Assessing the distribution and density of the Fishing Cat in Bhitarkanika mangroves of eastern India

by

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Under the supervision of

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AcSIR

July 2024

DECLARATION

I hereby declare that the work conducted under the thesis entitled **"Assessing the distribution and density of the Fishing Cat in Bhitarkanika mangroves of eastern India",** is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science** at the **Academy of Scientific and Innovative Research**. This research work has been carried out under the guidance and supervision of **Dr. Shomita Mukherjee**, **Senior Principal Scientist, SACON** and co-supervision of **Dr. G V Gopi, Scientist – F** and **Dr. Bivash Pandav, Scientist -G** of Wildlife Institute of India, Dehradun. The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my own work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.

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CERTIFICATE

This is to certify that the thesis by **Ashik C S** entitled "**Assessing the distribution and density of the Fishing Cat in Bhitarkanika mangroves of eastern India**" is an original and independent research work submitted to the **Academy of Scientific and Innovative Research**, for the award of the degree of **Master's in Wildlife Science**.

Ashik C S has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

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Abstract

Identifying the areas of occurrence, population, and the factors affecting the species distribution is critical in conservation and management. The Fishing Cat (*Prionailurus viverrinus*), a smaller feline native to South and Southeast Asia, is globally vulnerable and adapted to wetland habitats, with a diet primarily consisting of fish. This makes Bhitarkanika, a mangrove ecosystem, an ideal habitat for the Fishing Cat. This study was conducted to estimate the species density, determine the factors affecting its distribution, and assess the effect of lunar illumination and tidal fluctuation on Fishing Cat activity. Despite known occurrences of Fishing Cats in this area, there has been no proper assessment of their population or other ecological studies. Camera traps were deployed in 109 grids, each covering $1km^2$, across a total of 145 km^2, for 2878 trap nights. Camera trap locations are unbaited, with two cameras used to capture both flanks. Spatially explicit capture-recapture (SECR) was used to estimate the density, resulting in 0.6 ± 0.1 individuals per km^2. The abundance was also calculated, with an estimate of 99 ± 16 individuals. These density estimates from this study are close to recent high-density estimates for the species.

The canopy cover, the width of the creek, canopy cover and the distance to the aquaculture farms significantly influenced the Fishing Cat habitat use, indicating the need for the conservation of natural mangrove habitats and regulation of aquafarms present near the forest. In contrast, the presence of Saltwater Crocodile showed a negative effect on the distribution of Fishing Cats. The Fishing Cats were more active during the brighter nights of the moon phase (μ= 266.783, r= 0.051, $p< 0.01$) due to better visual detection. The activity was influenced both by the tidal fluctuations in terms of food resources from waterbodies and it is further enhanced by the lunar illumination during the night. Pairwise non-parametric tests showed that the probability distributions of Fishing Cat activity under lunar illumination and tide fluctuation (D= 0.125, p-value = 0.9885 and D= 0.125, p-value= 0.9899) were similar, indicating minimal

differences between each probability distribution. This study underscores the importance of protecting the mangrove habitat and controlling aquaculture expansion to ensure Fishing Cat survival in the Bhitarkanika National Park.

1. Introduction:

Globally, there are 41 species of cats belonging to 14 genera in the family Felidae, of which 33 species belong to small cats (Kitchener et al., 2017). The size of these wild cats varies from 1-2 kg Rusty-spotted Cat to 250 kg Bengal Tiger (Sunquist & Sunquist, 2020). Felids are obligate carnivores and play a major role in ecosystem functions, and understanding of their ecology, behavior, habitats, and threats is essential for their conservation. However, big cats have received comparatively more attention in research and conservation efforts (Brodie, 2009; Sanderson and Watson, 2011; Mugerwa et al., 2020) than smaller cats. All smaller cats are solitary and secretive in nature which makes them difficult to study despite advances in new methods and technology. The research on smaller cats is increasing significantly (Brodie, 2009), which helps in understanding the ecology and behavior of these lesser-known species. The Fishing Cat (*Prionailurus viverrinus*) is one such smaller cat, belonging to the leopard cat lineage that includes several Asian small cats (Sanderson & Watson, 2011).

The Fishing Cat (*Prionailurus viverrinus*) is a relatively lesser-known feline species found in South and Southeast Asia (Mukherjee et al., 2016). In 2016, the Fishing Cat was reclassified from "Endangered" to "Vulnerable" by the International Union for Conservation of Nature (IUCN) due to an increased amount of information available on their distribution than previously. Local populations of Fishing Cat are believed to be declining significantly due to human activities and the degradation of wetlands, rivers, and mangroves, which are potential habitats of the Fishing Cat (Mukherjee et al., 2012; Cutter 2015). This smaller cat is also listed in the Scheduled-I species of the Wild Life (Protection) Amendment Act 2022, which provides the most possible protection.

1.1 Global and regional distribution

This smaller cat has a wide but patchy distribution in the South and Southeast Asian lowlands (Mukherjee et al., 2016; Mishra et al., 2018; Silva et al., 2020). It has a decreasing trend of population status globally. In India, the Fishing Cat is reported to be found in different types of wetlands, especially along the east coast's mangrove zones and floodplains (Chakraborty et al., 2020). It is distributed in tiny patches of foothills of the Himalayas (Uttarakhand, Uttar Pradesh), in the northeast (Assam), along the east coast (Andhra Pradesh, Odisha, West Bengal, and Bihar), and in Rajasthan (Sunquist & Sunquist, 2002; Mukherjee et al., 2012, 2016; Sadhu & Reddy, 2013; Menon, 2014; Appel & Duckworth, 2016; Ahmed et al., 2017; Palei et al., 2018; Kolipaka et al., 2019; Chakraborty et al., 2020; Malla et al., 2023).

In Odisha, the Fishing Cat distribution is more prominent in the coastal regions where the mangrove provides a suitable habitat for its survival (Palei et al., 2018). Bhitarkanika National Park is the only Protected Area in the state that protects some populations of Fishing Cats (Palei et al., 2018). However, it is also found to occur in other habitats like human habitats, rice fields, aquaculture farms, and wetlands outside the Protected Areas (Palei et al., 2021), and there is a scarcity of information on the distribution and ecology of this cat in Odisha (Palei et al., 2018). It is reported to occur in Bhitarkanika, Similipal, Hadagarh, Chilika, Mangalajodi marshland, Puri, Ganjam, and Kendrapara (Das et al., 2023).

1.2 Habitat and behaviour

The Fishing Cat is a habitat specialist, and its habitat includes wetland areas like ponds, oxbow lakes, rivers, swamps, and mangroves (Adhya, 2011; Mukherjee et al., 2012; Cutter, 2015; Chakraborty et al., 2020; Mishra et al., 2022). These unique areas provide a critical habitat for the survival of the Fishing Cat. The mangroves are the tidal forest in the intertidal zones like estuaries, tidal creeks, lagoons, marshes, and mud flats on the east coast of India, harbouring some remnant populations of Fishing Cats. Habitat specialist animals are very prone to the changes in the surrounding environment, so identifying the factors that are influencing the occurrence of the specific animal plays a crucial role for conservation and management. Various factors that affect the availability of resources, movement, and other ecological aspects have to be examined.

The Fishing Cat is predominantly a nocturnal animal (Ganguly & Adhya, 2022). It is known for its exceptional ability to hunt in water, which most cat species avoid. It is perfectly adapted for life near water bodies like wetlands, mangroves, swamps, and rivers to hunt fish (Mukherjee et al., 2012, 2016; Cutter, 2015; Kolipaka et al., 2019). Fish forms the central part of its diet, followed by crabs in the mangrove habitat (Malla et al. 2023), but it may also prey on molluscs, arthropods, amphibians, reptiles, and small mammals in other habitats (Haque & Vijayan, 1993; Sunquist & Sunquist, 2002; Macdonald et al., 2010). The study of animal behaviour in relation to environmental variables provides crucial insights for wildlife conservation and management. Among these variables, climatic and weather patterns have a significant influence on animal behaviour (Cozzi et al., 2012). Moon light variation, in particular, has been observed to significantly impact the activity patterns of numerous nocturnal animals (Kotler et al., 2010, Penteriani et al., 2010, Prugh et al., 2014). Despite extensive research on various nocturnal species, the influence of moonlight on the activity patterns of Fishing Cat remains poorly understood, especially in mangrove habitats where water levels change with the lunar cycle.

Plate 1: Study species- Fishing Cat (Prionailurus_viverrinus) seen lounging amidst the pneumatophore roots in Bhitarkanika National Park.

1.3 Conservation challenge

Despite special adaptations, Fishing Cats face numerous conservation challenges, mainly because of habitat loss and degradation due to agriculture, urbanization, and infrastructure development (Mukherjee et al., 2012, 2016; Cutter, 2015). Many instances of human-Fishing Cat conflicts happen as they are involved in preying on fish from the aquacultures and fishing nets, posing a significant threat to their survival (Chakraborty et al., 2020; Palei et al., 2018). Mukherjee et al., (2016) reported that the global population of Fishing Cats has possibly declined by 30% during the last 15 years and is at grave risk of a further 30% decline in the coming years if the threats persist. Targeted study of the Fishing Cat is essential to help plan their conservation and management strategy.

1.4 Knowledge gaps and significance of this study

There had been no systematic study focusing on the Fishing Cat in Bhitarkanika National Park till now. Moreover, past Red List assessments do not report the presence of the species in Bhitarkanika National Park but people have sighted the species in this area (Palei et al., 2018). There is a paucity of information on Fishing Cat densities and the threats they face across much of their global distribution (Phosri et al., 2021). Since they occur in very varied ecosystems ranging from mangrove habitats to wetlands in semi-arid areas, conservation plans for the species are required to be region-specific. This study aims to decipher the distribution pattern, density estimates, and behavioural aspects such as activity during lunar cycles in the mangrove landscape of Bhitarkanika National Park. This would help the Park management in taking up necessary measures for the conservation of this species by undertaking location-specific intervention wherever needed.

1.5 Objectives

1. To understand how the patch heterogeneity in size influence the density of Fishing Cat across Bhitarkanika mangroves.
2. To assess the factors governing the occurrence of Fishing Cat in the Bhitarkanika mangrove
3. To assess the effects of lunar cycle and tidal fluctuation on Fishing Cat activity patterns.

Questions and expectations

1. How does the patch heterogeneity in size influence the density of Fishing Cat across the Bhitarkanika mangroves?

Hypothesis:

- The mainland (large patch) in the Bhitarkanika National Park shares its boundary with human habitation. Because of the proximity and connectivity of the mainland with human habitation, they are more prone to disturbance from humans, I expected the Fishing Cat density would be higher in the isolated islands (smaller patches) where there is a minimum disturbance from humans.

2. How are Fishing Cats distributed in Bhitarkanika mangroves?

Will be examining how Fishing Cats are distributed with respect to creeks, Saltwater crocodiles, and distance to aquafarms.

Hypothesis:

- The Fishing Cat diet primarily consists of aquatic prey like fish and crabs, which are abundant in the mangrove ecosystems (Malla et al., 2023). In Bhitarkanika mangroves, these aquatic preys are mainly found in the creeks. The availability of preys in the creeks depends on the tidal fluctuations. Therefore, I expected that Fishing Cats would be more distributed towards the creeks with wider width as the wider creek retain water during both high and low tide and have larger mudflat areas, ensuring a consistent supply of prey.
- Fishing Cats are also known to hunt fish in aquafarms that are located outside the National Park (Palei et al., 2018) as these offer easy prey. So, if this is the case, I expected them to be more distributed towards the fringe areas closer to aquafarms.
- Saltwater Crocodile and Fishing Cat share the same food resources in the Bhitarkanika mangroves to some extent. Considering the hypothesis, I expected Fishing Cat would avoid the areas of Saltwater Crocodile presence.

3. How do the lunar cycle and tidal fluctuations influence the activity of the Fishing Cat in the Bhitarkanika mangroves?

Hypothesis: Tidal fluctuation drives the ecosystem functionality in mangroves, with large portion of the mangroves being flooded during the spring tide, but not during the neap tide.

- Different phases of the moon affect the activities of certain nocturnal animals. As the Fishing Cat is predominantly a nocturnal species, visibility during the nighttime likely influence its activity, whether hunting of fishes in the water or other prey on land. The moon illumination would play an important parameter for shaping the activity pattern of the Fishing Cat. During the full moon and new moon, there will be strong high and low tides which results in the inundation of different habitats, enhancing the foraging activity of some fishes. The local fishermen also take advantage of this phenomenon to get high catch during fishing. So, I expect that the activity peaks during the full moon due to better visibility to catch the prey.
- During the low tide the water depth will be shallow, and mudflats are more exposed, providing the Fishing Cat opportunities to hunt for fish, crab, and other prey in the shallow water and on mudflats (Malla & Sivakumar, 2014), hence I expected the higher activity of the Fishing Cat during low tide, as shallow water would allow the Fishing Cat to both hunt the fishes and explore more mudflats.

2. STUDY AREA

2.1 Location

The Bhitarkanika National Park is located in the deltaic region of Brahmani and Baitarani rivers of the Kendrapara district of Odisha. It is situated between 20° 30' and 20° 48'N and 86° 46' - 87° 01'E on the northeastern coast of the state in Kendrapara district. Bhitarkanika National Park covers an area of 145sq. km and to the east of Bhitarkanika is the Gahirmatha Beach and Marine Sanctuary, which divides the Bay of Bengal from the swampy area covered with mangrove canopy. Bhitarkanika Wildlife Sanctuary was established in April 1975 and is spread across a 672-square-kilometer area, of which the core area of the sanctuary was designated as Bhitarkanika National Park in September 1998 with an area of 145 square kilometers.

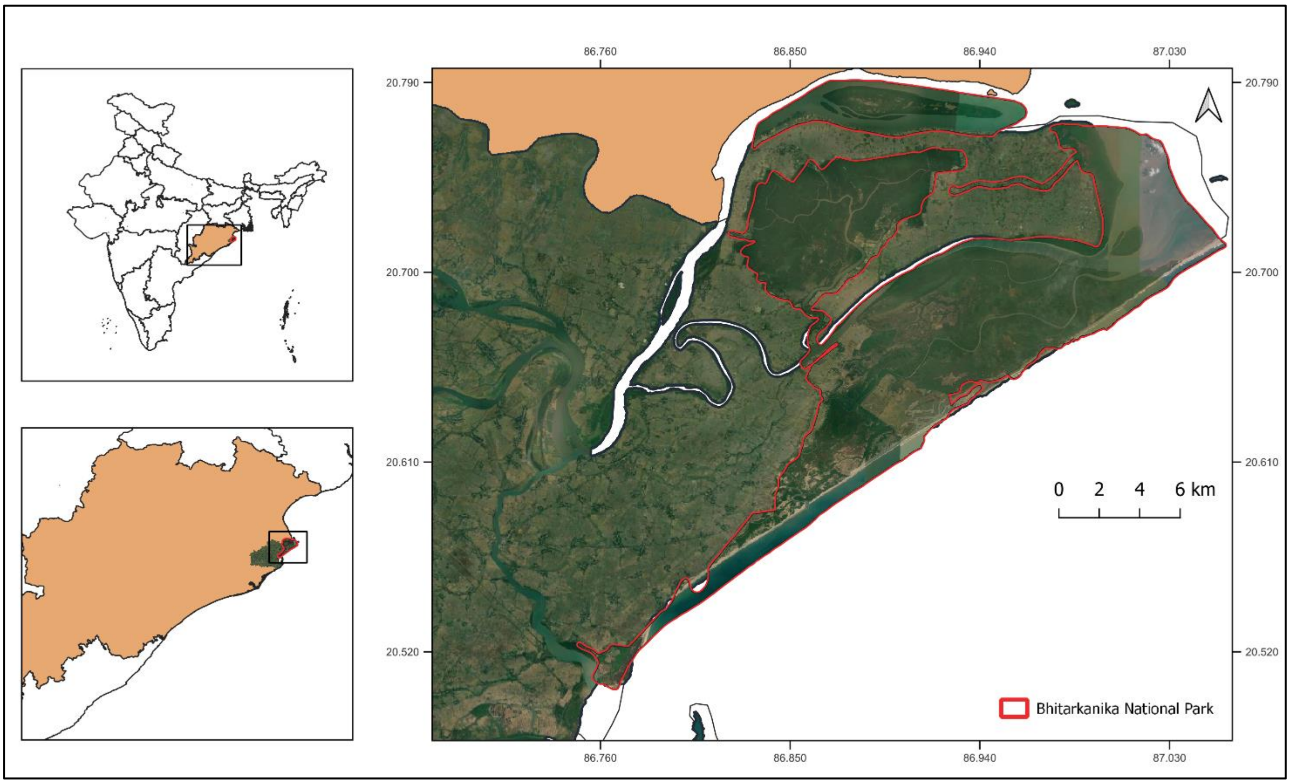

Fig.1 Study area map of the Bhitarkanika National Park in the Odisha state, India.

2.2 Study period

The study lasted seven months from December 2023 to June 2024. Fieldwork was conducted between mid-December 2023 and mid-April 2024; between mid-April and mid-June 2024, analysis and writing were completed.

2.3 Topography/ Geology

Bhitarkanika mangrove is one of the largest mangrove forests in India. The brackish and saline water sets the conditions which act as home to several unique flora and fauna. The national park is inundated by the rivers Brahmani, Baitharani, and Dhamra. The deltaic region formed by the rivers Brahmani and Baitarani creates several unique habitats like creeks, creeklets, and mudflats. The soil is mostly clayey loam with high organic content from the deposition of plant material.

2.4 Climate

There are three distinct seasons in this region: winter (October to January), summer (February to May), and rainy (June to September). The annual rainfall here varies from 920 to 3000mm. This region gets frequent inundation by the sea water during the high tide, as it is surrounded by the rivers and sea by all the sides. The temperature varies from 14°C in the month of January in winter to 40°C during the month of April and May in the summer. The weather is warm and humid throughout the year due to the proximity to the east coast of the Bay of Bengal. The wind blows from the south and south-west with the speed of 20km per hour between March to June. The relative humidity ranges from 60% to 85% all year long.

2.5 Vegetation type

In Bhitarkanika National Park the natural vegetation are broadly classified as: Mangrove Forest, Littoral scrub, Freshwater swamp forest, Salt marshes, Sand dunes, Aquatic vegetation (Hydrophytes) and Grassland. The Mangrove Forest is generally composed of species that are adapted to survive on the tidal mud with brackish water. Littoral scrub species occupy the arid saline soils behind the mangrove forest. The evergreen and deciduous species that are found in the freshwater swamps above the tide level forms the Freshwater swamp forest. The ground surface is mostly inundated by the salt water in Salt marshes. Sand dunes are found along the coastal strip toward the Bay of Bengal. Aquatic vegetations are also found on the shallow waters that are formed in the forest inlands. The Grassland is found near the freshwater swamp forest dominated by the tall grass species.

2.6 Biodiversity

Bhitarkanika mangroves act as an ecotone between land and sea, resulting in hosting the rich biodiversity. This area has also been classified as the second Ramsar site of its state after Chilika Lake. The national park is home for numerous unique flora and fauna.

2.6.1 Faunal diversity

Bhitarkanika National Park has one of the largest Saltwater Crocodile populations in India. According to the population estimation in the year 2024, there are around 1811 crocodiles in the national park. The coastal belt of the park serves as a breeding ground to two threatened marine species Mangrove Horseshoe Crab (*Carcinoscorpius rotundicauda*) and Olive Ridley Sea Turtle (Lepidochelys olivacea). The Mangrove horseshoe crab regularly migrates to the muddy breeding grounds in the mangroves to lay a number of eggs. The Olive ridley sea turtle also migrates to the sandy beaches of the national park every year for nesting. Many other reptiles like King Cobra (*Ophiophagus hannah*), Indian Rock Python (*Python molurus*), Common Krait (*Bungarus caeruleus*), Bronze-back Tree Snake (*Dendrelaphis tristis*), Dog-faced Water Snake (*Cerberus rynchops*), Spectacled Cobra (*Naja naja*), Checkered Keelback (*Fowlea piscator*), and Indian Rat Snake (*Ptyas mucosa*). Water Monitor (*Varanus salvator*) is commonly found, also there are Bengal Monitor Lizard (*Varanus bengalensis*) and Yellow Monitor (*Varanus flavescens*).

Mammals include Spotted Deer (*Axis axis*), Wild Boar (*Sus scrofa*), Rhesus Macaque (*Macaca mullata*), Fishing Cat (*Prionailurus viverrinus*), Leopard Cat (*Prionailurus bengalensis*), Jungle Cat (*Felis chaus*), Indian Golden Jackal (*Canis aureus*), Smooth Coated Otter (*Lutrogale perspicillata*), Indian crested porcupine (*Hystrix indica*), Small Indian civet (*Viverricula indica*), Sambar (*Rusa unicolor*) and Striped Hyena (*Hyaena hyaena*). This national park hosts 7 different species of kingfishers: Brown-winged Kingfisher (*Pelargopsis amauroptera*), Collared Kingfisher (*Todiramphus chloris*), Black-capped Kingfisher (*Halcyon pileata*), Stork-billed Kingfisher (*Pelargopsis capensis*), Pied Kingfisher (*Ceryle rudis*), White-throated Kingfisher (*Halcyon smyrnensis*), and Common Kingfisher (*Alcedo atthis*). Other important avifauna includes Mangrove Pitta (*Pitta megarhyncha*), Bar-headed Goose (*Anser indicus*), Spoon-billed Sandpiper (*Calidris pygmaea*), Watercock (*Gallicrex cinerea*), Pied Avocet (*Recurvirostra avosetta*), White-bellied Sea Eagle (*Icthyophaga leucogaster*), Pallas's Gull (*Ichthyaetus ichthyaetus*), and Grey-headed Lapwing (*Vanellus cinereus*). This is also one of the largest congregation sites for the breeding water fowls like Asian Openbill (*Anastomus oscitans*), Black-crowned Night Heron (*Nycticorax nycticorax*), Great Egret (*Ardea alba*), Oriental Darter (*Anhinga melanogaster*), Medium Egret (*Ardea intermedia*), Little Egret (*Egretta garzetta*), Cattle Egret (*Bubulcus ibis*), Grey Heron

(*Ardea cinerea*), Black-headed Ibis (*Threskiornis melanocephalus*), Little Cormorant (*Microcarbo niger*), and Lesser Adjutant (*Leptoptilos javanicus*). Mudskippers and Fiddler Crab are also found in this national park.

2.6.2 Floral diversity

Bhitarkanika is also rich in floristic diversity by having 372 species belonging to 262 genera under 100 families, of which 58 are mangrove species (Reddy et al., 2006). Major flora includes *Acanthus*, *Achrostichum, Aegialitis, Aglaia, Avicennia, Excoecaria, Brownlowia, Bruguiera, Ceriops, Rhizophora, Heritiera, Phoenix, Sonneratia* etc. A wild variety of rice (*Potresia coarctata*) is also found on tidal mudflats of Bhitarkanika. The tufted palm (*Phoenix paludosa*) is generally found in the drier areas within the mangrove forest and also in the surrounding. *Hydrilla verticillata*, *Lemna perpusilla* were some of the prominent aquatic plant species that are found in the shallow aquatic habitats.

2.7 Threats

This natural mangrove forest is under risk due to unauthorised, intensive prawn cultivations by the aquafarms. As the salinity increases due to high deposition of salts from the aquafarms, resulting in the barren or infertile land in the adjoining areas of the aquafarms. This leads to the spreading of aquafarms like cancerous cells. The disturbance through fishing and crab collection by the local people in the rivers and creeks of the forest creates an adverse effect on the wildlife movement. The runoff of untreated effluents from the aquaculture and agriculture to the rivers and creeks creates pollution in the water. Global warming is also another prominent threat for the mangroves due to gradual increase in the temperature and rate of precipitation.

3.STUDY DESIGN AND METHODS

For species that are elusive or not easily detectible either because of their behaviour, habitat preference, morphology or other ecological aspects, the application of camera trap to understand their ecology is a suitable method (Sutherland, 2006). A detailed information about the individual can be collected from the photographic records using the camera trap, allowing to identify each individual from their unique stripes and spots coat pattern (Karanth, 2006). A very few studies on the abundance and other ecological aspects of Fishing Cat have been done so far using the camera trap methods (Taylor et al., 2016; Rahman, 2017; Shankar et al., 2020; Yadav et al., 2020; Mishra et al., 2021; Phosri et al., 2021; Adhya et al., 2024)

3.1 Density estimation:

Field method

The camera traps have to be placed in such a way that a maximum number of individuals have to be detected (Otis et al., 1978). The primary factors that influence the spacing of camera traps are the habitat use and space usage of the species, as well as practical constraints. If the traps are spaced too far apart, there will be chances of missing the individuals whereas the closer traps increase the individual detection but it also reduces the space coverage (Karanth & Nichols, 2000). For this study, a grid of 1km² was established across the 145km² study area and cameras were deployed systematically in three consecutive phases, covering 40-45 km² in each phase. After inspecting the field sites during the reconnaissance survey, grids inaccessible through boat or walk were excluded. The traps were kept a minimum of 500m apart, based on the smallest radius of the female Fishing Cat home range (Ratnayaka, 2022; Cutter, 2014). The spacing was selected due to gaps in the home range information for the Fishing Cats, which limited the ability to use more precise spacing figures.

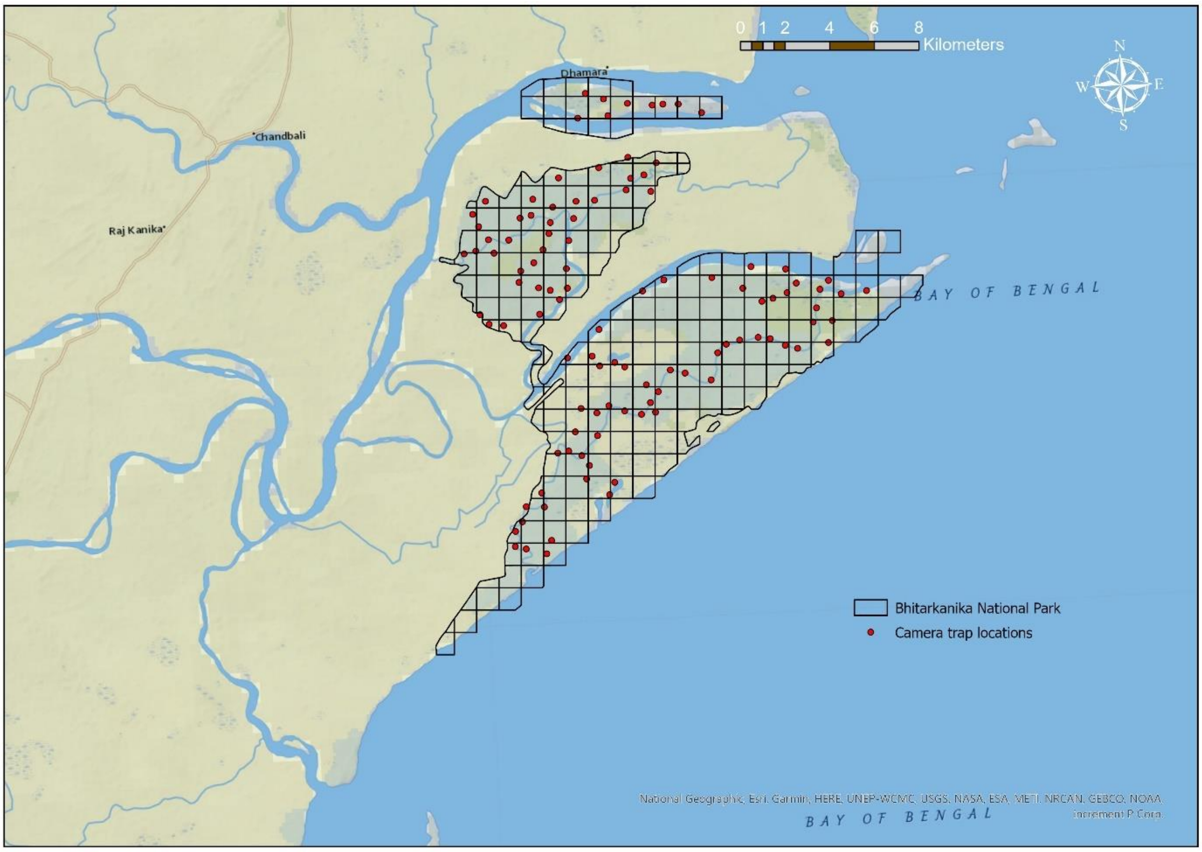

Fig 3.1. Satellite image showing the camera trap locations in the Bhitarkanika National Park.

The camera trap locations were unbaited and the trap locations were determined by the presence of pugmark, animal trails, and wedges of the creeks. Each of the two cameras in each camera station was positioned 6 metres apart and at a height of around 30-45 cm above the ground in the locations with the least amount of tidal influence. But in other locations where there are greater chances of submergence of camera traps by the high tide of spring tides, cameras were placed at the height of 80-100 cm above the ground facing the trial marks of the Fishing Cat. In six locations, there was a risk of complete submergence of the camera traps during high spring tides even after increasing the height of the cameras. Consequently, these cameras were removed for next 4-5 spring tide days and then repositioned after the tides receded. On average, a total of 25 camera trap days are maintained in each location, balancing time constraints with the goal of covering as much of the lunar cycle as possible. I used BROWNING trail cameras with invisible infrared flash, to minimise the disturbance from the flash. I sampled the Kanika range from mid-January to mid-February with 1284 trap nights, covering 48 locations in first phase and the Rajnagar range from mid-February to mid-April with 1594 trap nights, covering 61 locations in second and third phase.

Table 3.1: Overview of sampling details for camera trapping.

Time	**Range**	**Effective trapping area (km²)**	**Number of camera trap locations**	**Trap nights**
January –February	Kanika range	55.92	48	1284
February –April	Rajnagar range	82.68	61	1594

Analytical method

As previously mentioned, having unique stripes and spots each individual are identifiable by the photographs from the camera traps. Photographs that are difficult to interpret the coat pattern due to poor visibility or distortion were discarded, and only the photographs of adult individuals were retained for the identification. Individuals are identified by their unique patterns, primarily observed on the shoulder area, although sex determination from the photographs proved challenging in some cases. The identification process was initially conducted by three independent persons, and the results were subsequently compared to reach a consensus identification for each Fishing Cat.

Plate 2: Example of two separate images used to distinguish between individual Fishing Cats from their unique coat pattern.

Spatially explicit capture-recapture (SECR) was used to estimate the density by package 'secr' version 4.6.6 provided by the R (R Core Team 2023), using the maximum likelihood approach (Efford, 2022). Compared to the conventional capture-recapture approaches, SECR models overcome the edge effects for the estimation of animal populations (Borchers & Efford, 2008). SECR approach combines the state model and the spatial detection model, where the state model accounts for the animal home range and the spatial detection model relates the individual detection probability at the particular detector to the distance between the detector and the home range centre of the animal (Efford, 2022). A matrix of spatial capture history for each Fishing Cat is prepared which also contains data on camera trap IDs, coordinates, and operation history. A habitat mask with a buffer of 5km is prepared around the camera trap array, whereas the buffer value is obtained from the function 'suggest.buffer' in R to keep bias within bound. The non-habitat region is selectively removed using the ArcGIS Pro 3.1 in the making of mask, which includes the expanses of water zones of river and Bay of Bengal, and human settlements. The final habitat mask comprises the mangrove forest areas, creeks, and mudflats that falls inside the National Park boundaries covering an area of 166.25km^2. The commonly used half-normal detection function is integrated along with the set of limitations on parameters like detection probability (g0) and scale of movement (σ). To estimate the detection probability (g0 ~), behavioural response and finite mixture with 2 latent classes (h_2) is used apart from the null model, here h_2 accounts for the heterogeneity in the individual detection probability either due to age, sex, weight etc. To estimate the factors affecting the scale of movement, a finite mixture with 2 latent classes (h_2) is used apart from the null model (here h_2 accounts for the heterogeneity in the individual movement either due to age, sex, weight etc). Behavioural based model includes: a learnt response effect for all the trap array (*b*), and a transient response (Markovian response) on defection at preceding occasion (*B*). Environmental base includes factors like NDVI, nearest creek width, vegetation cover, and salinity. I compared the model's strength using the AICc (Akaike Information Criteria for small sample sizes) and relative AIC weight and selected the model with lowest AICc value (Akaike, 1973) for the inference.

3.2 Factors determining the Fishing Cat distribution

Field method

Understanding the distribution of the species and the covariates that are responsible is crucial in context of conservation and management of the concerned species. The distribution of Fishing Cat can be influenced by various factors in terms of resources, competition, disturbance, habitat type and quality, and other environmental factors. After the reconnaissance survey in the month of December the factors that could be affecting the Fishing Cat distribution in the Bhitarkanika National Park was determined. The covariates(factors) that are used in this study are salinity, human-caused disturbance, crocodile presence, width of the nearest creek, distance to the nearest aquaculture farms, canopy cover, canopy cover and NDVI. The data on the covariates were collected from the field and with help of GIS tools in ArcGIS Pro 3.1. A circular plot of 10 m radius is laid with the camera trap taken as the centre point. A circular plot is laid across each trap locations resulting in total of 109 circular plots. Information on covariates like salinity, human-caused disturbance, and crocodile presence are collected inside each circular plot during the deployment of the camera traps. Refractometer is used to measure the salinity of the water from the nearest water source from the trap. The salinity of the water at each trap location was observed to be vary depending on the type of the tide. During the high tide, the influx of the seawater towards the creeks results in higher salinity levels, while during low tide, the flow of freshwater from the river to the sea decreases salinity. So, the salinity of the water is measured both during the deployment of cameras and during the retrieval time, and the average salinity value for each trap location is calculated. The Human-caused disturbance is measured from the number of human footprints inside the circular plot. Crocodile presence is measured by observing the track marks or the sliding tracks of crocodiles on the mud surface inside the plot. The percentage of canopy cover over the circular plot was calculated using canopy cover application. Aquaculture farms that are present surround the half of the national park are manually digitised and extracted the nearest (Euclidean) distance to the camera trap locations using ArcGIS Pro 3.1. At each trap grid, the width of the nearest creek was also extracted. The canopy cover at each trap location was calculated by the NDVI (Normalized Difference Vegetation Index) map using satellite image having 10m resolution. Kernel density map was created using the SECR results. Density at each trap location is extracted using GIS tool from the kernel density map.

Analytical method

The density of Fishing Cat at each location was extracted from the SECR results and used as a response variable. I have used the Linear Regression Model to understand how the covariates influence the Fishing Cat distribution. Linear Regression Model is a statistical method used to model the relationship between the dependent and the independent variable, assuming that the relation is linear (Benoit, 2011). These are more flexible and more appropriate in analysing ecological relationships. This provides simple methods for establishing the functional relationship among variables and also the strength of the association between response and predictor variable is significant or not (Chatterjee & Hadi, 2015). I have used the Linear Regression Model for the analysis. After extracting the density for each grid, the density values are transformed to required scale by using 'log1p(x)' function in R, which computes as log (1+ x) where x is the response variable. This transformation is performed to address the issue of handling with the smaller density values. The modelling was conducted using a set of predictor variables (salinity, human-caused disturbance, crocodile presence, width of the nearest creek, NDVI, and distance to the nearest aquafarms). The correlation between the predictor variables was calculated, and one variable from each pair of highly correlated variables was retained for the analysis. The variables were then scaled to standardize before fitting the model, using 'scale' function in R. The full model was constructed using all the variables, and the relation between the response and the predictor variable was estimated. F-statistic and p-value was used to determine the model fit and significance.

3.3 Activity pattern of Fishing Cat with respect to moon phase and tidal fluctuations

Field method

Given the study area was a mangrove ecosystem and Fishing Cats are often more active during night, it appears that moon phases and variations in the tidal level have some sort of impact on the Fishing Cat activity. The activity record history of the Fishing Cat was obtained from the images of camera traps that are deployed in 109 locations in Bhitarkanika National Park. It takes approximately 29.5 days to complete one lunar cycle, which consists of different phases. These phases are also responsible for the formation of spring tides and neap tides due to lunar gravitational force. The moon phase type and the illumination percentage corresponding to each detection were recorded using the Moonphase SH 3.3 software. The tidal type and level were recorded for each detections using the DGS Tide software.

Analytical method

The lunar illumination percentages were also broadly categorized into four types: New moon (0-25%), first quarter or waxing moon and last quarter or waning moon (>25-75%), and

Full moon (>75-100%). The Fishing Cat activity with respect to moon phases was analyzed using the circular statistics in program Oriana (Kovach, 2011). Each observation time when a Fishing Cat was detected was recorded as the day since the new moon. Then to maintain this in the lunar cycle order, values are divided by the number of days in the lunar cycle (29.5). Later these were multiplied by 360 to represent the lunar cycle as a circular variable where 0°=360°= New moon and 180°= Full moon (Bhatt et al., 2021). The lunar cycle was transformed to 360° scale to perform the circular-linear correlation (Mardia & Jupp, 2000). Mean vector (μ) and the length of mean vector (r) were calculated. Similar to standard deviation, the length of the mean vector (r) indicates angular dispersion and has a value range of 0 to 1. A value closer to 1 indicates strong clustering of the data around the mean direction, while the value closer to 0 indicates the data points are spread out. Rao's spacing test (U) was performed to evaluate the uniformity of activity throughout the lunar cycle (Batschelet, 1981). Rao's spacing test (U) checks for the uniformity in the distribution of the data points around the circle and also the spacing between consecutive points, which Rayleigh test and Watson's test cannot (Bergin, 1991).

First, the Fishing Cat captures were categorized into two regions: (1) interior, which includes captures from cameras placed away from the mudflats towards the interior forest, and (2) shore, which includes captures from cameras placed on the mudflats. The demarcation line was defined where the trees begin, with areas containing mudflats classified as shore. This categorization was implemented to visualize the capture patterns of Fishing Cats more effectively. Lunar illumination was also considered to assess its impact on Fishing Cat activity, along with the variations in the number of Fishing Cat captures during high tide and low tide across both neap and spring tides. Given that tidal fluctuation and lunar illumination are correlated, an exploratory analysis was made by plotting a line graph using all three parameters. To standardize, all three parameters were summed to each period ranging from 1-24 hours by creating one-hour intervals. Then, at each period, the proportion was calculated by dividing each time period value with the total value to get the density distribution of each parameter concerning the time of the day. As the moon phases and tides are correlated, the activity of the Fishing Cat is tested with both parameters using a paired non-parametric test for the multimodal distribution. The Kolmogorov-Smirnov test was conducted in a paired way between (1) activity and moon illumination and (2) activity and tide fluctuation, as the test compares the distribution of two given samples.

4. RESULTS

Density estimation

Fishing Cats were detected in 7 out of 41 camera trap locations (17%) with 1102 trap nights from the first phase, 36 out of 47 trap locations (76.6%) with 1229 trap nights from second phase, and 14 out of 21 trap locations (66.6%) with 547 trap nights from the third phase. I obtained 675 photographs of Fishing Cat from the three phases out of which 643 photographs were selected as suitable for the identification of individuals. Due to inconsistencies in the captures of the right and left flank, the flank with the highest number of photographs was selected for the identification purposes. The identification process revealed 4 individuals in the first phase, 30 in the second phase, and 19 in the third phase. Later all three phases are considered as a single session as camera trapping was carried out in consecutive spatial blocks in the national park. The individuals that are identified were then compared between the phases, where 4 were identified similar from the second and third phase.

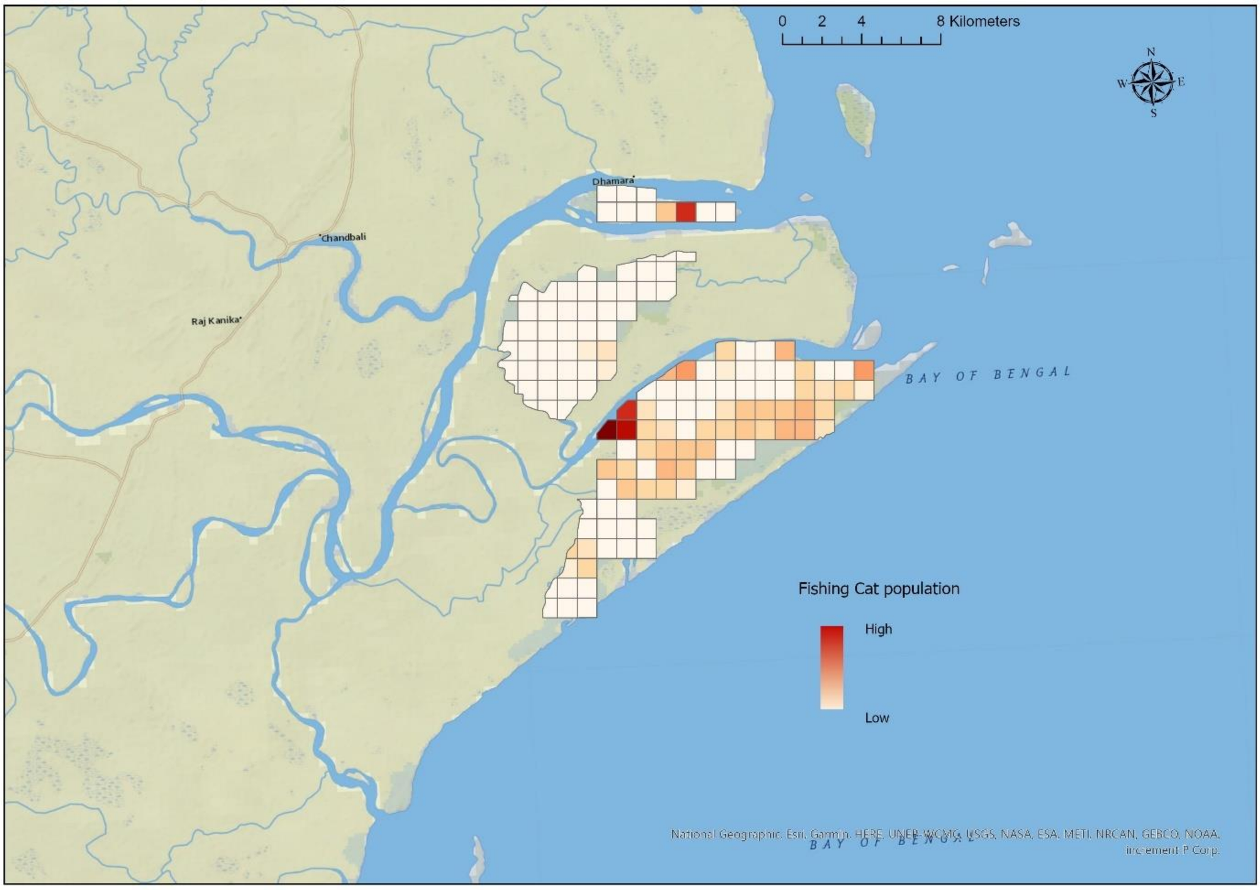

Fig. 4.1. Density heat map of Fishing Cat in Bhitarkanika National Park.

In total 49 individuals were identified out of 643 photographs based on their coat pattern. Identifying the sex was not possible as Fishing Cats were not captured in a position that facilitates determination in some photographs. Of the models run on g0 and σ, the top model was the heterogeneity in the scale of movement, with detection probability at constant ($g0 \sim 1$, $\sigma \sim h_2$), this model was having the lowest AICc value (AICc = 567.26) and highest AICc weightage (AICc weight = 0.78) making this a better supported model. This model suggests that there are two classes which are having a significant difference in the spatial extent of individual movements or home range sizes (class1 is having σ = 1644.97 m, 95% CI = 1352.22 - 2001.11 m; class2 is having σ = 456.17 m, 95% CI = 362.13 – 574.62 m). I estimated the density based on this selected model at D = 0.6 Fishing Cats per km² (95% CI = 0.41 – 0.86) and I estimated an overall abundance (±SE) of 99 ±16 individuals for the study area.

Table 4.1: Model selection for the estimates of Fishing Cat density from Spatially-explicit capture-recapture. 'AICc' is Akaike Information Criteria for small sample sizes, 'dAICc' is the absolute difference in AICc, and 'AICcwt' is the relative support of the model.

Models	**No. of parameters**	**AICc**	**dAICc**	**AICcwt**
D~1, g0~1, σ ~h2	5	567.26	0	0.78
D~1, g0~h2, σ ~h2	6	569.22	2.56	0.22
D~1, g0~h2, σ ~1	5	603.42	36.16	0
D~1, g0~1, σ ~1	3	640.5	72.38	0
D~1, g0~b, σ ~1	4	642.5	74.76	0
D~1, g0~B, σ ~1	4	642.5	74.76	0

Factors influencing the Fishing Cat distribution

Linear Regression Model

Table 4.2: Model coefficients and significance for each predicator variables incorporated.

	β Estimate	**Std. Error**	**t value**	**Pr(>|t|)**	**significance**
(Intercept)	0.21	0.01	14.03	< 2e-16	***
Width of the nearest creek	0.04	0.01	2.66	0.01	**
Distance to nearest aquaculture farms	0.12	0.01	7.91	3.25E-12	***
Crocodile presence	-0.03	0.02	-1.77	0.08	.
Human presence	0.04	0.02	2.31	0.02	*
NDVI	0.01	0.02	0.79	0.43	
Canopy cover	0.03	0.02	1.86	0.06	.

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

A Linear Regression model was fitted, after log transformation of density and standardizing the variables. The model with predictors fit the data much better than the model without predictors, as indicated by the F- statistic value of 14.76. With a P-value of 4.441e-12, it was extremely unlikely that a high F-statistic could have been seen by chance. The R- squared value of 0.4648 indicated that 46.48% of the variance in the response variable was explained by the model. The median residual value was - 0.01450, which, being closer to zero, indicated a good model fit.

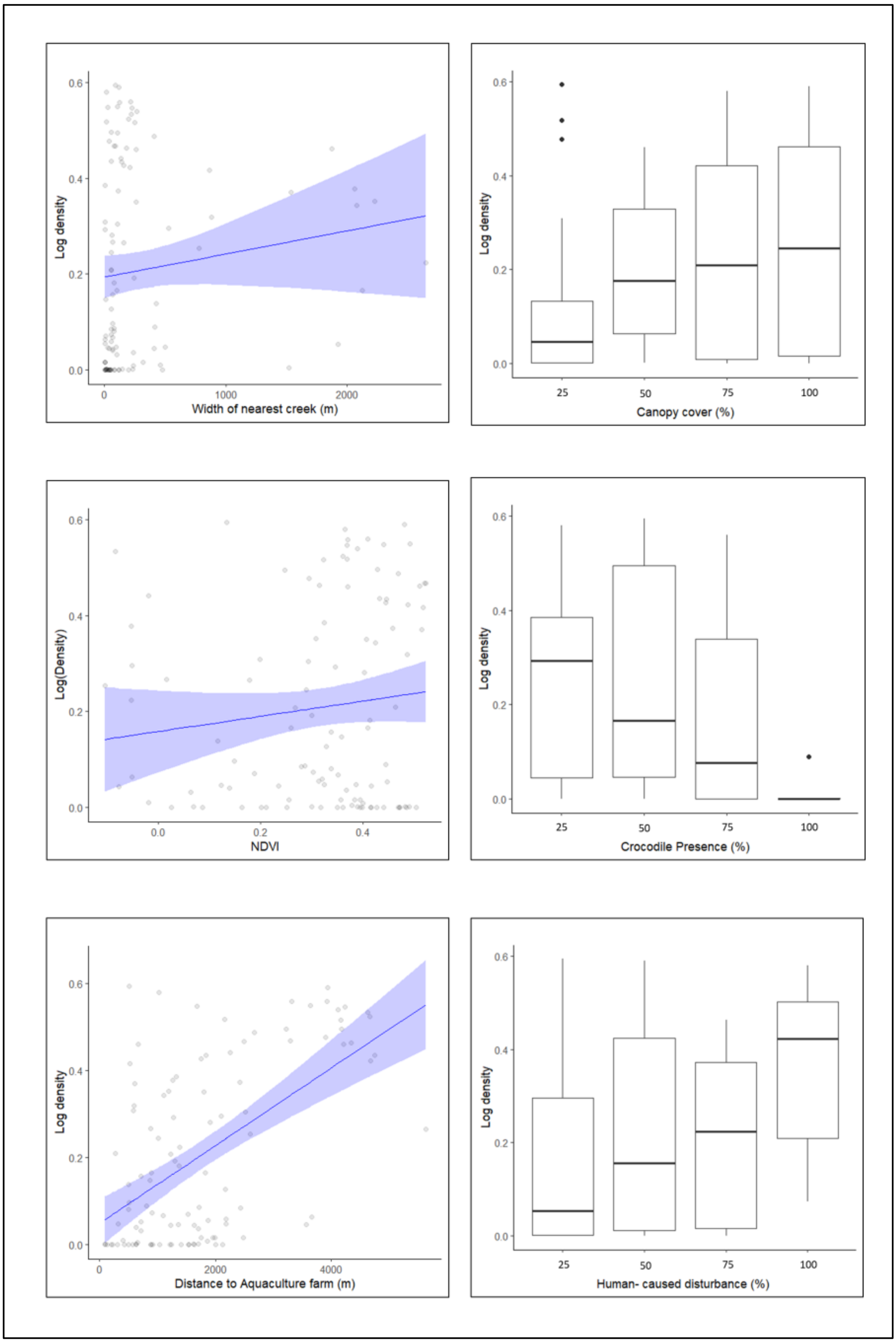

Fig 4.2 The effect of each covariate on the log density of Fishing Cat.

The Saltwater Crocodile presence showed a negative relation with the log density of Fishing Cat whereas the canopy cover showed the positive relation with moderately significant in both cases. The width of the nearest creek, distance to nearest aquafarms, and human-caused disturbance showed a significant positive relation. NDVI had no significant effect on the log density of Fishing Cat. Among all the included variables, the presence of crocodiles was the only factor that exhibited a negative relation with the log density of Fishing Cat. During the initial modeling, salinity and distance to the nearest aquaculture farms were found to be highly correlated. Consequently, salinity and human presence were excluded from the analysis, since I could not interpret the result in an ecological manner. From the results, for each unit increase in the scaled width of the nearest creek and distance to the nearest aquaculture farms, the log density of Fishing Cat would increase by 0.04061 and 0.12058 units, respectively. For each unit increase in the scaled canopy cover, the log density of Fishing Cat would increase by 0.02923 units, though this relation was not significant. Conversely, for each unit increase in the scaled crocodile presence, the log density of Fishing Cat would decrease by 0.02764 units.

Lunar cycle and tidal fluctuation

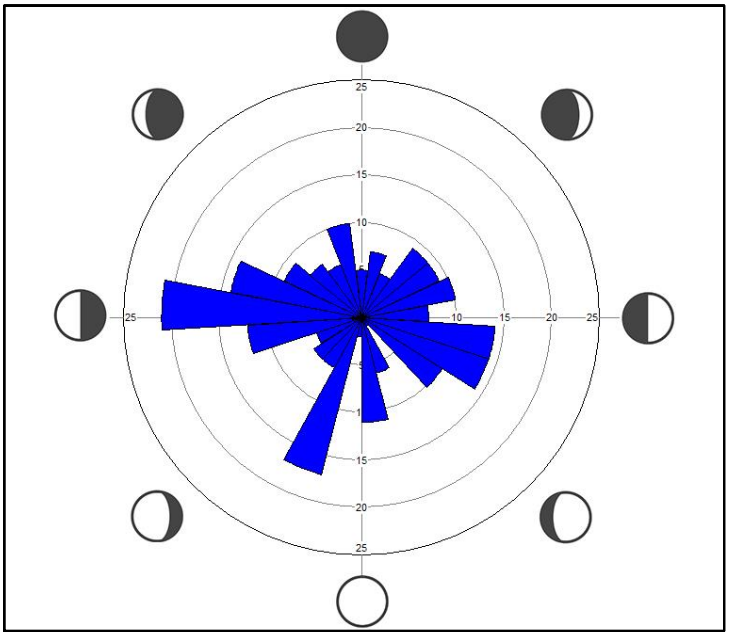

Fig. 4.2. Circadian distribution of Fishing Cat activity during the lunar cycle.

The results from Rao's spacing test showed that the activity of Fishing Cat was not uniform with the lunar cycle (U= 311.57, p< 0.01) and it also showed that statistically the activity was more during the waning moon (μ= 266.78, r= 0.05). The low length of mean vector (0.05) and the high circular variance (0.95) indicates that the Fishing Cat activity is weakly clustered.

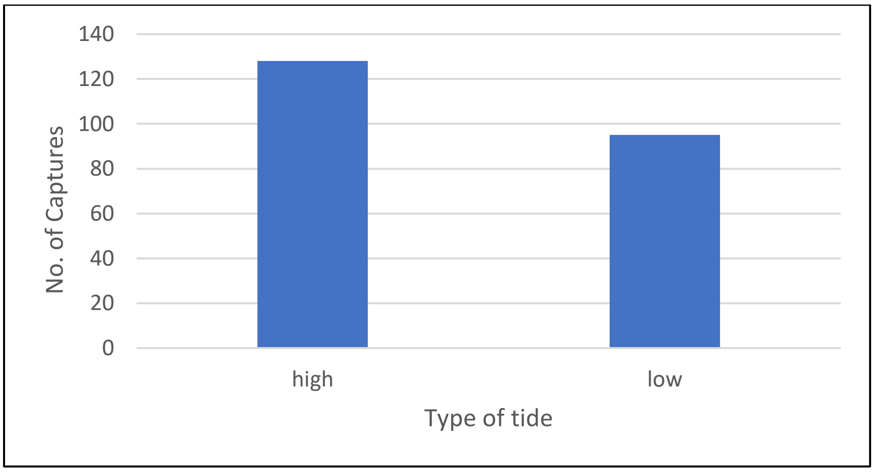

Fig 4.3 Number of Fishing Cat captures during high tide and low tide.

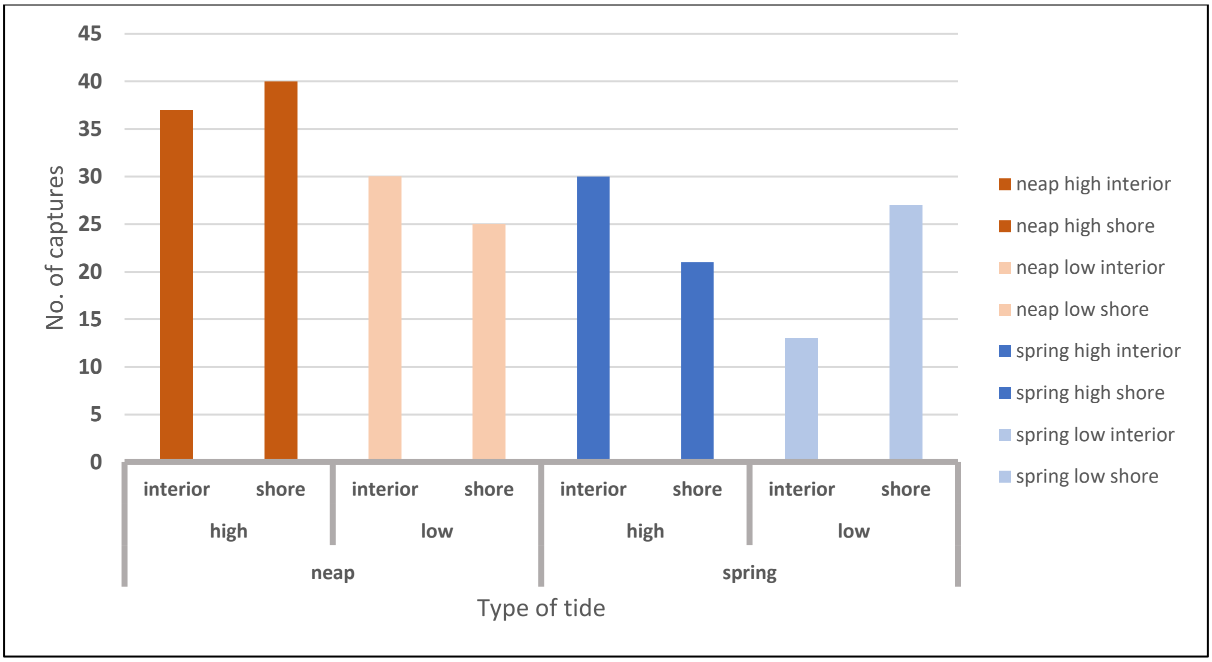

Fig 4.3 Number of Fishing Cat captures during each tide of spring and neap tide.

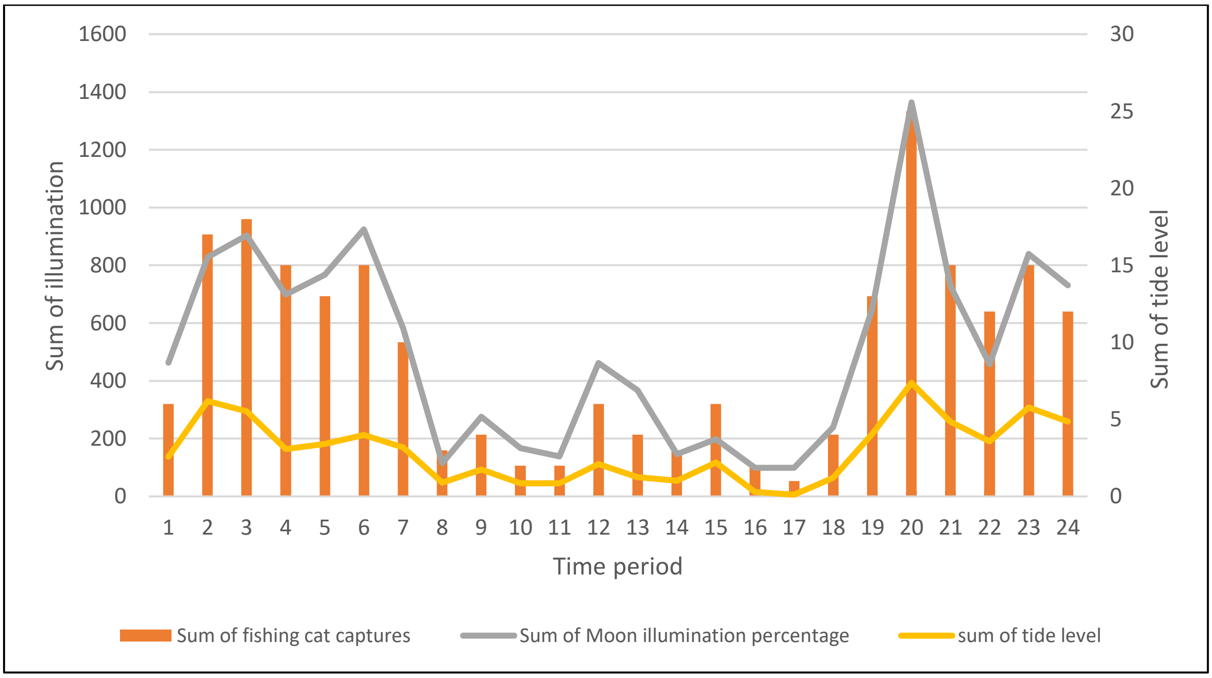

Fig 4.4. A graphic representation of the sums of Fishing Cats captures the moon illumination percentage and tide level for 24 hours.

In total, more Fishing Cats were captured during the high tide compared to the low tide. When high tides and low tides are differentiated between spring and neap tides concerning the interior and shore, it is observed that more Fishing Cats were captured on the shore during neap high tide and spring low tide (Fig 4.3). However, the Fishing Cats were more captured in the interior during neap low and spring high tide. A graph was plotted to understand the distribution of the number of captures, tide fluctuations, and lunar illumination. After visualizing the data through the graph, it was found that all three distributions were multimodal (Fig 4.4). Then, the probability density graph showed that these three parameters were in sequence by taking the proportion of all the parameters for each time period (Fig 4.5). A pair-wise K-S test was calculated to test the difference between the three distributions.

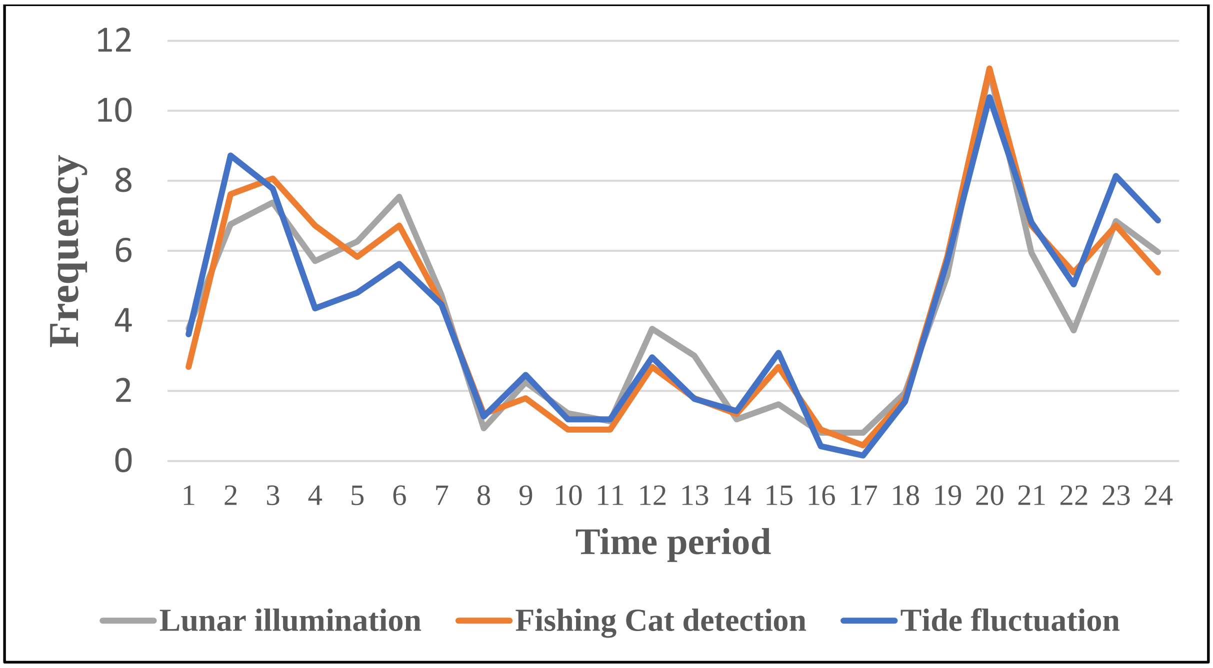

Fig 4.5. Probability density distribution of Fishing Cat activity, lunar illumination and tide fluctuation.

The K-S test in both paired tests (1) Fishing Cat activity and moon illumination and (2) Fishing Cat activity and tide fluctuation were insignificant (D= 0.12, p-value = 0.99 and D= 0.12, p-value= 0.99). The smaller value of KS statistics (D) explains that the two distributions were closer to each other and the higher value of p-value indicates that there is no significant difference between two distributions.

5. DISCUSSION

Estimating the density is crucial for studying, managing, and conserving populations of species, while advancing knowledge on species biology, behaviour, and ecology (Williams et al., 2002). Understanding habitat-use by species and the factors that affect its distribution, would further enhance the knowledge about the species and aid in conservation. This is particularly important for endangered and rare species. From this study I estimated the density of Fishing Cat, and also determined the factors influencing its distribution and activity in Bhitarkanika National Park.

Density and population

A Camera trap-based method without baits was adopted to minimize disturbance. This study provides the first density estimates for Fishing Cat in Bhitarkanika National Park. Few studies are available on density estimates for the Fishing Cat. The density estimated for the study area in Bhitarkanika was 0.6 individuals / km^2, aligning with the recent estimate by Adhya et al. (2024) in Chilika. The coefficient of variation (CV) which represents precision for the density estimate was 19.04%, close to Chilika (14.49%) and more precise than previous estimates with CVs of 177%, and 30% from Malla (2016), and Phosri et al., (2021) respectively. The variation in the mean calculated scale of movement (σ ~h2) suggests two latent classes of Fishing Cats: one showing lower scale of movement and other showing larger scale of movement. These differences in the home ranges are likely due to sex heterogeneity, generally in felids the home ranges of males are larger than that of females (Cutter, 2014; Chen et al., 2016; Mochado et al., 2017). Along with the previous estimates (Adhya et al., 2024; Malla et al., 2016) and the current estimate, it is evident that the east coast of India supports a larger population of Fishing Cats compared to the other regions (Nair, 2012; Mishra, 2016; Das et al., 2017; Phosri et al., 2021).

From the density heatmap, it is clear that there is a contrast in the density between the two ranges of the National Park, with higher density in the Rajnagar range compared to Kanika range. Due to absence of the terrestrial top predator, and availability of both terrestrial and aquatic prey along with minimal disturbance from humans, Bhitarkanika National Park provides an ideal habitat for small and medium sized mammals. The high density of Fishing Cat from the study area is likely due to the absence of a large predator, abundant food resources through waterways, and the larger part of the boundaries adjoining waterbodies causing lower disturbance or habitat destruction.

Factors affecting the distribution of Fishing Cat

The factors influencing the Fishing Cat distribution in the study area were examined with the Linear Regression Model. The analysis identified that the width of the nearest creek, NDVI, canopy cover, and distance to the nearest aquafarms showed a positive relation with the number of Fishing Cats but negatively related with crocodile presence. Distance to the aquafarms showed a positive relation, which suggests that with an increase in the distance to the aquafarms, the probability of the presence of Fishing Cats increases. The aquafarms are distributed outside the National Park boundaries, but the camera traps were deployed only within the National Park. My results indicate that the probability of occurrence decreases within forests if aquafarms are adjoining them, indicating that the cats move towards the aquafarms for food resources. These findings of attraction towards aquafarms are consistent with previous studies (Adhya, 2011; Mukherjee et al., 2012). The positive relation of the canopy cover and NDVI with the number of individuals of Fishing Cat indicates that dense vegetation areas are preferred over the open areas by the species. This observation was consistent with the previous studies from Chitwan National Park (Mishra et al., 2018), where they prefer tall grass cover, which provides them with cover and shelter. The preference of wider creeks width by the Fishing Cat, is likely because of the higher availability of resources (due to tidal water) both during the high and low tide. The chief diet of Fishing Cat consists of aquatic prey, and this resource is available largely during the high tide in the creeks with the smaller width, suggesting that Fishing Cats are found more often near the wider creeks where resources are available during both tides. The negative relation with the presence of crocodiles indicates that the Fishing Cats avoid the areas with greater crocodile presence. The Saltwater Crocodile is a top predator, and its primary diet consists of aquatic prey in the study area. As both the predators share common food resources, Fishing Cats avoid areas where the probability of crocodile presence is high. The crocodile presence observations from this study show that the highest number of crocodiles was recorded from the Kanika range; this was also consistent with the *Estuarine Crocodile Census* report from the Odisha Forest Department, where the Kanika range had the highest population of Saltwater Crocodiles (Kanika range= 1422 and Rajnagar= 272 crocodiles). Due to the high probability of crocodiles, it is likely that the Fishing Cats have a lower presence in the Kanika range, reducing the probability of encountering crocodiles. No previous studies have focused on the interactions between the Fishing Cat and Saltwater Crocodile or any other top predators, the possible explanation being avoidance of a larger predator.

From this study, it is observed that despite both ranges being characterized by similar mangrove covers and creeks, Fishing Cats are more sparsely distributed and with a lower density in the Kanika range. The large population of crocodiles and the presence of a significant number of aquaculture farms around the Kanika range are likely affecting the Fishing Cat population more severely in the Kanika Forest. However, aquafarms have their detrimental effects where Fishing Cats are attracted to areas with much higher threat level.

Supporting the hypothesis, a greater number of Fishing Cats were captured by the camera traps in areas closer to wider creeks. These creeks have larger mudflat areas and retain water during low tides. Fishing Cats were found to avoid areas with high numbers of crocodiles, likely to avoid interaction. However, contrary to the hypothesis, Fishing Cats were less distributed towards the fringe areas near aquaculture farms. The large population of crocodiles and the significant number of aquaculture farms near to the Kanika range, seem to affect the Fishing Cat population more severely. The combination of avoiding the crocodiles within the forest and the presence of aquaculture farms in the vicinity may be driving Fishing Cats to venture out of the forest area.

Lunar illumination and tidal fluctuation

The results from this study suggest that the moon illumination percentage affected the activity of the Fishing Cat. Given the limited time, this study covered three lunar cycles during the sampling period. The results from the three lunar cycles indicate that the Fishing Cat is more active from the first quarter to third quarter moon phases. The illumination percentage is higher during these phases than in the waning to waxing phase. As this is the first study looking at the effect of lunar illumination on this species, the findings were compared with another closely related small felid (*Prionailurus bengalensis*) from Assam (Bhatt et al., 2021), contradicting it was more active just before the first quarter. Tidal fluctuations vary the amount of water in the creeks and the flow pattern to the smaller creeks inside the forest. Therefore, the availability of aquatic prey for the Fishing Cat also varies according to tide and is not equally available during all periods of the day. The paired K-S test results showed that the Fishing Cat activity followed the tide and lunar periods. The test results and the graph explain how Fishing Cat activity varies in accordance with tidal fluctuations and lunar illumination conditions. From the graph, as the tide parameter attains a peak (in other words, the increased availability of aquatic prey), the activity also peaks during that period, and this process is enhanced by lunar illumination during the night, as daytime does not have any effect. Overall, the Fishing Cat follows the tide pattern for the resources and the illumination during night enhances the activity by providing more visibility to hunt the aquatic prey in the brackish water.

It is hypothesized that Fishing Cats would exhibit greater activity during the full moon, favoring the hypothesis, Fishing Cats were indeed active during the full moon phase. Nevertheless, the study also found that the highest levels of activity were observed from the first to third quarter of the moon phases, extending beyond the full moon phase.

6.CONCLUSION

This study aimed to estimate the Fishing Cat's density, investigate the factors affecting its distribution, and examine the influence of lunar illumination and tidal fluctuations on its activity in Bhitarkanika National Park. The findings indicate that this national park supports a high density of Fishing Cats. The dense mangrove covers and the wider creeks favour the Fishing Cat distribution, which offers essential habitat features. Conversely, the presence of crocodiles negatively affects the distribution of Fishing Cats, resulting in low density of Fishing Cats in the areas where crocodile presence is high. Additionally, the proximity of aquaculture farms to the forest boundary also adversely affects Fishing Cat distribution in the forest area. The study resulted in tide fluctuations and lunar illumination influencing the Fishing Cat activity in the study area, as it affects the prey availability and nocturnal foraging behaviour, respectively.

While the present study was conducted within the protected area, it is essential to note that non-protected areas outside the park may hold the potential for Fishing Cat populations. More studies are necessary to explore these areas and to understand the impact of aquaculture farms on Fishing Cat distribution and population dynamics beyond the protected area. By identifying the population and the areas with a high population of Fishing Cats, necessary conservation measures can be adopted and implemented to ensure the long-term survival of this vulnerable species. Addressing the factors influencing the Fishing Cat populations and developing targeted management strategies is crucial for effectively conserving this species.

10. Caveat

The first objective was to assess how the patch heterogeneity influences the Fishing Cat density, which means how the density varies between the mainland (larger patch) and the islands (smaller patch). Since the size of some patches were too small and the quantum of data obtained was insufficient to address this objective rigorously, I instead estimated the overall density of Fishing Cat for the study area. Although a few captures of Fishing Cats were obtained from the islands, only a single capture was recorded from the larger patch in the Kanika range. This did not meet the minimum criteria to run SECR analysis to estimate the density of Fishing Cat for different patches.

10.Appendix

Table A: Correlation matrix for the predictor variables.

	Salinity	**Width of the nearest creek**	**Crocodile presence**	**Human-caused disturbance**	**NDVI**	**Distance to nearest aquaculture farm**	**Canopy cover**
Salinity	1	-0.19	-0.46	0.05	-0.44	0.72	-0.08
Width of the nearest creek	-0.19	1	-0.09	0.04	-0.26	-0.5	-0.07
Crocodile presence	-0.46	-0.09	1	-0.64	-0.21	-0.24	-0.21

Human-caused disturbance	0.05	0.04	-0.64	1	0.16	-0.27	-0.18
NDVI	-0.44	-0.26	-0.21	0.16	1	-0.27	0.29
Distance to nearest aquaculture farm	0.72	-0.5	-0.24	-0.27	-0.27	1	-0.05
Canopy cover	-0.08	-0.07	-0.21	-0.18	0.29	-0.05	1

11. Reference:

- Adhya, T., Dey, P., Das, U., & Hazra, P. (2011). Status survey of Fishing Cat (Prionailurus viverrinus) in Howrah and Hooghly, West Bengal. Intermediate report submitted to the small grants programme, WWF, India.
- Adhya, T., Banerjee, S., Dey, P., Nanda, S., Santra, S., & Nesha, I. (2024). Density estimation of the globally threatened Fishing Cat Prionailurus viverrinus through a participatory science approach in the Chilika lagoon, eastern India. Endangered Species Research, 54, 1-13.
- Ahmed, M. F. (n.d.). Endangered Fishing Cat Prionailurus viverrinus: Status, Distribution and Conservation in Assam, India.
- Appel, A., & Duckworth, J. W. (Eds.). (2016). Proceedings of the First International Fishing Cat Conservation Symposium, 25–29 November 2015, Nepal. Fishing Cat Working Group.
- Batschelet, E. (1981). Circular statistics in biology. Academic Press.
- Benoit, K. (2011). Linear regression models with logarithmic transformations. *London School of Economics, London*, *22*(1), 23-36.

- Bergin, T. M. (1991). A comparison of goodness-of-fit tests for analysis of nest orientation in western kingbirds (Tyrannus verticalis). The Condor, 93(1), 164-171.
- Bhatt, U., Adhikari, B. S., Habib, B., & Lyngdoh, S. (2021). Temporal interactions and moon illumination effect on mammals in a tropical semievergreen forest of Manas National Park, Assam, India. Biotropica, 53(3), 831-845.
- Borchers, D. L., & Efford, M. G. (2008). Spatially explicit maximum likelihood methods for capture–recapture studies. Biometrics, 64(2), 377-385.
- Brodie, J. F. (2009). Is research effort allocated efficiently for conservation? Felidae as a global case study. Biodiversity and Conservation, 18, 2927-2939.
- Chadha, S., & Kar, C. S. (1999). *Bhitarkanika, myth and reality*. Natraj Publishers.
- Chakraborty, S., Barik, S., Saha, R., Dey, A., Deuti, K., Venkatraman, C., Mazumdar, S., & Saha, G. K. (2020). Camera-trap records of Fishing Cat (Prionailurus viverrinus) from East Medinipur (West Bengal, India), and notes on threats to this population. Écoscience, 27(3), 149-156.
- Chatterjee, S., & Hadi, A. S. (2015). *Regression analysis by example*. John Wiley & Sons.
- Chen, M. T., Liang, Y. J., Kuo, C. C., & Pei, K. J. C. (2016). Home ranges, movements and activity patterns of leopard cats (Prionailurus bengalensis) and threats to them in Taiwan. Mammal Study, 41(2), 77-86.
- Cozzi, G., Broekhuis, F., McNutt, J. W., Turnbull, L. A., Macdonald, D. W., & Schmid, B. (2012). Fear of the dark or dinner by moonlight? Reduced temporal partitioning among Africa's large carnivores. *Ecology*, *93*(12), 2590-2599.
- Cutter, P. A. S. S. A. N. A. N., & Cutter, P. E. T. E. R. (2009). Recent sightings of Fishing Cats in Thailand. Cat News, 51, 12-13.

- Cutter, P. (2014). Fishing Cat Ecology: Food habits, home ranges, habitat use and mortality in a human-dominated landscape around Khao Sam Roi Yot area, Peninsular Thailand (Doctoral dissertation, University of Minnesota).
- Das, Ashis Kumar, Rajesh Kumar Behera, Sandeep Kumar Mohapatra, Smrutirekha Acharya, Swarup Ranjan Mohanty, Basudev Tripathy, and Anil Mohapatra. "First photographic evidence of Fishing Cat, *Prionailurus viverrinus* (Bennett, 1833) in Tampara Lake, Ganjam, Odisha." *Records of the Zoological Survey of India* (2023): 159-164.
- Efford, M. (2022). secr: spatially explicit capture-recapture (R package version 4.5.5). Retrieved from https://cran.r-project.org/web/packages/secr/index.html
- Ganguly, D., & Adhya, T. (2022). How Fishing Cats Prionailurus viverrinus Bennett, 1833 fish: describing a felid's strategy to hunt aquatic prey. Mammalia, 86(2), 182-189.
- Gopi, G. V., & Pandav, B. (2007). Avifauna of Bhitarkanika mangroves, India. Zoos' Print Journal, 22(10), 2839-2847.
- Haque, N. M., & Vijayan, V. (1993). Food habits of the Fishing Cat Felis viverrina in Keoladeo National Park, Bharatpur, Rajasthan. Journal of the Bombay Natural History Society, 90, 498-500.
- Jhala, Y. V., Qureshi, Q., & Yadav, S. P. (Eds.). (2021). *Status of Leopards, Co-predators and Megaherbivores in India 2018*. National Tiger Conservation Authority.
- Karanth, K. U., & Nichols, J. D. (2000). Ecological status and conservation of tigers in India. Final Technical Report (February 1995 to January 2000).
- Karanth, K. U., Nichols, J. D., Kumar, N. S., & Hines, J. E. (2006). Assessing tiger population dynamics using photographic capture–recapture sampling. Ecology, 87(11), 2925-2937.

- Kolipaka, S. S., Srivastava, D. P., Prasad, S., & Rust, N. A. (2019). Fishing Cat conservation in human-dominated landscapes in West Bengal, India.
- Kovach, W. L. (2011). Oriana–circular statistics for Windows, ver. 4. Kovach Computing Services.
- Kotler, B. P., Brown, J., Mukherjee, S., Berger-Tal, O., & Bouskila, A. (2010). Moonlight avoidance in gerbils reveals a sophisticated interplay among time allocation, vigilance and state-dependent foraging. *Proceedings of the Royal Society B: Biological Sciences*, *277*(1687), 1469-1474.
- Kitchener, A. C., Breitenmoser-Würsten, C., Eizirik, E., Gentry, A., Werdelin, L., Wilting, A., Yamaguchi, N., et al. (2017). A revised taxonomy of the Felidae: The final report of the Cat Classification Task Force of the IUCN Cat Specialist Group. Cat News.
- Macdonald, D. W., Loveridge, A. J., & Nowell, K. (2010). Dramatis personae: An introduction to the wild felids. In D. W. Macdonald & A. J. Loveridge (Eds.), Biology and conservation of wild felids (pp. 3-58). Oxford University Press.
- Malla, G., Ray, P., Yellapu, S., Malla, S., Hayward, M., Reddy, B., & Kuppusamy, S. (2023). Fish on the platter! Investigating the dietary habits of Fishing Cats (Prionailurus viverrinus) in the Godavari Delta, India. bioRxiv.
- Malla, G., & Sivakumar, K. (2014). The Coringa Mangroves-Realm of the Fishing Cat. Sanctuary Asia, 34(6), 60-65.
- Malla, G. (2016). Ecology and conservation of Fishing Cat in Godavari mangroves of Andhra Pradesh. In Proceedings of the First International Fishing Cat Conservation Symposium (pp. 25-29).
- Mardia, K. V., & Jupp, P. E. (2009). Directional statistics. John Wiley & Sons.
- Menon, V. (2014). Indian mammals: a field guide. Hachette India.

- Mishra, R. (2016). Conservation status of the Fishing Cat in Chitwan National Park, Nepal. In A. Appel & J. W. Duckworth (Eds.), *Proceedings of the First International Fishing Cat Conservation Symposium* (pp. 25-28). Fishing Cat Working Group.
- Mishra, R., Basnet, K., Amin, R., & Lamichhane, B. R. (2018). Fishing Cat Prionailurus viverrinus Bennett, 1833 (Carnivora: Felidae) distribution and habitat characteristics in Chitwan National Park, Nepal. Journal of Threatened Taxa, 10(11), 12451-12458.
- Mishra, R., Gautam, B., Kaspal, P., & Shah, S. K. (2021). Population status and threats to Fishing Cat Prionailurus viverrinus (Bennett, 1833) in Koshi Tappu Wildlife Reserve, Eastern Nepal. Nepalese Journal of Zoology, 5(1), 13-21.
- Mishra, R., De Iongh, H. H., Leirs, H., Lamichhane, B. R., Subedi, N., & Kolipaka, S. S. (2022). Fishing Cat Prionailurus viverrinus distribution and habitat suitability in Nepal. Ecology and Evolution, 12(4), e8857.
- Mugerwa, B., Adhya, T., Ratnayaka, A., Thudugala, A. S. H. A. N., Napolitano, C. O. N. S. T. A. N. Z. A., & Sanderson, J. (2020). Are we doing enough to protect the world's small wild cats? Cat News, 71(Spring), 41-47.
- Mukherjee, S., Appel, A., Duckworth, J. W., Sanderson, J., Dahal, S., Willcox, D. H. A., Herranz Muñoz, V., et al. (2016). Prionailurus viverrinus. The IUCN Red List of Threatened Species 2016: e.T18150A50662615. Retrieved from https://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T18150A50662615.en
- Mukherjee, S., Adhya, T., Thatte, P., & Ramakrishnan, U. (2012). Survey of the Fishing Cat Prionailurus viverrinus Bennett, 1833 (Carnivora: Felidae) and some aspects impacting its conservation in India. Journal of Threatened Taxa, 4(14), 3355-3361.
- Otis, D. L., Burnham, K. P., White, G. C., & Anderson, D. R. (1978). Statistical inference from capture data on closed animal populations. Wildlife Monographs, 62, 3-135.

- Palei, N. C., Rath, B. P., Behura, S., & Palei, H. S. (2021). New elevation record of Fishing Cat occurrence in Odisha, eastern India. Zoology and Ecology, 28(2), 16-17.
- Penteriani, V., Delgado, M. D. M., Campioni, L., & Lourenco, R. (2010). Moonlight makes owls more chatty. *PloS one*, *5*(1), e8696.
- Phosri, K., Tantipisanuh, N., Chutipong, W., Gore, M. L., Giordano, A. J., & Ngoprasert, D. (2021). Fishing Cats in an anthropogenic landscape: A multi-method assessment of local population status and threats. Global Ecology and Conservation, 27, e01615.
- Prugh, L. R., & Golden, C. D. (2014). Does moonlight increase predation risk? Meta-analysis reveals divergent responses of nocturnal mammals to lunar cycles. *Journal of animal ecology*, *83*(2), 504-514.
- Rahman, H. A. (2017). Mammal biodiversity in the northeast forests, and the distribution of Fishing Cats in Bangladesh. University of Delaware.
- Ratnayaka, A. A. W., Serieys, L. E. K., Prasad, T., Leighton, G. R. M., Sanderson, J. G., & Leung, L. K.-P. (2022). Urban habitat use and home ranges of Fishing Cats in Colombo, Sri Lanka. Mammalian Biology, 102(1), 271-277.
- Reddy, C. S., Pattanaik, C. H. I. R. A. N. J. I. B. I., Dhal, N. K., & Biswal, A. K. (2006). Vegetation and floristic diversity of Bhitarkanika National Park, Orissa, India. Indian Forester, 132(6), 664-670.
- Ridout, M. S., & Linkie, M. (2009). Estimating overlap of daily activity patterns from camera trap data. Journal of Agricultural, Biological, and Environmental Statistics, 14(3), 322-337.
- Sadhu, A. (2013). First evidence of Fishing Cat in Ranthambhore Tiger Reserve. Current Science, 123(12), 1419-1420.

- Sanderson, J. G., & Watson, P. (2011). Small wild cats: The animal answer guide. Johns Hopkins University Press.
- Silva, A. P., Mukherjee, S., Ramakrishnan, U., Fernandes, C., & Björklund, M. (2020). Closely related species show species-specific environmental responses and different spatial conservation needs: Prionailurus cats in the Indian subcontinent. Scientific Reports, 10(1), 18705.
- Shankar, A., Salaria, N., Sanil, R., Chackaravarthy, S. D., & Shameer, T. T. (2020). Spatio-temporal association of Fishing Cats with the mammalian assemblages in the East Godavari mangrove delta, India. Mammal Study, 45(4), 303-313.
- Sunquist, M., & Sunquist, F. (2002). *Wild cats of the world*. University of chicago press.
- Sutherland, W. J. (Ed.). (2006). Ecological census techniques: A handbook. Cambridge University Press.
- Taylor, I. R., Baral, H. S., Pandey, P., & Kaspal, P. (2016). The conservation status of the Fishing Cat Prionailurus viverrinus Bennett, 1833 (Carnivora: Felidae) in Koshi Tappu Wildlife Reserve, Nepal. Journal of Threatened Taxa, 8(1), 8323-8332.
- Williams, B. K., Nichols, J. D., & Conroy, M. J. (2002). Analysis and management of animal populations. Academic Press.
- Yadav, B. P., Appel, A., Shrestha, B. P., Dahal, B. R., & Dhakal, M. (2020). The Fishing Cat Prionailurus viverrinus (Bennett, 1833) (Mammalia: Carnivora: Felidae) in Shuklaphanta National Park, Nepal. Journal of Threatened Taxa, 12(16), 17203-17212.