Nest site selection in Pallas's Fish-eagle and nesting behaviour in the Rajaji-Corbett landscape

by

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Dissertation Thesis

Submitted to Academy of Scientific and Innovative Research

For the partial fulfilment for the degree

Master of Science
in
Wildlife Science

Under the supervision of

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Dr. Bivash Pandav
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Wildlife Institute of India

DECLARATION

I hereby declare that the work conducted under the thesis entitled **"Nest site selection in Pallas's Fish-eagle and nesting behaviour in the Rajaji-Corbett landscape",** 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. Ashish Jha**, **Scientist C, Wildlife Institute of India** and co-supervision of **Dr. Bivash Pandav, Scientist G, Wildlife Institute of India** and **Dr. R. Suresh Kumar, Scientist E, Wildlife Institute of India**. 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 **Abhishek Tangaria** entitled "**Nest site selection in Pallas's Fish-eagle and nesting behaviour in the Rajaji-Corbett landscape"** 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**.

Abhishek Tangaria 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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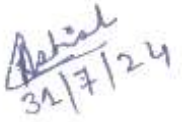

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ACKNOWLEDGEMENTS

My first thank should go to my father, Late Shri Murli Dhar, who always appreciated my curiosity in animals and taught me to love every animal. I want to thank my mother for letting me study in WII and of course for paying the fee.

My words cannot explain my gratitude for the amount of efforts put in by my supervisor Dr. Ashish Jha, for always helping me without judging me, and without doing belittlement. His expertise in developing my thesis is uncompareable. He helped me in R based analyis a lot. I like to thank Dr. Bivash Pandav for his invaluable support during my field surveys. His reputation with the Uttrakhand Forest department helped a lot with my stay and field support. I extend my thanks to Dr. R. Suresh Kumar for refining my ideas and constant pressure to work hard.

I like to thank my friend Prakash (Parku) for his immense help during behavior sampling without his help this study would not have resulted in what it is now. I enjoyed his company when we were alone in field and his stupid questions. I want to thank Ranju bhai for his cooking and presence during the field survey, I thank Gulam ji for accompanying during surveys in Corbett Tiger Reserve. Special thank to Abhimanyu for finding two nests in his study area during his surveys.

These 2 years were among the best time of my life and without Dr. Navendu Page and Dr. Lallian I would not have been selected for WII. I thank all my faculty members for their support. Special thanks to Dr Bilal for his assistance in equipment without any hesitation. I'd like to thank our legend, Qamar sir, Dr Vishnupriya and Varun for his extremely helpful comments.

I feel these years are incomplete without my classmates especially Bindu (Boka) for always nagging me to work, making my reports and doing final edits. I thank Arnab (Blacky), Shilpa, Rakshit, Shashank, Niyaz, for all the parties we had.

I like to thank Ashish bro for his immense help in spatial analysis and other analysis. I thank Mohit, Joel, Abhishek(Anna), Dev, Richard and Abhinav for the time we spent together. I like to thank mess staff for cooking delicious food.

There is no greater joy than living your childhood dream,

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EXECUTIVE SUMMARY

This study investigates the nest site selection and nesting behavior of Pallas's Fish-eagle (PFE) across the sub-Himalayan tract in India, addressing a significant knowledge gap in the species' natural history. PFE, classified as Endangered globally and of high conservation concern nationally, exhibits unique nesting preferences and ecological requirements. Prior research, including studies from Bhutan and Bangladesh, has highlighted the species' preference for unobstructed nest trees and proximity to water sources and human settlements. However, comprehensive data from India remains limited.

The study aims to explore factors influencing PFE's nest site selection, such as habitat quality, microclimate, food availability, and protection from predators and human disturbance. Additionally, it seeks to document the species' reproductive behavior, including hatchling development, parental duties, and nest predation pressures.

Surveys covered segments of the Ganga, Kohlu, Kho, Palain, Mandal, Asan Barrage, Dakpatthar Barrage, and Ramganga, recording data on sightings and nest characteristics. A total of twelve nests were found, with only one destroyed by a storm. The majority of nests were built on *Bombax ceiba* and *Shorea robusta* trees, with an average height of 29.9m and GBH of 473cm. Behavioral observations were conducted at three accessible nests, monitoring parental presence, predator interactions, and nest guarding behavior.

Spatial analysis in ArcGIS Pro considered various land cover types and environmental factors, finding that barren land and rangeland significantly influenced nest site selection. Euclidean distances to different land cover types and elevation were also key factors. Statistical analyses using R revealed correlations between tree height

and nest height, and generalized linear models highlighted the impact of land cover and environmental variables on nest presence.

Nest trees were typically tall and robust, with *Bombax ceiba* and *Shorea robusta* being the most commonly used species. These trees provided unobstructed branches and greater accessibility. The study also highlighted the importance of open land around the nest tree, aiding in vigilance and territory defense. At a macro scale, the presence of barren land and flooded regions positively influenced nest site selection, while slope and distance from rangeland showed negative correlations.

Behavioral observations at three nests revealed high predation pressure, particularly from crows, and kites. The presence of human settlements increased predation incidents, affecting parental investment in nest defense.

INTRODUCTION

Natural selection has driven species to select the best habitats to maximise survival and reproduction preferentially (Fuller, 2012). Birds prefer nesting sites with ensured food supply, commodious micro-habitats, and protection from adverse weather conditions and predators (Tapia & Zuberogoitia, 2018). Nest-site selection depends on habitat quality and breeding events (Doligez & Boulinier, 2008). The decision-making process behind nest-site selection is influenced by several factors, including the availability of foraging habitat, protection of the nest and the young ones, the nest's microclimate, and the spatial interactions within the community (Smith et al., 1982). Birds make various types of nests depending on their body size and choice of habitat. Generally, large avian species construct nests using twigs, forming platform-like structures. In contrast, small species typically build more compact nests with finer materials, often intricately woven together and rigidly attached to their surroundings using spider or insect silk (Collias, 1964). Each species exhibits unique preferences for the placement, elevation, alignment, protective structures, accessibility, and visibility of their chosen nesting habitats (Tapia et al., 2007a).

Owing to their considerable weight, tree-nesting raptors look for tall, sturdy trees where tree girth also plays a vital role in their reproductive success. In a study on Red-shouldered Hawks, nesting and fledgling success positively correlated with tree height and diameter (Rottenborn et al., 2000). Vegetation structure, nest predation, nesting density, food availability, microclimate, nest structure and substrates, perch availability, competitors, and human disturbance also affect nest site selection.

Gerrard et al. (1975) studied variables influencing Bald eagles' choice of nest sites in Canada and found that nests were more frequently found along the shores of large lakes and rivers. Berkelman et al. (1999) studied the prey selection and foraging success

of the Madagascar fish eagle and found that it requires bodies of water with large shoreline trees and prefers trees with more unobstructed branches and greater accessibility.

Raptors, such as Fish-Eagles, heavily depend on water bodies for foraging. Large-bodied raptor population dynamics are mainly influenced by three primary variables: predation, food availability, and nest site accessibility (Newton, 2010). Bald Eagles in the boreal forests of Canada tend to choose nesting sites within 200m of large lakes and rivers (Gerrard et al., 1975). The size of a nest directly correlates with the size of the raptor. These vast nests result from high nest site fidelity, with old nests being refurbished with additional nesting material every breeding season. Such large nest structures are easily detectable and act as a signal of nesting territories (Newton, 2010).

India hosts five of ten species of fish-eagle species found across the globe; Pallas's Fish-eagle *(Haliaeetus leucoryphus)*, Lesser Fish-eagle (*Icthyophaga humilis*), Grey-headed Fish-eagle (*Icthyophaga ichthyaetus*), White-bellied Fish-eagle (*Haliaeetus leucogaster*), White-tailed Sea-eagle (*Haliaeetus albicilia*). Pallas's Fish-eagle (here after; PFE) are winter visitors and goes back to their summer grounds in Mongoli, Kazakhstan and Sounthern Russia (BirdLife International, 2020), while Lesser Fish-eagle (here after; LFE) (Karuthedathu, 2023), and Grey-headed Fish-eagle (here after; GFE) (Clark et al., 2023) are resident population in the Rajaji-Corbett landscape in Uttrakhand. All these species co-exist in the western part of Corbett Tiger Reserve, while LFE and PFE are found throughout the landscape. Globally, PFE is classified as Endangered by the IUCN; nationally, the species is placed under the 'High' conservation category (SoIB, 2020). LFE and GFE are classified as Near Threatened according to IUCN; nationally GFE has 'moderate' , and LFE has 'low' conservation status (SoIB, 2020).

Figure 1: Chilla nest on a *Bombax ceiba* tree

Figure 2: Fledgling stage of PFE, Andher nest

Figure 3: LFE in its typical habitat, sitting on a branch, over hanging on river Kho

Figure 4: Breeding pair sitting on the nest, *Bombax ceiba* tree

Figure 5: Adult Pallas's Fish-eagle

Pallas's Fish-eagle *(Haliaeetus leucoryphus)* is distributed across South Russia, Central and South Asia, and a sizable breeding population is reported from the states adjoining the Himalayas in India (Steele, M. 2017). These birds prefer altitudes up to 1800 m in the Himalayan foothills (Naoroji, R. 2006), and breed from December to April (Chowdhury et al., 2022). The clutch consists of 2–3 eggs, with an incubation period lasting 40–45 days, followed by an additional 60 days for the hatchling to acquire flight capabilities (Naoroji, R. 2006).

Information on PFE nesting ecology in India and neighbouring nations comes from anecdotal sightings and studies on few nests. Jamtsho et al. (2023) found that PFE in Bhutan preferred nest trees with unobstructed branches and good visibility for foraging and defence. Chowdhury et al. (2022) found that PFE in Bangladesh nest at a mean density of 1.2 nests per 100 km², nests were located close to human settlements, wetlands, and rivers.

The current distribution shows that these birds breed in northern India, northeast India, Bhutan, and Bangladesh. This makes it important to study PFE in northern India. The lack of descriptive information on the PFE in India presents a knowledge gap in our understanding of the species' natural history in India. For such a wide-ranging and threatened species, information on nesting ecology throughout its distribution range is crucial for effective conservation and management. This study intends to look at the factors affecting nest site selection and aims to fill the research gap by conducting a comprehensive study on its nesting ecology to determine critical factors along the sub-Himalayan tract. The study also intends to observe the hatchling to fledgling development, sharing of parental duties, and nest predation pressure due to co-occurring raptor species and crows. This will enable us to protect both the habitat and species.

Objectives

Objective 1: To understand the factors affecting nest site selection and tree selection of Pallas's fish-eagles

a) What factors are affecting the nest site selection in Pallas's fish-eagle at the landscape level?
b) What are the factors affecting nest tree selection?

Objective 2: To understand the predation pressure and nesting behavior in Pallas's fish eagles

a) What are the different species of co-occurring raptors present at various nest sites?
b) What is the change in parental presence on nest w.r.t. growth of nestling?

METHODS

STUDY AREA

The Rajaji-Corbett landscape within the western Himalayas and the Shivalik hills spans from the Kalsi Reserve Forest in Haryana to the Kosi River in Uttrakhand.Renowned for its unique geographical position, it serves as a transitional area between the Himalayas and the Gangetic plain, encompassing latitudes of 29° 05' to 30° 43' N and longitudes of 77° 19' to 79° 25' E, covering an expanse of approximately 10,000 km² (C1). Geomorphologically, the landscape presents highly dissected terrain in the south and gentle slopes in the north. Vegetation predominantly includes Tropical Moist Deciduous Forest (Group 3C/C2), Tropical Dry Deciduous Forest (Group 5B/C1 & C2), Subtropical Pine Forest (Group 9/C1 & DS1), Subtropical Dry Evergreen Forests (Group 10/C1), and Himalayan Moist Temperate Forest (Group12/C1) (Champion & Seth, 1968)

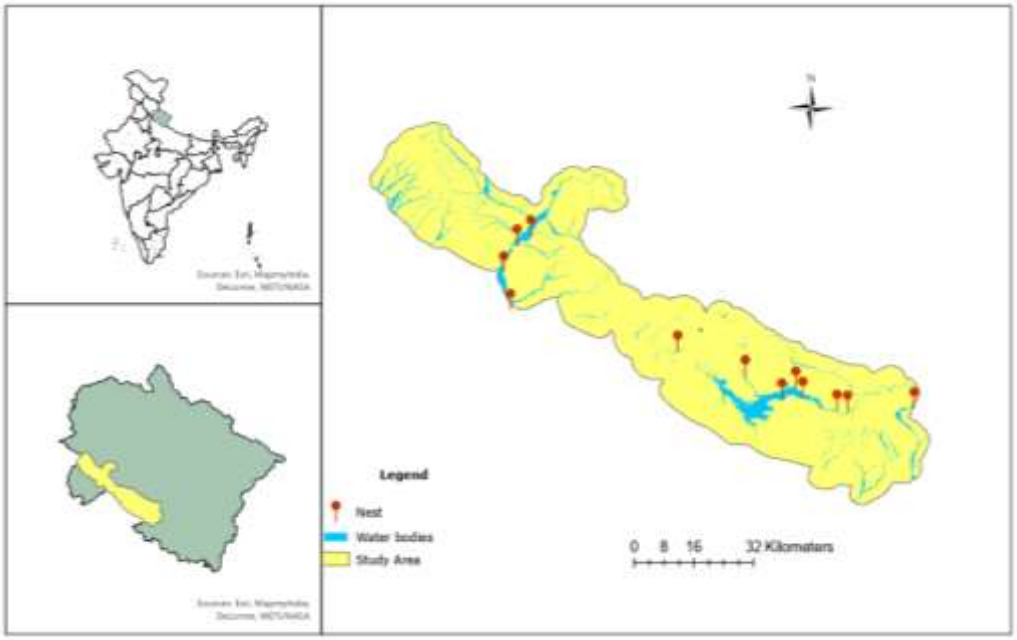

Figure 6: Location of PFE nests identified (red pins) during the study in the Rajaji- Corbett landscape in the state of Uttarakhand, India.

NEST SURVEY AND LFE SURVEY

The study area encompasses many potential habitats for both species of fish eagles, which rely on fish as their primary food source. Therefore, the survey efforts were only concentrated along the riverbanks. The rivers surveyed include segments of the Ganga, Kohlu, Kho, Palain, Mandal, Asan Barrage, Dakpatthar Barrage, and Ramganga. Upon sighting a LFE or PFE, data such as walking angle, distance, sighting angle, and observer location were meticulously recorded. In cases where a PFE was seen, added time was given to search for nests. At every nest, tree species, height, and GBH of the nest tree were recorded, and at every 45° nearest tree species, distance to nest tree, GBH and height were recorded; trees with GBH < 50cm were excluded as they were too weak to carry the weight of the nest.

Spatial analysis was performed in ArcGIS Pro; all the projections were made in WGS 1984 UTM to calculate Euclidean distances and from all the variables, i.e., Water, Forest, Crop, Barren land, Rangeland, Built area, Flooded area, Slope, Aspect, and Altitude. Area percentage underof different LULC typestype within a 3 kKm^2 buffer was also calculated. These variables were considered based on literature. A study in Bangladesh by Chowdhury et al., 2022, suggested that these birds were found within 100 m of human settlements. Similarly, water is essential as their feeding grounds.

BEHAVIOR SAMPLING

Behavior sampling was conducted at three out of twelve nests (11 active nests, one destroyed) selected based on accessibility, visibility, and the presence of chicks. The chosen nests were located near the range offices of Anjani, Chilla, and Andher. Initial behavioral observations were made at the Chilla and Andher nests at the end of January, before the commencement of field surveys. Once the survey to find nests was completed,

the three selected nests were observed four days a week. Two people carried out these observations, each dedicating four hours daily to each nest.

At each nest, we recorded the time spent by the parent birds in the nest, near the nest, and away from the nest on a tree or snag, from where they could check for potential nest predators. We also collected data on predation pressure by noting interacting species, their behaviour, and the parent's responses to these interactions. Occasionally, we gathered data on the birds' diet, detailed diet classification was not possible as we kept a safe distance to minimise disturbance to the birds.

Due to logistical limitations, such as the lack of permission to fly drones and the absence of high-resolution cameras, the feeding behaviour was not recorded.

ANALYSIS

All the statistical analyses were carried out using R ver 4.2.2. The LULC (land use land cover), and other GIS-based analyses were carried out using ArcGIS Pro. Euclidean distance and raster value of each variable for all the point locations, including nests and 60 random point locations generated in a buffer of 2.5km radius, were used to run a generalised linear model (GLM). Correlation between variables was assessed using the R library, "corrplot", and variables with correlation coefficient> 0.6 were omitted.

At the macro level, three times the number of nests, i.e., 36 random points, were generated in the study area within 750m MSL since all the nests were below 550m. These points were given a buffer of 3000 m radius, points where the buffer overlapped more than 50% were removed before various analyses were run. The percentage cover of each LULC type was extracted to run GLM.

At the micro level, tree selectivity was analysed using Ivlev-Jacob's selectivity indices. Along with selectivity, a GLM was performed to see the effect of predictor variables such as tree species, GBH, height, and distance to nest on the response variable, nest presence and absence.

Behaviour data was used to understand the predator pressure at each site. Since the sampling effort differed for each site, samples were standardised based on the observational duration of each nest. Nest guarding behaviour was analysed by the presence or absence of an adult on or off the nest and the change in guarding behaviour with the growth of chick.

RESULT

The surveys were conducted during daylight hours, covering 92.9km on foot. A total of 12 nests were found during the survey; only one nest was found to be destroyed due to a storm, and the remaining nests were active. While many nest locations were already known, this fieldwork led to discovering four new nests. These newly identified nests are in Anjani, Andher, Dassowala, and Kohlu. Out of eleven nests, there is no information regarding of chicks fledged in six nests, and there was one chick each in the Anjani, Leed, and Champion road nest. There were two chicks fledged from Chilla nest and three chicks fledged from Andher nest.

A total of 32 LFE were sighted during the survey. There were a variable number of sightings within each river or subsets of the river- river Kohlu had the maximum encounter rate (0.6LFE/km) followed by Ramganga (0.53LFE/km) and so on. (=sighting/effort). The table below gives the number of PFE nest and LFE spotted in each river.

Table 1: The sampling effort, number of sightings and encounter rate of LFE and PFE during river surveys conducted between (add start and end months and year)

River surveyed	Distance walked (km)	LFE sighted	PFE Nest	Encounter Rate (LFE/km)
Kohlu	13.3	8	1	0.6
Kho	12	6	0	0.5
Mandal	11.6	4	0	0.34
Ramganga	20.6	11	5	0.53
Palain	15	0	1	0
Ganga	15.6	3	4	0.19
Asan	2.8	0	0	0
Dakpatthar	2	0	0	0
Kosi	1	0	1	0

NEST SITE SELECTION

Out of all the 12 nests, the maximum number of nests were built on *Bombax ceiba* (n=5), followed by *Shorea robusta* (n=3), *Holoptelea integrifolia* (n=2), and snags (n=2).

Table 2: Nest tree characteristics of PFE nests with mean (± SE).

Tree Species	Tree Height(m)	Nest Height(m)	GBH (cm)	Primary branches
Bombax ceiba	29.4 (±2.1)	24.8 (±2.45m)	546.6 (±66.3)	10.8 (±2.31)
Shorea Robusta	35.33 (±0.67)	29 (±4.04m)	476.3 (±113)	6 (±3.05)
Holoptelea integrifolia	28 (±1)	26 (±0m)	442.5 (±97.5)	11 (±1)
Snag	25 (±1)	23.5 (±2.12)	319.5 (±69.5)	3.5 (±)

The average height of the preferred tree was 29.9 m (±2.16 m), and the average height of the nest was 24.9 m (± 1.72m), while the average GBH was 473 cm (± 156 cm). Eight of the 11 active nests were found in the top 10% of the nest trees. Tree height and nest height were positively correlated (*r=0.81, n=).*

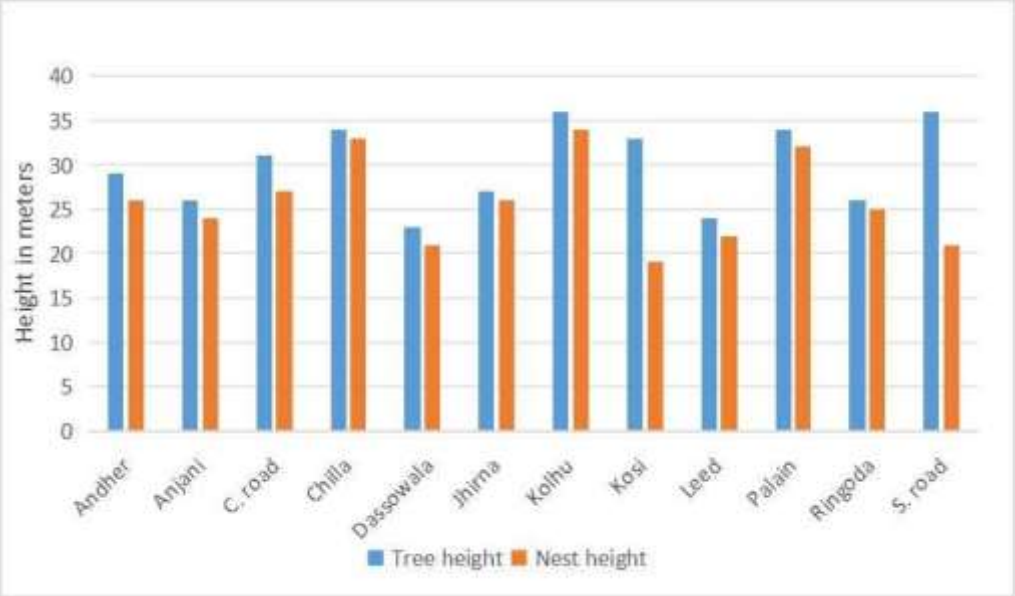

Figure 7: The heights of nesting trees and PFE nests at different locations.

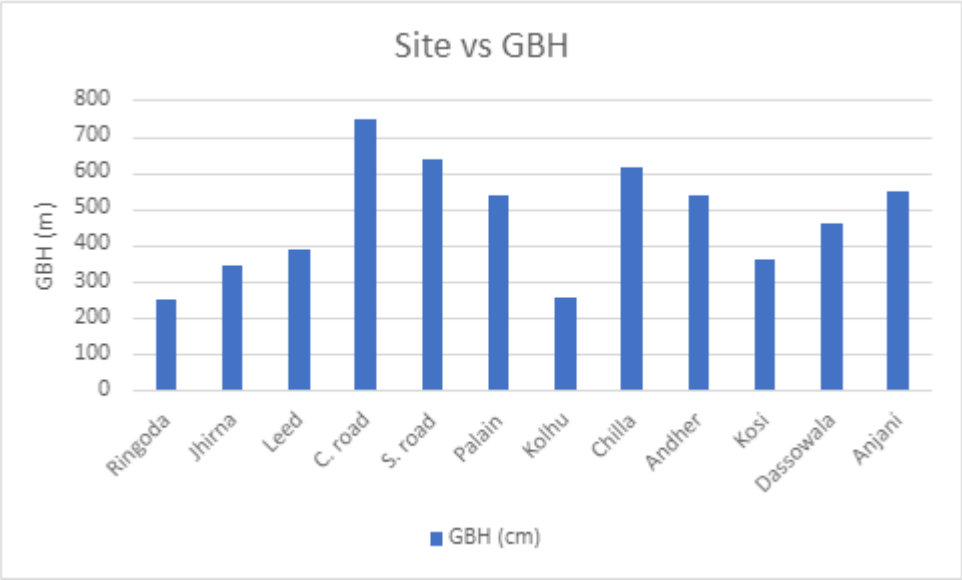

Figure 8. Distribution of GBH across nest trees at different locations.

Two different GLM approaches were made to understand nest site selection:

- The presence (1) and absence (0) of nests were modeled against land cover percentages. The best fit model showed that only percentage area under barren land has a significant effect on the nest site selection.

Table 3: Parameter estimates from the best (with the lowest ΔAIC) generalized linear model to determine effect of different LULC classes in a three km buffer on nest site selection.

Family = Binomial					
Formula = nest ~ flooded + barren + crop					
Coefficients:					
	Estimate	SE	z value	p	
(Intercept)	-1.1492	0.51967	-2.211	**0.027**	*
flooded	93.8345	54.6557	1.717	0.086	
barren	0.53871	0.22941	2.348	**0.0189**	*
crop	-0.1924	0.09934	-1.937	0.0527	
AIC: 37.641	R^2 = 0.38				

- Second, we modelled nest presence and absence against Euclidean distance to different land cover types, altitude, slope and aspect. The best-fit model showed that distance to rangeland, slope and aspect (p-value < 0.05) are negatively affecting nest site selection, while distance to built-up area had a weak but significant influence.

Table 4: Parameter estimates from the best (with the lowest ΔAIC) generalized linear model are used to determine the effect of distance to different LULC classes on nest site selection.

Family = Binomial					
Formula = nest ~ rangeland + slope + builtup + aspect + forest					
Coefficients:					
	Estimate	SE	z value	p	
(Intercept)	0.85448	1.06398	0.803	0.42192	
rangeland	-0.0046	0.00209	-2.197	**0.02804**	*
slope	-0.298	0.15102	-1.973	**0.04851**	*
forest	0.00696	0.00409	1.699	0.0893	
aspect	-0.0106	0.00476	-2.222	**0.02629**	*
builtup	0.00039	0.00015	2.588	**0.00964**	**
AIC = 49.517		R^2 = 0.40			

Selection of tree for nesting was analysed using Ivlev-Jacob's selectivity, the results are as follows:

Table 5: Ivlev- Jabob selectivity indices for nest tree

Species	Ivlev	Jacobs
Acacia catechu	-1	-1
Anogeissus latifolia	-1	-1
Bombax cieba	0.51	0.65
Falconeria insignis	-1	-1
Holoptelia integrifolia	0.8	0.89
Syzygium cumini	-1	-1
Cordia myxia	-1	-1
Mallotus nudiflorus	-1	-1
Shorea robusta	0.3	0.37
Snag	0.4	0.47

Nest tree (1) and nearest tree (0) were modelled with various tree characteristics, and the best fit model showed only the height of the tree as the most significant with (*p*-value >0.001).

Table 6: Parameter estimates from the best (with the lowest ΔAIC) generalized linear model are used to determine the effect of tree characteristics on nest site selection.

Family = Binomial

Formula = nest ~ Ht + GBH

Coefficients:

	Estimate	SE	z value	p	
(Intercept)	-8.3272	1.929	-4.317	**<0.001**	***
Ht	0.2802	0.0733	3.822	**0.00013**	***
GBH	0.00363	0.02128	-0.171	0.86441	

AIC = 48.475 R^2 = 0.40

The total observation duration was 293.6 hours. Andher nest was only observed for 57 cumulative hours as the chicks fledged in late March. The Chilla nest was monitored for 115 hours, and the Anjani nest was monitored for 121 hours.

Chilla nest had the highest number of crows present among all three sites; a chi-squared test ($\chi 2 = 165.02$, df = 6, $p < 0.001$) was run to see the significant difference within sites.

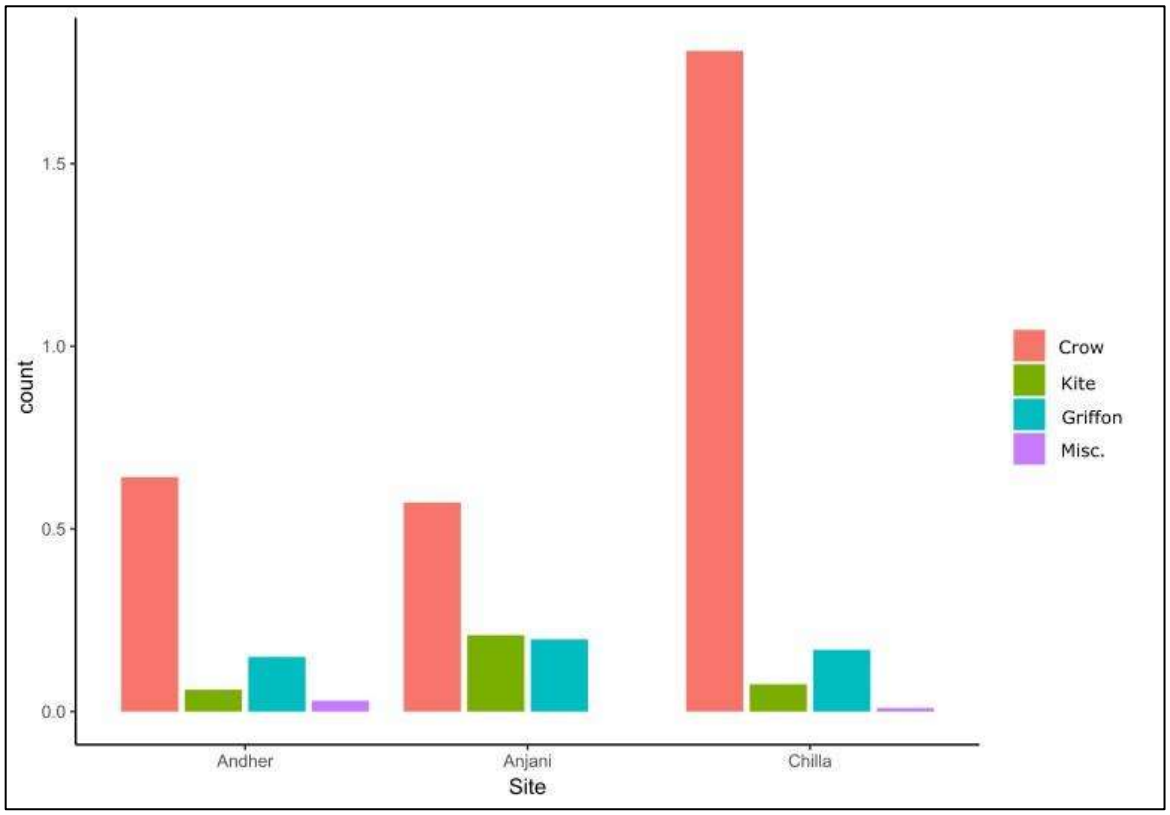

Figure 9: Standardised count of various co-occurring raptors and crows vs site

Parental presence and absence at each site were plotted w.r.t month to see the change in time spent on the nest as the chick grows, and differences were found significant within the site with chi-value (χ^2 = 43.16, df = 2, p< 0.001)

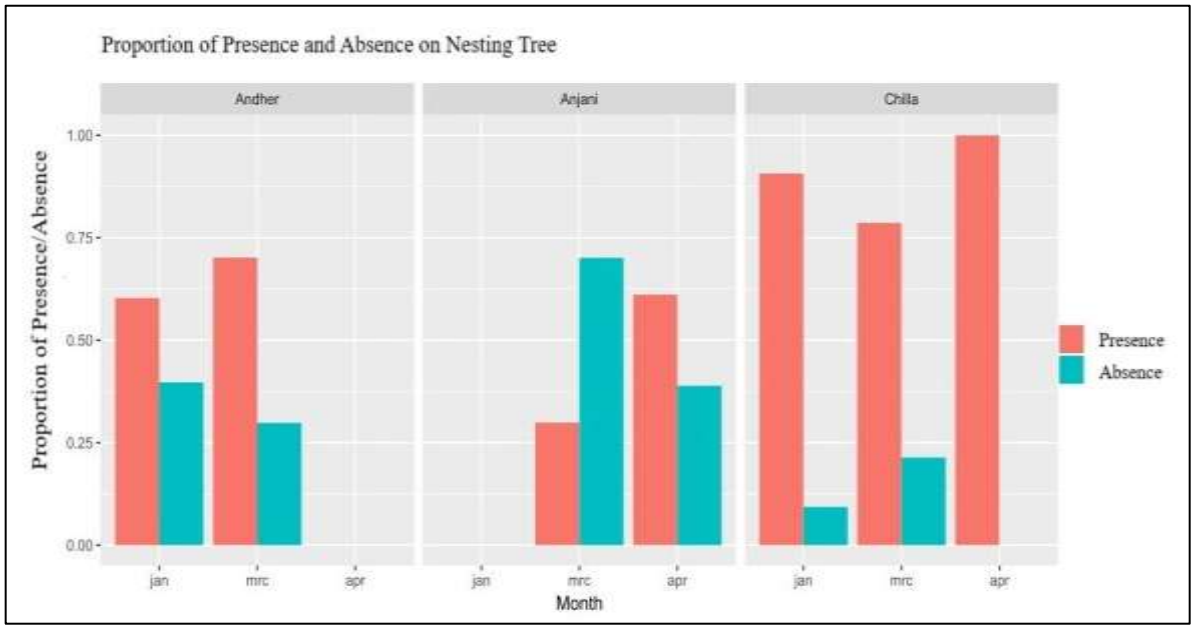

Figure 10: Proportion of presence and absence of parent birds at the nest at each site across the three months

DISCUSSION:

This study aimed to examine nest site selection for Pallas's fish eagle. The survey found twelve nests, of which eleven were active, and one was destroyed by a storm (as communicated by the forest department). These birds are piscivorous and heavily dependent on water bodies for their food (Sourav et al., 2011; Chowdhury et al., 2020), so they nest close to the nearest water source. All nests were found within protected areas (PA), this was contrasting with the study on Pallas's fish eagle nests in Bangladesh by(Chowdhury et al., 2020), where nests were found within 100m of human settlements. This suggests that the Indian population might be less tolerant of human presence.

NEST TREE SELECTION

Nest trees with more unobstructed branches and a greater arc of accessibility than the nearby trees are crucial factors in tree selection. The substantial differences between the nest tree height and surrounding tree height suggest that PFE selects the tallest tree from nearby trees. This difference enables them to move easily into the nest with a greater arc of accessibility (Newton, 2010). Eight of all the nests were found in the top 10% (3m) of the nest tree, giving them the least available crown density for easy accessibility to the nest. These birds make platform nests, which also act as a territorial signal to other co-occurring raptor species (Newton, 2010); the tallest tree selected, with crown density (0-25%), provides the advantage of displaying platform nests. In a study on Gray-headed fish-eagles by (Tingay et al., 2006; Miron and Chowdhury, 2019), birds were found to be using trees with low crown density (<25%).

The tree species also plays a significant role in selecting nesting sites; in the selectivity analysis, *Holoptelea integrifolia* had the highest Ivlev-Jacob selectivity values, followed by *Bombax ceiba*, Snag, and *Shorea robusta*. Apart from all the selected trees, it showed a high avoidance of the nearest trees. These trees were favoured in the

winter season, as they were devoid of any foliage (Mishra et al., 2021). It also provides these birds with a view overlooking the water bodies.

All nesting trees had a higher average GBH than the average of the nearest trees. This means that birds select trees that provide support for their heavy nests. All the species selected had a GBH higher than 250 cm, which shows a preference for trees with more robust bases to withstand intense weather conditions in the Himalayan foothills. These nests require support to survive against windy conditions. Except for two nests, the rest were made on trees with three or more supporting branches, which provide additional support to the base of the nest.

NEST SITE SELECTION

A thorough analysis of environment variables at the macro scale was done by comparing the area of various classes of LULC type in the vicinity of the nest. However, the results are contrary to previous inferences (Chowdhury et al., 2020). The area under barren land had the highest coefficient estimate in the GLM compared to other land use types. This shows that PFE preferred tall trees in open land with larger GBH in areas surrounding it. A barren area around the nest tree is advantageous in overlooking the territory, with an unobstructed view of prey and competitors. According to the model, the flooded region had the highest estimate values, suggesting a strong preference is shown toward flooded areas, which have low understory vegetation compared to land. It might be due to many of the nests being present in the river islands (nest site: Dassowala, Chilla, Leed and Ringoda), which stay submerged during the monsoon, but during winter, these places give PFE open land around the nest tree for better vigilance, unobstructed accessibility and a direct view of the nearest water body.

In the model for distance from LULC classes, Altitude, Aspect and Slope, distance to buildings was shown as the most significant variable, with an extremely low

estimate. The model showed a negative relation between the probability of finding a nest and rangeland- as we go away from rangeland, the probability of encountering a nest decreases; usually, the forest is separated from a more extensive water body with sparsely distributed trees and shrubs. In this study, this was seen in all the nests except two (Palain and Kohlu), which had the highest under-story vegetation compared to all the other nests. The model showed a negative relation with slope. It suggests that trees that can be potential nesting trees require an average slope of 3°. Slope is found to be directly related to tree height as seen in a study (Qingshan et al., 1998). This is seen in many species of tall trees, where harsh weather can uproot trees on steeper slope, the tree will experience more turbulence, which in turn can cause nests to fall from trees, leading to nest failure.

Even though the models do not show water in any test as a significant variable, through personal field experience, there is a high affinity with the distance to the water body, as seen in many other piscivore raptors. It is evident in a study on another sympatric species, the Gray-headed fish eagle (Miron & Chowdhury, 2019). There was an average of 66% forest cover across all the nests, which relates to low levels of disturbances in these protected areas.

This study also looked at interaction with other co-occurring species during the breeding season, October to May, as opposed to what (Chowdhury et al., 2022) reported for the population in Bangladesh, which breeds from October to April. During the study, the stages of nests in the study area differed; nests in Corbett were at a later stage of chick development with chicks having juvenile plumage. At the same time, nests on Ganga were in the initial stages, with incomplete fledgling plumage. Therefore, behaviour studies were conducted on nests along the banks of the Ganga to observe parental care and pressure from other co-occurring raptor species.

Raptors, like other carnivore species, defend their territory from other predators and scavengers (Tapia & Zuberogoitia, 2018). PFE are also territorial, especially during the breeding season. Even though the large platform nests act as a signal of territory, few co-occurring raptors are always looking for leftover food inside and can also steal chicks. These co-occurring raptors were seen attacking the PFE and nestlings during the behaviour observations. During the study on PFE nesting behaviour, the parent birds were seen defending the nest from species such as Crows (*Corvus macrorhynchos*), Kites (*Milvus migrans*), Griffons (*Gyps. Spp.*), Ospreys (Pandion haliaetus), Black-winged kites (*Elanus caeruleus*), Changeable Hawk-eagle (*Nisaetus cirrhatus*), Steppe Eagle (*Aquila nipalensis*), Cinereous vulture (*Aegypius monachus*), and Egyptian vulture (*Neophron percnopterus*). Some of these birds actively attacked or tried to rob the nest, while for some, the presence of the species made PFE chase the individual.

CO-OCCURRING PREDATORS

This study of PFE nesting behaviour was carried out on three different nests along the river Ganga: Chilla, Andher and Anjani. Chilla and Anjani's nests were on the Bombax tree, outside the forest, and had more open vegetation than Andher, which was on the fringe of the forest. Nest in Chilla faced an extremely high number of mobbing and chasing from crows compared to other nests. It could be due to the presence of small settlements near the Chilla range. These settlements attracted more crows, which, during the breeding season of PFE, keep mobbing these birds to steal from the birds and nests or, if there is an opportunity, may pick on the nestlings in the early stage of development.

Chilla nest had three eggs (comms. with forest dept.), but only two chicks fledged. Are crows the reasons? Any site having high predation pressure results in lower breeding success. Breeding in places with remarkably high predators can also lead to nest failure (Newton 1998). The energy utilised to keep the nestling warm and bring food on time in

winter was used to defend the territory. The number of crows was so high that both the parents had invested much more than the other two nests.

The story for Anjani and Andher was different than for Chilla; these birds had predation pressure, which does not look like a result of an altered environment. Due to its location away from the settlement, Anjani had a comparatively smaller number of interactions with crows but comparable interactions with Kites and Griffons. Most of the time, these birds were seen sitting on or around the nest tree. Even when one of these birds left the nest for hunting, the other parent chased these birds away.

A similar trend was observed across all the sites when the plot was made with parent birds on the nest tree and away from the nest tree. During the early nesting period, these birds tend to nest more, and this decreases as the chick starts to grow more. Due to the unavailability of data in February, the nest between Anjani and Andher shows a clear decrease in time spent by parents on the nest tree and an increase in the time away from the nest. However, this was not the case with the nest in Chilla; the time spent on the nest increased from January to March. Chilla nest had a very high number of crows, which made it hard for these birds to tend to the chicks.

CONCLUSION

This study confirms that PFE nests near water bodies with an average distance of ~200m and a distance to forest was 101m. Nests were found away from human-dominated LULC classes with an average distance of 3.9 km. Trees with minimal crown density were selected, favouring species such as *Bombax ceiba*. All the nest trees were taller than 20m and were present in place with an average slope of 3°. Barren land has the most significant effect on site selection, followed by flooded land cover. Initially, parent birds spend more time at the nest, and as the chick grows, there is a decrease in the time spent on the nest to bring more food and chase away other predators. Nest close to settlements

(Chilla) saw a much higher presence of crows than the other two. Consequently, parental presence at the nest was highly influenced by the number of co-occurring predators found near the nest.

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