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Cover: Freshly emerged Footman Moth *Nepita conferta* from the cocoon on a brightly painted wall in the Nilgiris. Digital art on Procreate. © Aakanksha Komanduri.

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Distribution of Smooth-coated Otters (Mammalia: Carnivora: Mustelidae: *Lutrogale perspicillata*) in the coastal mangroves of Maharashtra: a case study of Savitri River and Kalinje Mangrove Ecosystem

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Abstract: This study aimed to document the distribution of Smooth-coated Otters *Lutrogale perspicillata* within two ecologically distinct but poorly studied habitats in Maharashtra.: the Savitri River covering a 65 km stretch from Mahad to Bankot in Ratnagiri District, and the Kalinje Mangrove encompassing 8.4 km^2 in Raigad District. Using indirect sign surveys, we estimated that otters occupied 36% of the surveyed length of the Savitri River and 13% of the Kalinje Mangrove area. Encounter rates were recorded at 0.65 signs/km in the Savitri River, and 0.41 signs/km in the Kalinje Mangrove. These observations contribute to baseline understanding of otter habitats in these landscapes and offer useful insights for conservation. Promoting long-term protection of otters will require collaboration with diverse stakeholders including fisherfolk, students and local forest departments to foster awareness, encourage co-existence, and integrate otter conservation into community-based stewardship.

Keywords: Encounter rate, GIS, habitat, otter conervation, percentage of occurrence, research, survey.

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Author contributions: SRP has conceptualized and designed they study; conducted field surveys, sign surveys, and data collection; performed data analysis and interpretation; and led manuscript writing and revisions. MM provided project faciliation, administration support, and coordination with revelant authorites, and contributed inputs towards study planning and implementation. Both authors reviewed and approved the final manuscript.

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INTRODUCTION

India is home to three otter species: the Smooth-coated Otter *Lutrogale perspicillata*, the Asian Small-clawed Otter *Aonyx cinerea*, and the Eurasian Otter *Lutra lutra*. Since most freshwater sites lie outside protected areas or Ramsar-listed wetland sites, otter populations face threats from land use changes. According to the Amendments in the Wild Life (Protection) Act, 2022, these otters are listed as Schedule species, prohibiting hunting, trapping, trade, or killing. Populations continue to decline due to unsustainable development, large-scale wetland conversion, deteriorating water quality, and poaching (Duplaix & Savage 2018).

In the tropics, protected areas occupy less than 10% of the total area, and a substantial amount of biodiversity exists outside protected areas (Schmitt et al. 2009). In landscapes lacking protected areas, human-modified landscapes often provide critical habitats and refuges for biodiversity (Chazdon et al. 2009). As protected areas continue to shrink and human-modified landscapes continue to expand, conservation and research attention must be focused on these heterogeneous landscapes, especially river basins. Conservation of charismatic species like otters in such a heterogeneous landscape is critical, as they occupy some of the best habitats available for them. The habitats are essential for otters, providing space for spraint deposition, grooming, and creation of holts (dens), which play a vital role in their social interactions and in marking territories.

Our main objective is to improve the understanding of Smooth-coated Otters in the Kalinje Mangrove of Raigad District, and along the Savitri River between Raigad and Ratnagiri districts of Maharashtra.

METHODS

Study Area

Kalinje (18.039° N, 73.029° E) is a small village situated between Harihareshwar and Shrivardhan, known for its stunning mangroves and diverse wildlife. Most people residing here are either fishermen, drivers, or employees. In recent years, mangrove tourism has become popular as more and more people are recognizing the values of this unique ecosystem. The Mangrove Foundation of the Maharashtra Forest Department has undertaken a community-based conservation initiative, called Kalinje Ecotourism, for the upliftment of local communities.

Savitri River (18.048° N, 73.165° E) is one of five rivers originating from Mahabaleshwar in Maharashtra. It flows through Bankot Village en route to the Arabian Sea, and forms a natural boundary between Ratnagiri and Raigad districts. Most villagers residing on the banks of the Savitri are involved in fishing and agriculture.

Baseline data on the distribution of otters in Raigad, Maharashtra.

Sign surveys: For the study of the distribution of otters and their habitat preference, the sign survey method was used. Sign surveys are generally done by looking for indirect evidence of the species such as scat/spraints (Image 11), latrines, pugmarks (Image 8), leftover food, and dens/burrows/holts (Images 9 & 10). Our study area was divided into multiple transects of 1,000 x 50 m (Prakash et al. 2012; Atul et al. 2014; Patil & Yardi 2022). To ensure spatial independence, transects werelaid at intervals of 500 m. The study area was thoroughly surveyed for “otter sites” (signs/evidence of otter presence) and “non-otter sites” (signs/evidence of otter absence), recording:

a. Date and time of the survey.
b. GPS location.
c. The presence & absence of otter signs.
d. Anthropogenic activities or any other disturbances.
e. Den locations: The active dens were noted as “active plots” and inactive dens were marked as “inactive plots” (Images 9 & 10).

Spatial habitat data: GIS software was used to map down vegetation cover, otter distribution, and denning sites along the river stretch. As vegetation cover plays a major role in the selection of denning sites, it served as an aid in the evaluation of potential wildlife habitats. Observed anthropogenic activities along the river stretch were also mapped to understand the impact on the distribution pattern of otters.

Analysis: To estimate the percentage of area occupied by otters, we used Principal Component Analysis (PCA) coupled with logistic regression. These scores were considered as percentages of the Occurrence of Otters.

Encounter rate method: Based on the survey/ transect length, which was Savitri River as well as Kalinje Mangrove. The transect length was kept the same throughout the site and duration (Manjrekar & Prabu 2014).

$$\text{Encounter Rate} = \frac{\text{No. of sightings}}{\text{Total km covered}}$$

The analysis was carried out separately for both Savitri and Kalinje. We also analysed seasonal encounter rates

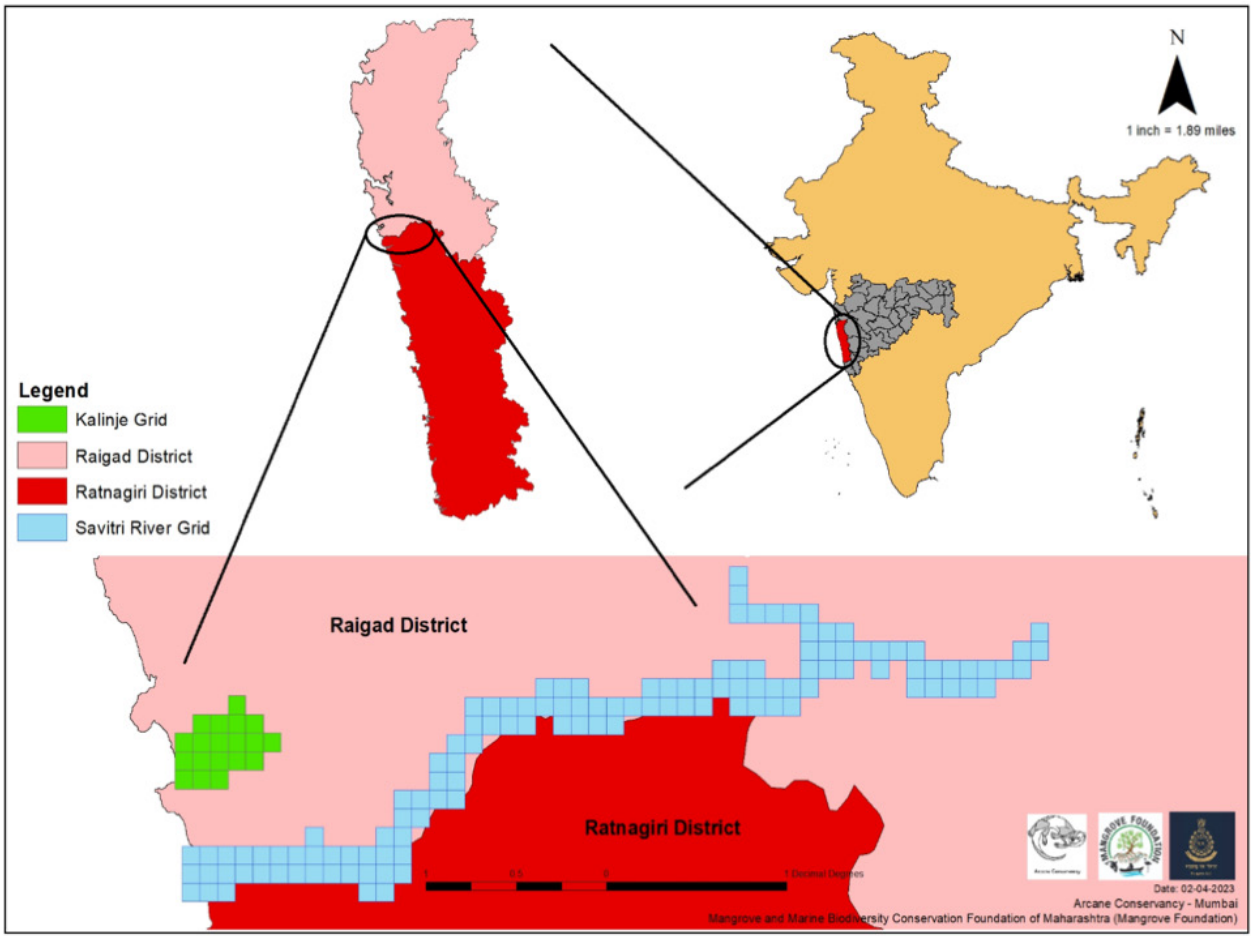

Image 1. Map showing the Savitri River (field site) situated between Raigad and Ratnagiri districts.

by considering pre-monsoon and post-monsoon surveys.

RESULTS

Savitri River

To achieve the study's objectives, a 1 x 1 km grid was deployed along the entire Savitri River, starting from Mahad to Velas, using Google Earth and ArcGIS software. A total of 124 grids were created along the Savitri River (Image 2).

Of these, 103 transect surveys were conducted, covering the river from Bankot to Mahad on the right bank and from Mahad to Bagmandala on the left bank. Certain sites, such as Umroli and Nigdi, remained inaccessible owing to presence of crocodiles (Image 3). Out of the 124 grids, 92 were surveyed, with 34 grids showing positive otter presence.

From the 103 surveys conducted along the Savitri River, 37 surveys yielded positive otter signs (Image 7), indicating that 36% of the area was occupied by otters. The sign surveys were influenced by tidal variations (high and low tides), which affected the detection probability of signs. In total, 67 otter signs were observed during the surveys, including denning areas (holts) and defecation areas, primarily on mangrove island patches.

Kalinje Mangrove

A total of 19 grids were created in the Kalinje Mangrove (Image 4). Each grid had a survey transect with fixed replicates. These surveys assessed the presence or absence of otters, recorded habitat parameters, and noted any threats to the habitat. Additionally, camera trapping was conducted at selected sites based on the presence of direct and indirect otter signs. A total of 296 hours were spent on camera trapping across the Kalinje and Savitri areas (Images 5 & 6).

In the Kalinje Mangrove, 19 grids were surveyed, and 39 transects were conducted. Priority was given to active otter sites to maximize sightings. Surveys were

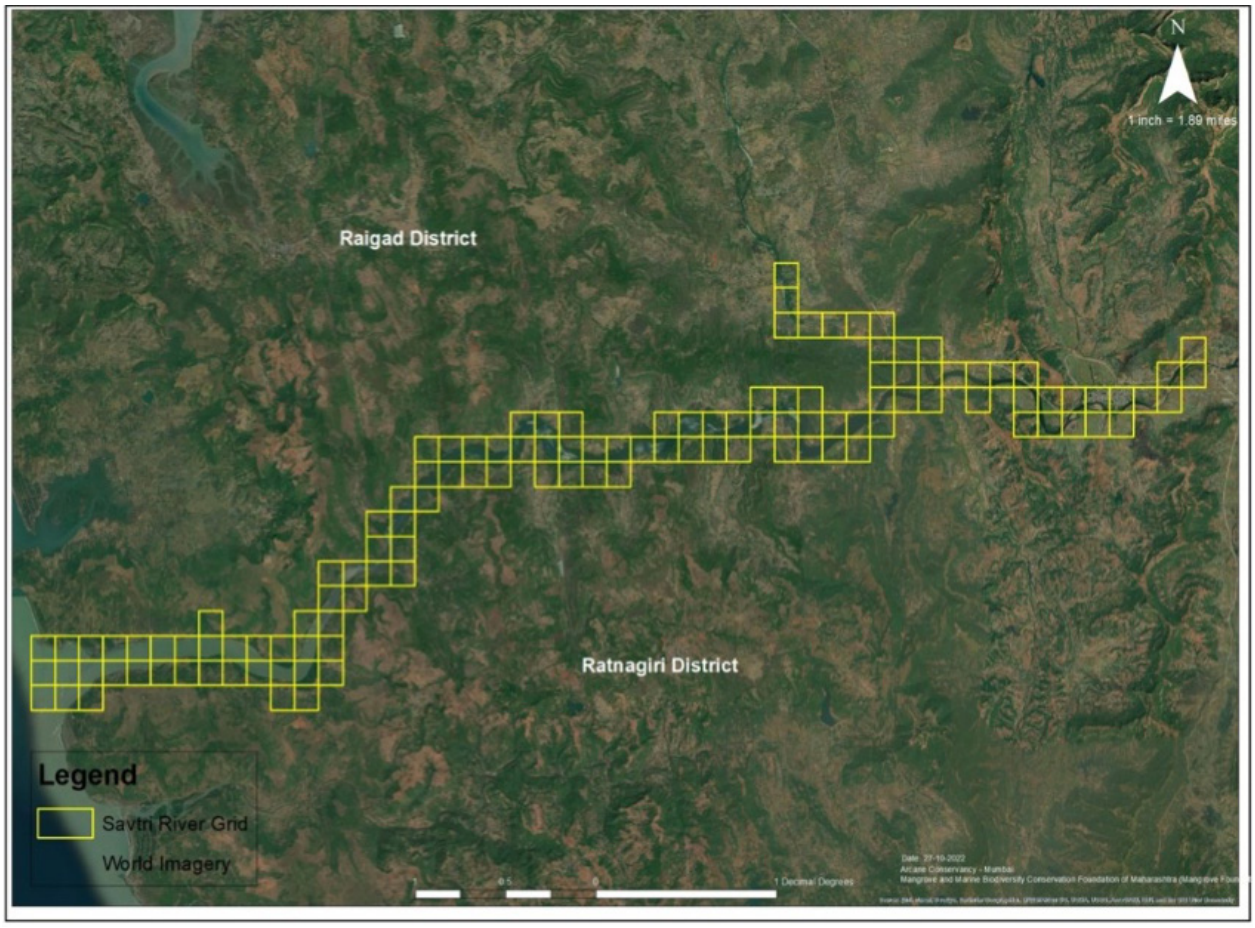

Image 2. Map of survey grid deployed on the Savitri River from Mahad to Velas.

Image 3. Drone shot of a crocodile basking, observed during the otter survey. © Siddharth Pednekar - Arcane Conservancy Trust.

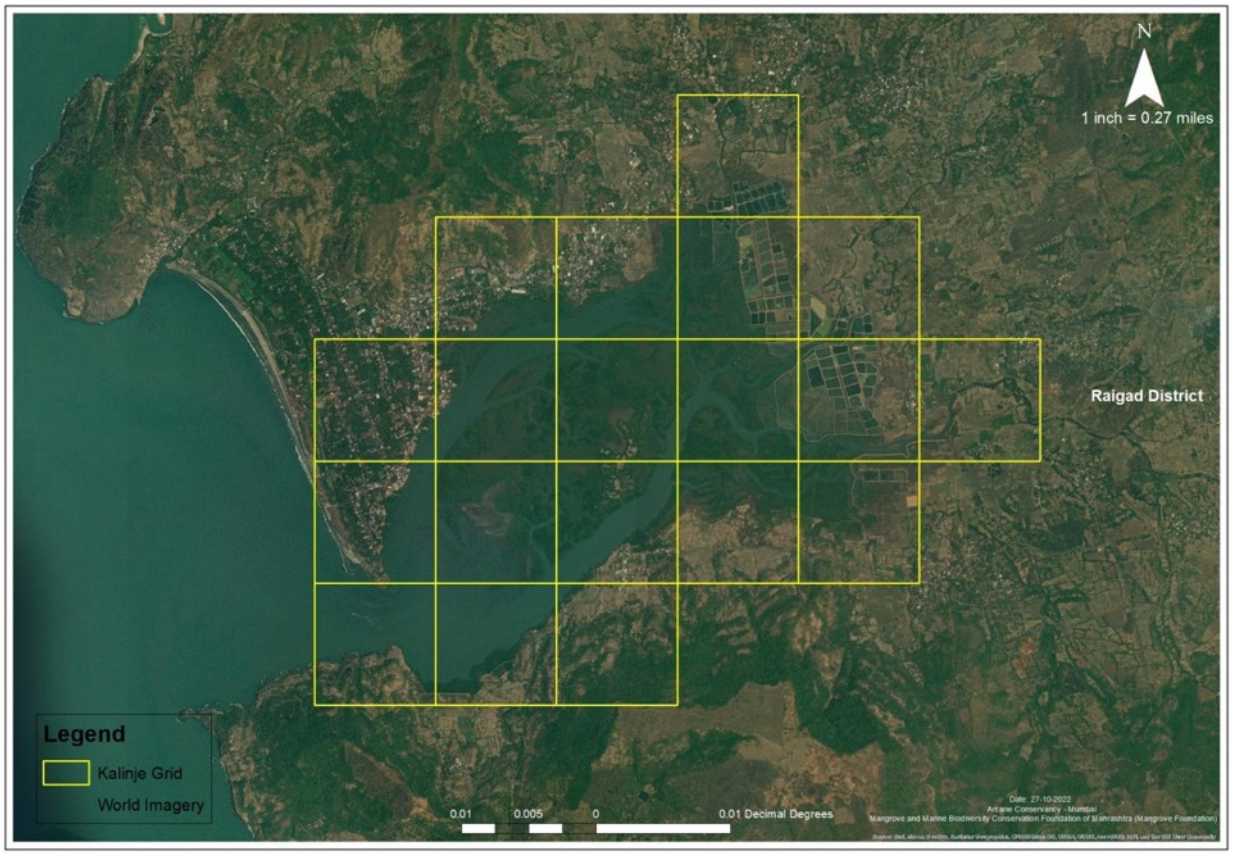

Image 4. Map showing 1 x 1 km survey grid deployed on the Kalinje Mangrove.

Image 5. Camera trap image showing Smooth-coated Otter resting in a mangrove patch in Kalinje. © SArcane Conservancy Trust.

Image 6. Camera trap image showing a pair of Smooth-coated Otters near Shipole Village on Savitri River. © Arcane Conservancy Trust.

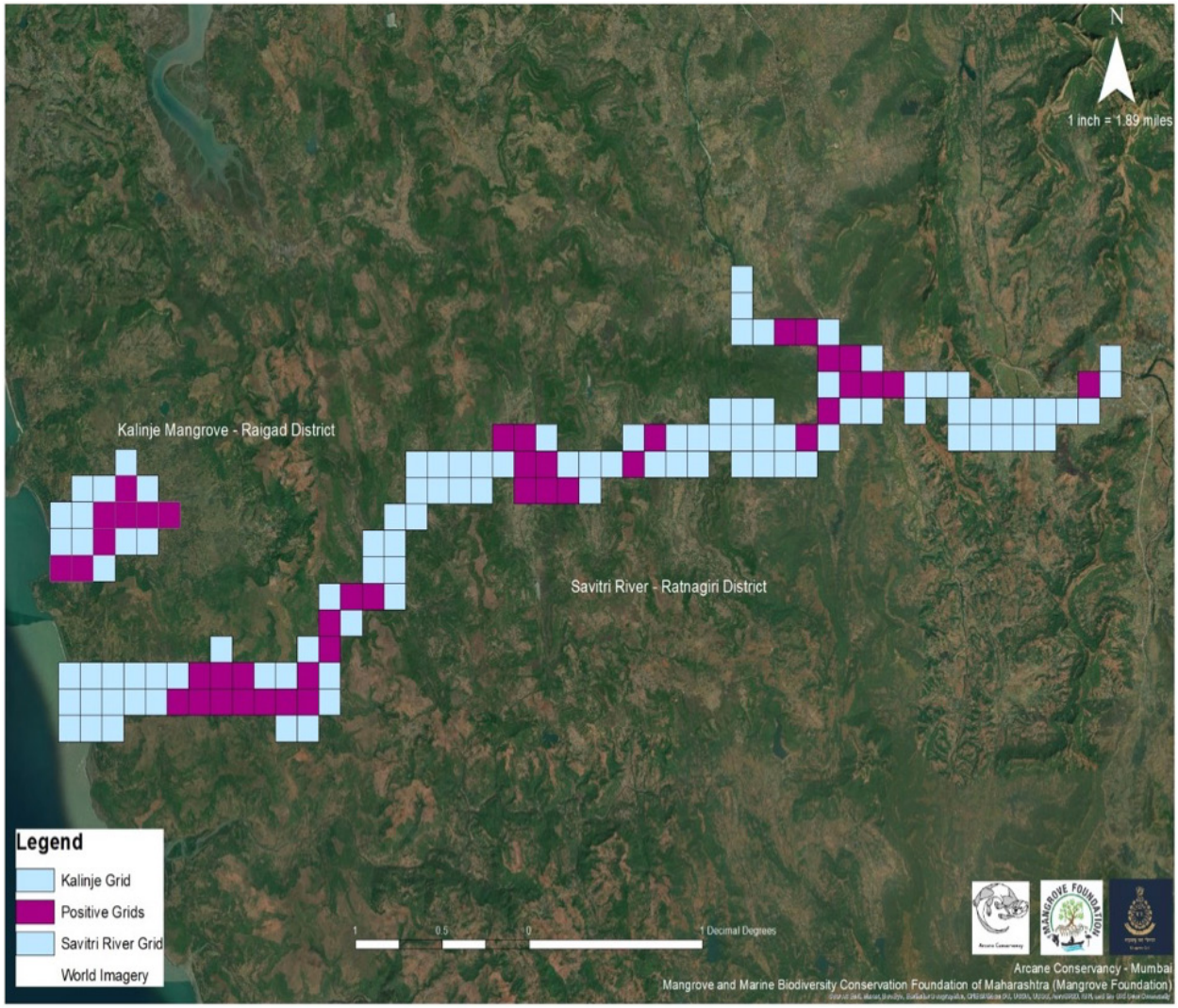

Image 7. Map showing positive field sites/ grids with observed otter signs.

Table 1. Results of principal component analysis with eigenvalues, percentage of variance, and the contribution of habitat variable of Smooth-coated Otters in Savitri River (PC1) and Kalinje Mangrove (PC2).

Variable	PC1 – Savitri River	PC2 – Kalinje Mangrove
Main River	0.740	0.180
Creek	0.690	0.540
Bandh	0.710	0.480
Sandy Bank	0.650	0.320
Farmland	-0.600	-0.620
Rocky Bank	-0.670	-0.220
Elgen Values	4.31	1.54
% Variance	**35.92%**	**12.82%**
%Cumulative Variance	**35.92%**	**48.74%**

Image 8. Otter pugmark. © Arcane Conservancy Trust.

Table 2. Table summarizing the key results for both study locations.

Parameters	Savitri River	Kalinje Mangrove
Total length	65.26 km	8.40 km^2
Total number of grids	124	19
Total number of grids surveyed	92	18
Total number of transects carried	103	39
Encounter rate	0.65 signs/km	0.41 signs/km
Detection probability pre-monsoon	0.53 signs/km	0.66 signs/km
Detection probability post-monsoon	0.67 signs/km	0.38 signs/km

Image 9. An inactive otter den (debris fallen, entrance covered with twigs & leaves). © Arcane Conservancy Trust.

also carried out at and near fish and prawn farms, where informal interviews with workers confirmed regular otter visits. A total of 12 boat surveys were also conducted. Two FnX IR Camera traps were deployed in areas with a high concentration of otter signs, such as defecation or denning areas.

Of the 19 grids surveyed, 8 showed otter signs in the Kalinje Mangrove (Image 7). From the 39 surveys conducted, five yielded positive otter signs, contributing to an estimated 12.82% of the area occupied by otters. A total of 16 otter signs were recorded, with six signs observed in mangrove patches and 10 signs on muddy embankments near prawn farms, particularly on the 'bandhs' (Hindi: Mud embankments) of abandoned prawn farms.

Comparative Seasonal Analysis

Between May 2022 and February 2023, 103 surveys were conducted along the Savitri River and 39 transects in the Kalinje Mangrove. The total distance covered was 103 km for the Savitri River and 39 km for the Kalinje Mangrove. The encounter rate for otter signs (pugmarks and spraint) was 0.65 signs/km along the Savitri River and 0.41 signs/km in the Kalinje Mangrove.

Seasonal patterns were analyzed to understand otter

Image 10. Active otter den. © Arcane Conservancy Trust.

Image 11. Otter spraint/ scat (presence of fish scales and small bones). © Arcane Conservancy Trust.

detection probability during pre- and post-monsoon seasons (May–June and November–January). Due to the shorter study duration in the pre-monsoon period, achieving the same number of surveys for each season was challenging.

For the pre-monsoon season, three surveys were conducted in the Kalinje Mangrove and 15 in the Savitri River, resulting in detection probabilities of 0.53 signs/km and 0.66 signs/km, respectively. In the post-monsoon season, 88 transects were conducted along the Savitri River and 36 in the Kalinje Mangrove, yielding encounter rates of 0.67 signs/km and 0.38 signs/km, respectively.

CONCLUSIONS

The estimated proportion of the length of Savitri River occupied by Smooth-coated Otters was 36% based on our sign survey. This suggests that otters are relatively widespread across approximately one-third of the surveyed areas, utilizing different sections of the river for foraging, resting, denning, and other activities. In contrast, the Kalinje Mangrove showed a lower occupancy rate of 12.8%, indicating a more limited distribution of otters in this habitat.

Our encounter rates of 0.65 signs/km in the Savitri River and 0.41 signs/km in the Kalinje Mangrove reflect the challenges of detecting otter signs in dynamic environments where tides regularly submerge and expose the riverbanks. This fluctuation likely reduces the visibility of otter signs, impacting the detection probability and suggesting that our estimates may be conservative.

The principal component analysis (PCA) further supports these observations. In Savitri River, PC1 accounted for 35.9% of the variance and revealed that otter presence is positively associated with key riverine features such as main river channels, creeks, bandhs, and sandy banks. These variables were consistently linked to habitat use, underscoring their ecological importance. In contrast, PC2 in the Kalinje Mangrove accounted for 12.8% of the variance, with otters showing a preference for creeks and bandhs, although the overall influence of habitat variables was lower, reflecting limited habitat suitability in this mangrove-dominated system. Additionally, farmland and rocky banks were negatively associated with otter presence across both landscapes, likely due to disturbance and poor suitability for resting and denning. These results suggest that otters prefer relatively undisturbed, structurally diverse aquatic environments, and actively avoid modified banks.

The survey suggests that without such baseline data, there will be a lack of informed decision-making, which might lead to a further decline in the population of the species or its suitable habitat. The presence/absence data will be vital in creating conservation hotspots.

Table 3. GPS locations of otter signs.

	Latitude	Longitude	Type of sign	Species ID
1	17.985	73.081	Defecation area	Smooth-coated Otter
2	17.98586	73.084	Scat/Spraint	Smooth-coated Otter
3	17.985	73.085	Scat/Spraint	Smooth-coated Otter
4	17.985	73.086	Scat/Spraint	Smooth-coated Otter
5	17.984	73.087	Scat/Spraint	Smooth-coated Otter
6	17.984	73.087	Scat/Spraint	Smooth-coated Otter
7	17.981	73.092	Scat/Spraint	Smooth-coated Otter
8	17.981	73.092	Scat/Spraint	Smooth-coated Otter
9	17.981	73.092	Scat/Spraint	Smooth-coated Otter
10	17.981	73.094	Scat/Spraint	Smooth-coated Otter
11	17.98094	73.095	Defecation area	Smooth-coated Otter
12	17.979	73.098	Defecation area	Smooth-coated Otter
13	17.980	73.098	Defecation area	Smooth-coated Otter
14	18.04178	73.038	Defecation area	Smooth-coated Otter
15	18.048	73.046	Defecation area	Smooth-coated Otter

A significant amount of otter distribution lies outside protected areas, emphasizing the need for research projects that can generate information on such species. This information could be useful in future with respect to undertaking sustainable developmental activities and implementing effective conservation measures (Defries et al. 2010).

Advances in technology such as camera traps have proven invaluable in this research. These tools allow for the non-intrusive monitoring of otters, providing insights into their behaviour and activity patterns.

In conclusion, this study highlights the need for ongoing research and the integration of modern technologies in wildlife conservation. Our data suggest that otters have a relatively widespread distribution over approximately one-third of the surveyed area, utilizing different sections of the river for foraging, resting, denning, and other activities.

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Image 12. A Smooth-coated Otter foraging through the mangroves. © Arcane Conservancy Trust.

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