricultural rural settlements.

The 10 forest patches in Northeast Bangladesh (Moulovibazar and Habigonj district) are bound between N24.07 E91.25 and N24.36 and E91.13, and managed by the Bangladesh forest department (FD) under seven forests ranges. The FD administration is hierarchically divided into Forest circles, forest circles are further divided into division, and division into forest ranges. Ranges are an administrative unit of the forest department. Each range has an officer responsible for day to day operation. In the reserve forests, where resource extraction is allowed, the range officer’s responsibilities primarily include managing natural resources and generating increased forest revenue. Each range is further divided into forest *beat*, the smallest division of forest administration. A forest beat office primarily protects the forest from intruders and employs a number of forest guards, the foot soldiers of the forest department.

The topography of Northeast Bangladesh is hilly with elevations ranging from 50 to 300 m above sea level. Numerous streams and swampy areas crisscross the region. Remaining forests are mostly of three types: hill forest, shrubs, and mixed bamboo forest (Forest Department of Bangladesh 2012). Northeast Bangladesh shares an international boundary with two of the Indian states, Tripura and Assam. Annual temperature ranges from 32 °C (August-October) to 9 °C (January), and nearly 80% of the annual average rainfall (3,334 mm) occurs between May and October (Quazi & Ticktin 2016).

Study site selection

Initially, I have selected five out the 10 forest patches for my study based on their size. I selected forests greater than 50 km^2 in size, as my primary target species were felids in the Northeast Bangladesh, and I wanted to maximize my potential for capture by selecting areas more likely to support a population. This selection process led me to choose Atora Hill Reserve Forest (Atora hill), Patharia Hill Reserve Forest (Patharia hill), Raghunandan Hill Reserve Forest (Raghunandan hill), Rajkandi Reserve Forest (Rajkandi forest), and Tarap Hill Reserve Forest (Tarap hill) as potential study sites. However, Raghunandan hill proved inaccessible because the military stopped all access to that area, after discovering a military base of a revolutionary army from a neighboring country with large amounts of arms and ammunition. The four remaining accessible forest patches varied in terms of total area, Atora hill is ~100 km^2, Rajkandi forest is ~62 km^2, Tarap hill is ~82 km^2, and Patharia hill is ~60 km^2.

The only protected area within these four forest reserves is the Rema-Kalenga wildlife sanctuary (~17.5 km^2), situated within the Tarap Hill Reserve Forest. This forest patch is the only among my study areas that is not well connected with a greater forested landscape in India. Among the three remaining areas, the Atora hill and Rajkandi forest are extensions of larger forest tracts in India which expand into Bhutan, and Myanmar. The Rajkandi forest is also connected across India to the Kasalong Reserve Forest Chittagong Hill Tracts, in Bangladesh (Figure 3). Meaning these two forests are only politically excluded from greater forested landscapes, and not ecologically isolated. The Patharia hill also has connectivity with a larger forest, however geopolitics (building fences at the border) and unplanned development in both countries have reduced that connectivity.

Local climate and hydrologic patterns are similar across all four reserve forests, but area and disturbance patterns differ (Quazi & Ticktin 2016). Forest composition is also similar, except in the THRF which lacks the mixed bamboo vegetation that is abundant in the other three reserve forests. Mixed bamboo vegetation is a vital source of revenue generation for the forest department, as once every five years they lease out the entirety of the bamboo population in a forest reserve for extraction. The lessor then protects the area until they have finished extraction. Additionally, the forest dwelling indigenous group known as *Khashi* inhabit the edge of these reserve forests. Within the reserve Khasi grow betel, a commercially valuable vine that needs support of other plants (Quazi and Ticktin 2016). The *Khashi* protect their part of the forests from other human users, however they also clear all other understory vegetation with fire in order to ensure the highest growth rate of their betel leaves. Further, some of the forested areas are under teak plantation, however, in my survey I excluded teak plantations due to the extremely high human activity.

Methods

Camera trapping

Between May 2014 and January 2015, for varying date ranges, I operated camera trap stations in my four study areas, (Atora hill n = 6 trap stations, Patharia hill n = 10, Rajkandi forest n = 12, and Tarap hill n = 16), for a total of 179, 357, 399, and 552 trap nights respectively (Table 1, Fig 1). At each station, I deployed a single Bushnell Trophy Cam HD™ camera, which uses an infrared flash to limit trap shyness. In order to maximize independence for my initial target species (small-medium sized felids) I set trap stations approximately 1.1 km apart (the radius of an estimated minimum home range for leopard cat) and in a roughly circular grid, deviating to the contour of the forest patch. Each trap station location was first identified using a paper map of the study area. Upon reaching the location in the field I would then choose a camera trap location within 200 m based on likely travel routes of felids, i.e., along trails. I mounted each camera to a tree, approximately 25-30 cm above the ground, with metal chain, and inside a theft proof box made of steel. To maximize the capture probability of felids I used scent based lures, either Calvin Klein Obsession for Men (CK obsession) (n = 36 trap stations) or chicken body parts (n = 8) and dependent on location an additional visual attractant (n = 26). Visual attractants were not used in areas where they would lead to potential theft by increasing location visibility to humans. For stations with CK Obsession I applied 4-6 sprays of the cologne to cotton balls, which I then placed either on the ground or affixed to a tree, using either rubber tubing or the cut base of a water bottle to shield it from rain.

For stations with chicken parts I placed the portion of chicken in a plastic bag, punctured to allow the scent to escape, and affixed to a tree at least 3 m above the ground to limit scavenging. For stations with a visual attractant I affixed chicken feathers with wire to a tree branch at around 25 to 30 cm above the ground. All attractants were placed in front of the cameras at a distance of 2 to 3 m. Each camera was active for 24 hours per day and programmed to take two photos per trigger event, with a 15 second delay before a subsequent trigger event could occur. Cameras were set to record time and date of each photographs.

I set the first camera trap on May 1, 2014, and removed the last camera trap on January 29, 2015 (Table 1). In total, I set 44 trap stations across the four sites, however I lost 11 cameras to theft and 3 cameras permanently malfunctioned, resulting in 30 effective trap stations. This resulted in a total of 1334 trap night across all four study sites. I checked each camera trap in 15 to 20 day intervals to change the batteries if needed, and to assess whether the cameras were still active. On occasion, apart from theft, I found that people/animals had also moved the direction of a camera. To limit observer bias I was with my team for 43 of the 44 cameras stations installed, and had a field guide, who had assisted me in setting 15 previous trap stations, install 1 of 44 camera stations.

Questionnaire survey

I conducted felid conflict surveys in a sample of the villages surrounding each of the four study sites. Questionnaires were designed in English, following the questionnaire structure developed by McCarthy (2013) for felid conflict in Sumatra, and adapted for my survey area. When administering the questionnaire my survey teams spoke in Bangla and often the rural dialect so that the respondent could understand it completely and answer to the best of their abilities. The questionnaire consisted of 12 questions (Appendix C) developed to elucidate information regarding; 1) previous livestock depredation attributed to felids, 2) incidents of retribution killings of the felid, 3) incidental sightings of felid species, and 4) the respondent's attitude toward conservation of felids in the adjoining forests.

To ensure that I had an even distribution of surveys around each study site I systematically selected target villages a-priori to conducting my surveys. To randomize survey effort within a village, I first generated random points within 2000 meters of a forest patch using ArcGIS. I then chose households closest to the randomly generated points for administering surveys. I surveyed a total of 265 households surrounding my 4 study areas (Patharia hill = 55, Tarap hill = 70, Rajkandi forest = 80, and Atora hill = 55).

To administer surveys, I employed three survey teams, each consisting of one male, one female, and a local guide. I used male/female teams to ensure that female respondents would be able to participate even when a male head of household was not present. In rural Bangladesh, a female will not typically talk openly with an unknown male. I trained each survey team in administering the questionnaire, including the details of each question and the local etiquette of conversation. All teams conducted the first 10 surveys together, with each team member given equal effort in asking questions, to standardize the survey method.

During an interview, the team member administering the questions would also write down the answers. To limit the respondents bias associated with a lack of knowledge regarding species identification I incorporated photographs of many different species (both target and non-target) as well as photos of the same species with different pelage characteristics and taken from different angles into our questionnaire. Photos included that of tiger, common leopard, clouded leopard, marbled cat, golden cat, jungle cat, fishing cat, large Indian civet, common palm civet, and Bengal fox. I also cross validated their information with nearby household respondents, especially in the cases of direct killing of wild felids. Though our key target species for the conflict and attitude survey was felids, I did record information on different species coming into conflict with humans by raiding crops, and sometimes even their homes, e.g., elephant, wild boars, and rhesus monkeys.

Data analysis

I constructed species accumulation curves in R version 3.2.0 (R Core Team 2016) using function specaccum in the vegan library using the recommended Kindt's exact method (Oksanen et al. 2015). I computed the estimates using three methods: Chao's method, jackknife, and bootstrapping. Chao's method is beneficial when many individuals are only captured a few times, while jackknife and bootstrapping tend to underestimate species richness if there are many rare species or too few samples. However, Chao's method is less precise than the other two methods, and may not work if the average capture probability is large (Smith and Belle 1984, Chao 1987).

I used trap detection rate as an index of relative abundance between study sites. Although the constraints associated with using indices have received much attention (Jennelle et al. 2002; Sollmann et al. 2013), they have received some validation in the context of camera trap studies (Carbone et al. 2001, O'Brien et al. 2003; Rovero et al. 2005; McCarthy et al. 2008). I have calculated trap detection rates (D) for each species as the number of independent photographs captured of a species (C) per 100 trap nights by using the formula: $D = C \times 100/\sum N$; here $\sum N$ is the total number of camera trap-nights accumulated during the study, accounting for camera loss (due to theft) and or malfunctions. I have considered photos as independent if they were either captured at different trap stations, or if there is more than 30 min between captures of a species at an individual trap station.

Finally, I summarized conflict data based on location, species involved, livestock loss, and levels of dislike, and/or retribution. In formulating conservation strategies, I have evaluated species richness across my four study sites in conjunction with the level of conflict in the region.

Results

Camera trapping

I accumulated a total of 1334 trap nights throughout the 4 study areas and recorded 8692 photographs of various species, including human (Table 2). I recorded 27 mammal species, including human and three domestic and feral species (i.e. domestics dogs, feral and domestic cattle, and feral water buffalo). The 23 wild mammal species consist of 6 orders and 15 taxonomic families. I counted 11, 14, 16, and 17 species of mammals in Atora hill, Patharia hill, Rajkandi forest, and Tarap hill respectively excluding human.

Species accumulation curves revealed that all four sites are similar in terms of species detection rate and sampling effort (Figure 4), with approximately 12 species detected per 100 trap nights. However, estimated curves did not reach the asymptote in any of the of the study areas, and richness estimates from each method, Chao, Jacknife, and Bootstrapping, across all sites, were within one standard error of each other (Table 3).

Sorenson similarity index revealed that the Atora Hill Reserve Forest, and Patharia Hill Reserve Forest, are most similar in terms of species assemblage with 50% similarity, while the PHRF and Rajkandi Reserve Forest are next most similar with 40% similarity. AHRF and RRF are least similar in terms of species assemblage with only 21% similarity (Table 4).

In my data, apart from human, only five mammal species were common across all four study areas, the common palm civet, Indian muntjac, Irrawaddy squirrel, Himalayan crestless porcupine, and pig-tailed macaque (Figure 5). Unidentified rats were also present in each area, but due to their smaller size I could not identify them to the species level. There were no species exclusive to Atora hill; however, Patharia hill, Rajkandi forest, and Tarap hill had three, two, and three exclusive species of mammal respectively. I recorded capped langur, elephant, and ferret badger only in Patharia hill, Asiatic jackal and yellow-throated marten only in Rajkandi forest, and crab-eating mongoose, Pallas's squirrel, and small Indian civet only in Tarap hill. Apart from humans and cattle, the mammals recorded on camera most often were Indian muntjac, wild boar, large Indian civet, and Irrawaddy squirrel with total of 76, 69, 66, and 47 independent captures respectively.

Questionnaire survey

I interviewed a total 260 households across the northeast of Bangladesh (Table 7). Of these households, 2, 4, 12, 13, 39, 146 households claimed that they had lost livestock to the clouded leopards, the Asiatic golden cats, the fishing cats, the common leopards, the leopard cats, and the jungle cats respectively. The clouded leopard was blamed for livestock loss in only one of the study areas (PHRF). I used the market price of the livestock to calculate the total economic loss due to the perceived felid attack. As per the respondents they lost their cattle to the clouded leopard, and the total monetary loss was 20,000 Bangladeshi taka (BDT). Asiatic golden cat was blamed in 4 cases, only in Patharia hill, and they claimed that golden cat killed 12 chickens, the total amount of financial loss was ~3,600 BDT. Respondents blamed fishing cat for their livestock loss in 12 cases in Tarap hill, Rajkandi forest, and Patharia hill, for killing 1 dog and 37 chickens, the total financial loss was ~31,700 BDT. People blamed common leopard for their livestock loss in 13 cases across all four study areas, including the killing 1 dog, 4 goats, and 6 cattle, with a total estimated monetary loss of 86, 000 BDT. The leopard cat was blamed for killing 8 goats, 19 ducks, and 110 chickens in Patharia hill, Rajkandi forest, and Tarap hill, with an estimated financial loss of 132,400 BDT. Finally, the jungle cat was blamed for most of the cases of livestock losses across the region, people claimed that the jungle cat killed total 1101 chickens and 105 ducks in total, and caused monetary loss of 251,700 BDT (Table 8).

Respondents claimed that either they have killed or witnessed killing of 165 jungle cats, 38 leopard cats, 4 fishing cats, 2 golden cats, and 2 common leopards over the 10-year period (Table 6).

Respondents expressed overall negative attitude toward felid conservation in the northeast Bangladesh, both in terms of likings and desired protection status, however it varies for species. Across the region, people disliked the jungle cat most and don’t want any kind of protection for this cat. Although people expressed somewhat positive views in terms of likings, they mostly denied any kind of protection in their respective areas (Table 5).

Discussion

My study confirmed a high level of mammal species richness in northeast Bangladesh, which warrants immediate conservation measures. Although species richness is similar across the four forest patches, there are some differences in the four areas in terms of protection status, connectivity, and human stressors, which influences community composition at the patch level. Evaluating community composition in relation to these factors can help inform conservation strategies for northeast Bangladesh. Furthermore, the questionnaire survey provided insight into human antagonism towards wildlife in the region, highlighting the difficulty faced in planning and executing conservation actions.

Protected areas are a crucial means to conserve wildlife from habitat loss and other anthropogenic stressors, however the protected area network can be ineffective if poorly designed and without targeting any particular species (Hoffmann et al. 2010). The only protected area among my study areas is part of the Tarap Hill Reserve Forest (THRF) and known as Rema-Kalenga Wildlife Sanctuary (RKWS). At only 17.5 km^2 in size, this protected area is inadequate to harbor any large ranging species, with even small cats like the Asiatic golden cat (Catopuma temminckii) having a home range of around 30 km^2 (Grassman et al. 2005; Mccarthy et al. 2015). Although the RKWS does harbor more muntjac and wild boars, which can be suitable prey item for the large carnivores (Rabinowitz 1991). My findings suggested that RKWS supported more species of wild mammals and has minimal human disturbance, e.g., there were no cattle or human photographed during the survey; however, I did lose a number of cameras due to theft. Cattle compete with wild herbivores and have a negative impact on wild herbivores abundance (Madhusudan 2003), which could explain why in my other three study areas, each with higher levels of cattle photographed, I found a lower detection rate of muntjac and wild boar.

In addition to protected status, connectivity between forested patches can have an impact on patch level biodiversity in relation to species persistence and recolonization (Fahrig and Merriam 1985, 1994). For species that are rare, and restricted in the types of habitat through which they can disperse, connectivity is of primary importance and must be considered in management decisions. The Atora hill and Rajkandi forest patches in northeast Bangladesh have higher levels of connectivity with the Manas-Namdhapa TCL and I observed Asiatic golden cat in both, but not in the other forest patches where connectivity is low. This suggests that maintaining the current connectivity to the forested areas in the Manas-Namdhapa TCL may be important to the continuing existence of felid species in Northeast Bangladesh, although increased protection within the forest patches may be necessary to avoid creating a population sink.

A third factor that is likely affecting biodiversity in the forest patches of Northeast Bangladesh is the presence of human stressors. These human stressors come in the form of resource extractors within the forest (betel leaf, bamboo, etc.), tribal villages within the managed forests and their free ranging cattle, and the surrounding anthropogenic habitats of villages, plantations, and industry. It is suggested that forested areas in the tropics which are surrounded by a larger proportion of anthropogenic habitats host mammal communities with lower species richness and lower species diversity (Ahumada et al. 2011), however mesopredators, especially those with the omnivorous feeding habits might be well accustomed with the high human disturbance and thrive in absence of the larger predators. Indeed, I found mesopredators such as large Indian civet, small Indian civet, masked palm civet, common palm civet, the leopard cat, and mongoose spp. are present across Northeast Bangladesh, while I did not find any large carnivores or large ungulates (i.e. Sambar, gaur etc.) in the region. Viverrids play a vital role in maintain forest function as they also disperse seeds of different plants (Rabinowitz 1991), and their continued presence in Northeast Bangladesh is important. Although hunting for consumption is a major threat to the large Indian civet in different parts of the Southeast Asia (Timmins et al. 2016), there is no such evidence of consummate hunting of large Indian civet in the northeast Bangladesh.

Although there have been some in-depth studies on tiger-human conflict and public attitudes towards tiger conservation in the Sundarbans (Rahman et al. 2010, Inskip et al. 2013), no such study had been conducted regarding small felids and outside the Sundarbans area. By trying to understand public perception toward small felids and conflict between felids and human in Northeast Bangladesh I can better inform conservation management plans. Although the questionnaire survey cannot eliminate bias and the respondents often exhibited a lack of understanding regarding the species which are responsible for their livestock loss, it can still provide insight into their attitude and views regarding species and species conservation.

Human perception plays an important role in wildlife conservation (Breitenmoser et al. 2012), and in Northeast Bangladesh public attitudes toward conservation of wild felids are negative in general. Local people consider predators, including the smaller cats, as a threat to their lives and livelihood. Often they are favorable toward large cats which do not exist locally, as they are of no threat, but they tended to abhor small cats, especially jungle cats, which they blame for killing their poultry. Indeed, my survey revealed that most people blame the jungle cat for killing their livestock, especially chickens and ducks. This may be true in most of the cases, as people know this cat very well due to its relative abundance in agricultural areas and villages. Regardless, the loss has led to a general resentment of all small-medium size felids despite the claimed monetary loss being relatively low. Many individual families' earnings are low enough that even limited livestock loss may have a large effect on their health and wellbeing, and even for those who are little affected, the perceived threat may eventually lead to antagonism toward wildlife in general.

Apart from the more apparent direct threats to biodiversity in Northeast Bangladesh, global climate change is also impacting the region, with erratic weather patterns, uncertainty in flash flood occurrence, and prolonged dry seasons affecting local agriculture. The continued destruction of local forests is further exacerbating the issue. Northeast Bangladesh used to be a very wet and swampy area, and the entire landscape was crisscrossed by numerous small, hilly, streams locally known as "*Chara*". Unfortunately, due to excessive logging, those streams are unable to catch water during the wet season, which is accelerating soil erosion, and further affecting the local agriculture, human health, and livelihoods (DeCose et al. 2012). Conserving the remaining mammal biodiversity in Northeast Bangladesh will not reverse the impact of climate change, however it could help mitigate some of the exacerbated impacts. The mesopredators that occur in the northeast of Bangladesh are mostly omnivorous, and play some significant role in maintaining plant diversity by spreading seeds of many different species (Rabinowitz and Walker 1991). By conserving the forested patches, and the biodiversity within, they can continue to act as a buffer to at least some of the threats promised by continuing climate change.

Management recommendation and future research needs

Although my sample size was small, my results suggest that there are not many species with large home range sizes left in the region, except elephants, which use the landscape between Bangladesh and India. No larger felids were recorded during my study, not even clouded leopard, and there may be too few resources or too much human conflict for larger carnivores and their prey. However, there are valid causes to conserve the remaining mammal diversity, and I outline a few key concepts/strategies for such conservation below.

Currently, only 17.5 km^2 is protected out of 82 km^2 in Tarap hill reserve forest, but this forest harbors several large mammals. Expanding protected status to a larger area may promote long-term viability of the species and inherent diversity in this forest patch. Furthermore, it is imperative to protect areas with better connectivity to large forested reserves. Our results suggest that Rajkandi hosts almost same diversity of mammals as Tarap hill, despite being smaller in size, and having much higher levels of human pressure. This may be due to the connectivity with the larger forested landscape allowing Rajkandi forest to help support species such as the golden cat, black bear, and red serow. If protection is ensured throughout the 60 km^2 area of Rajkandi forest, it will provide better shelter for more species.

Connectivity between the forested patches is very crucial to sustain wildlife populations over a longer period, allowing for gene flow and dispersal (Powell 2012). Tea gardens, rubber plantation, homestead forests, bamboo grove, and swamps may play an important role in connecting all these areas, and further in-situ research should be conducted to explore this potential.

Financing large conservation activity is of course a critical issue for a developing country. However, there can be some self-sustaining measures to support conservation, which could provide greater economic benefit to the society. Northeast Bangladesh is a growing tourism area, where a numbers of luxury resorts exist, and thousands of people are visiting each year. To date their visits are confined to the smaller national parks, waterfalls, lakes, and large water bodies. One potential shift in land-use could be for the Bangladesh forest department to lease out some of the forested area for non-extractive recreation. Currently there are many areas they lease every five years, for bamboo extraction, within Rajkandi forest, Atora hill, and Patharia hill reserve forests. This leasing generates very nominal revenue to the government, is minimally profitable for the leaseholders, and most importantly destroys the habitat for many species. By instead leasing these areas to eco-tourism the new leaseholders would be incentivized to protect the forests for their own benefit. There are many opportunities for eco and adventure tourism, including the scenic beauty of the forests, one of the largest waterfalls in the country, bamboo rafting, birding, rock climbing etc. This private-public partnership would be a large undertaking, and would likely require input from NGOs with community based conservation experience, but it may ultimately provide an excellent opportunity to create a win-win situation for every stakeholder in the region.

In conclusion, my study provided the baseline for mammal species richness and community composition in the northeast forest patches of Bangladesh. This will enable managers to make decisions that are more informed and, potentially, to reconsider the current conservation management scheme. To conserve the remaining diversity in this human dominated landscape is a serious undertaking, however if properly protected the northeast Bangladesh can play an important role in contributing to the larger landscape of the Manas-Namdhapa TCL. Public-private partnerships, targeted protected areas, and proper education among the local people may shift the scenario toward an improved future with a win-win situation for both the humans and the wild mammals that live across northeast Bangladesh.

TABLES

Table 1 Four study sites in the northeast of Bangladesh, and the dates at which camera trap stations were initiated and completed. Number of effective stations is accounting for cameras lost to theft or malfunction, and trap nights is the number of active traps multiplied by the number of days they were active.

Site	Date initiated	Date completed	Num. stations (num. effective)	Trap nights
Patharia hill reserve forest	May 1, 2014	June 17, 2014	10 (7)	311
Tarap hill reserve forest	May 30, 2014	September 29, 2014	16 (9)	496
Rajkandi reserve forest	October 27, 2014	January 29, 2015	12 (10)	399
Atora hill reserve forest	December 1, 2014	January 27, 2015	6 (4)	128

Table 2 Species captured by camera trap in four study areas in the northeast of Bangladesh during biodiversity surveys between May 2014 and January 2015.

SL.	Order	Family	Common Name	Species	Number of independent photo (Detection rate)				
					Overall	Atora hill	Patharia hill	Rajkandi forest	Tarap hill
1	Carnivora	Felidae	Asiatic golden cat	*Catopuma temminckii*	4(.30)	2 (1.56)	0(0)	2(.50)	0(0)
2			Leopard cat	*Prionailurus bengalensis*	9(.67)	0(0)	3(.96)	5(1.25)	1(.20)
3		Canidae	Asiatic jackal	*Canis aureus*	1(.07)	0(0)	0(0)	1(.25)	0(0)
4			Domestic dog	*Canis familiaris*	2(.15)	0(0)	1(.32)	0(0)	1(.20)
5		Mustelidae	Ferret badger	*Melogale personata*	1(.07)	0(0)	1(.32)	0(0)	0(0)
6			Yellow-throated marten	*Martes flavigula*	2(.15)	0(0)	0(0)	2(.50)	0(0)
7		Viverridae	Common palm civet	*Paradoxurus hermaphroditus*	24(1.80)	9(7.03)	11(3.54)	1(.25)	3(.60)
8			Large Indian Civet	*Viverra zibetha*	66(4.95)	4(3.13)	0(0)	43(10.78)	19(3.83)
9			Masked palm civet	*Paguma larvata*	7(.52)	0(0)	1(.32)	0(0)	6(1.21)
10			Small Indian civet	*Viverricula indica*	2(.15)	0(0)	0(0)	0(0)	2(.40)
11		Herpestidae	Crab-eating mongoose	*Herpestes urva*	6(.45)	0(0)	0(0)	0(0)	6(1.21)
12			Mongoose spp.		1(.07)	0(0)	0(0)	1(.25)	0(0)
13	Artyodactyla	Bovidae	Cattle	*Bos Taurus*	126(9.45)	6(4.69)	0(0)	120(30.08)	0(0)

14			Water buffalo	*Bubalus bubalis*	23(1.72)	2(1.56)	0(0)	21(5.26)	0(0)
15		Cervidae	Indian Muntjac	*Muntiacus vaginalis*	76(5.70)	3(2.34)	21(6.4)	10(2.51)	44(8.47)
16		Suidae	Wild boar	*Sus scrofa*	69(5.17)	0(0)	19(6.11)	8(2.01)	42(8.47)
17	Proboscidea	Elephantidae	Elephant	*Elephas maximus*	3(.22)	0(0)	3(.96)	0(0)	0(0)
18	Rodentia	Hystricidae	Malayan Porcupine	*Hystrix brachyura*	26(1.95)	1(.78)	6(1.93)	18(4.51)	1(.20)
19		Sciuridae	Pallas's squirrel	*Callosciurus erythraeus*	1(.07)	0(0)	0(0)	0(0)	1(.20)
20			Particolored flying squirrel	*Hylopetes alboniger*	3(.22)	2(1.56)	0(0)	0(0)	1(.20)
21			Irrawaddy squirrel	*Callosciurus pygerythrus*	47(3.60)	1(.78)	2(.64)	25(5.51)	19(3.83)
22		Muridae	Rat spp.		24(1.80)	2(1.56)	6(1.93)	4(1.0)	12(2.42)
23	Primate	Hominidae	Human	*Homo sapiens*	288(21.59)	11(8.59)	11(3.54)	258(64.66)	8(1.61)
24		Cercopitheci dae	Pig-tailed macaque	*Macaca leonina*	27(2.02)	1(.78)	13(4.18)	11(2.76)	2(.40)
25			Rhesus macaque	*Macaca mulatta*	6(.45)	1(.78)	0(0)	2(.50)	3(.60)
26			Capped langur	*Trachypithecus pileatus*	1(.07)	0(0)	1(.32)	0(0)	0(0)
27	Scandendtia	Tupaiidae	Northern Tree shrew	*Tupaia belangeri*	9(.67)	0(0)	5(1.61)	0(0)	4(.81)

Table 3 Recorded and estimated mammal species richness in four study areas, Atora hill, Patharia hill, Rajkandi forest, and Tarap hill, in the northeast of Bangladesh. Estimates based on Chao, Jackknife, and Bootstrap species richness estimators that account for species which were not captured during camera trapping. Camera trapping occurred between May 2014 and January 2015.

	Atora hill		Patharia hill		Rajkandi forest		Tarap hill	
Estimate type	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Recorded Species	11	-	14	-	16	-	17	-
Chao	13.65	3.46	17.98	5.27	17.50	2.28	21.15	4.87
Jackknife	14.96	1.98	17.98	1.99	19.00	1.73	22.00	2.23
Bootstrap	12.94	1.37	15.80	1.18	17.56	1.05	19.31	1.28

Table 4 Sorenson similarity for mammal communities between four study areas, Atora hill, Patharia hill, Rajkandi forest, and Tarap hill, in the northeast of Bangladesh, based on a camera study conducted between May 2014 and January 2015.

	Atora hill	Patharia hill	Rajkandi forest
Patharia hill	0.50		
Rajkandi forest	0.21	0.40	
Tarap hill	0.35	0.26	0.33

Table 5 Households survey results from four study areas, Atora hill, Patharia hill, Rajkandi forest, and Tarap hill, in the northeast of Bangladesh. Numbers indicate the number of livestock depredation events by felids as reported by villagers. Villages and households were selected randomly from the surrounding landscape and surveys were conducted in 2014-2015.

Area	Number of households	Clouded leopard	Common leopard	Asiatic golden cat	Fishing cat	Leopard cat	Jungle cat
Atora hill	55	0	2	0	0	5	31
Patharia hill	55	2	3	4	4	3	33
Rajkandi forest	80	0	3	0	2	15	42
Tarap hill	70	0	5	0	6	16	40
Total	260	2	13	4	12	39	146

Table 6 Numbers of felids reportedly killed by local people in the northeast of Bangladesh between 2005-2014. Numbers are from a 260 household surveys conducted in 2014-2015 and represent only a sample of households surround four forested patches.

Area	Clouded leopard	Common leopard	Asiatic golden cat	Leopard cat	Fishing cat	Jungle cat
Atora hill	0	0	0	6	0	29
Patharia hill	0	0	2	1	0	5
Rajkandi forest	0	1	0	10	4	84
Tarap hill	0	1	0	21	0	47
Total	0	2	2	38	4	165

Table 7 Number of domestic animals reported as lost to felids and monetary loss claimed by 260 respondents to a household survey in the northeast Bangladesh. Surveys were conducted surround four of ten remnant forest patches in 2014-2015.

	Area	Dog	Goat	Sheep	Cattle	Chicken	Duck	Monetary loss
Clouded leopard	Atora hill	0	0	0	0	0	0	0
	Patharia hill	0	0	0	2	0	0	20000
	Rajkandi forest	0	0	0	0	0	0	0
	Tarap hill	0	0	0	0	0	0	0
	Total	0	0	0	2	0	0	20000
Common leopard	Atora hill	1	0	0	1	0	0	12,000
	Patharia hill	0	0	0	2	0	0	19,000
	Rajkandi forest	1	0	0	2	0	0	30,000
	Tarap hill	0	4	0	1	0	0	25,000
	Total	1	4	0	6	0	0	86,000
Asiatic golden cat	Atora hill	0	0	0	0	0	0	0
	Patharia hill	0	0	0	0	12	0	3,600
	Rajkandi forest	0	0	0	0	0	0	0
	Tarap hill	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	3,600
Fishing cat	Atora hill	0	0	0	0	0	0	0
	Patharia hill	1	0	0	1	15	0	12,500
	Rajkandi forest	0	0	0	0	1	0	15,000
	Tarap hill	0	0	0	0	21	0	4,200
	Total	0	0	0	0	37	0	31,700
Leopard cat	Atora hill	0	0	0	0	13	0	3,900
	Patharia hill	0	0	0	0	0	0	0
	Rajkandi forest	0	8	0	0	59	9	52,000
	Tarap hill	0	0	0	0	38	10	10,600
	Total	0	8	0	0	110	19	66,500
Jungle cat	Atora hill	0	0	0	0	232	27	54,500
	Patharia hill	0	2	0	4	244	0	48,800
	Rajkandi forest	0	0	0	0	340	46	81,800
	Tarap hill	0	0	0	0	285	32	66,600
	Total	0	0	0	0	1101	105	251,700

Table 8 Public attitudes as reported in 260 household surveys of villagers surrounding four study areas, Atora hill, Patharia hill, Rajkandi forest, and Tarap hill, in the northeast of Bangladesh (2014-2015), toward six different felid species and their desired protection. The views are scaled from 1 to 5, 1 = Absolute dislike, 2 = Dislike, 3 = Neutral, 4 = Like, 5 = Like very much; and for protection 1 = No protection, 2 = Limited protection, 3 = Neutral, 4 = Protected, 5 = Strict protection. The species are listed as CLP = clouded leopard, CL = common leopard, AGC = Asiatic golden cat, LC = leopard cat, FC = fishing cat, and JC = jungle cat.

Area	Respondent	Like/Dislike	Percent						Protection	Percent protection					
			CLP	CL	AGC	LC	FC	JC		CLP	CL	AGC	LC	FC	JC
Atora hill	55	1	11%	11%	11%	20%	11%	33%	1	18%	18%	18%	18%	18%	42%
		2	40%	40%	40%	40%	40%	36%	2	35%	35%	35%	35%	35%	36%
		3	35%	35%	35%	18%	35%	15%	3	7%	7%	7%	7%	7%	7%
		4	13%	13%	13%	22%	13%	16%	4	24%	24%	24%	24%	24%	15%
		5	2%	2%	2%	0%	2%	0%	5	16%	16%	16%	16%	16%	0%
Patharia hill	55	1	12%	12%	12%	12%	12%	12%	1	48%	48%	48%	48%	48%	48%
		2	48%	48%	48%	48%	48%	48%	2	12%	12%	12%	12%	12%	12%
		3	8%	8%	8%	8%	8%	8%	3	4%	4%	4%	4%	4%	4%
		4	28%	28%	24%	28%	28%	28%	4	32%	32%	32%	32%	32%	32%
		5	4%	4%	4%	4%	4%	4%	5	4%	4%	4%	4%	4%	4%
Rajkandi forest	80	1	9%	9%	10%	10%	10%	20%	1	5%	10%	5%	21%	11%	34%
		2	35%	35%	35%	35%	36%	41%	2	0%	0%	0%	4%	4%	5%
		3	25%	25%	23%	24%	25%	24%	3	4%	5%	1%	11%	11%	15%
		4	26%	26%	25%	26%	24%	10%	4	4%	8%	4%	19%	15%	15%
		5	5%	5%	5%	5%	5%	5%	5	0%	0%	1%	6%	5%	4%
Tarap hill	70	1	7%	7%	7%	7%	7%	18%	1	11%	11%	11%	11%	11%	15%
		2	20%	20%	20%	20%	20%	24%	2	20%	20%	20%	20%	20%	30%
		3	17%	17%	17%	17%	17%	21%	3	14%	14%	14%	14%	14%	24%
		4	23%	23%	23%	23%	23%	3%	4	39%	39%	39%	39%	39%	9%
		5	4%	4%	4%	4%	4%	0%	5	16%	16%	16%	16%	16%	0%

FIGURES

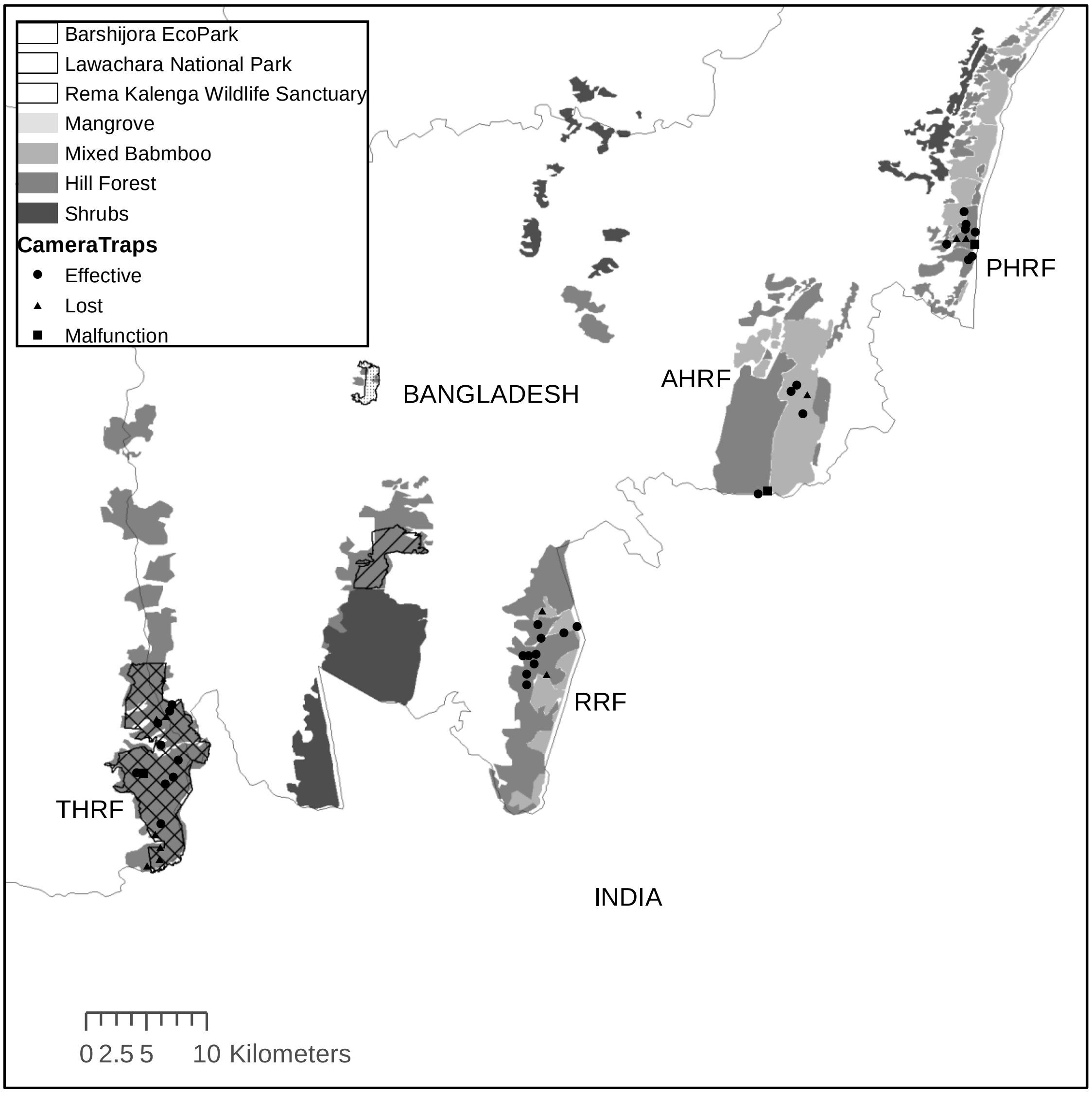

Figure 1 Four camera-trap study areas, Atora hill reserve forest (AHRF), Patharia hill reserve forest (PHRF), Rajkandi reserve forest (RRF), and Tarap hill reserve forest (THRF), in the northeast of Bangladesh. Cameras were placed for varying periods between May 2014 and January 2015. Additional forest patches not surveyed are also shown.

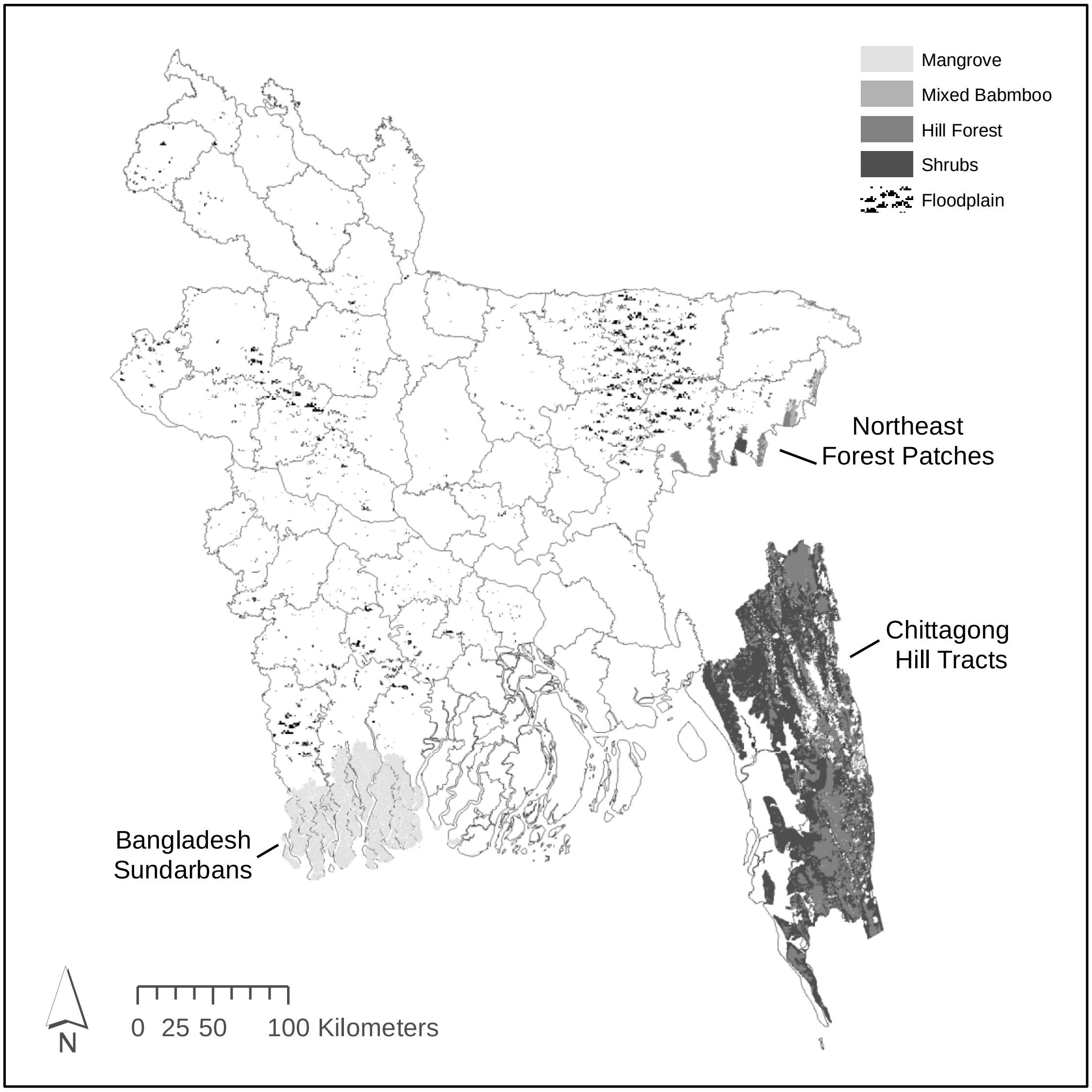

Figure 2 A simplified map of Bangladesh depicting select remaining habitats throughout the country. Camera surveys for mammal biodiversity were conducted between May 2014 and January 2015 in the Northeast Forest Patches.

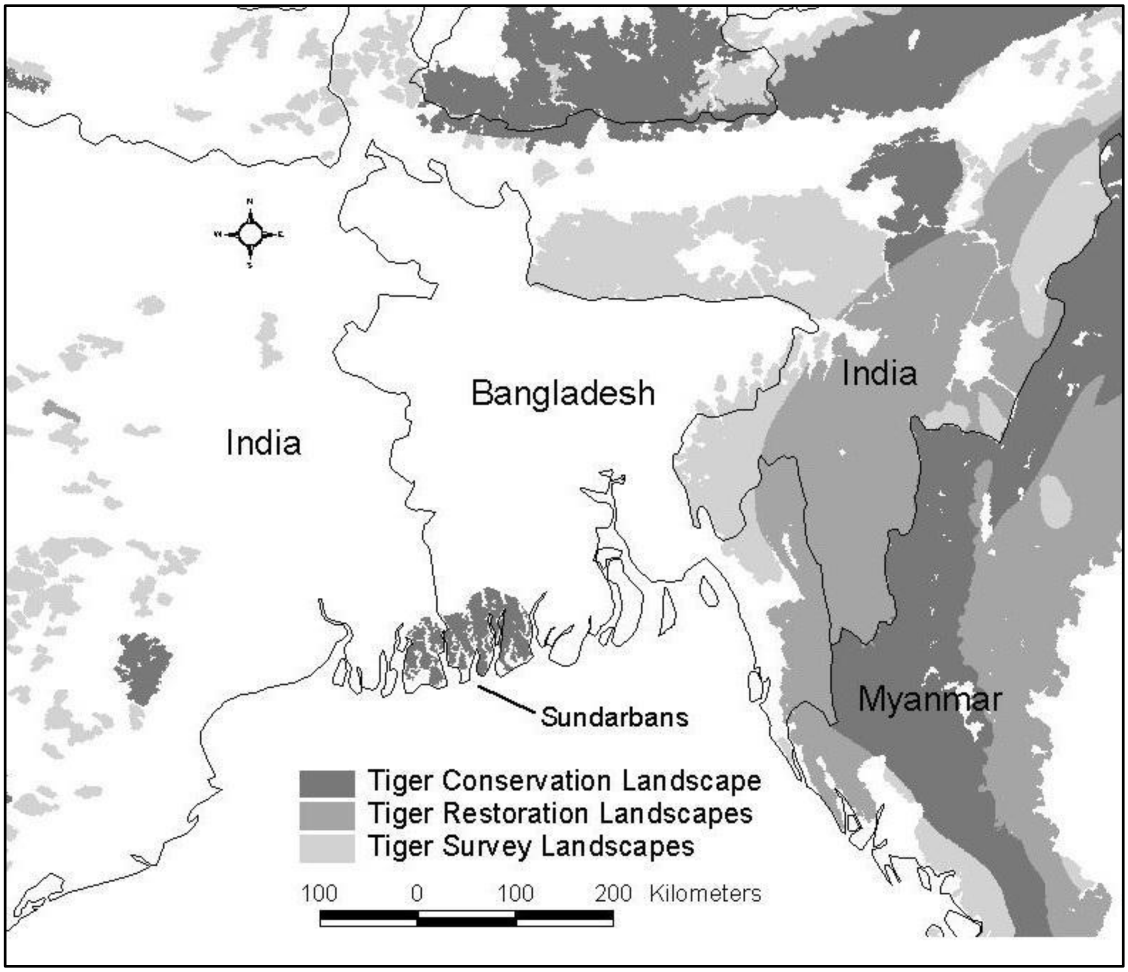

Figure 3 Tiger conservation landscape in and around Bangladesh, source (Sanderson, et al. 2006)

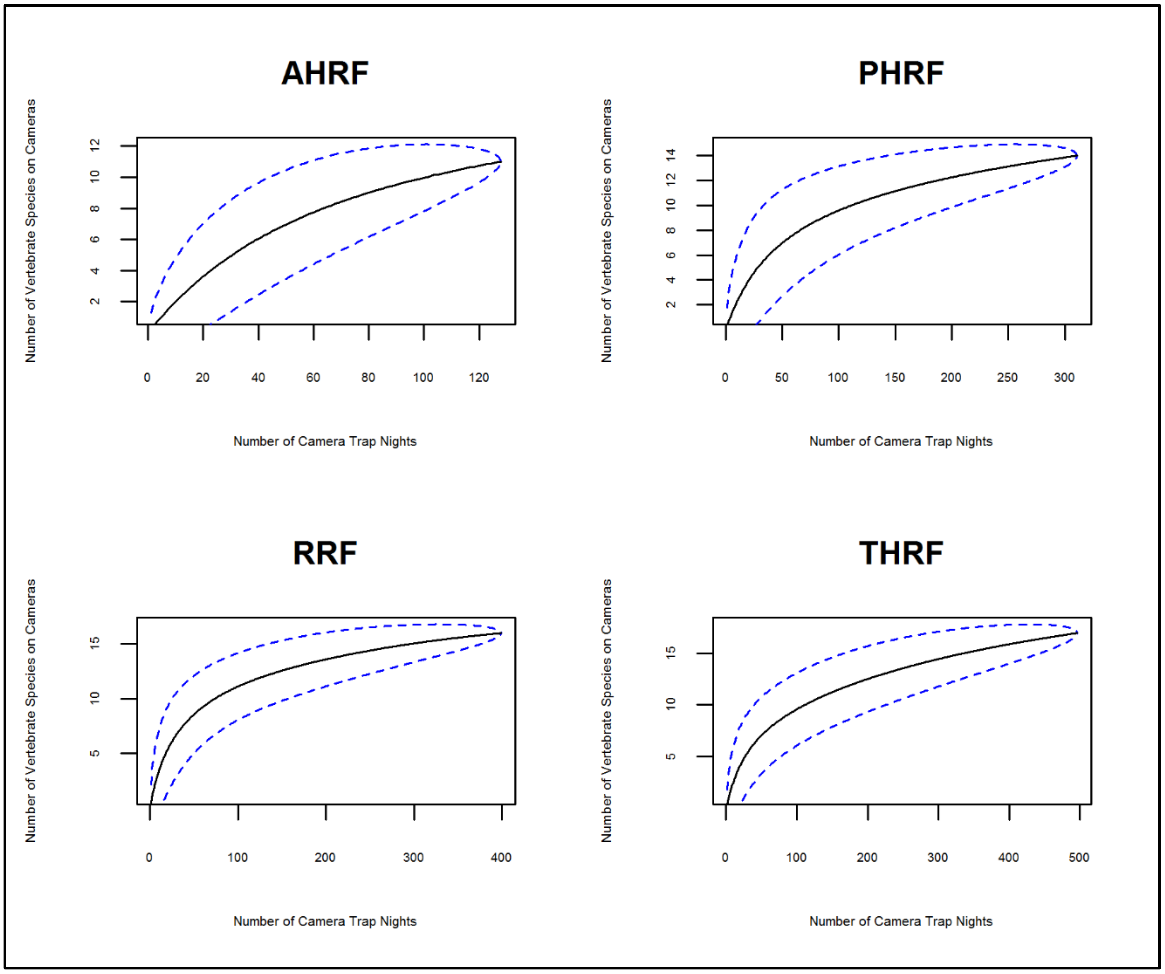

Figure 4 Species accumulation curves based on camera-trap image capture in four study areas, Atora hill reserve forest (AHRF), Patharia hill reserve forest (PHRF), Rajkandi reserve forest (RRF), and Tarap hill reserve forest (THRF), in the northeast of Bangladesh. Cameras were placed for varying date ranges between May 2014 and January 2015. Camera trap nights refers to the number of active cameras multiplied by the number of nights they were active in each study area.

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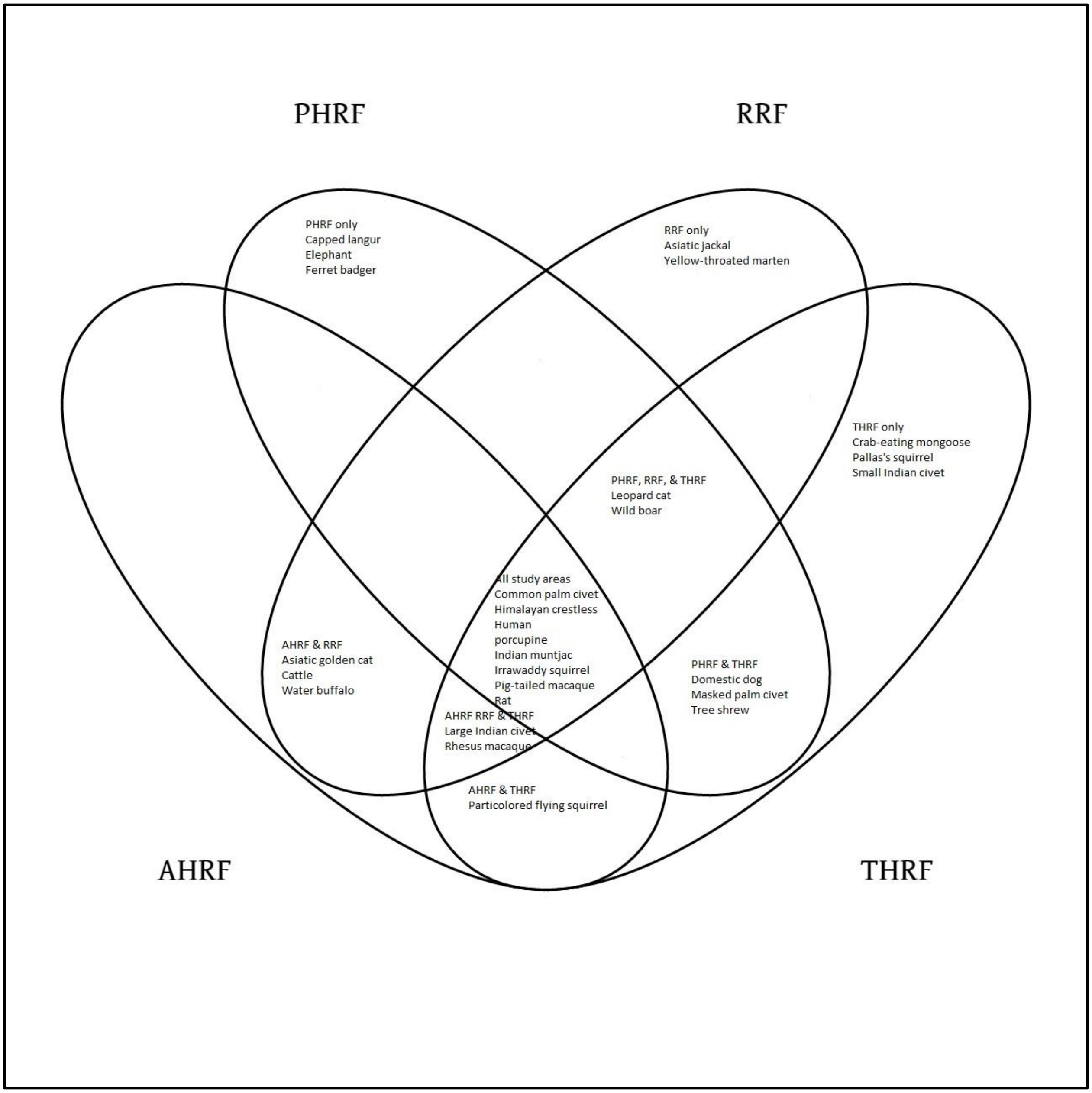

Figure 5 Venn-diagram of species similarity between study areas depicting shared and discrete mammalian species composition in four study areas, AHRF, PHRF, RRF, and THRF in the northeast of Bangladesh, based on camera-trap surveys between May 2014 and January 2015

Chapter 2

PREDICTIVE DISTRIBUTION OF THE FISHING CATS (PRIONAILURUS VIVERRINUS) IN BANGLADESH

Abstract

The fishing cat (*Prionailurus viverrinus*) is a small cat classified in the Prionailurus lineage. Their occurrence is strongly associated with mangrove, wetland, swamp, and rivers in South and Southeast Asia. Within Bangladesh, fishing cats are one of 8 felids known to occur, however very little is known about their distribution within the country. Fishing cats are assessed as Vulnerable by the IUCN global red list, due to extensive threat to its survival throughout the range countries. In the absence of a robust presence/absence survey, as is often the case, presence only data can offer an alternative to predict species distributions. Here, using maximum entropy modeling in MAXENT, I have developed a predictive model of the distribution of the fishing cats throughout Bangladesh, based on presence only fishing cat occurrence records, i.e., camera trap images, and confirmed sightings. I have included a total of 70 geographic locations representing fishing cat occurrence throughout Bangladesh in our models. I used spatial filtering and created three different model scenarios, scenario I (all fishing cat locations), scenario II

(balanced model), scenario III (reduced locations). I have also created bias file to reduce the sampling bias. Our results suggest that the Sundarbans and the wetlands in the northeast are the most suitable habitat for fishing cats. Conserving fishing cats require collaborative effort among different government and non-governmental agencies as well conservation scientists. I suggest to promote fishing cat as conservation icon for the wetland biodiversity, which may provide a positive image for the cats, and foster a desire to maintain Bangladesh as one of the fishing cat's strongholds.

Introduction

The fishing cat (*Prionailurus viverrinus*) is a small felid classified in the Prionailurus lineage with mainland leopard cat (*P. bengalensis*), flat-headed cat (*P. planiceps*), and rusty-spotted cat (*P. rubiginosus*), and newly classified cat Sunda leopard cat (P. javanensis) (Kitchener et al. 2017). Fishing cats have Asiatic origins (Sunquist and Sunquist 2002) and, currently, a discontinuous distribution (Mukherjee et al. 2016). Their occurrence is strongly associated with mangrove, wetland, swamp, and rivers in South and Southeast Asia (Adhya 2014; Cutter 2015; Mukherjee et al. 2016). Within Bangladesh, fishing cats are one of 8 felids known to occur (Khan 2004), however very little is known about their distribution within the country (Rahman and McCarthy 2014).

Bangladesh is the largest delta in the world, and most of the landscape is a relatively recent formation (within ~ 0.01 MYA) (Reimann 1993), due to extensive sedimentation deposited by the Ganges, and the Brahmaputra rivers. Both rivers are in the top 10 largest rivers in the world based and discharge, and both originate from the largest mountain range of the world the Himalaya (Reimann 1993). Approximately 27% of the 147,000 km^2 that make up Bangladesh are mangrove, wetland, and rivers cover types (DOE 2015). These cover types are ideal habitat for the fishing cats (Mukherjee et al. 2016).

Fishing cats are assessed as Vulnerable by the IUCN global red list, due to extensive threat to its survival throughout the range countries (Mukherjee et al. 2016). Recent surveys from India, Nepal, and Thailand suggested that fishing cat populations are decreasing (Mukherjee et al. 2012; Adhya 2014; Cutter 2015). The most recent countrywide red list assessment in Bangladesh assessed fishing cats as locally endangered on the assumption that their numbers decreased by at least 50% in the last 2 decades (Feeroz 2015). This finding was based on estimated habitat loss rather than specific numbers, and, to date, there have been no scientific studies to quantify their population density, occupancy, and trends in Bangladesh. The lack in research on fishing cats means there is also no reliable countrywide estimate of fishing cat populations. Chowdhury et al. (2015) did assess some spatial aspects of fishing cat mortality using news resources over a three-year period in Bangladesh. Other data are the result of by-catch in camera trap surveys for other species (e.g., Dey et al. 2015) and anecdotal reports of sightings, mostly by the birders, who travel extensively in the wetland areas (Rahman et al. 2016).

In the absence of a robust presence/absence survey, as is often the case, presence only data can offer an alternative to predict species distributions (Phillips et al. 2006). MaxEnt is a recently introduced presence-only modeling technique that functions by minimizing the relative entropy between two probability densities which are defined in covariate space, one estimated from the presence data and one estimated from the background landscape (Elith et al. 2011). Maxent is relatively insensitive to the spatial errors associated with location data, requires few locations for the construction of useful models, and appears to perform better than other presence-only models (Elith et al. 2011).

Here, I have developed a predictive model of the distribution of the fishing cats throughout Bangladesh, based on presence only fishing cat occurrence records, i.e., camera trap images, and confirmed sightings. have used maximum entropy modeling in MAXENT (version:3.3.3k; www.cs.princeton.edu/~schapire/maxent/) to develop our predictions. By developing a predicted distribution of fishing cats in Bangladesh I begin to fill in some of our knowledge gap for this Vulnerable species, and identify key areas for fishing cat conservation and future research in Bangladesh. Our results may also serve as a baseline for future fishing cat status assessments.

Study area

I applied species distribution modeling to the entirety of Bangladesh. Bangladesh is a small sub-tropical country in South Asia. Geographically the country is located between 20º34′-26º33′ N latitudes and 88º01′-92º41′ E longitudes. Bangladesh is the ninth most densely populated country in the world with an area of 148,460 km^2 and a human density of 1,266 persons/Km^2 (BBS 2011). The majority of land in Bangladesh is part of a fertile delta formed by the Ganges and the Brahmaputra. The climate of Bangladesh is tropical monsoon. Abundant rainfall during the monsoon (July-October) is followed by a cool winter period (November-February), then a hot and dry summer (March-June). In the hot season, the average maximum and minimum temperatures are 34ºC and 21ºC, respectively. The average maximum and minimum temperatures in winter are 29ºC and 11ºC, respectively.

Methods

Species records

I have collected a total of 70 geographic locations representing fishing cat occurrence throughout Bangladesh. Among them, 51 were bycatch camera trap photos of fishing cats, captured during research on tigers by the Bangladesh forest department, one was a camera trap record from the Chittagong Hill Tracts (Chakma 2015), and one was camera trap record from the floodplain of the Northeast Bangladesh (Sayam U.

Choudhury pers. comm. 2016). The remaining 17 occurrence records are from different naturalists, birders, and scientists from throughout Bangladesh. I used only recent sighting record as there are rapid changes in land use pattern, and conversion of the wetlands into urban or rural settlement is a common scenario in many parts of the country. I have also discarded 20 records due to either ambivalent visual identification, pugmarks only, or a lack of specific GPS coordinates.

Environmental variables

I have selected variables of potential biological relevance for the distribution of fishing cats in Bangladesh. I have used four climatic variables, three geographic variables, two potential prey variables, and one anthropogenic variable (Table 9). I have selected these four climatic variables from 19 available bioclimatic variables in the WorldClim database (http://www.worldclim.org/bioclim, Hijmans et al. 2005) to reduce the auto-correlation inherent in climactic datasets. River and landcover data were obtained from the Bangladesh Forest Department (Bangladesh Forest Department 2012). Given the fishing cat is a habitat specialist and strongly associated with the wetlands and mangrove forest, using the landcover data, I calculated the percentage of the mangrove and wetland cover types for a given location by using a 10 km^2 buffer, based on the mean home range of fishing cat (~10 km^2; Sunquist and Sunquist 2002; Cutter 2015). I then calculated the Euclidian distance from the nearest river to each given location in ARCMAP 10.2 (ESRI Inc. Redlands, California, USA). Further, I obtained fish production data from the Bangladesh department of Fisheries (FRSS 2015). I used two different fish production variables (fish production natural and fish production culture) as a surrogate of prey availability for fishing cats, as studies have suggested that fish comprise ~50% of a fishing cat's diet (Adhya 2014; Mukherjee et al. 2016). Finally, given Bangladesh is one of the most densely populated countries on earth, I used the human population density, from Center of Geographic Information System, Bangladesh (CEGIS), as a potential covariate in our model.

Data preparation

Prior to fitting the models in Maxent, I have prepared a raster of each potential covariate using ARCMAP 10.2 (ESRI Inc. Redlands, California, USA). I resampled each raster to have a spatial resolution of 30 arc-seconds (~1 km), matching that of the BioClim variables which had the coarsest resolution.

Spatial filtering

Outside the Sundarbans, Chittagong Hill Tracts, and forest tracts of the Northeast, the rest of Bangladesh has not been systematically surveyed for fishing cats, especially the vast wetlands in the northeast, southwest, northwest and central part of the country, which have not been the target of any study focusing on fishing cat or other mammals. This adds some bias to my fishing cat presence locations, where I have 51 records from the Sundarbans only (an area that is approximately 4% of Bangladesh), and the remaining 19 points are from the rest of the country. To minimize this bias in the model I followed two hierarchies of spatial filtering (Kramer-Schadt et al. 2013). First, I reduced the number of points from the Sundarbans to 19 via random selection of the 51 records, with a limit that no two randomly selected occurrence points could be within the same 10 km^2 region, again based on average home range size for the fishing cat. Nineteen points was chosen to match the number of points available outside the Sundarbans, thus giving this model a total of 38 occurrence points. In the second stage, I further reduced the number of records in the Sundarbans by randomly selecting records to produce a sample with the same density as outside of Sundarbans. As only 19 records were detected outside of Sundarbans (19/23,000 km^2) as per the total area of occurrence (AOO) of the fishing cats in Bangladesh is 29,000 km^2 (Feeroz 2015) and the Sundarbans is 6,000 km^2, I included only 4 records from the Sundarbans (4/6,000 km^2).

Bias file

I manipulated the background sampling effort with two alternative species-specific 'bias files' representing the relative sampling effort or record density (Kramer-Schadt et al. 2013). Species records were mapped on a 1-km^2 grid, and each cell was given a value of 1 if it contained a record. I subsequently summed the number of records across the Moore neighborhood of each cell to produce a map of 'sampling' density. I used this width- restricted moving window approach to ensure that only those cells were included in the bias files where I were absolutely sure that the species was sampled. If there was no record, a cell was assigned the value 0.1, indicating a tenth of the sampling effort of a value of 1. I further assessed the sensitivity of bias files by assigning values of 0.01 to cells with no records to yield a scenario closer to non-sampling.

Maxent modeling

I ran MaxEnt version 3.3.3a (www.cs.princeton.edu/~schapire/ maxent; Phillips et al. 2006) with default settings as follows: random test percentage = 20; regularization multiplier = 1; maxi- mum number of background points = 10,000. I ran 500 replicates and used mean relative occurrence or suitability probabilities predicted for further analyses. As measures of species distribution modeling (SDM) accuracy or discriminative power, respectively, I used the threshold-independent area under the curve

(AUC) of the receiver operating characteristic (ROC) plot (Fielding and Bell 1997) produced by MaxEnt. Models with an AUC > 0.7 have been shown to have good discriminatory power (Hosmer and Lemeshow 1989).

I ran three model scenarios in Maxent, model scenario I (all locations), which included all fishing cat locations, model Scenario II (balanced model), with the Sundarbans point set reduced to 19 locations and thus a total of 38 locations across Bangladesh, and model scenario III (reduced model), where using the reduced dataset of 4 locations from the Sundarbans for a total of 23 locations across Bangladesh.

Results

All three models were well fit by Maxent, with AUC values >0.85 (Table 10), and model scenario I (all locations) had the highest AUC value with the lowest SD (AUC 0.941, SD 0.037). Percentage of landcover under the mangrove and wetland cover type consistently had the highest relative contribution to predicting fishing cat distributions in all three model scenarios, despite some variation across models (Table 11). In model scenario I and II (balanced model) the distance from river and the precipitation in the driest month covariates had the highest contribution to predicting fishing cat distribution after the percentage of landcover under mangrove and wetland, however between scenario I and II their rank was reversed, i.e., distance from river was ranked 2nd in scenario I and 3rd in scenario II, and precipitation of the driest month was ranked 2nd in scenario I and 3rd in scenario II. In scenario III (even-density locations), the minimum temperature in the coldest month had the second highest contribution to predicting fishing cat distributions, followed by precipitation in the driest month and precipitation in the wettest month. Other covariates had less than a 5% relative contribution to the predicted fishing cat distribution (Table 11).

Each of the top ranked covariates in scenario I and II had a similar effect on predicted fishing cat distribution (Appendix B). In each scenario (I & II) the predicted fishing cat distribution increased with an increase in wetland and mangrove cover types, increased with an increase in the precipitation during the driest month of the year, and decreased as the distance to nearest river increased. In model scenario III, again predicted fishing cat distribution increased with an increase in wetland and mangrove cover types, and with an increase in precipitation during the driest month, but decreased with colder temperatures in the coldest month, and decreased as precipitation increased in the wettest month.

The resultant fishing cat distribution prediction maps suggest that mangrove and wetlands of the Sundarbans and the wetlands in the northeast, southwest, and central Bangladesh are the most suitable habitat for the fishing cats in all three models (Figure 6). Part of the Chittagong Hill Tracts also came across as marginally suitable for the fishing cats.

Discussion

The predictive distribution model provides insight into potential distributions of fishing cats based on relative suitability of habitat across Bangladesh (Merow et al. 2013; Guillera-Arroita et al. 2014). Although, this model does not tell us which areas have higher population densities it does identify the regions where I have known and potential fishing cat populations. As fishing cats are habitat specialist, it is not surprising that best predictor for all three model scenarios was the percent of landcover under the mangrove and wetland cover types, however, the added climatic envelope information derived from precipitation in the wettest and driest months, as well as temperature in the coldest month, helps to more precisely delineate potential habitat. The resultant map will allow managers to design conservation measures targeting fishing cats beyond just focusing on wetland and mangrove forest.

Given Maxent is a maximum entropy model it is designed to accommodate what I know (presence) while limiting any restraint on what I don't know (absences). Thus, even though our data is dependent on sampling effort, it does not completely preclude us from interpreting results in areas not surveyed. Indeed I tried to limit any constraint on absences by implementing a sampling effort bias file (Kramer-Schadt et al. 2013). Further, though they are not resource selection models, Maxent models do point to relationships between distribution and key covariates. Maxent uses species presence and environmental data to obtain a picture of environmental characteristics at presence sites and at background locations to estimates the probability distribution describing characteristics of sites at which the species occurs (Guillera-Arroita et al. 2014).

Taking all of this into account I can look at predicted distributions to inform conservation measures as well as guide future research efforts. Specifically, I can see that the Sundarbans and the wetlands in the northeast of Bangladesh are two key areas for fishing cat occurrence. In the Sundarbans, the fishing cats share habitat with tigers (*Panthera tigris*), however in the vast wetlands of the northeast fishing cats are the apex predator. Of these two areas, the only large protected landscape is within the Sundarbans where 1,397 km^2 out of 6,000 km^2 is a protected area (Khan 2004). In the northeast of

Bangladesh, only a small portion of the wetlands are protected, i.e. "*Baikka beel*" bird sanctuary and "*Tanguar haor*", 1 km^2 and 28 km^2 respectively. Although, earlier reports suggested fishing cat occurrence in some of the other protected areas in the northeast and southeast Bangladesh, our camera trapping effort in the northeast failed to record any fishing cat within the forested landscape of the hilly region (Chapter 1, this volume).

Given the majority of our projected fishing cats distribution in Bangladesh occurs in areas without protection, the species is thus more vulnerable to a diverse array of threats, including direct killing by the local people, habitat alteration, and pollution specific to the wetlands (Thompson 2003; Chowdhury and Clemett 2006; Chowdhury et al. 2015). Ongoing economic development in the country is a mounting pressure on the remaining landscape that supports fishing cat populations. Indeed, recent industrial expansion in the northeast Bangladesh may affect wetlands by replacing the wetland cover types and discharging industrial effluent to the wetlands.

Although identifying potential distributions of fishing cats, and the threats faced in different spatial regions is an important first step in developing conservation strategies for fishing cats in Bangladesh, there is still a large knowledge gap. The foremost research need is a population analysis of fishing cats in Bangladesh using robust and rigorous scientific methods, i.e. spatially explicit capture-recapture (SCR) (Royle et al. 2013), especially in those areas where habitat is more suitable, i.e. the Sundarbans and the wetlands in the northeast. Given that most ongoing camera trapping efforts, e.g., to monitor tigers by the Bangladesh forest department in the Sundarbans, are focused on tigers, and thus not appropriately designed for fishing cat population studies, there is a need for targeted fishing cat research.

Management recommendations

One of the critical issues regarding conservation of wetlands in Bangladesh is the involvement of various stakeholders in decision making. There are numerous government agencies responsible for different resources within the wetlands, i.e., the Ministry of Land regulates the land management, the Ministry of Water Resources regulates water related issues, the Ministry of Fisheries is responsible for fish management, and the Ministry of the Environment and Forestry is responsible for wildlife in the landscape. Conservation of fishing cats in the wetlands will require collaborative efforts amongst the agencies, and the local resource users. In order to increase collaboration, it may be useful to enhance the public image of the fishing cat. Selecting the fishing cat as a symbol of wetland biodiversity may help to create a positive image of the fishing cat, which will enable better marketing for the conservation measures. Informing the public, and the relevant government agencies of the fishing cat's importance as an apex predator in the wetland area, e.g., that half of the fishing cat's diet is rodents, a known pest to local agriculture, so conserving fishing cat will also improve human livelihoods, may also aid in pulling stakeholders together for conservation coordination.

Long term Conservation of the fishing cat requires robust scientific research and collaborative efforts. Coordination among the government, non-governmental organizations, donor agencies, and local stakeholders are essential. Our effort of delineating the distribution of fishing cats in Bangladesh is the first step toward that, as it gives a baseline map for stakeholders to use. Further research will allow managers to initiate conservation measures based on sound science. Bangladesh is one of the last remaining strongholds for the fishing cats in the world, making this endeavor even more critical for the species.

TABLES

Table 9 Variables used in a Maxent model to predict fishing cat distribution in Bangladesh based on 70 occurrence records from camera-capture as well as expert anecdotal sightings.

Variables	Reference
Distance from river	Bangladesh Forest Department 2012
Elevation	Bioclim
Fish production (natural)	FRSS 2015
Fish production (culture)	FRSS 2015
Human population density	BBS/CEGIS 2011
Maximum temperature of warmest month	Hijmans et al. 2005
Minimum temperature of coldest month	Hijmans et al. 2005
Precipitation of the driest month	Hijmans et al. 2005
Precipitation of the wettest month	Hijmans et al. 2005
Percent of landcover covered by mangrove forest and wetland	Bangladesh Forest Department 2012

Table 10 Area under the curve (AOC) and standard deviation (SD) model fit estimates from Maxent for three different model scenarios assessing fishing cat distributions in Bangladesh. Models were based on 70 original occurrence records and scenarios were various subsets of these records. Scenario I included all occurrence observations, scenario II reduced records to provide numerical balance between the Sundarbans and the rest of Bangladesh, and scenario III reduced records further to provide a point density equivalence between the Sundarbans and the rest of Bangladesh

Model scenario I		Model scenario II		Model Scenario III	
AUC	SD	AUC	SD	AUC	SD
0.941	0.037	0.900	0.076	0.866	0.128

Table 11 Estimates of relative percent contribution (RC) and permutation importance normalized to percentages (PI) for variables used in MaxEnt modeling of the fishing cat distributions in Bangladesh, under three model scenarios.

Variables	Model scenario I		Model scenario II		Model scenario III	
	RC	PI	RC	PI	RC	PI
Distance from river	11.5	0.9	4.5	1.3	.2	.5
Elevation	.5	2.1	.3	.4	.2	1.8
Fish production (natural)	1.1	4.4	.8	2.1	1.9	2.4
Fish production (culture)	.2	.3	.5	.5	.5	.6
Human population density	1	3.1	3.5	6.3	2.7	9.6
Maximum temperature of warmest month	.1	1.2	1.9	5.9	2.7	10.7
Minimum temperature of coldest month	.4	1.5	2	1.9	17.8	5.3
Precipitation of the driest month	11.1	18.4	7.3	5.5	7.3	13.5
Precipitation of the wettest month	2	2.1	2.3	.1	5.5	0
Percent of landcover covered by mangrove forest and wetland	72	66	76.9	76.8	61.3	55.7

FIGURES

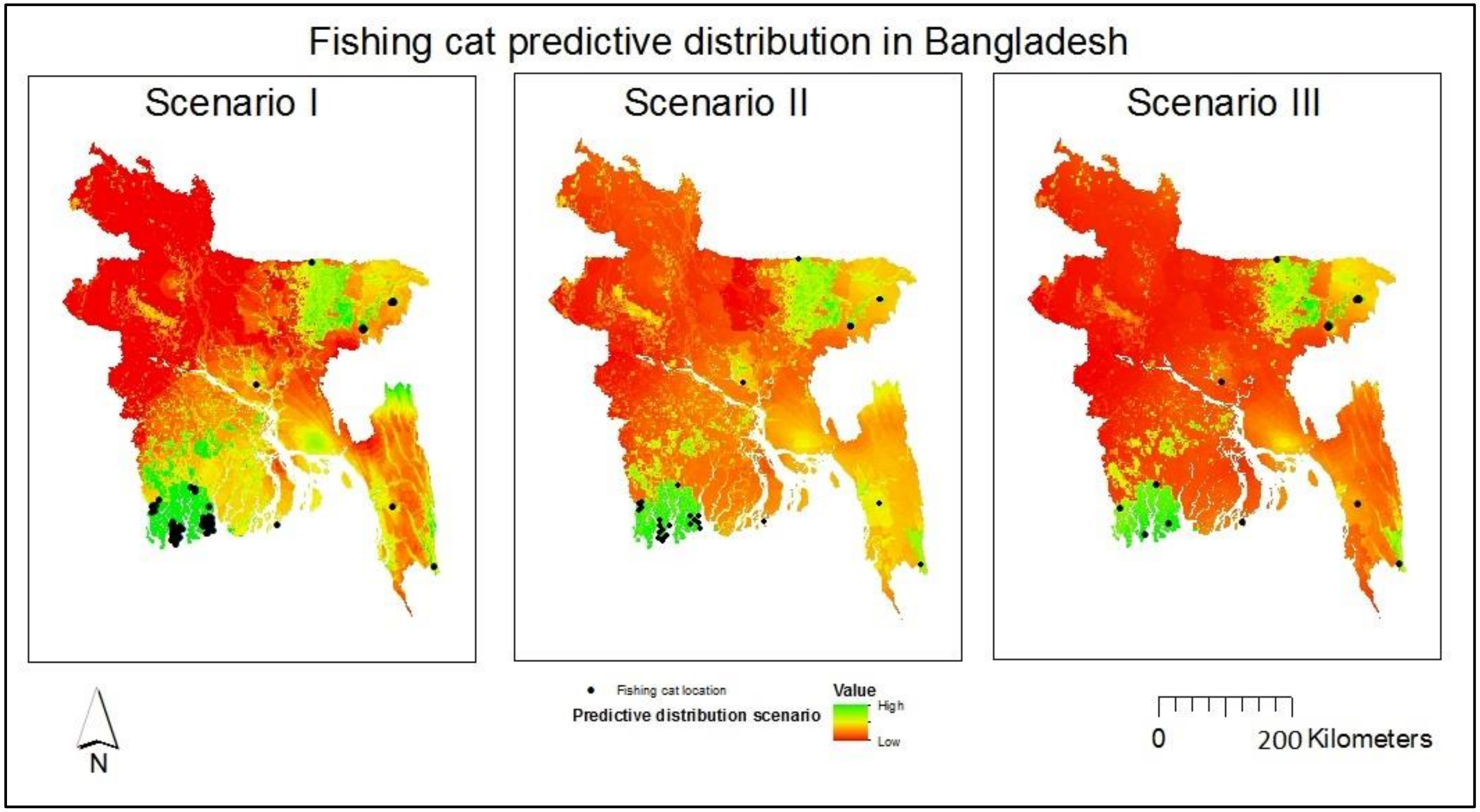

Figure 6 Predicted distribution of fishing cats in Bangladesh based on three model scenarios in Maxent. Models were based on 70 original occurrence records and scenarios were various subsets of these records. Scenario I included all occurrence observations, scenario II reduced records to provide numerical balance between the Sundarbans and the rest of Bangladesh, and scenario III reduced records further to provide a point density equivalence between the Sundarbans and the rest of Bangladesh.

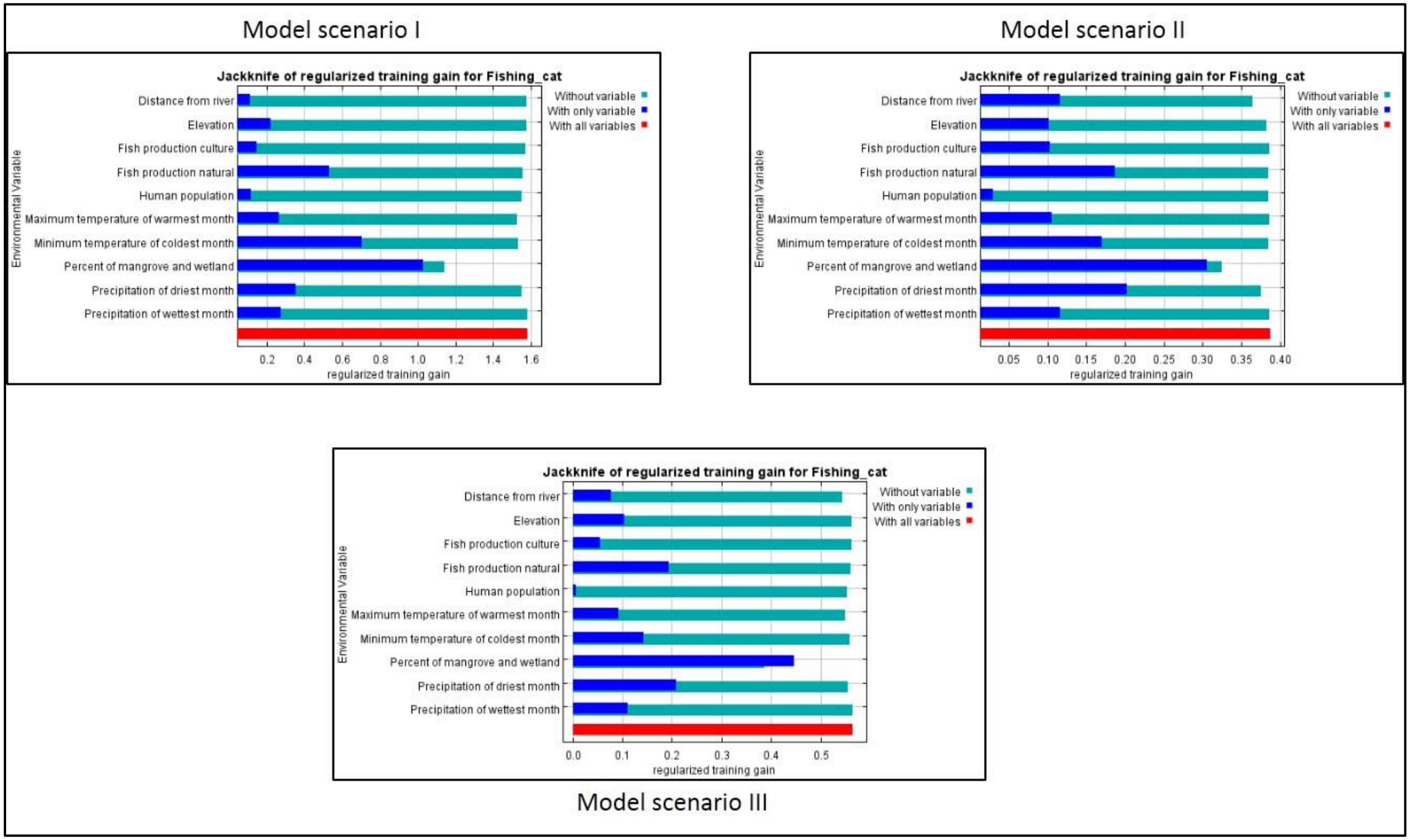

Figure 7 Jackknife analyses of individual predictor variables important in the development of the full model for fishing cats in relation to the overall model quality or the "regularized training gain." Blue bars indicate the gain achieved when including only that variable and excluding the remaining variables; gray bars show how much the gain is diminished without the given predictor variable.

REFERENCES

Adhya, T. 2014. "Habitat Use and Diet of Two Sympatric Felids-the Fishing Cat (Prionailurus Viverrinus) and the Jungle Cat (Felis Chaus) - in a Human-Dominated Landscape in Suburban Kolkata.". MS thesis. Tata Institue of Fundamental Research.

Ahumada, J A, C E Silva, K Gajapersad, C Hallam, J Hurtado, E Martin, A McWilliam, et al. 2011. "Community Structure and Diversity of Tropical Forest Mammals: Data from a Global Camera Trap Network." *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences* 366 (1578): 2703–11. doi:10.1098/rstb.2011.0115.

Bangladesh Forest Department. 2012. GIS map of forest cover in Bangladesh. Dhaka.

Barlow, Adam C.D. 2009. "The Sundarbans Tiger: Adaptation, Population Status and Conflict Management." . PhD dissertation. University of Minnesota.

Barlow, Adam C.D., Md. Ishtiaq U. Ahmed, Md. Mizanur Rahman, Alam Howlader, Alexander C. Smith, and James L.D. Smith. 2008. "Linking Monitoring and Intervention for Improved Management of Tigers in the Sundarbans of Bangladesh." *Biological Conservation* 141 (8): 2032–40. doi:10.1016/j.biocon.2008.05.018.

Bernard, Henry, Abdul Hamid Ahmad, Jedediah Brodie, Anthony J Giordano, Lifescape International, New York, and New York. 2013. "Camera-Trapping Survey of Mammals in and Around Imbak Canyon Conservation Area in Sabah , Malaysian Borneo." *The Raffles Bulletin of Zoology* 61 (2): 861–70.

Bernard, Henry, Esther L Baking, Anthony J Giordano, Oliver R Wearn, and Abdul

Hamid Ahmad. 2014. “Terrestrial Mammal Species Richness and Composition in Three Small Forest Patches within an Oil Palm Landscape in Sabah, Malaysian Borneo.” *Mammal Study* 39 (October 2015): 141–54. doi:10.3106/041.039.0303.

Chakma, Suprio. 2015. “Assessment of Large Mammals of the Chittagong Hill Tracts of Bangladesh with Emphasis on Tiger (Panthera Tigris)". PhD dissertation. University of Dhaka..”

Chowdhury, N, S., and Clemett, A. E. V. 2006. “Industrial Pollution and Its Threat to Wetlands in Bangladesh: Mokesh Beel Wetland in Kaliakoir.” Dhaka.

Chowdhury, S. U., Chowdhury, A. R., Ahmed, S., and Muzaffar, S. B. 2015. “Human-Fishing Cat Conflicts and Conservation Needs of Fishing Cats in Bangladesh.” *Cat News* 62 (Spring): 4–7.

Cutter, P. 2015. “Fishing Cat Ecology: Food Habits, Home Ranges, Habitat Use, and Mortality in a Human-Dominated Landscape around Khao Sam Roi Yot Area, Peninsular Thailand.” MS thesis. University of Minnesota. doi:10.1017/CBO9781107415324.004.

DeCose, P. J., Thompson, P. M., Ahmad, I. U., Sharma, R. A., Mazumder, A. H., ed. 2012. *Protected Area Co-Management Where People and Poverty Intersect*. Dhaka: Nishorgo Network.

Dey, T. K., Kabir, M. J., Ahsan, M. M., Islam, M. M., Chowdhury, M. M. R., Hassan, S., Roy, M., Qureshi, Q. Naha, D., Kumar, U., and Jhala, Y. V. 2015. “First Phase Tiger Status Report of Bangladesh Sundarbans.” Khulna.

DOE. 2015. “Fifth National Report of Bangladesh to the Convention on Biological

Diversity.” Dhaka.

Elith, Jane, Steven J. Phillips, Trevor Hastie, Miroslav Dudík, Yung En Chee, and Colin J. Yates. 2011. “A Statistical Explanation of MaxEnt for Ecologists.” *Diversity and Distributions* 17 (1): 43–57. doi:10.1111/j.1472-4642.2010.00725.x.

Feeroz, M. M., Hasan, M. K., and Khan, M. M. H. 2013. *Biodiversity of Bangladesh. Volume I*. Dhaka: Aranyak Foudnation.

Feeroz, M. M. 2015. “Prionailurus Viverrinus.” In *IUCN Bangladesh. Red List of Bangladesh Vollume 2*, 93–93. Dhaka: IUCN Bangladesh country office.

Fielding, A H, and J F Bell. 1997. “A Review of Methods for the Assessment of Prediction Errors in Conservation Presence/ Absence Models.” *Environmental Conservation* 24 (1). University of Delaware: 38–49. doi:10.1017/S0376892997000088.

FRSS. 2015. “Fisheries Statistical Report of Bangladesh. Fisheries Resources Survey System (FRSS).” Dhaka.

Grassman, Lon I., Michael E. Tewes, Nova J. Silvy, and Kitti Kreetiyutanont. 2005. “Ecology of Three Sympatric Felids in a Mixed Evergreen Forest in North-Central Thailand.” *Journal of Mammalogy* 86 (1): 29–38. doi:10.1644/1545-1542(2005)086<0029:EOTSFI>2.0.CO;2.

Guillera-Arroita, Gurutzeta, José J. Lahoz-Monfort, and Jane Elith. 2014. “Maxent Is Not a Presence-Absence Method: A Comment on Thibaud et Al.” *Methods in Ecology and Evolution* 5 (11): 1192–97. doi:10.1111/2041-210X.12252.

Hijmans, Robert J., Susan E. Cameron, Juan L. Parra, Peter G. Jones, and Andy Jarvis.

2005. “Very High Resolution Interpolated Climate Surfaces for Global Land Areas.” *International Journal of Climatology* 25: 1965–78. doi:10.1002/joc.1276.

Hoffmann, Michael, Craig Hilton-taylor, Ariadne Angulo, Monika Böhm, Thomas M. Brooks, Stuart H. M. Butchart, Kent E. Carpenter, et al. 2010. “The Impact of Conservation on the Status of the World ’s Vertebrates.” *Science* 330 (6010): 1503–9. doi:10.1126/science.1194442.

Hosmer, D. W. and Lemeshow, S. 1989. *Applied Logistic Regression*. New York: Wiley.

Islam, M. A., Uddin, M., Aziz, M. A., Muzaffar, S. B., Chakma, S., Chowdhury, S.U., Chowdhury, G. W., Rashid, M. A., Mohsanin, S. Jahan, I., Saif, S., Hossain, M, B., Chakma, D., Kamruzzaman, M., and Akter, R. 2013. “Status of Bear in Bangladesh: Going, Going, Gone?” *Ursus* 24 (1): 83–90. doi:10.2192/URSUS-D-12-00010.1.

IUCN Bangladesh. 2015. *Red List of Bangladesh Volume 2: Mammals*. Dhaka: IUCN Bangladesh country office.

Khan, M. M. H. 2004. “Ecology and Conservation of the Bengal Tiger in the Sundarbans Mangrove Forest of Bangladesh.” PhD dissertation. University of Cambridge. 336 p.

Kitamura, S, S Thong-Aree, S Madsri, and P Poonswad. 2010. “Mammal Diversity and Conservation in a Small Isolated Forest of Southern Thailand.” *The Raffles Bulletin of Zoology* 58 (1): 145–56.

Kitchener, A. C., Breitenmoser-Wursten Ch., Eizirik, E., Gentry, A., Werdelin, L., Wilting, A., Yamaguchi, N., Abramov, A. V., Christiansen, P., Driscoll, C., Duckworth, J. W., Johnson, W., Luo S.-J., Meijaard, E., O’donoghue, P., Sanderson, J., Seymour, S. et al. 2017. “A Revised Taxonomy of the Felidae. The Final Report of the Cat Classification Task Force of the IUCN/SSC Cat Specialist Group. Cat News Special Issue 11."

Kramer-Schadt, Stephanie, Jürgen Niedballa, John D. Pilgrim, Boris Schröder, Jana Lindenborn, Vanessa Reinfelder, Milena Stillfried, et al. 2013. "The Importance of Correcting for Sampling Bias in MaxEnt Species Distribution Models." *Diversity and Distributions* 19 (11): 1366–79. doi:10.1111/ddi.12096.

Madhusudan, M. D. 2003. "Living amidst Large Wildlife: Livestock and Crop Depredation by Large Mammals in the Interior Villages of Bhadra Tiger Reserve, South India." *Environmental Management* 31 (4): 466–75. doi:10.1007/s00267-002-2790-8.

McCarthy, J., Dahal, S., Dhendup, T., Gray, T. N. E., Mukherjee, S., Rahman, H., Riordan, P., Boontua, N., and Wilcox, D. et al. 2015. "Catopuma Temminckii. The IUCN Red List of Threatened Species 2015."

Merow, Cory, Matthew J. Smith, and John A. Silander. 2013. "A Practical Guide to MaxEnt for Modeling Species' Distributions: What It Does, and Why Inputs and Settings Matter." *Ecography* 36 (10): 1058–69. doi:10.1111/j.1600-0587.2013.07872.x.

Mohd. Azlan, J., and Lading, E. 2006. "CAMERA TRAPPING AND CONSERVATION IN LAMBIR HILLS NATIONAL PARK, SARAWAK." *Raffles Bulletin of Zoology* 54 (2): 469–75.

Mukherjee, S., Appel, A., Duckworth, J. W., Sanderson, J., Dahal, S., Wilcox, D. H. A., Herranz M. V., Malla, G., Ratnayaka, A., Kantimhanti, M., Thudugala, A., Thaung, R., Rahman, H. 2016. “Prionailurus Viverrinus , Fishing Cat.” The IUCN Red List of Threatened Species 2016: e.T18150A50662615. http://dx.doi.org/10.2305/IUCN.UK.20162.RLTS.T18150A50662615.en

Mukherjee, S, T Adhya, P Thatte, and U Ramakrishnan. 2012. “Survey of the Fishing Cat Prionailurus Viverrinus Bennett, 1833 (Carnivora:Felidae) and Some Aspects Impacting Its Conservation in India.” *JoTT Communication* 4 (14): 3355–61..

Muzaffar, Sabir Bin, M. Anwarul Islam, M.M. Feeroz, M. Kabir, S. Begum, S. Mahmud, and Suprio Chakma. 2007. “Habitat Characteristics of the Endangered Hoolock Gibbons (Hoolock Hoolock) of Bangladesh: The Role Tree Species Richness.” *Biotropica* 39 (4): 539–45. doi:10.1111/j.1744-7429.2007.00298.x.

Muzaffar, Sabir Bin, M. Anwarul Islam, Dihider Shahriar Kabir, Mamunul Hoque Khan, Farid Uddin Ahmed, Gawsia Wahidunnessa Chowdhury, M. Abdul Aziz, Suprio Chakma, and Israt Jahan. 2011. “The Endangered Forests of Bangladesh: Why the Process of Implementation of the Convention on Biological Diversity Is Not Working.” *Biodiversity and Conservation* 20 (7): 1587–1601. doi:10.1007/s10531-011-0048-6.

Nakashima, Yoshihiro, Eiji Inoue, Miho Inoue-Murayama, and Jum Rafiah Abd Sukor. 2010. “Functional Uniqueness of a Small Carnivore as Seed Dispersal Agents: A Case Study of the Common Palm Civets in the Tabin Wildlife Reserve, Sabah, Malaysia.” *Oecologia* 164 (3): 721–30. doi:10.1007/s00442-010-1714-1.

Phillips, S. J., Dudik, M., and Schapire, R. E. et al. 2004. “A Maximum Entropy

Approach to Species Distribution Modeling.” In *Proceedings of the Twenty-First International Conference on Machine Learning*, 655–62. doi:10.1145/1015330.1015412.

Phillips, Steven, Robert Anderson, and Robert Schapire. 2006. “Maximum Entropy Modeling of Species Geographic Distributions.” *Ecological Modelling* 190 (3–4): 231–59. doi:doi: 10.1016/j.ecolmodel.2005.03.026.

Powell, R. A. 2012. “Movements, Home Ranges, Activity, and Dispersal.” In *Carnivore Ecology and Conservation*, edited by R. A. Boitani, L. and Powell, 1st ed., 506. Oxford: Oxford University.

Quazi, Shimona A., and Tamara Ticktin. 2016. “Understanding Drivers of Forest Diversity and Structure in Managed Landscapes: Secondary Forests, Plantations, and Agroforests in Bangladesh.” *Forest Ecology and Management* 366. Elsevier B.V.: 118–34. doi:10.1016/j.foreco.2016.01.024.

Rabinowitz, A R. 1991. “Behaviour and Movements of Sympatric Civet Species in Huai Kha Khaeng Wildlife Sanctuary, Thailand.” *Journal of Zoology* 223: 281–98. doi:10.1111/j.1469-7998.1991.tb04765.x.

Rabinowitz, Alan R, and Susan R Walker. 1991. “The Carnivore Community in a Dry Tropical Forest Mosaic.” *Journal of Tropical Ecology* 7 (1): 37–47.

Rahman, H. A., and McCarthy, J. L. 2014. “Observation of a Juvenile Fishing Cat in Bangladesh.” *Cat News* 61 (2): 22–23.

Reimann, K.-U. 1993. *Geology of Bangladesh*. 1st ed. Berlin - Stuttgart: Gebruder Borntrager.

Royle, J. A., Chandler, R. B., Sollmann, R. and Gardner, B. 2013. *Spatial Capture-Recapture*. 1sted. Oxford: Elsevier Inc.

Sanderson, E., Forrest, J., Loucks, C., Ginsberg, J., Dinerstein, E., Forrest, J., Loucks, C., Ginsberg, J., Dinerstein, E., Seidensticker, J., Leimgruber, P., Songer, M., Heydlauff, A., O'Brien, T., Bryja, G., Klenzendorf, S., Wikramanayake, E. 2006. "Setting Priorities for the Conservation and Recovery of Wild Tigers: 2005–2015, The Technical Assessment." *WCS, WWF, Smithsonian, and NFWF-STF*. New York-Washington D. C.

Smith, Brian D., Gill Braulik, Samantha Strindberg, Benazir Ahmed, and Rubaiyat Mansur. 2006. "Abundance of Irrawaddy Dolphins (Orcaella Brevirostris) and Ganges River Dolphins (Platanista Gangetica Gangetica) Estimated Using Concurrent Counts Made by Independent Teams in Waterways of the Sundarbans Mangrove Forest in Bangladesh." *Marine Mammal Science* 22 (3): 527–47. doi:10.1111/j.1748-7692.2006.00041.x.

Sodhi, Navjot S., Mary Rose C Posa, Tien Ming Lee, David Bickford, Lian Pin Koh, and Barry W. Brook. 2010. "The State and Conservation of Southeast Asian Biodiversity." *Biodiversity and Conservation* 19 (2): 317–28. doi:10.1007/s10531-009-9607-5.

Sunderland, T.C.H.; Sayer, J.A.; Minh-Ha, H.; eds., ed. 2013. *Evidence-Based Conservation*. Routledge. doi:10.4324/9780203128466.

Sunquist, Melvin E., Sunquist, Fiona. 2002. *Wild Cats of the Wolrd*.

Thompson, P. 2003. "Restoring Wetland Environments and Biodiversity : Lessons from

MACH." Dhaka.

Timmins, R. J., Duckworth, J. W., Chutipong, W., Ghimirey, Y., Wilcox, D. H. A., Rahman, H., Long, B., and Choudhury, A. et al. 2016. "Viverra Zibetha. The IUCN Red List of Threatened Species 2016."

APPENDIX A

Example camera-trap photos from surveys in four study areas in the northeast of Bangladesh between May 2014 and January 2015.


Bushnell
Camera Name 75°F23°C
08-16-2014

Bushnell
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08-16-2014 05:41:43

Bushnell
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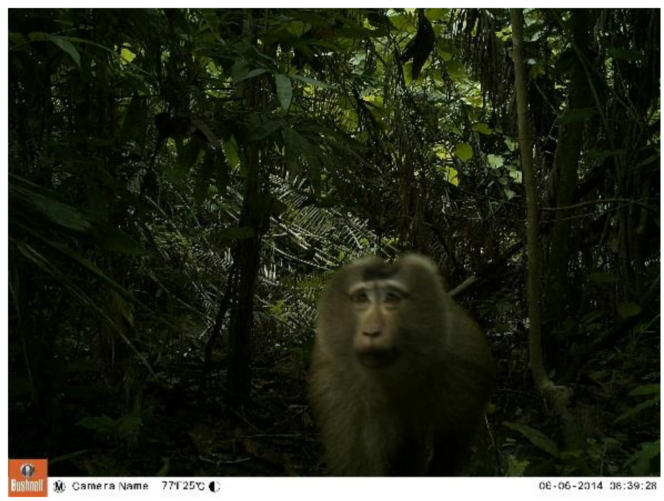
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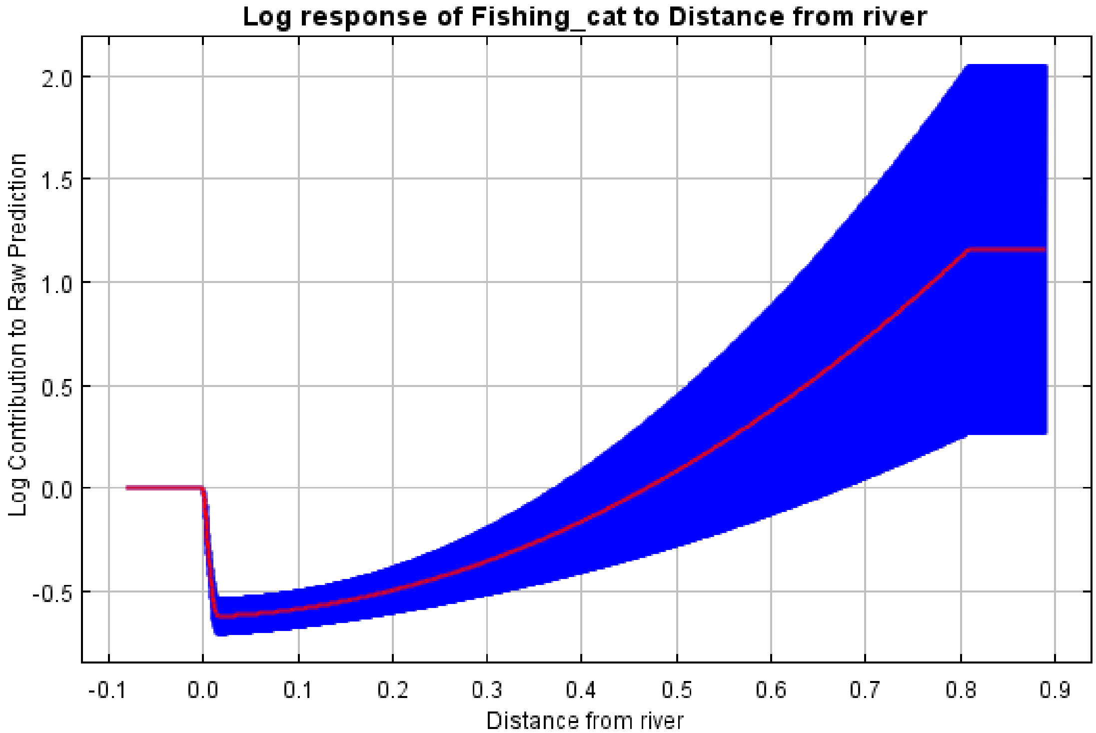
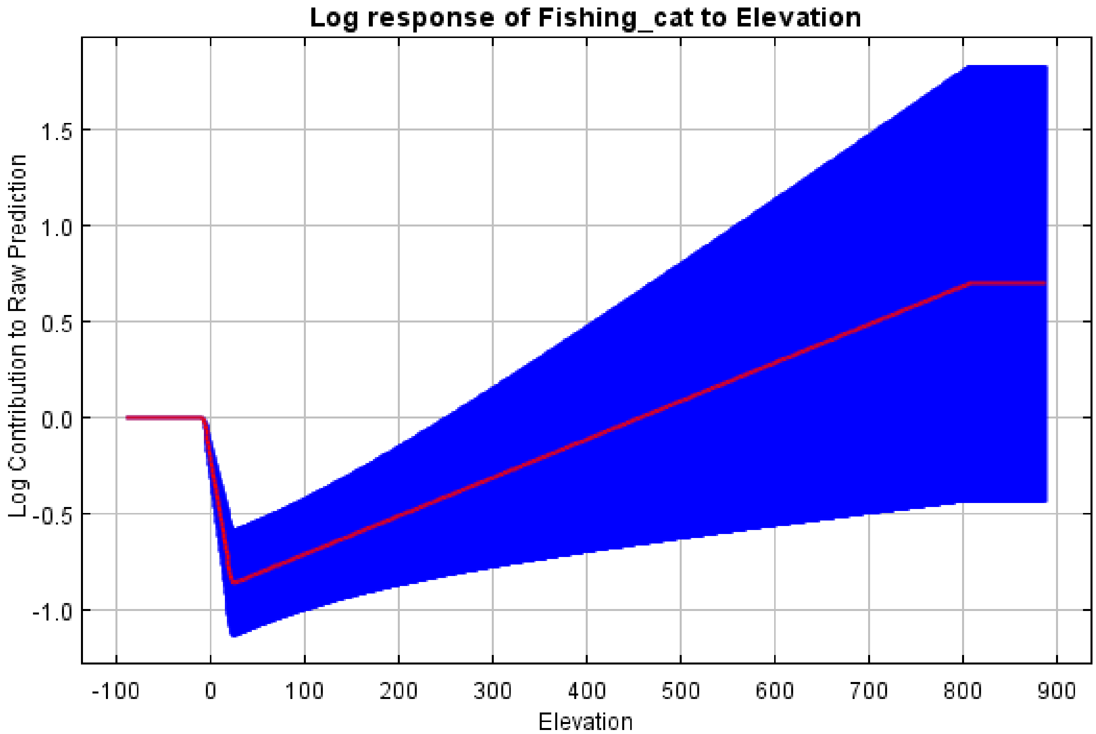
APPENDIX B

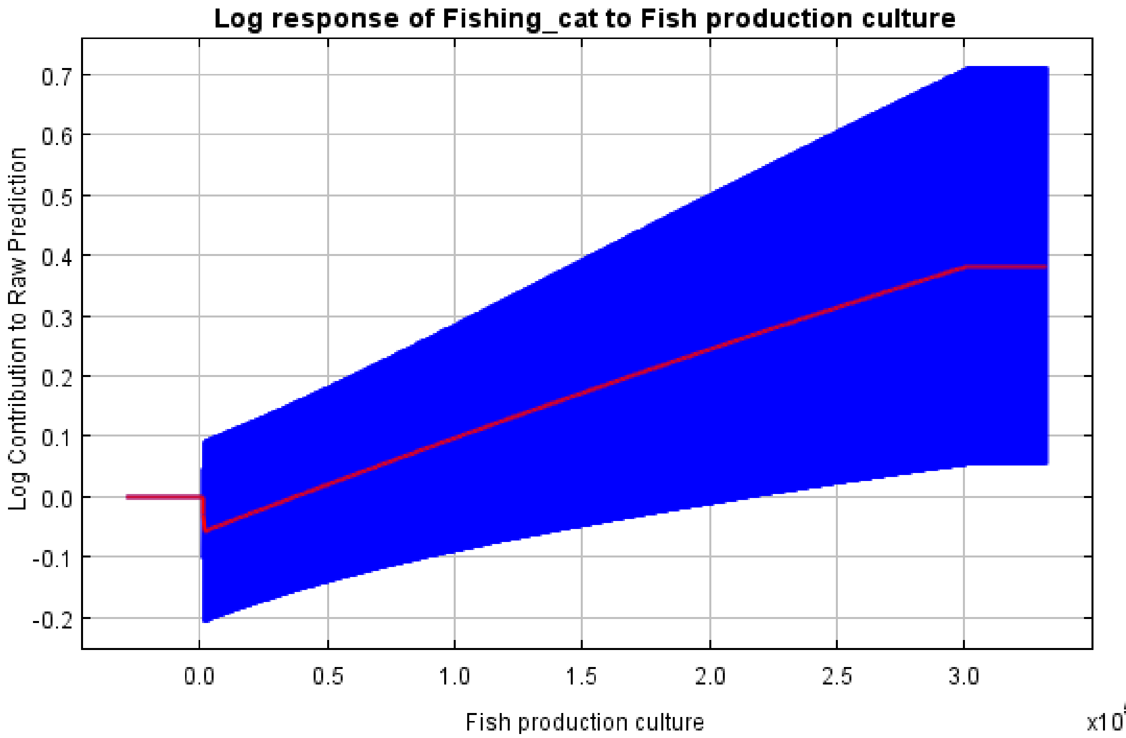
Response curves for the predictive distribution modeling

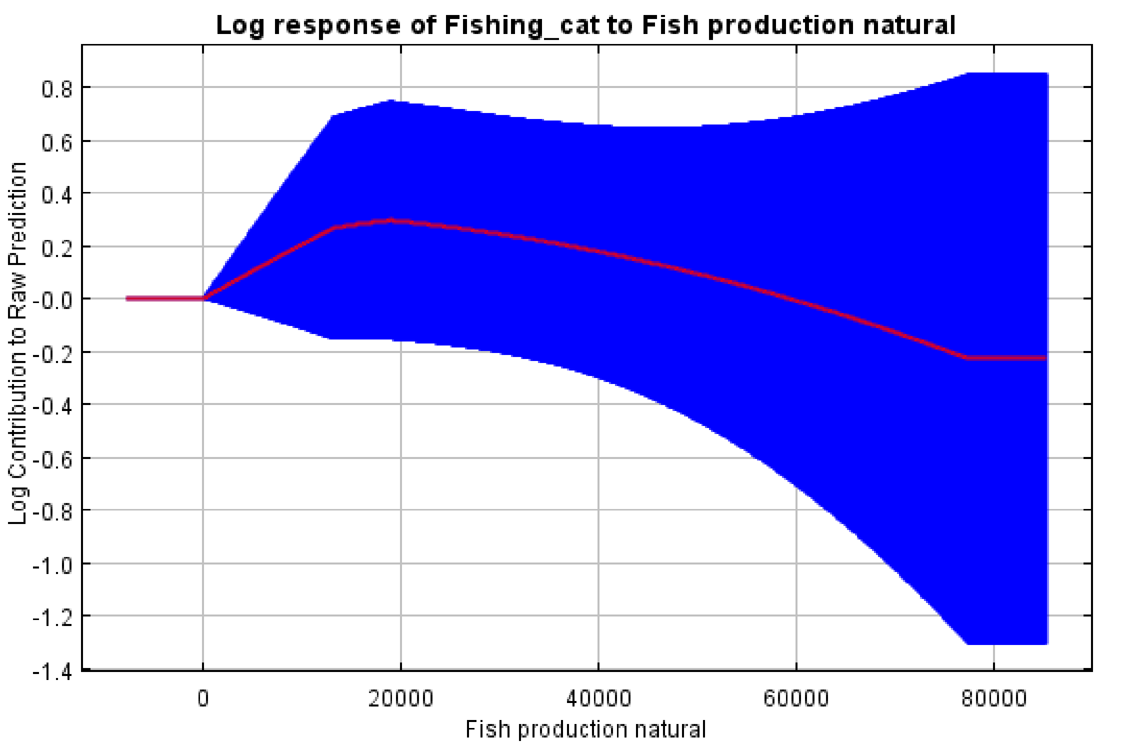
These curves show how each environmental variable affects the Maxent prediction for fishing cat distribution in Bangladesh. The (raw) Maxent model has the form exp(...)/constant, and the curves show how the exponent changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. The curves show the mean response of the 500 replicate Maxent runs and the mean +/- one standard deviation (blue, two shades for categorical variables).

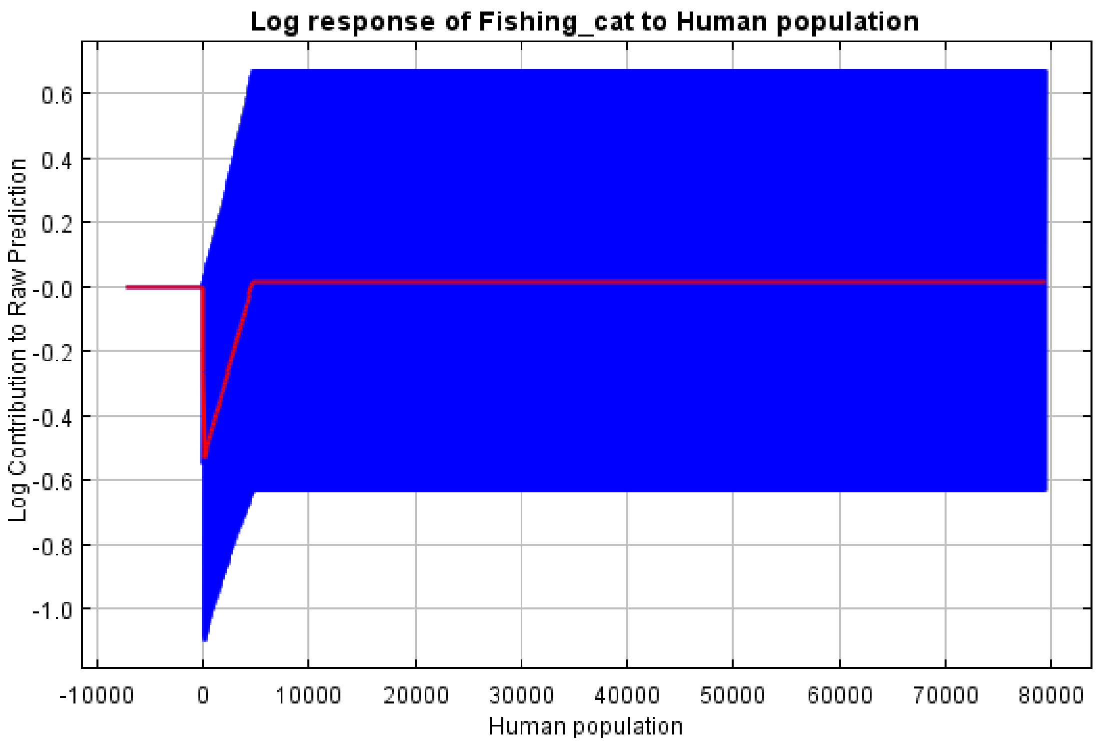
Model scenario I

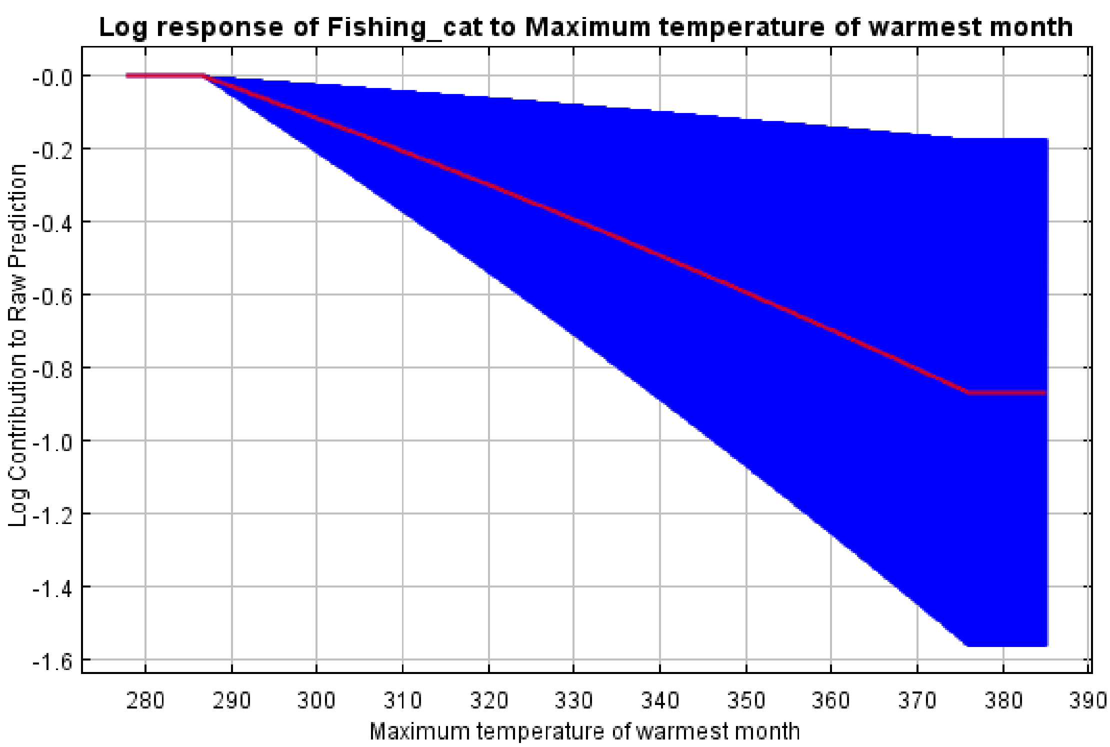


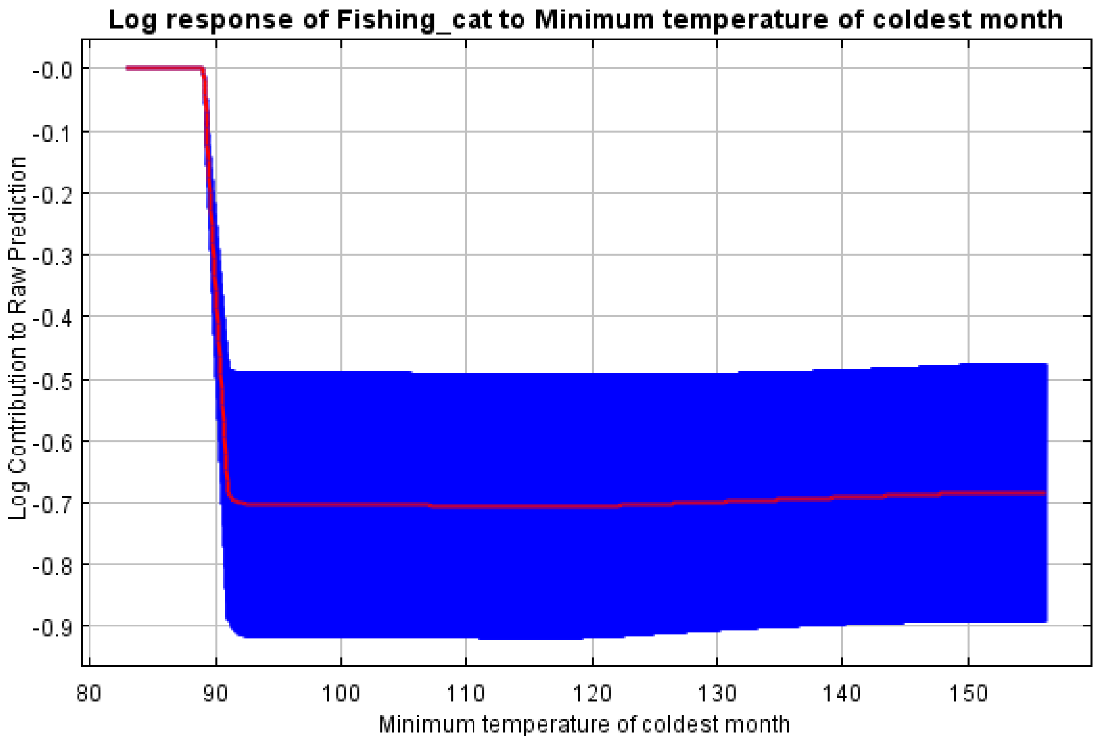


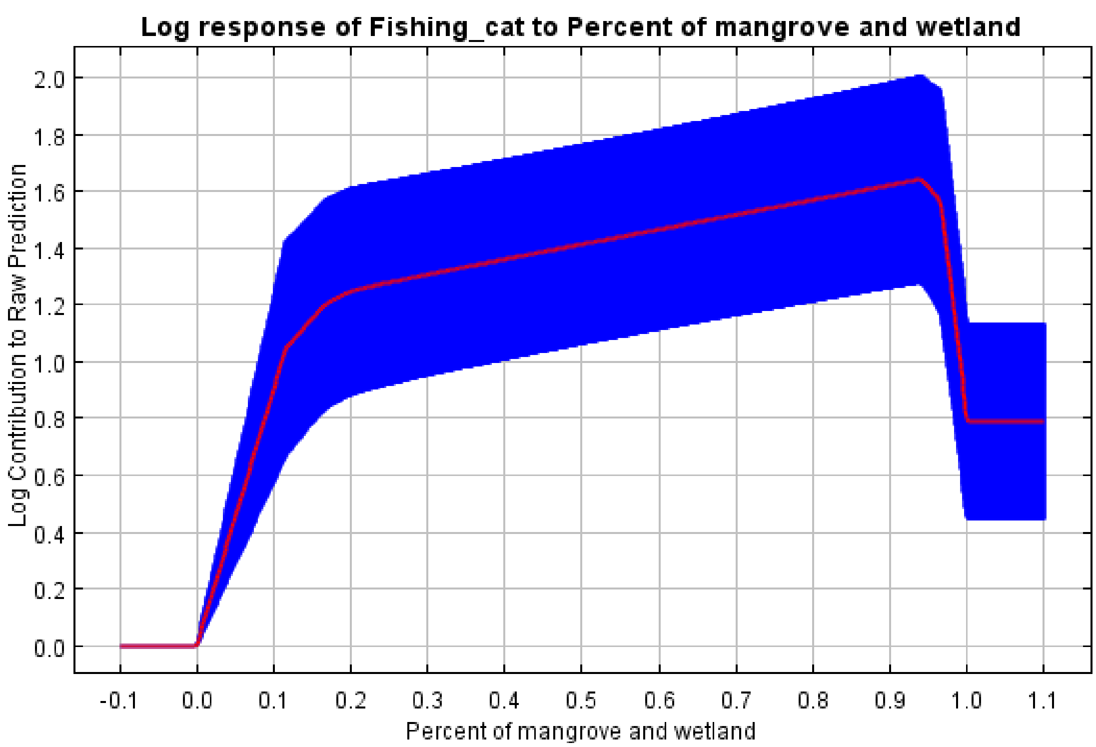

Log response of Fishing_cat to Fish production culture
Log Contribution to Raw Prediction
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Fish production culture
x10^5

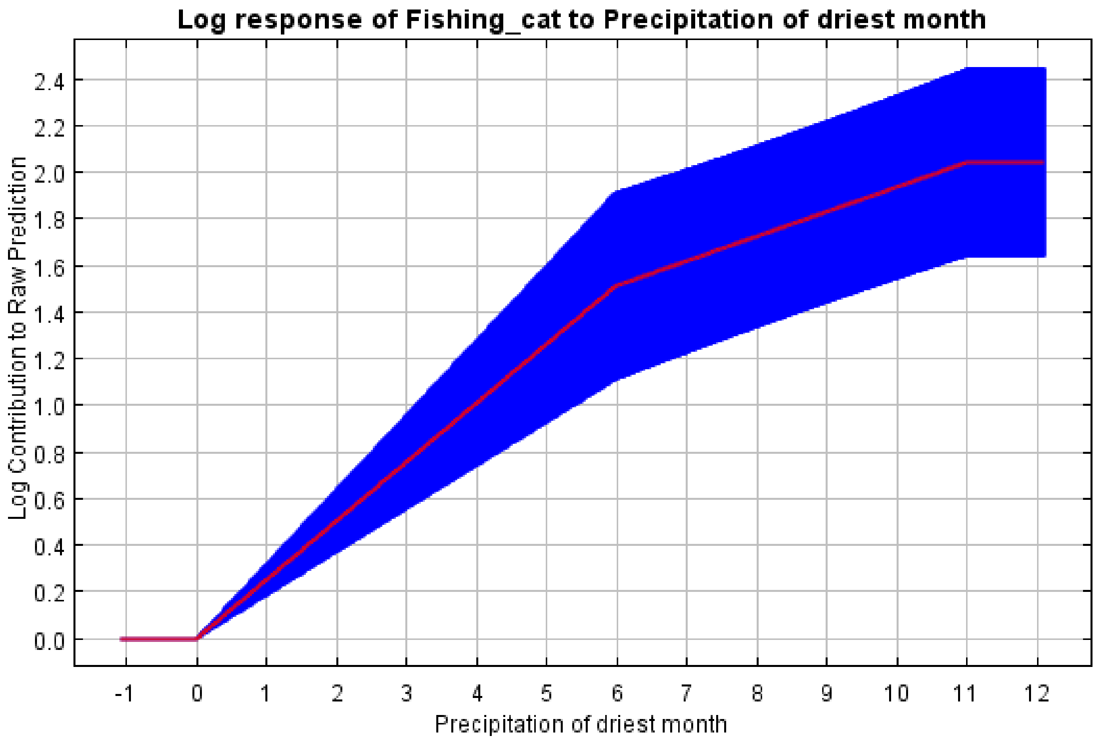

Log response of Fishing_cat to Fish production natural
Log Contribution to Raw Prediction
0.8
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
0
20000
40000
60000
80000
Fish production natural

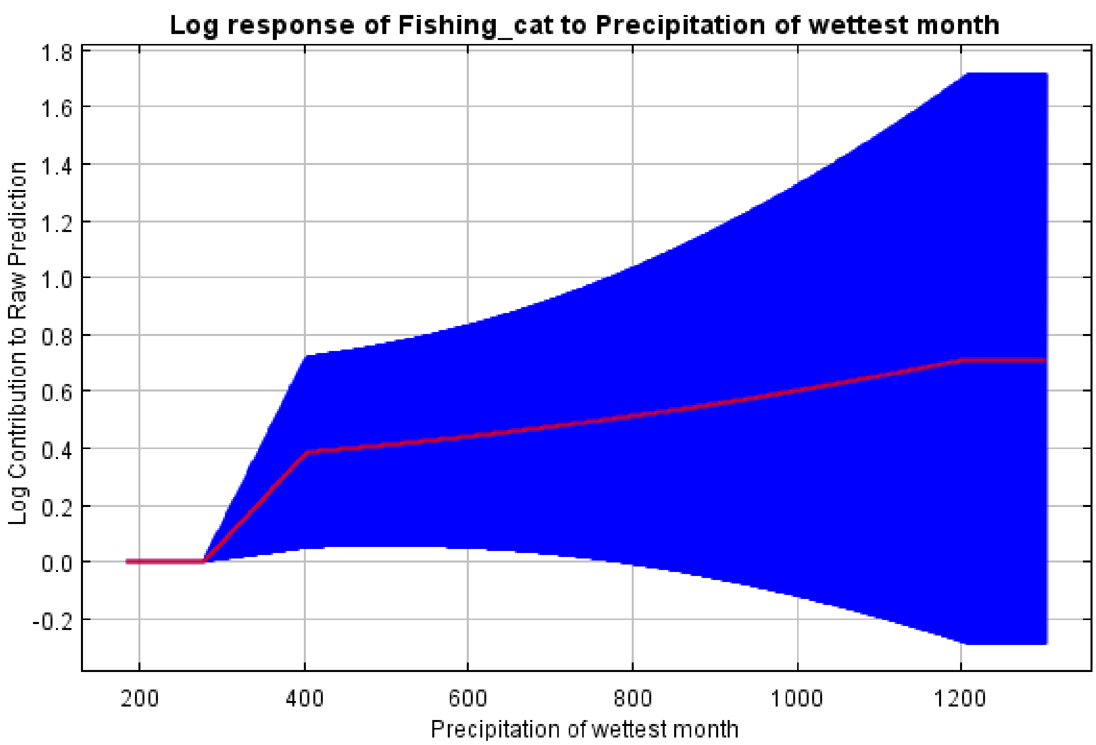

Log response of Fishing_cat to Human population
Log Contribution to Raw Prediction
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-10000
0
10000
20000
30000
40000
50000
60000
70000
80000
Human population


Log response of Fishing_cat to Maximum temperature of warmest month
Log Contribution to Raw Prediction
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
280
290
300
310
320
330
340
350
360
370
380
390
Maximum temperature of warmest month

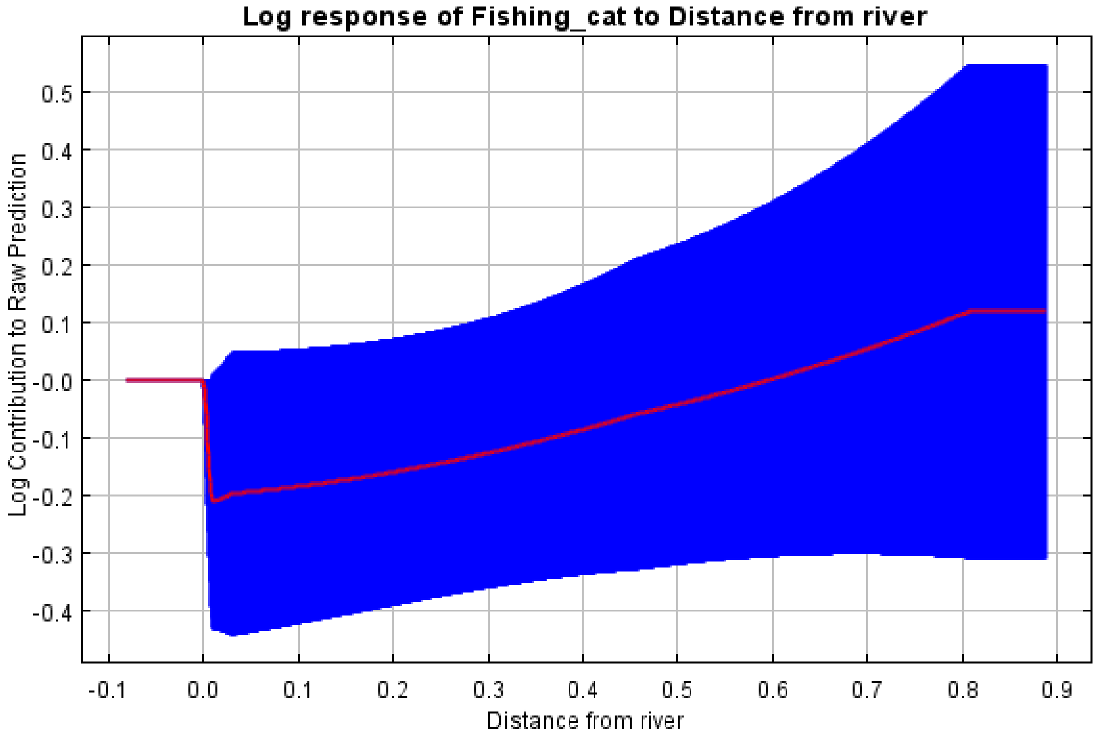

Log response of Fishing_cat to Minimum temperature of coldest month
Log Contribution to Raw Prediction
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
80
90
100
110
120
130
140
150
Minimum temperature of coldest month

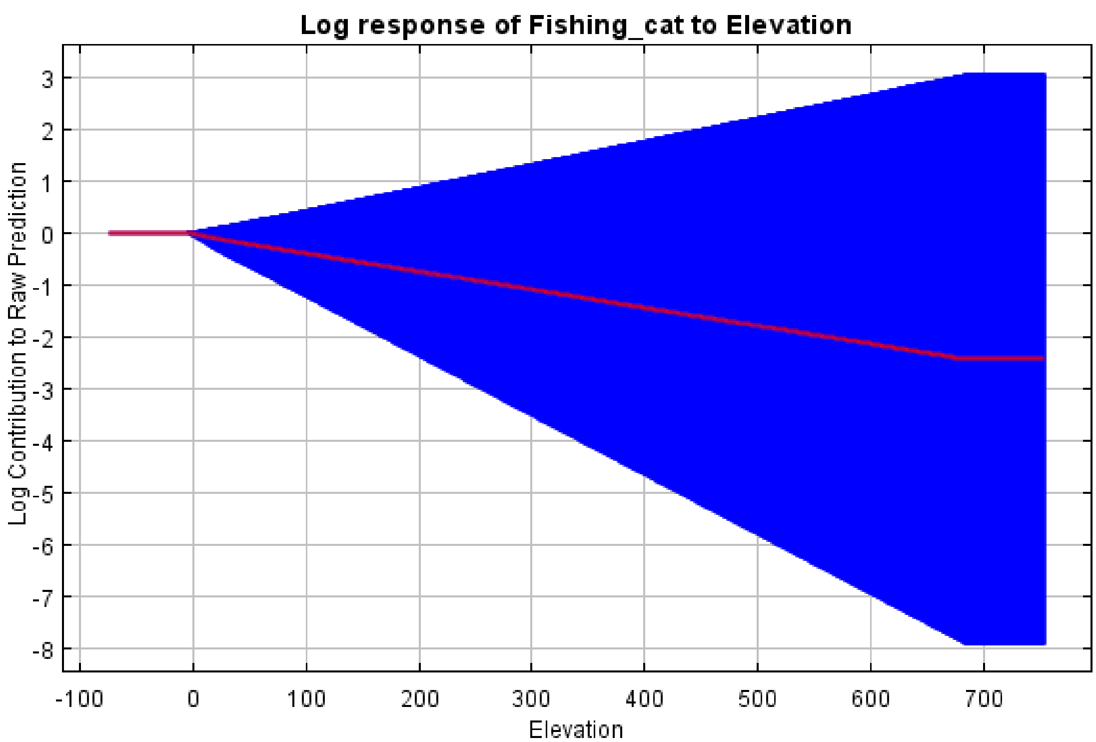

Log response of Fishing_cat to Percent of mangrove and wetland
Log Contribution to Raw Prediction
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Percent of mangrove and wetland

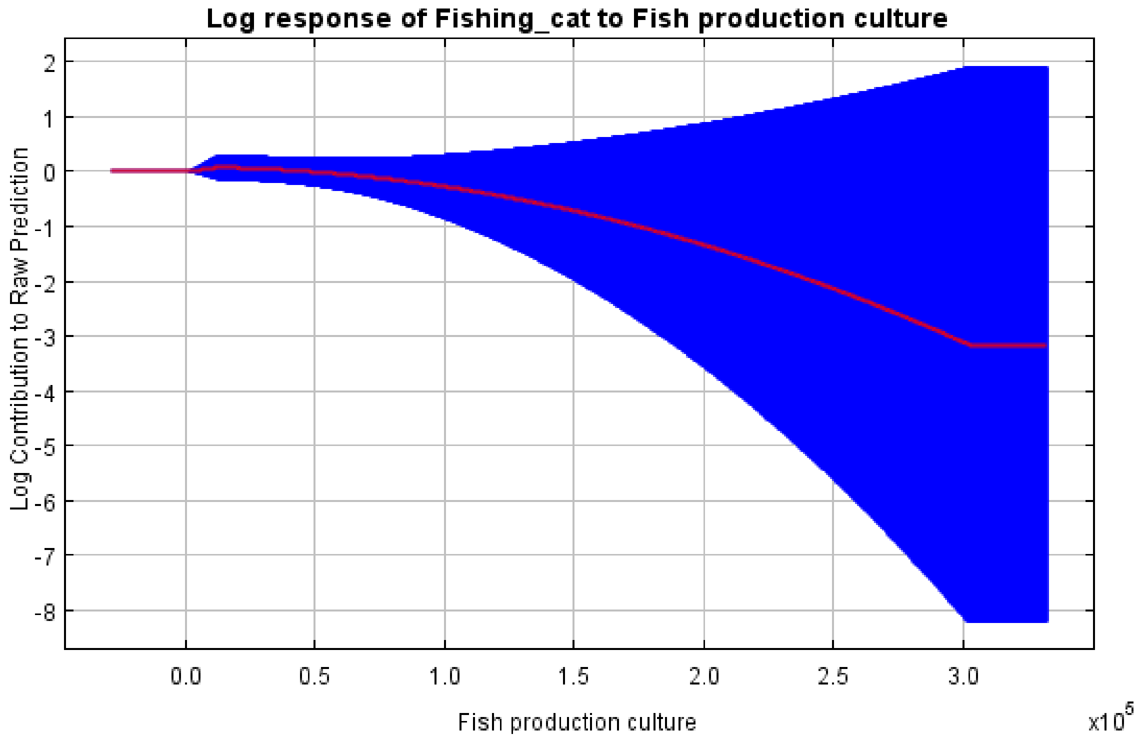

Log response of Fishing_cat to Precipitation of driest month
Log Contribution to Raw Prediction
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
Precipitation of driest month

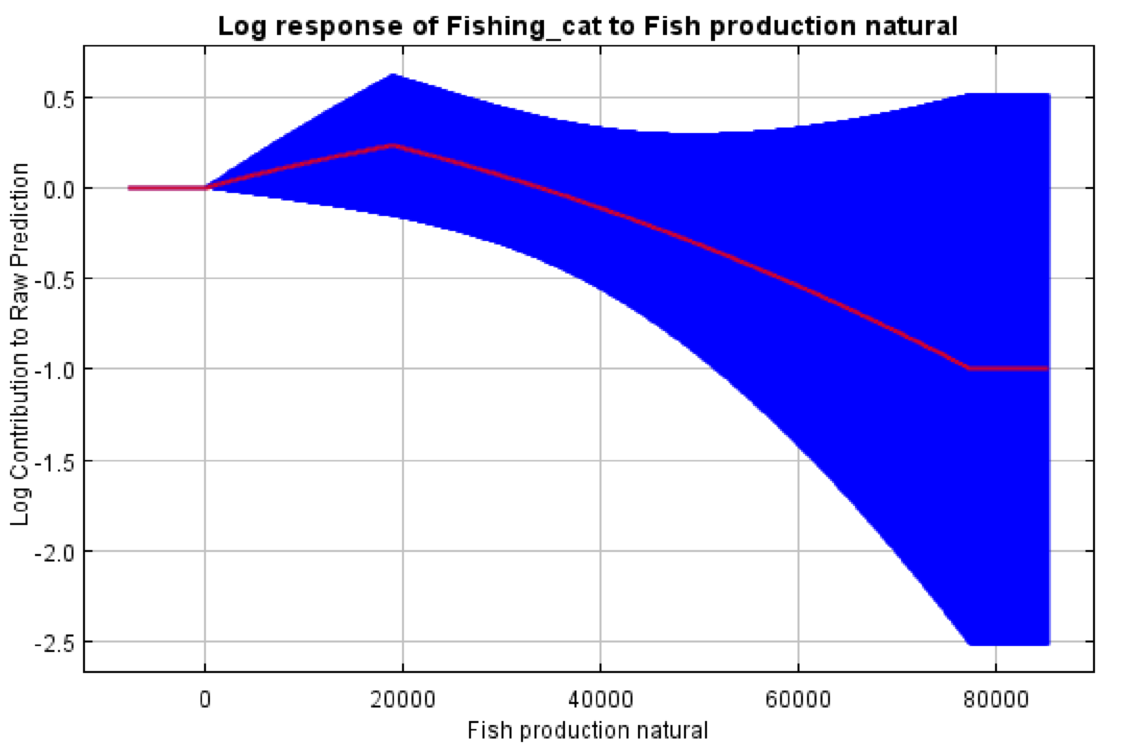

Log response of Fishing_cat to Precipitation of wettest month
Log Contribution to Raw Prediction
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
200
400
600
800
1000
1200
Precipitation of wettest month

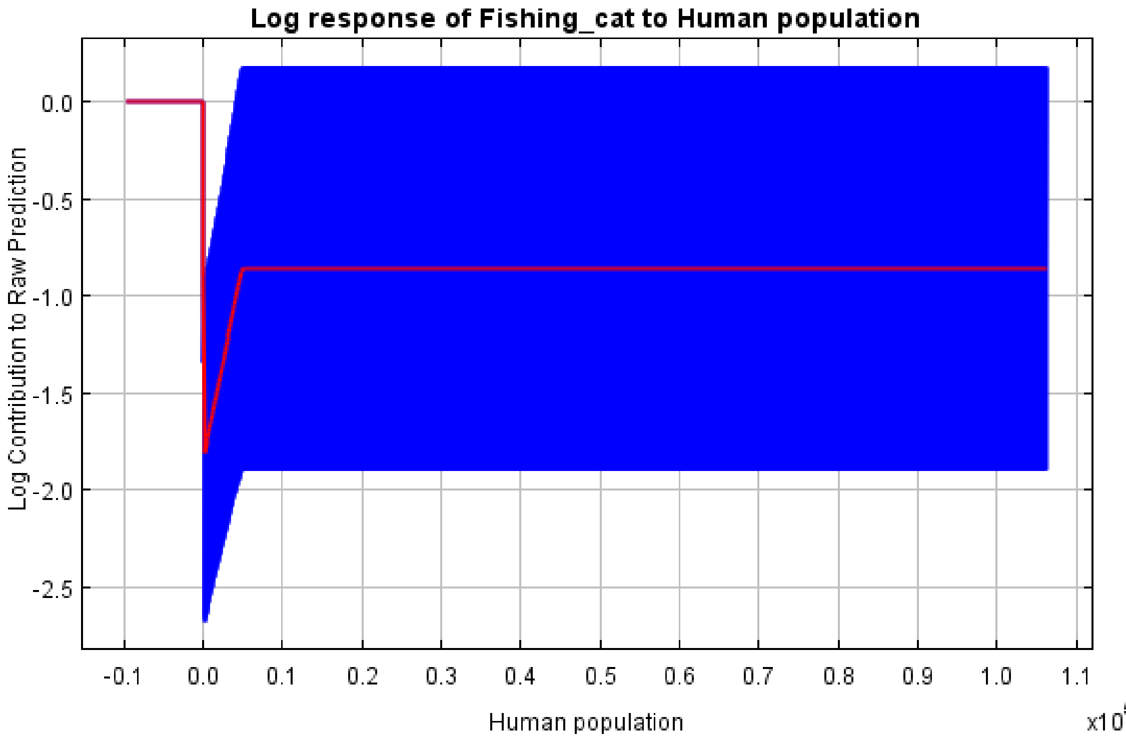
Model scenario II

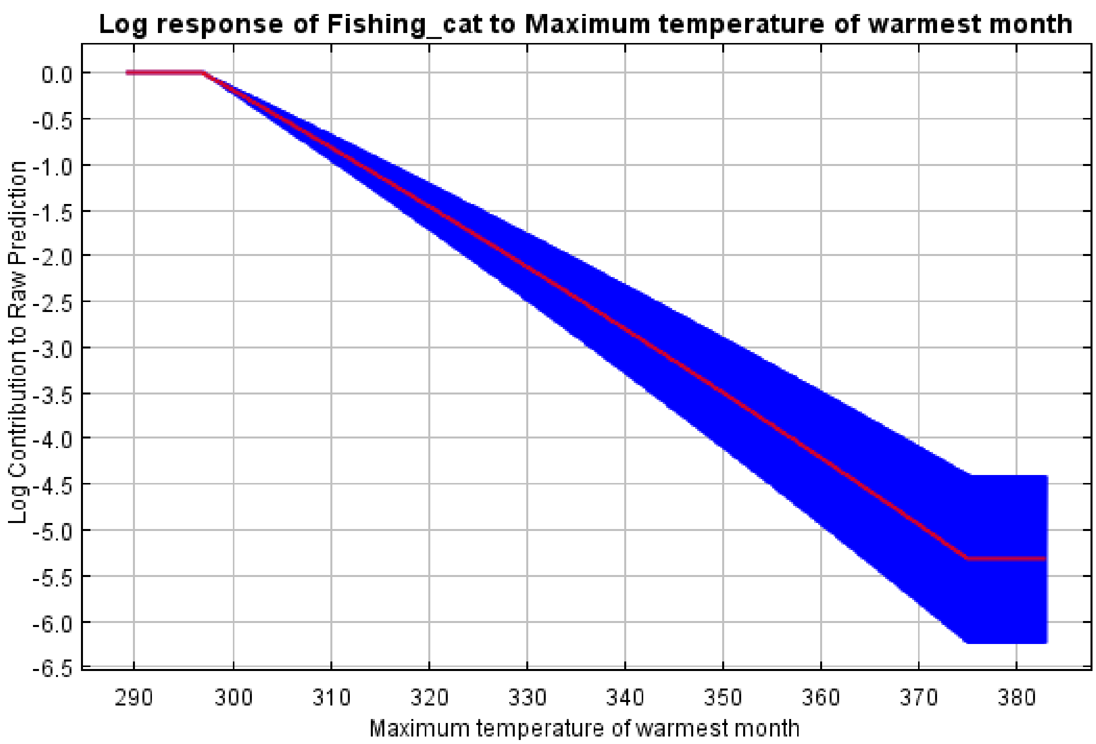


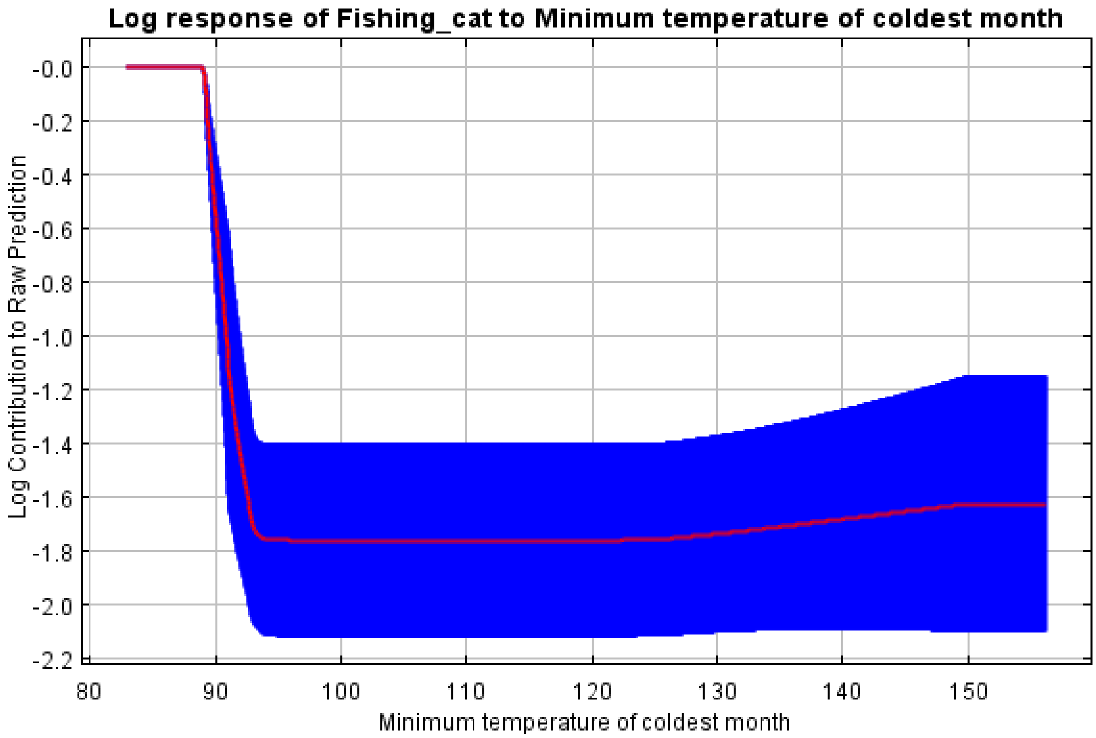


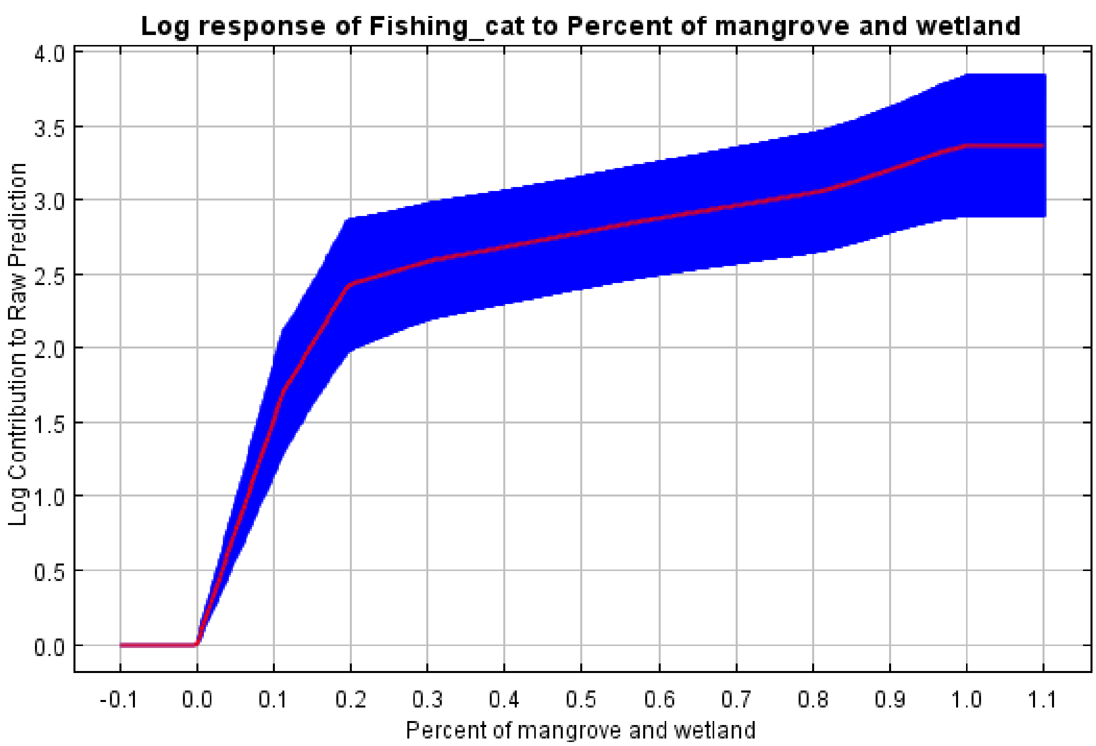

Log response of Fishing_cat to Fish production culture
Log Contribution to Raw Prediction
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Fish production culture
x10^5

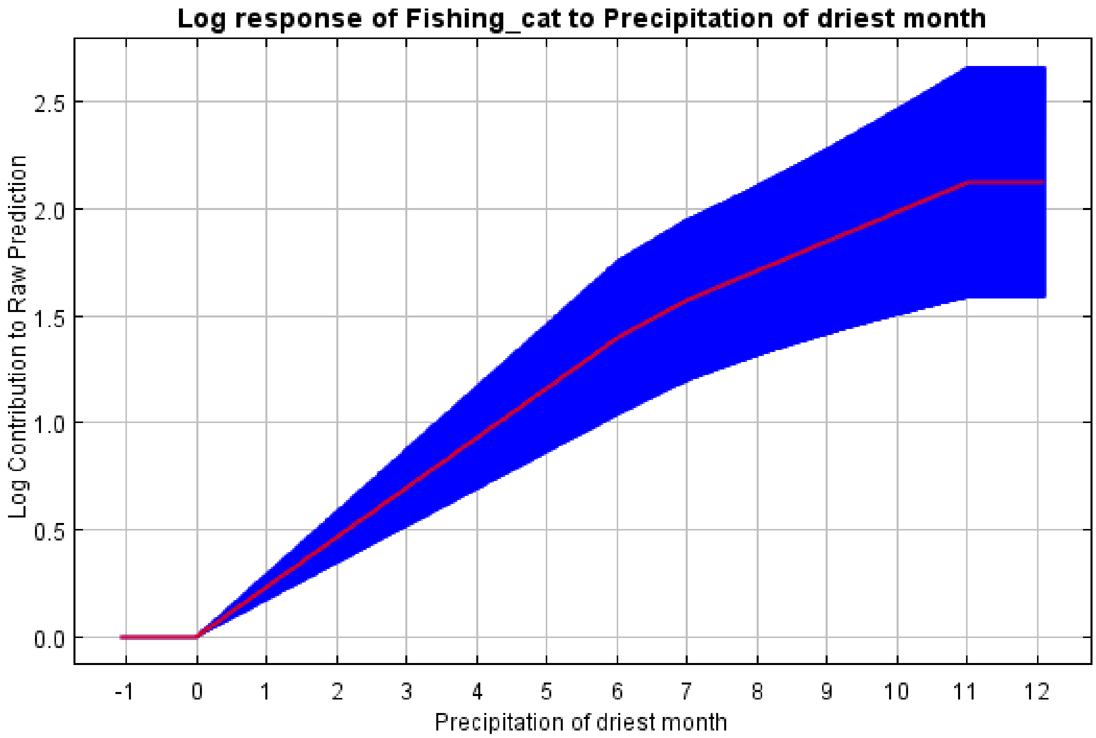

Log response of Fishing_cat to Fish production natural
Log Contribution to Raw Prediction
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0
20000
40000
60000
80000
Fish production natural

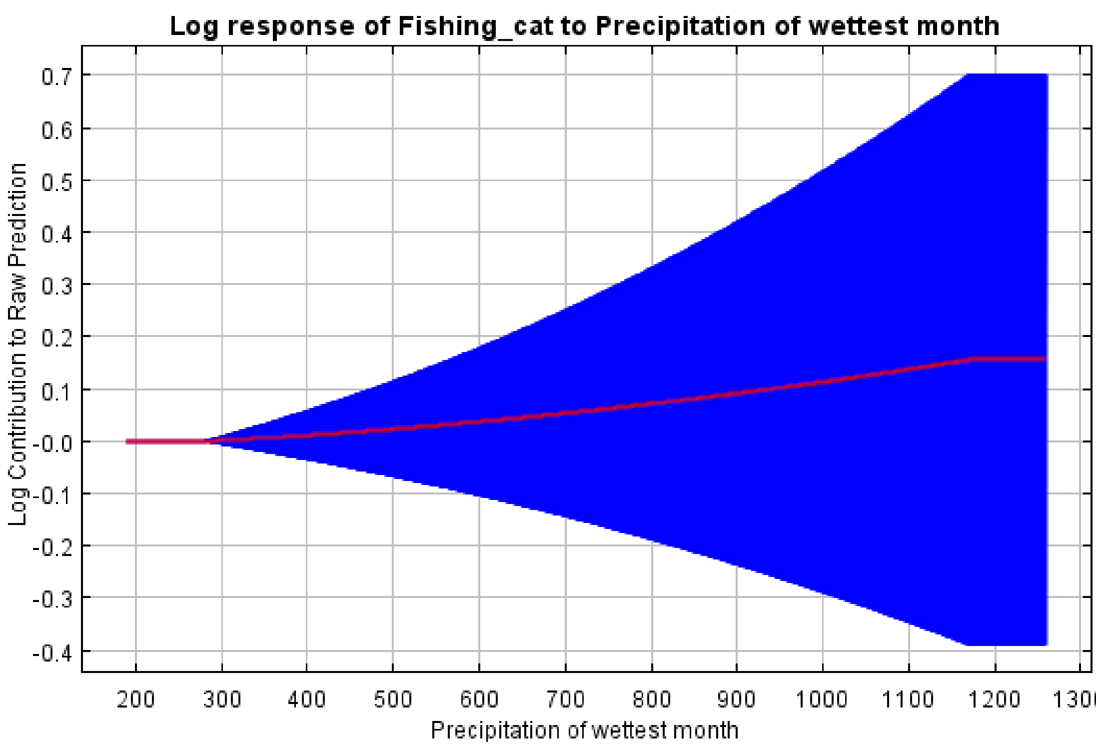

Log response of Fishing_cat to Human population
Log Contribution to Raw Prediction
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Human population
x10^5


Log response of Fishing_cat to Maximum temperature of warmest month
Log Contribution to Raw Prediction
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
-6.0
-6.5
290
300
310
320
330
340
350
360
370
380
Maximum temperature of warmest month

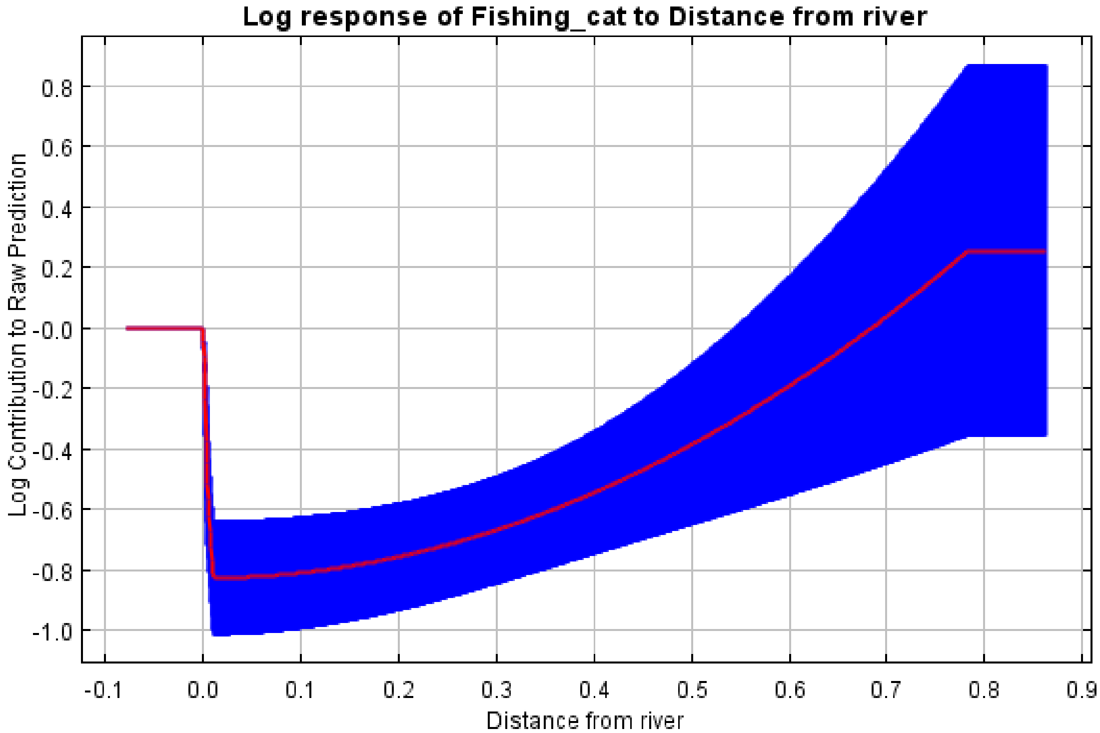

Log response of Fishing_cat to Minimum temperature of coldest month
Log Contribution to Raw Prediction
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
-2.2
80
90
100
110
120
130
140
150
Minimum temperature of coldest month

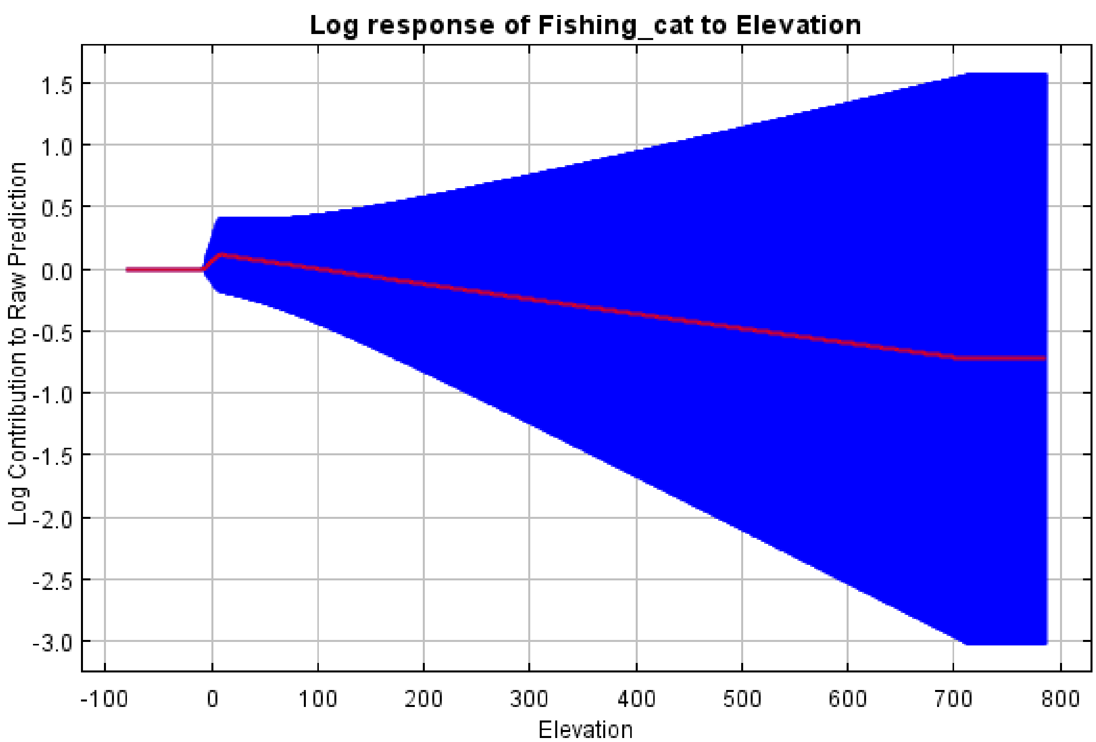

Log response of Fishing_cat to Percent of mangrove and wetland
Log Contribution to Raw Prediction
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Percent of mangrove and wetland

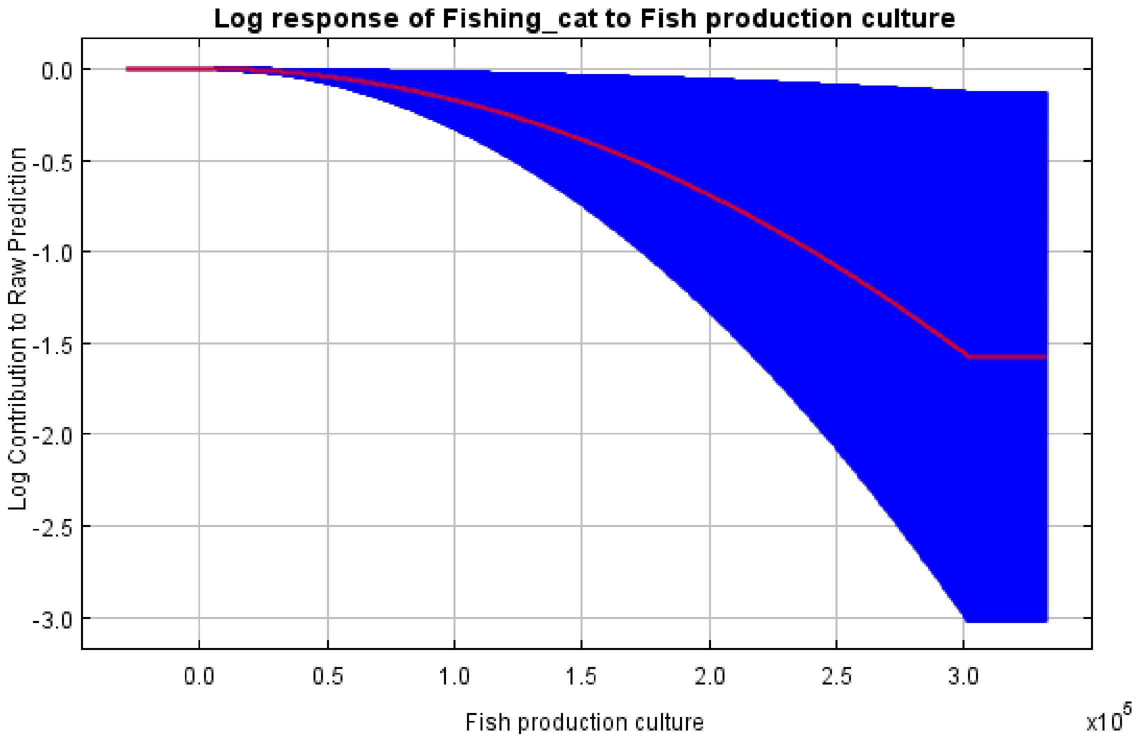

Log response of Fishing_cat to Precipitation of driest month
Log Contribution to Raw Prediction
2.5
2.0
1.5
1.0
0.5
0.0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
Precipitation of driest month

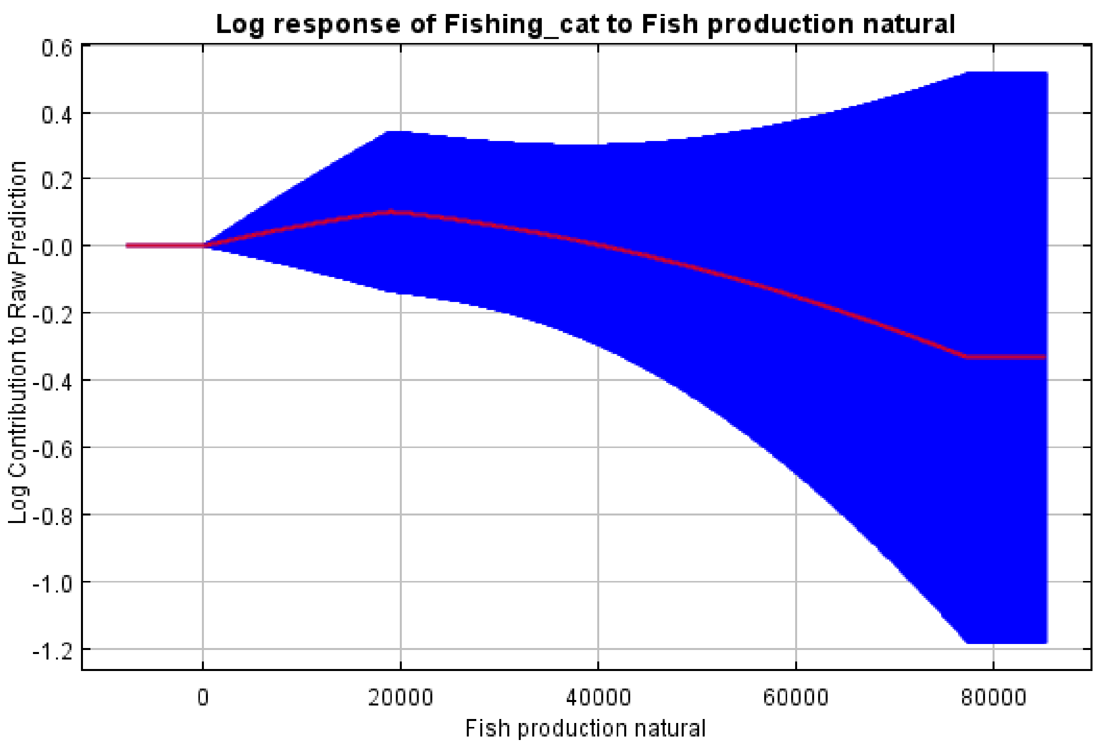

Log response of Fishing_cat to Precipitation of wettest month
Log Contribution to Raw Prediction
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Precipitation of wettest month

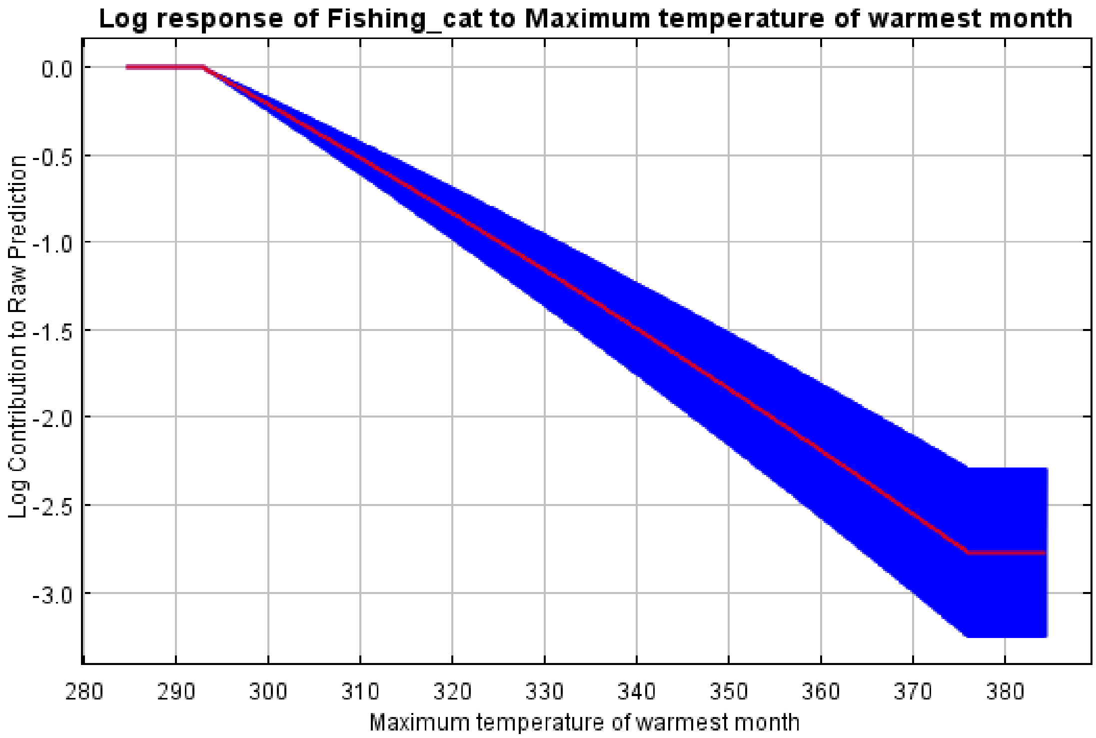
Model scenario III

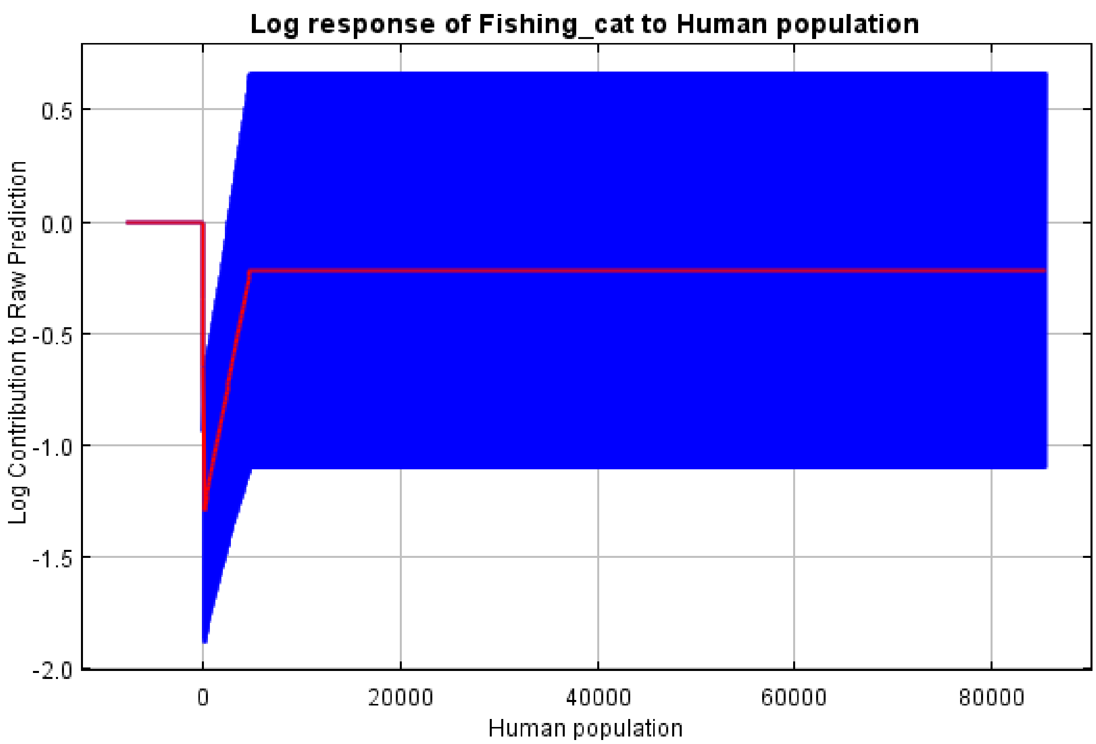


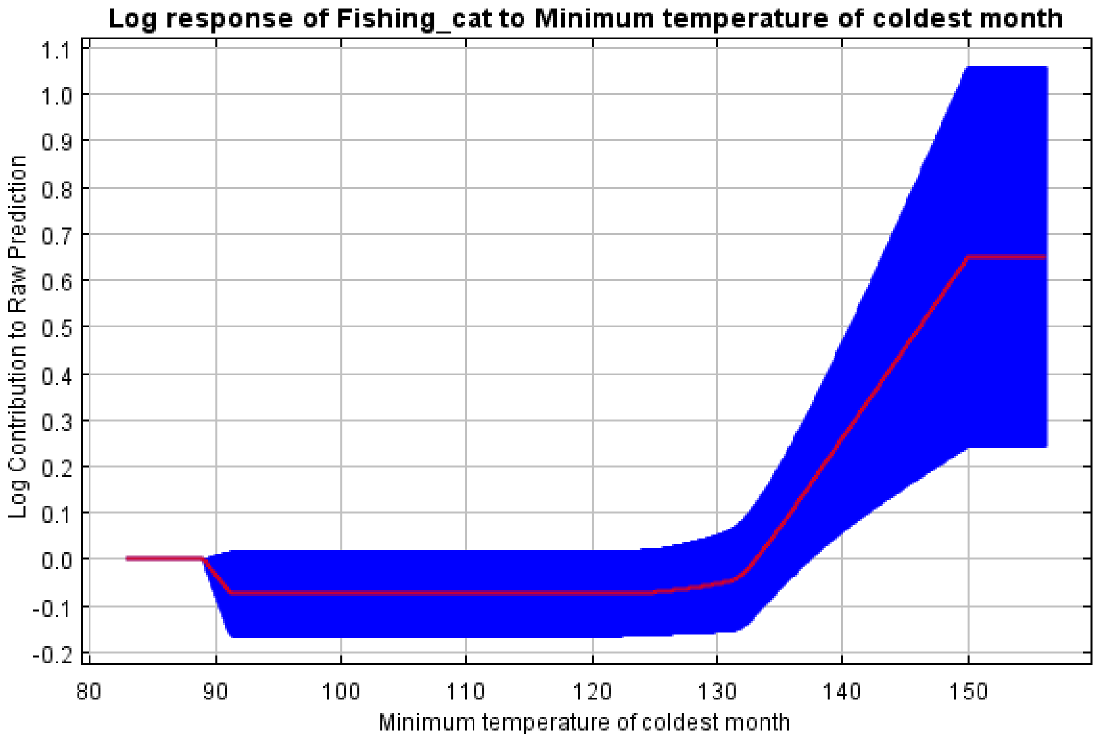



Log response of Fishing_cat to Fish production culture
Log Contribution to Raw Prediction
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Fish production culture
x10^5

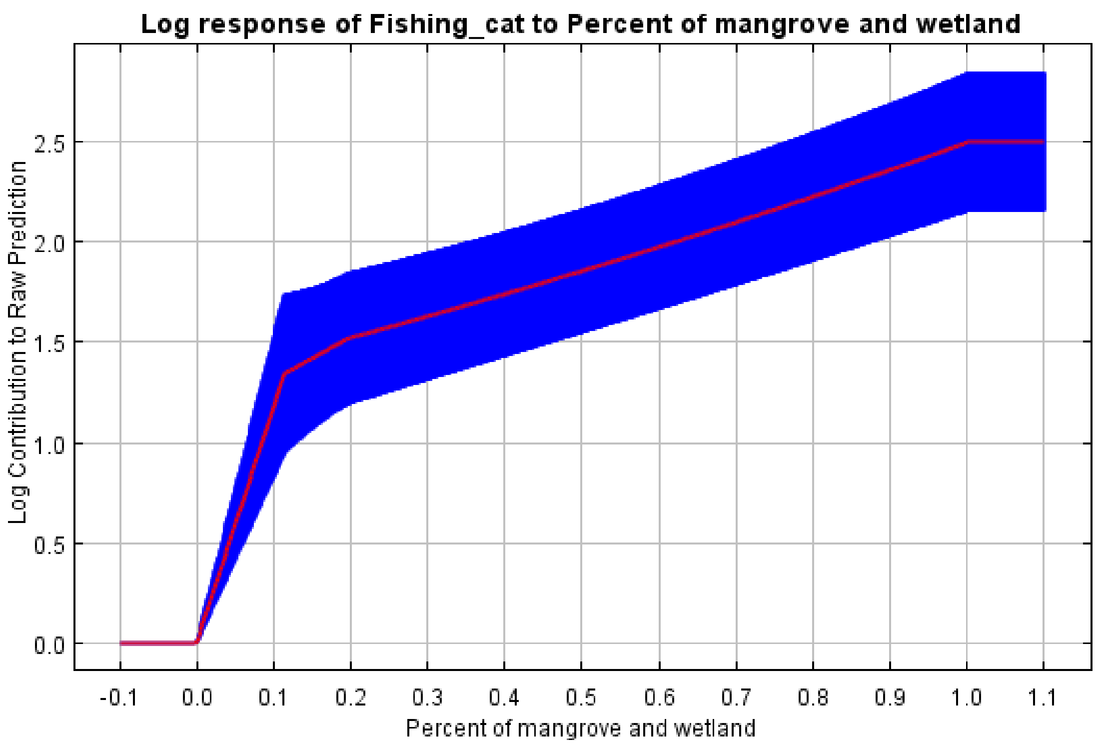

Log response of Fishing_cat to Fish production natural
Log Contribution to Raw Prediction
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
0
20000
40000
60000
80000
Fish production natural


Log response of Fishing_cat to Maximum temperature of warmest month
Log Contribution to Raw Prediction
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
280
290
300
310
320
330
340
350
360
370
380
Maximum temperature of warmest month

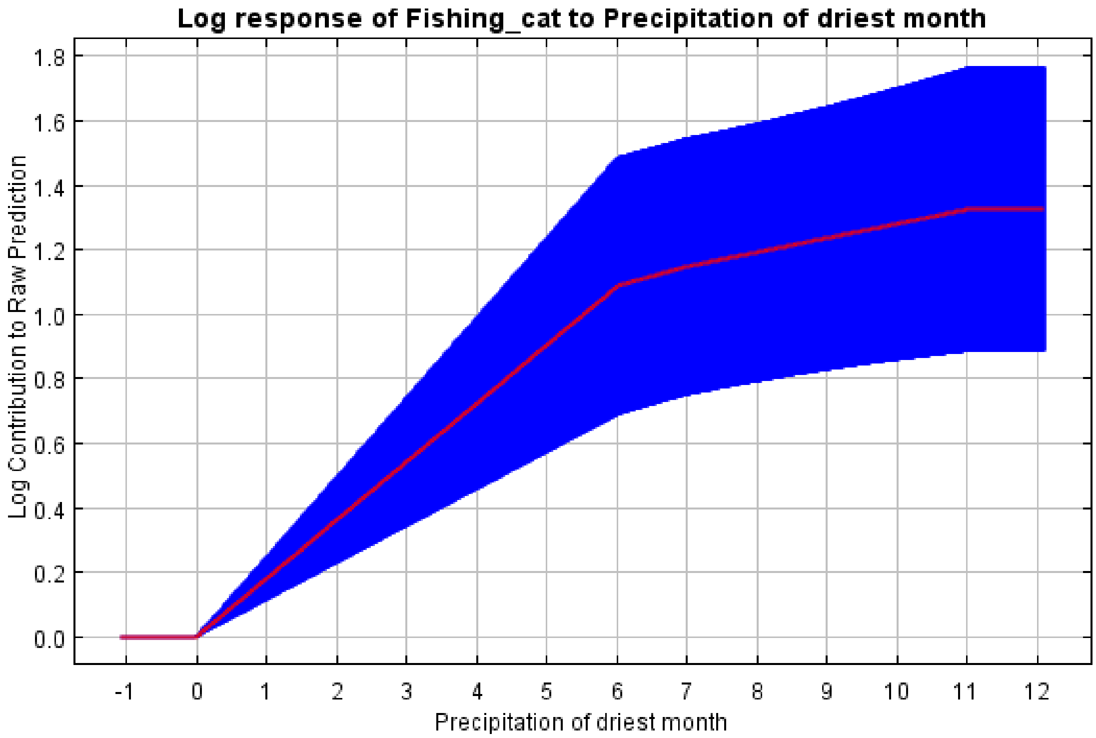

Log response of Fishing_cat to Human population
Log Contribution to Raw Prediction
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0
20000
40000
60000
80000
Human population

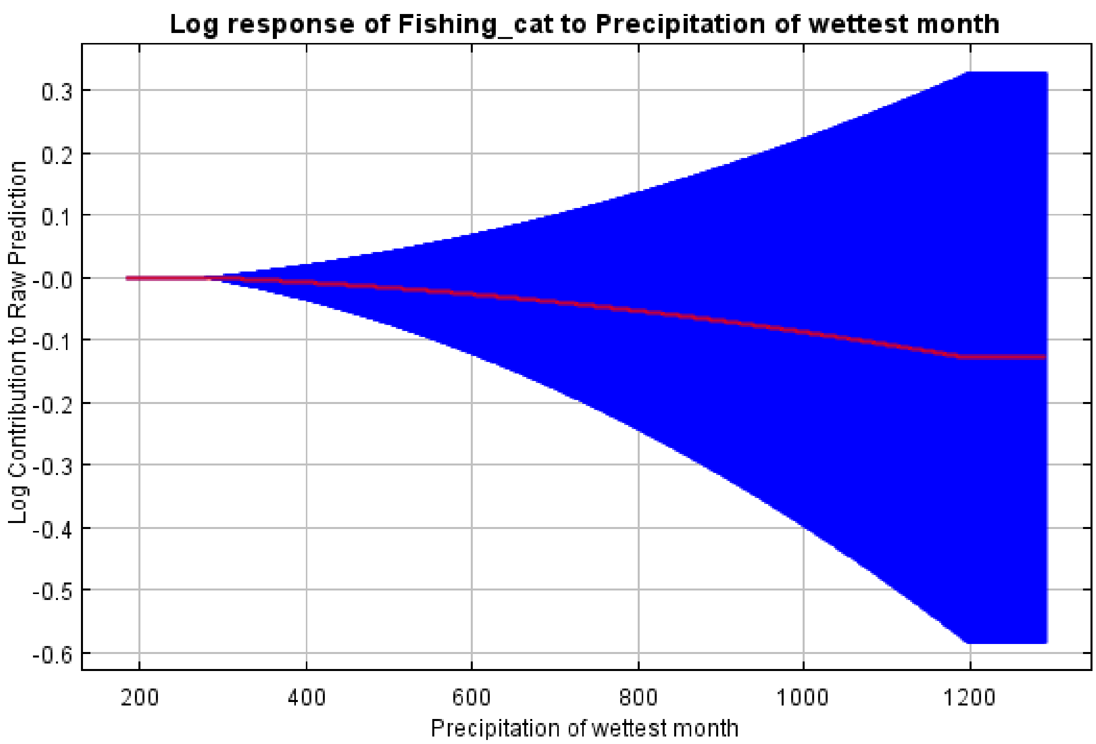


Log response of Fishing_cat to Minimum temperature of coldest month
Log Contribution to Raw Prediction
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
80
90
100
110
120
130
140
150
Minimum temperature of coldest month



Log response of Fishing_cat to Percent of mangrove and wetland
Log Contribution to Raw Prediction
2.5
2.0
1.5
1.0
0.5
0.0
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Percent of mangrove and wetland


Log response of Fishing_cat to Precipitation of driest month
Log Contribution to Raw Prediction
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
Precipitation of driest month


Log response of Fishing_cat to Precipitation of wettest month
Log Contribution to Raw Prediction
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
200
400
600
800
1000
1200
Precipitation of wettest month

APPENDIX C

Questionnaire for the household survey

Household Surveys of Interactions with Wild Felids at Rajkandi Reserve Forest, Komolgonj, Moulovibazar, Sylhet, Bangladesh.

The Study of the Ecology and Conservation of Sympatric Felids in North-east Bangladesh

Bangladesh Wild Cat Research Initiative

Survey Date:	_____________	Survey Number:	_____________
Respondent's Name:	_____________	Respondent's ID:	_____________
Sex:	_____________	Age:	____________
Occupation:	_____________	Interviewer:	_____________
Latitude:	_____________	Longitude:	_____________
Village	_____________	Union:	_____________
Sub-District	Komolgonj	District	Moulovibazar

Type of Crops Grown:____

Farm Size (ha):____

Type of Livestock:	Number:
________________________________	________________________________
________________________________	________________________________
________________________________	________________________________

1. Which of the following cat species have you seen here (show pictures) in the past 10 years (If none of these animals was seen, skip to question 6)?

1. Clouded Leopard	4. Common Leopard
2. Asiatic Golden Cat	5. Leopard Cat
3. Fishing Cat	6. Jungle Cat

2. If the following species were sighted, what habitats were they seen in (Check all that apply)?

Clouded Leopard:

1 Natural forest	5 Plantation
2 Forest edge	6 Crop field
3 Lowland	7 Hills
4 Village	8 Other___________

Asiatic Golden Cat:

1 Natural forest	5 Plantation
2 Forest edge	6 Crop field
3 Lowland	7 Hills
4 Village	8 Other_______________

Leopard Cat:

1 Natural forest	5 Plantation
2 Forest edge	6 Crop field
3 Lowland	7 Hills
4 Village	8 Other_______________

Fishing Cat:

1 Natural forest	5 Plantation
2 Forest edge	6 Crop field
3 Lowland	7 Hills
4 Village	8 Other_______________

Common Leopard

1 Natural forest	5 Plantation
2 Forest edge	6 Crop field
3 Lowland	7 Hills
4 Village	8 Other_______________

Jungle Cat

1. Natural forest	5 Plantation
2 Forest edge	6 Crop field
3 Lowland	7 Hills
4 Village	8 Other_______________

3. If the following species were sighted, were they inside or outside RRF (Check all that apply)? **Clouded Leopard:**

1 Inside RRF boundaries

2 Outside RRF boundaries

3 Both inside and outside RRF boundaries

Common Leopard:

1 Inside RRF boundaries

2 Outside RRF boundaries

3 Both inside and outside RRF boundaries

Asiatic Golden Cat:

1 Inside RRF boundaries

2 Outside RRF boundaries

3 Both inside and outside RRF boundaries

Leopard Cat:

1 Inside RRF boundaries

2 Outside RRF boundaries

3 Both inside and outside RRF boundaries

Fishing Cat:

1 Inside RRF boundaries

2 Outside RRF boundaries

3 Both inside and outside RRF boundaries

Jungle Cat:

1 Inside RRF boundaries

2 Outside RRF boundaries

3 Both inside and outside RRF boundaries

3. Please mark all areas where you have seen each species on the maps provided.

5. How many times have you seen each species in the past 10 years?

	1-5	6-10	11-50	51+
Clouded Leopard	□	□	□	□
Common Leopard	□	□	□	□
Asiatic Golden Cat	□	□	□	□
Leopard Cat	□	□	□	□
Fishing Cat	□	□	□	□
Jungle Cat	□	□	□	□

6. Do you think each species is increasing or decreasing in the area?

	Increasing	Decreasing	Don't Know
Clouded Leopard	□	□	□
Common Leopard	□	□	□
Asiatic Golden Cat	□	□	□
Leopard Cat	□	□	□
Fishing Cat	□	□	□
Jungle Cat	□	□	□

7. Have any of these species ever raided your livestock (If no, skip to question 9)?

	Yes	No
Clouded Leopard	□	□
Common Leopard	□	□
Asiatic Golden Cat	□	□
Leopard Cat	□	□
Fishing Cat	□	□
Jungle Cat	□	□

8. If yes to any of the above, how many animals have you lost to the following species over the past 10 years?

Clouded Leopard

Animals Raided:

Dogs	1	2	3	4	5	6	7	8
Goats	1	2	3	4	5	6	7	8
Sheep	1	2	3	4	5	6	7	8

Cows	1	2	3	4	5	6	7	8
Chickens	1	2	3	4	5	6	7	8

Total Monetary Loss in BDT: ____________

Common Leopard

Animals Raided:

Dogs	1	2	3	4	5	6	7	8
Goats	1	2	3	4	5	6	7	8
Sheep	1	2	3	4	5	6	7	8
Cows	1	2	3	4	5	6	7	8
Chickens	1	2	3	4	5	6	7	8

Total Monetary Loss in BDT: ____________

Asiatic Golden Cat

Animals Raided:

Dogs	1	2	3	4	5	6	7	8
Goats	1	2	3	4	5	6	7	8
Sheep	1	2	3	4	5	6	7	8
Cows	1	2	3	4	5	6	7	8
Chickens	1	2	3	4	5	6	7	8

Total Monetary Loss in BDT: ____________

Leopard Cat

Animals Raided:

Dogs	1	2	3	4	5	6	7	8
Goats	1	2	3	4	5	6	7	8
Sheep	1	2	3	4	5	6	7	8
Cows	1	2	3	4	5	6	7	8
Chickens	1	2	3	4	5	6	7	8

Total Monetary Loss in BDT:____________

Fishing Cat

Animals Raided:

Dogs	1	2	3	4	5	6	7	8
Goats	1	2	3	4	5	6	7	8
Sheep	1	2	3	4	5	6	7	8
Cows	1	2	3	4	5	6	7	8

Chickens	1	2	3	4	5	6	7	8

Total Monetary Loss in BDT:___________

Jungle Cat

Animals Raided:

Dogs	1	2	3	4	5	6	7	8
Goats	1	2	3	4	5	6	7	8
Sheep	1	2	3	4	5	6	7	8
Cows	1	2	3	4	5	6	7	8
Chickens	1	2	3	4	5	6	7	8

Total Monetary Loss in BDT:__________

9. What are your feelings about the following species?

Clouded Leopards:

□ □ □ □ □

1=Dislike Very Much 2=Dislike 3=Neutral 4=Like
5=Like Very Much

Common Leopards:

□ □ □ □ □

1=Dislike Very Much 2=Dislike 3=Neutral 4=Like
5=Like Very Much

Asiatic Golden Cats:

□ □ □ □ □

1=Dislike Very Much 2=Dislike 3=Neutral 4=Like
5=Like Very Much

Leopard Cats:

□ □ □ □ □

1=Dislike Very Much 2=Dislike 3=Neutral 4=Like
5=Like Very Much

Fishing Cats:

□ □ □ □ □

1=Dislike Very Much 2=Dislike 3=Neutral 4=Like
5=Like Very Much

Jungle Cats:

□ □ □ □ □

1=Dislike Very Much 2=Dislike 3=Neutral 4=Like
5=Like Very Much

10. Do you think that the following species should be protected in RRF?

Clouded Leopards:

□ □ □ □ □

1=No Protection 2=Limited Protection 3=Neutral 4=Protected 5=Strict Protection

Common Leopards:

□ □ □ □ □

1=No Protection 2=Limited Protection 3=Neutral 4=Protected 5=Strict Protection

Asiatic Golden Cats:

□ □ □ □ □

1=No Protection 2=Limited Protection 3=Neutral 4=Protected 5=Strict Protection

Leopard Cats:

□ □ □ □ □

1=No Protection 2=Limited Protection 3=Neutral 4=Protected 5=Strict Protection

Fishing Cats:

□ □ □ □ □

1=No Protection 2=Limited Protection 3=Neutral 4=Protected 5=Strict Protection

Jungle Cats:

□ □ □ □ □

1=No Protection 2=Limited Protection 3=Neutral 4=Protected 5=Strict Protection

11. Have you heard of any of the following species being killed in this area during the past 10 years?

	No	Yes	If yes, how many?
Clouded Leopard	□	□	_________
Common Leopard	□	□	_________
Asiatic Golden Cat	□	□	_________

Leopard Cat	◻	◻	________
Fishing Cat	◻	◻	________
Jungle Cat	◻	◻	________

Is there anything else that you want to tell us about these species and their conservation?

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