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Habitat Use and Conservation Threats of Otters in The Western Bend of Karnali River, Nepal

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Nepal

A dissertation submitted

In partial fulfilment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology and Environment

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Habitat Use and Conservation Threats of Otters in The Western Bend of Karnali River, Nepal

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March 2025

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Declaration

I hereby declare that the work presented in this dissertation "**Habitat use and conservation threats to otters in the Western Bend of Karnali River, Nepal**" has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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Certificate of acceptance

This dissertation work submitted by Madan Acharya entitled "**Habitat use and conservation threats to otters in the Western Bend of Karnali River, Nepal**" has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper Ecology and Environment.

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Abstract

Otters are carnivorous mammals in the family Mustelidae. They face many conservation challenges, including habitat loss, pollution, lack of resources, illegal hunting and trade. Three species of otters- the Eurasian otter (*Lutra lutra*), the smooth-coated otter (*Lutrogale perspicillata*), and the Asian small-clawed otter (*Aonyx cinerea*) are recorded from Nepal. Due to limited studies, baseline information on otters is lacking for most of the wetland sites in Nepal. This study investigated the habitat use and conservation threats of otters in the Western Bend of the Karnali River in western Nepal. Otter distribution was surveyed using direct observations and recording indirect signs, such as scat, pugmarks and food remains, environmental and anthropogenic variables potentially affecting their occurrence were also recorded in the field. Logistic regression model identified key habitat factors influencing otter occurrence, including river width (CI -4.36–0.62, $P < 0.05$), water current (CI = -2.35 to -0.8, $p < 0.05$), and substrate type width (CI 0.49–2.12, $P < 0.05$). Results indicate that otters prefer narrower river sections with small stone bank substrates and moderate water flow, while avoiding areas with high human density (CI -10.15– -3.12, $P < 0.05$) and domestic dog presence (CI 0.95–4.94, $P < 0.05$). Conservation threats such as habitat degradation, illegal fishing, and human encroachment were documented from the study area. The study highlights the need for targeted conservation efforts, including habitat protection and community-based program to mitigate human activities as well as dog-otter conflict, to ensure the long-term survival of otters in this ecologically significant region. Findings provide baseline data for future monitoring and management initiatives.

शोध सारांश

ओतहरू Mustelidae परिवारमा पर्ने मांसाहारी स्तनपायी हुन् । ओतहरूले धेरै संरक्षण चुनौतीहरू सामना गर्छन्, जसमा बासस्थानको क्षति, प्रदूषण, स्रोतहरूको अभाव, अवैध शिकार र व्यापार प्रमूख चुनौतीहरू हुन । नेपालमा तीन प्रजातिका ओतहरू- कालो ओत (*Lutra lutra*), खैरो ओत (*Lutrogale perspicillata*), र सानो ओत (*Aonyx cinerea*) पाईन्छन् यद्यपि, नेपालका अधिकांश भुभागमा ओतहरूको आधारभूत जानकारीको अभाव छ । पश्चिम नेपालमा पर्ने कर्णाली नदीको पश्चिमी मोडमा ओत प्रजातीमा गरिएको यस अध्ययनमा कर्णाली नदीको उक्त क्षेत्रमा ओत प्रजातिको वासस्थान उपयोग र संरक्षण चुनौतीहरूको अनुसन्धान गरिएको छ । अध्ययनमा प्रत्यक्ष अवलोकन तथा ओतको दिसा, पदचिन्ह र ओतले नदी छेउमा बाँकी छाडेको खाना जस्ता अप्रत्यक्ष संकेतहरूको आधारमा ओतको वितरण मुल्यांकन गरिएको छ । यससंगै ओतलाई प्रभाव पार्ने वातावरणिय र मानवजन्य भेरियवलको डाटा संकलन गरिएको छ । लजिस्टिक रिग्रेसन मोडेलिङको प्रयोग गरेर वासस्थान छनोटमा प्रभाव पार्ने प्रमुख कारकहरू जस्तै नदीको चौडाइ, पानीको प्रवाह, र नदी किनाराको स्वरूप पहिचान गरिएको छ । ओतहरूले साँघुरो नदी खण्ड, मध्यम पानी प्रवाह, र साना आकारका ढुंगायुक्त किनारहरू बढी रुचाउने तथ्य नतिजाले देखाएको छ भने मानव अतिक्रमण तथा घरपालुवा कुकुरको उपस्थितिलाई नरुचाउने तथ्य देखाएको छ । यस अध्ययनले अवैध माछा मार्ने प्रवृत्ति, वासस्थान नष्टिकरण, र मानव अतिक्रमण जस्ता प्रमुख संरक्षण चुनौतीहरूलाई दर्शाएको छ जसले गर्दा यस क्षेत्रको पारिस्थितिकीय सन्तुलन कायम राख्न वासस्थान संरक्षण तथा समुदाय आधारित सचेतना कार्यक्रमहरू आवश्यक देखिएको छ । अध्ययनका निष्कर्षहरूले भविष्यमा हुने अनुगमन र व्यवस्थापन नीतिहरूका लागि महत्वपुर्ण आधार प्रदान गर्नेछन् ।

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List of abbreviations

Abbreviated form	Details of abbreviations
AIC	Akaike Information Criterion
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
GLM	Generalized Linear Model
HDI	Human Disturbance Index
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature and Natural Resources
LCI	Lower Confidence Interval
NT	Near Threatened
UCI	Upper Confidence Interval
QGIS	Quantum Geographic Information System
VIF	Variation Information Factors
VU	Vulnerable

1. Introduction

1.1 Background

Freshwater ecosystems are the only home for one-third of the world's vertebrate species, they are essential to maintaining global biodiversity but, changes made by humans to natural river systems have a significant impact on aquatic biodiversity (Dudgeon et al., 2006). Otters are semi-aquatic, apex predator found throughout world, playing a crucial role in maintaining the ecological balance of freshwater ecosystems by regulating fish populations, which helps maintain biodiversity and ecosystem health (Kathariya et al., 2023; Kruuk, 2006). However, they are facing conservation challenges due owing to the degradation in aquatic habitats.

Nepal is home to three of the thirteen otter species that exist globally: the Eurasian otter (*Lutra lutra*), the smooth-coated otter (*Lutrogale perspicillata*), and the Asian small-clawed otter (*Aonyx cinereus*) (Jha et al., 2020), among them Asian Small-clawed Otter have not been recorded in Nepal; for more than a century and a half since 1839 (Acharya et al., 2023) but it was recently recorded from far western Nepal after 185 years (Shrestha et al., 2025). The Karnali River Basin, which encompasses a network of rivers, tributaries, and wetlands, serves as a significant habitat for the otter species (Acharya & Rajbhandari, 2011; Jha et al., 2020; Kathariya et al., 2023). Eurasian otter is listed in Near Threatened, Smooth-coated otter and Asian-small clawed otter are Vulnerable in the IUCN Red List of Threatened Species at global scale (Khoo et al., 2021; Loy et al., 2022; Wright et al., 2021).

Otter inhabits a range of habitats, including rivers, lakes, marshes, waterways and the coastline (Kruuk, 2006; Mason & Macdonald, 1986). Otters are also recorded above 4,000 m in Tibet (Mason & Macdonald, 1986), while in Karnali River they are recorded from higher altitude of Mugu to the flat land of Bardia (Acharya et al., 2023; Gwachha et al., 2023; Jha, 2018; Kathariya et al., 2023; Shrestha et al., 2023). Otters face significant threats due to habitat destruction, water pollution, human encroachment, and unsustainable fishing practices (Kafle, 2011; Kathariya et al., 2023). Human-induced changes such as pollution, habitat destruction, and water management practices (e.g., dam construction) pose significant threats to habitats of aquatic animals (Shrestha et al., 2022). For instance, water pollution resulting from agricultural runoff and industrial effluents can degrade water quality, reducing the availability of prey and suitable habitats (Awasthi et al., 2024; Cook et al., 2022). Sand mining and deforestation along riverbanks can lead to habitat fragmentation, further

threatening otter populations (Kathariya et al., 2023; Shrestha et al., 2022). Studies conducted in a number of Asian nations have shown that otters often favor isolated environments with little human activity and stay away of highly disturbed areas (Basnet et al., 2020; Gupta et al., 2020). Otters are resilient to highly modified anthropogenic landscapes (Lee, 1996; Theng & N, 2016), flexible in habitat selection and able to recover from low numbers (Weinberger et al., 2016).

Study on habitat use and conservation threats identification is helpful in guiding conservation and management of a species (Noon et al., 2012). These foundational concepts can help us to determine where to focus conservation efforts and how much time and money to allocate on them.

1.2 Statement of the problem

Numerous studies in Nepal have focused on habitat preference and threats for otter in Nepal (Acharya et al., 2023; Awasthi & Yoxon, 2018; Gwachha et al., 2023; Kathariya et al., 2023; Thapa et al., 2020), but majority of work is done in National Park or in the Terai restricted to certain places. There's a noticeable gap in research on otters in the western region of Nepal, particularly in the remote and rugged landscapes, where studies are almost entirely lacking. The Nepal Otter Action Plan 2020 acknowledges these shortcomings and intends to rapid field surveys for the baseline data on otter population (Thapa, 2020). Despite informal observations in Western Bend of Karnali River, there has been lack of scientific work. Western Bend of Karnali River is a possible key habitat for otters, yet there is almost no research on otters. Along with natural degradation human activities such as illegal fishing, pollution, and riparian deforestation are likely affecting otter habitats (Anoop & Hussain, 2004; Nawab & Hussain, 2012; Raha & Hussain, 2016), but these impacts remain poorly understood in the Karnali River basin.

1.3 Objectives

1.3.1 General objective

The general objective of this study was to investigate the habitat use otters in the Western Bend of Karnali River, Nepal and the conservation threats on them.

1.3.2 Specific objectives

i. To assess the habitat use of otters in the Western Bend of Karnali River

ii. To identify the conservation threats on otters along the study area.

1.4 Research questions

i. What habitat variables determine habitat use by otters in the Western Bend of Karnali River?

ii. What are the major conservation threats to otters along the Western Bend of Karnali River?

1.5 Significance of the study

Otters are the keystone species and top predator in aquatic ecosystems, and their extinction could lead to cascade effects throughout the entire ecosystem (Fortin et al., 2005; Kruuk, 2006). Otters also acts as flagships for freshwater conservation and their presence indicates good aquatic health since they are sensitive to pollution (Kruuk, 2006; Mason & Macdonald, 1986). Understanding their habitat and the threats they face is vital for creating an effective conservation plan. However, there is currently no available information on the habitat usage and threats to otters in the Western Bend of the Karnali River. Therefore, studying these aspects is crucial for otter conservation. Additionally, the data obtained from this research can contribute to the long-term monitoring of the species in this region.

1.6 Limitations of the study

The study has following limitations:

i. Observations in the field were done only in the daytime.

ii. Forty-eight km riverbank could not be surveyed due to inaccessible terrain.

2. Literature review

2.1 Habitats of otters

Globally there are thirteen species of otters in sub-family Lutrinae inhabiting a wide range of aquatic environments, from marine coasts to freshwater rivers and lakes, and are found on every continent except Australia and Antarctica. (Duplaix & Savage, 2018; Kruuk, 2006; Mason & Macdonald, 1986). Otters are recorded from sea level to elevations greater than 4000m (Duplaix & Savage, 2018; Mason & Macdonald, 1986). In context to Nepal, three species of otters are recorded (Jnawali et al., 2011; Thapa, 2020). Eurasian otters (*Lutra lutra*) primarily inhabit freshwater ecosystems, including mountain streams, rivers, and lakes (Chanin, 2000). In Nepal, their presence has been documented in several protected areas, such as the Annapurna Conservation Area, Makalu Barun National Park, Koshi Tappu Wetland, Bardia National Park, and the Ghodaghodi Lake Area, as well as in 21 districts across the country (Acharya & Rajbhandari, 2011; Jnawali et al., 2011). Smooth-coated otters (*Lutrogale perspicillata*) are distributed across major river basins, including the Koshi, Narayani, Karnali, and Mahakali, with potential habitats in the Annapurna Conservation Area and Chitwan, Bardia, and Shuklaphanta National Parks, where specific locations have been identified within Bardia and Shuklaphanta (Jnawali et al., 2011). The Asian small-clawed otter (*Aonyx cinereus*) was recently confirmed in Nepal after a gap of 185 years, with a recorded sighting in the Dadeldhura district (Shrestha et al., 2025). Historically, unverified reports suggested its presence in Makalu Barun National Park and the Kailali and Kapilvastu districts (Jnawali et al., 2011; Thapa, 2020).

Habitat preferences of otters are shaped by a complex interplay of biotic and abiotic factors. Otters prefer to use habitats where biotic factors, particularly the availability and diversity of prey, are optimal, such as fish-rich stretches of rivers and wetlands with minimal human interference (Nawab & Hussain, 2012). Abiotic factors such as water depth, flow velocity, and the structure of riverbanks also significantly influence habitat preferences (Anoop & Hussain, 2004; Nawab & Hussain, 2012; Raha & Hussain, 2016). Manandhar et al. (2023) identified 21 fish species using field sampling and DNA barcoding, with *Barilius* spp. and *Schizothorax* spp. being the most abundant, while environmental DNA (eDNA) techniques revealed a richer diversity with 46 species in the Karnali River. Earlier studies have reported

up to 51 fish species in the Karnali River system through traditional morphological and genetic analyses (Khatri et al., 2020).

The Karnali River, known for its swift currents and deep pools, provides ideal habitats for the otter which are integral to the health of the aquatic ecosystem, serving as bio-indicators of water quality and ecosystem stability (Awasthi & Yoxon, 2018; Jha et al., 2020). Otters tend to favor habitats with moderate water flow and adequate depth that facilitate efficient hunting and provide shelter from predators (Jonah Dias et al., 2022). The post-monsoon period, characterized by receding water levels and increased prey availability, presents unique environmental conditions that influence the behavior and habitat preferences of otters (Raha & Hussain, 2016).

2.2 Conservation threats on otters

Otters face a number of challenges for existence. Human-induced changes such as pollution, habitat destruction, and water management practices (e.g., dam construction) pose significant threats to habitats of aquatic animals (Shrestha et al., 2022). Their populations are increasingly threatened by various anthropogenic and environmental factors (Kruuk, 2006). For instance, water pollution resulting from agricultural runoff and industrial effluents can degrade water quality, reducing the availability of prey and suitable habitats (Awasthi et al., 2024; Cook et al., 2022). In Asia, otters face habitat fragmentation from wetland conversion for aquaculture and human settlements (Anoop & Hussain, 2004). Sand mining and deforestation along riverbanks can lead to habitat fragmentation, further threatening otter population (Kathariya et al., 2023; Shrestha et al., 2022). Local communities depend on the river for agriculture and fishing, leading to potential conflicts with otter populations (Dahal et al., 2020). Another significant risk is pollution, which can cause bioaccumulation and health issues for otters by depositing heavy metals, pesticides and industrial pollutants in water bodies (Mason & Macdonald, 1986). High concentration of mercury and polychlorinated biphenyls (PCBs) in freshwater systems have been related in studies to otters immunological and reproductive suppression (Carpenter et al., 2014). Declination of otter population has been made worse by illegal poaching for their pelts, particularly in South and Southeast Asia, which is fueled by a strong demand in the illicit wildlife trade (Gomez et al., 2017).

Feral dogs are another significant threats to otter, in an study at Cauvery River at Karnataka, India, Prakash et al. (2014) concludes that the regions with null dog abundance has wide

prediction probability. In Southern Chile, dogs are found to be acting reservoirs of infectious diseases in otter where Canine distemper virus (CDV) is thought to be transmitted among individuals by direct contact trade (Barros et al., 2022).

Studies in various Asian countries have documented that otters tend to avoid heavily disturbed areas and prefer secluded habitats with minimal human activity (Basnet et al., 2020; Gupta et al., 2020). Otter presence is negatively significant to human accessibility, where as distance to urban center and distance to road are non-significant for the occurrence (Tolrà et al., 2024). Asian otter species would benefit from a larger, less fragmented, and more protected range area due to climate change, but this range would also be moved into areas where human disturbance is more prevalent (Cianfrani et al., 2018). Otters are resilient to greatly modified fabricated landscapes (Lee, 1996; Theng & N, 2016), adaptable while choosing a habitat (Weinberger et al., 2016) and able to recover from low numbers (Weinberger et al., 2016).

The Human Disturbance Index (HDI) is an integrated measure that captures the level of human influence on natural ecosystems by combining factors like land use, resource use, and pollution, offering a dynamic view of human pressure across space and time (Wang et al., 2023). The HDI helps scientists and decision-makers understand how much people are affecting the environment, making it easier to spot damaged areas and focus conservation efforts where they're needed most (Falcone et al., 2010). By translating complex human-environment interactions into quantifiable data, HDI supports informed decision-making in land use, and biodiversity conservation strategies (Wang et al., 2023). The index allows for comparison of human disturbances across regions and over time, which helps evaluate the effectiveness of environmental policies and restoration efforts (Hannah et al., 1995).

Although several studies have documented the general habitat preferences and distribution patterns of otters globally and within Nepal (Chanin, 2000; Duplaix & Savage, 2018; Jnawali et al., 2011) , there remains a significant research gap in understanding habitat use and conservation threats at a localized scale, particularly in ecologically sensitive yet underexplored areas like the Western Bend of the Karnali River. While earlier research has outlined key habitat parameters such as water depth, flow velocity, and prey availability (Anoop & Hussain, 2004; Nawab & Hussain, 2012; Raha & Hussain, 2016), few studies have integrated these ecological variables with spatially explicit human disturbance metrics to assess their combined influence on otter presence. Moreover, the application of tools such as

HDI quantifies anthropogenic pressure across landscapes (Falcone et al., 2010; Wang et al., 2023), remains limited in otter-specific conservation studies in Nepal. Given the rapid environmental changes and growing anthropogenic pressures (such as pollution, sand mining, and infrastructure development) on riverine ecosystems (Kathariya et al., 2023; Shrestha et al., 2022), there is an urgent need for localized, data-driven assessments that can inform effective conservation strategies. This study seeks to address this gap by evaluating the habitat use and identifying conservation threats to otters in the Western Bend of the Karnali River, combining field-based ecological observations with spatial analysis of human disturbance.

3. Materials and methods

3.1 Study area

This study was conducted in post-monsoon, particularly in the month of November and December (28 October 2024 to 6 November 2024, 9 December 2024 to 21 December 2024) in Karnali River located at western Nepal (28°58'40" to 28°42'25"N and 80°58'55" to 81°32'48"E). The Karnali River is formed by the confluence of the Mugu Karnali, Humla Karnali and Tila Karnali rivers upstream of the study area, while within the study area, it is joined by the Seti, Thuligad, and Bheri rivers as major tributaries. This section of the Karnali presents a distinct feature known as the Western Bend, where sudden directional shift from south to north, forming a river bend in western direction approximately 200 kilometers shaping a diverse environment of interconnected riverine systems with Seti and Bheri Rivers, wetlands, and bordering forests (McMaster, 2019). The Survey was begun from Surkhet-Dailekh-Accham tri-border to Kuine along the Karnali River covering 150 km river bank upto the nearby border of Bardiya National Park, contributing to its ecological significance (Acharya & Paudel, 2020; Shrestha et al., 2022).

The basin features diverse landscapes, from the Mahabharat Range to the Dun Valleys, with a subtropical to temperate climate. Seasonal variations, particularly the monsoon and post-monsoon periods, significantly impact river hydrology and otter habitat availability (Dahal et al., 2020; Rolls et al., 2012). The region's vegetation includes riverine forests and grasslands, with dominant species like sal (*Shorea robusta*) and khair (*Acacia catechu*), providing essential habitat for otters.

The basin supports a rich biodiversity of fauna, including numerous fish species, which are the primary prey for otters (Acharya & Paudel, 2020). Using field sampling and DNA barcoding, researchers identified 21 fish species, with *Barilius* spp. and *Schizothorax* spp. being the most abundant, while environmental DNA (eDNA) techniques revealed a richer diversity with 46 species in the Karnali River (Manandhar et al., 2023). Earlier studies have reported up to 51 fish species in the Karnali River system through traditional morphological and genetic analyses (Khatri et al., 2020).

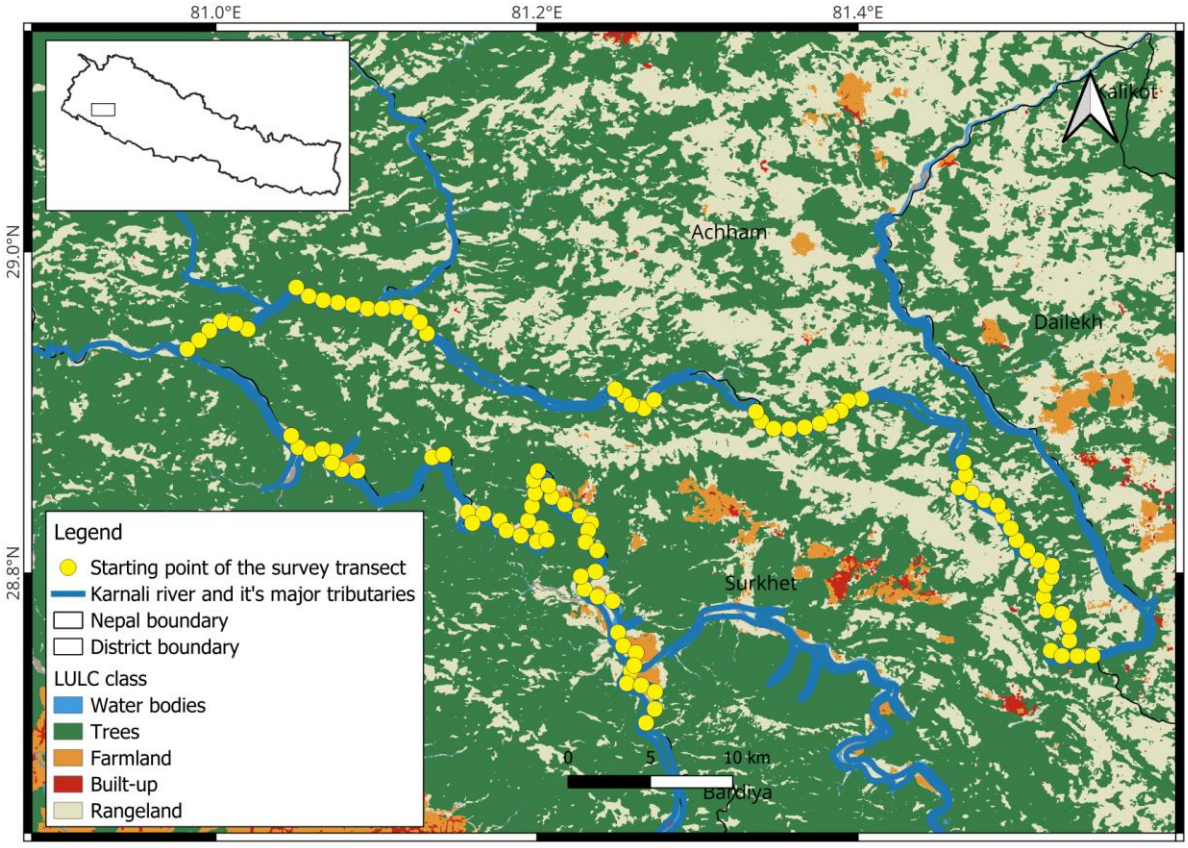

Figure 1. Study area showing the Western Bend of Karnali River with land use classes and survey transects

3.2. Methods

Field surveys of otters often rely on observing tracks, scat, latrines, prey remains, and dens (Mason & Macdonald, 1987; Wilson & Delahay, 2001). Scat distribution was used as a proxy for otter distribution (Sittenthaler et al., 2020). After gaining the research permission from the Department of Forest and Soil Conservation and Division Forest Office Bheri, field survey was carried out from 28th October, 2024, also called the post-monsoon, when water levels in the rivers drop, leaving mud and sand banks exposed to record otter sign.

The probabilities of detection of otter signs were assumed to be similar across survey grid squares as the surveys was carried out along a comparable terrain. The entire river length of study area was divided into 1 km segments along the riverbank on Surkhet side (Savage & Jamwal, 2023). At the start of each transect, one plot measuring 100 m length and 10 m width was surveyed for otter signs and environmental variables. Since, otter scats are scarce, it was recorded whenever encountered along the transects, unless prohibited by inaccessible terrain. Direct observation and indirect signs of otter (scat, pugmark and food remain) were searched

in each plot. A plot or transect with direct observation of otter and indirect signs of otter was defined as an “otter positive” site. Scat was identified by prey species remnants (fragments of fish, frog, crab, rodents), and a fishy odor (Mason & Macdonald, 1987) and photographs of scats was confirmed later by research specialists. Scats were recorded separately when observed more than 5 m apart (Melquist & Hornocker, 1983; Newman & Griffin, 1994). The pH value of water was recorded using digital pH meter (pHep, HANNA Instruments, accuracy ±0.1). A floating ball was used throughout the survey to measure the water current (in m/s) by timing how long it takes to travel 10 meters (Gordon et al., 2004). River width was measured using range finder (TM-1000, 7×25 Laser Range Finder). The bank substrate was visually estimated along each transect and categorized into four types: sand and mud (<1 cm), small stones (1–10 cm), large stones (11 cm–0.5 m), and rock (>0.5 m), based on predefined size classes (Platts et al., 1983). Mean vegetation cover was estimated at the start, middle, and end of each transect and categorized into five classes: bare (0–5%), low (5–25%), moderate (25–50%), high (50–75%), and dense (>75%) (Platts et al., 1983).

Three habitat disturbances affecting otters were assessed within a 100-meter radius of each transect: dog abundance, cattle or cattle tracks, and trash presence. Each disturbance type was scored based on its observed intensity. Dog abundance was categorized as none (0), light (1–3 dogs), moderate (4–6 dogs), and severe (more than 6 dogs). Similarly, cattle presence or tracks were classified as none (0), light (1–10), moderate (11–20), and severe (more than 20). Trash was evaluated based on its estimated coverage within the 100-meter zone, with categories including none (0), light (up to 5%), moderate (10%), and severe (more than 10%) (Falcone et al., 2010). The number of houses within a 500-meter radius was initially estimated using a handheld range finder (TM-1000, 7×25 Laser Range Finder) during field surveys to assess human settlement density (Falcone et al., 2010), and later verified through satellite imagery using Google Earth Pro (Google LLC, 2024).

Potential threats (habitat loss/fragmentation, excavation, infrastructure development, human disturbance and water quality) was noted and broadly characterized. Conservation threats was identified and ranked on a four point scale: Very high, High, Medium and Low (Boitani & Fuller, 2000). The HDI was calculated by integrating conservation threats recorded throughout the field survey which quantifies the intensity of human impacts on ecosystem (Falcone et al., 2010).

3.3. Data analysis

Data was compiled and imported to R-Studio for the statistical analysis (R Core Team, 2023). The continuous variables were first standardized using the *scale()* function, and their normality was assessed through the Shapiro-Wilk test using the *shapiro.test()* function from base R (R Core Team, 2023). To examine multicollinearity, a Pearson correlation test was conducted with the *cor()* and *cor.test()* functions, identifying variable pairs with high correlation coefficients ($|r| > 0.7$). A correlation matrix was created to visualize the strength and direction of relationships among the standardized continuous variables using the corrplot package (Wei & Simko, 2021). Highly correlated predictors were discarded based on predictive relevance to mitigate multicollinearity.

Further, Variance Inflation Factors (VIFs) were computed using the 'vif()' function from the car package (Fox & Weisberg, 2018), to detect any variables contributing to excessive multicollinearity ($VIF > 5$). To assess associations between categorical variables, both Chi-square and Fisher's exact tests were applied using the 'chisq.test()' and 'fisher.test()' functions in base R. Since no significant multicollinearity or inflated variance was detected, all variables were retained for subsequent analyses.

A logistic regression model was developed to predict otter occurrence based on habitat variables (Pearce & Ferrier, 2000). The full model selection using the dredge function identified the most parsimonious models based on AIC criteria (Aho et al., 2014). The final averaged model retained significant predictors, emphasizing the important of habitat variables in influencing otter occurrence (Burnham, 2002).

Confidence intervals for the averaged model parameters were computed to assess the reliability of coefficient estimates (Cumming, 2012). The intervals provided insights into the precision of the estimated effects, reinforcing the importance of key habitat variables (Ishwaran & Lu, 2019). To illustrate the impact of key predictors on the otter occurrence, several visualizations were generated (Upson et al., 1989).

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4. Results

Otters were confirmed in the study area via diresct observation as well as indirect sign survey i.e., scats, pugmarks and food remains. Otters were recorded in 35 transects out of 102 transects studied in the Western Bend of Karnali River. Direct observation was recorded in 12 transects while indirect records; scats and pugmarks were recorded in 2 and 27 transects respectively.

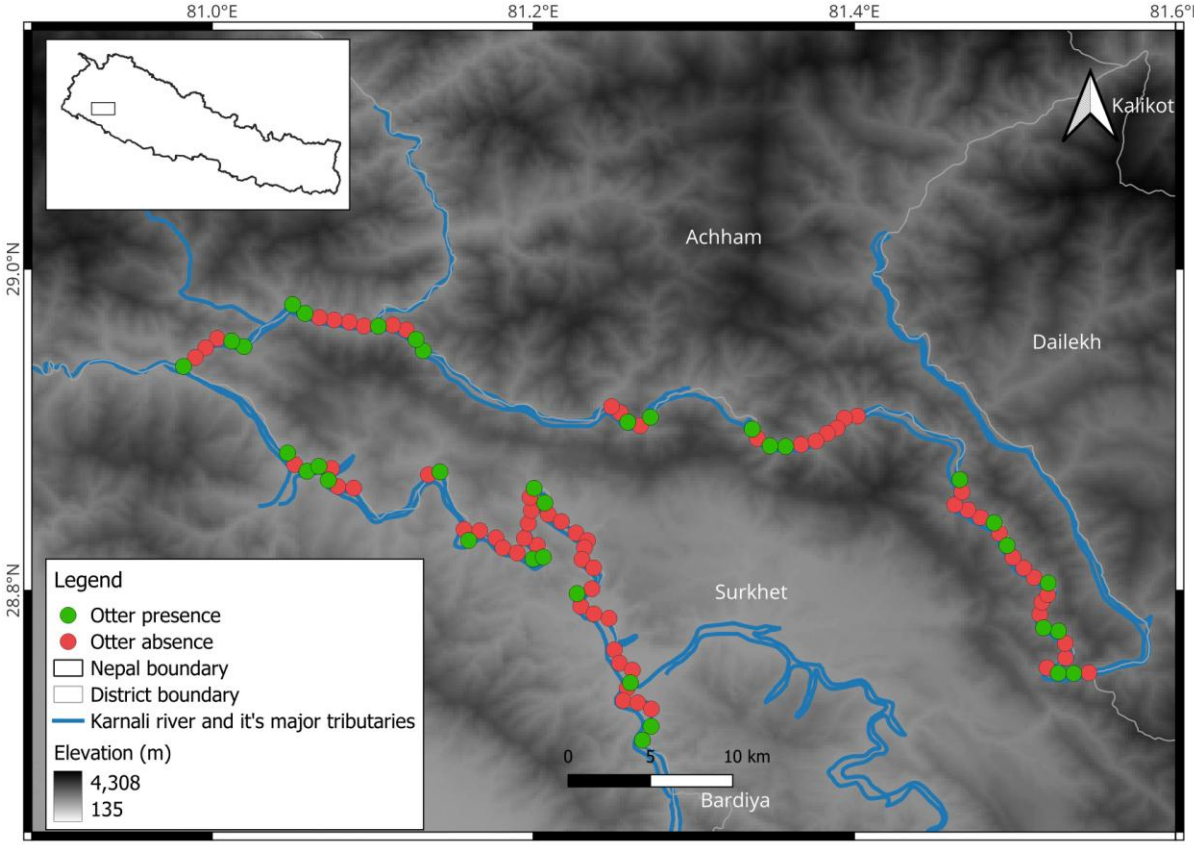

Figure 2. Study area showing the presence and absence of otter along survey transects

River width (115.2±60.83), water currnet (0.25±0.06), small stone bank substrate (26.25±10.29), number of house within 500 m of river (5.24±6.97) were recorded across the survey region. Among the presence points, the enviromnetal categorical variables are recorded as, river slope (steep 25, 71.43%; moderate 8, 22.86%; gentle 1, 2.86%; flat 1, 2.86%) and vegetation cover (dense 17, 48.58%; high 7, 20.00%; moderate 9, 25.71%; low 2, 5.71%) while the human-induced variables are recorded as dog abundance (none 26, 74.29%; light 7, 20.00%; moderate 2, 5.71%), and distance to human settlement (none 5, 14.29%; light 30, 85.71%).

Table 1. Models (ΔAICc ≤ 2) averaged parameters and their lower confidence interval (LCI) and upper confidence interval (UCI) describing factors affecting the habitat use by Otter.

Parameters	Estimate	Std. Error	LCI	UCI	Z	P
Intercept	-3.93	1455.40	-2895.12	2887.27	0.01	0.99
Bank substrate: Small stone	1.31	0.41	0.49	2.12	3.14	**0.01**
Bank substrate: Large stone	-0.25	0.32	-0.87	0.38	0.77	0.44
Dog abundance: None	2.94	1.00	0.95	4.94	2.89	**0.01**
Dog abundance: Moderate	0.71	1.93	-3.13	4.55	0.36	0.72
Near house number	-6.63	1.77	-10.15	-3.12	3.70	**0.01**
River width	-2.50	0.94	-4.36	-0.62	2.61	**0.01**
Water current	-1.21	0.57	-2.35	-0.8	2.09	**0.04**
Vegetation cover: Low	-0.73	1455.41	-2891.93	2890.48	0.01	0.99
Vegetation cover: Moderate	1.64	1455.41	-2889.56	2892.84	0.01	0.99
Vegetation cover: High	1.96	1455.41	-2893.17	2889.24	0.01	0.99
Vegetation cover: Dense	-3.08	1455.41	-2894.29	2888.12	0.01	0.99
HDI	-2.46	1.91	-6.26	1.32	1.93	0.20

Note: Otter occurrence (presence/absence) was response variable while bank substrate, dog abundance, near house number, river width, water current, vegetation cover and HDI were predictive variables. Significant effects are in bold.

4.1. Habitat use of otters

The analysis of factors influencing otter habitat use revealed several significant predictors. The presence of small stone bank substrate was positively associated with otter occurrence (β = 1.31, CI 0.49–2.12, P < 0.01), suggesting a preference for such habitats. Conversely, large

stone bank substrate did not show a significant effect (β = -0.25, CI -0.87–0.38, P = 0.44) (Table 1).

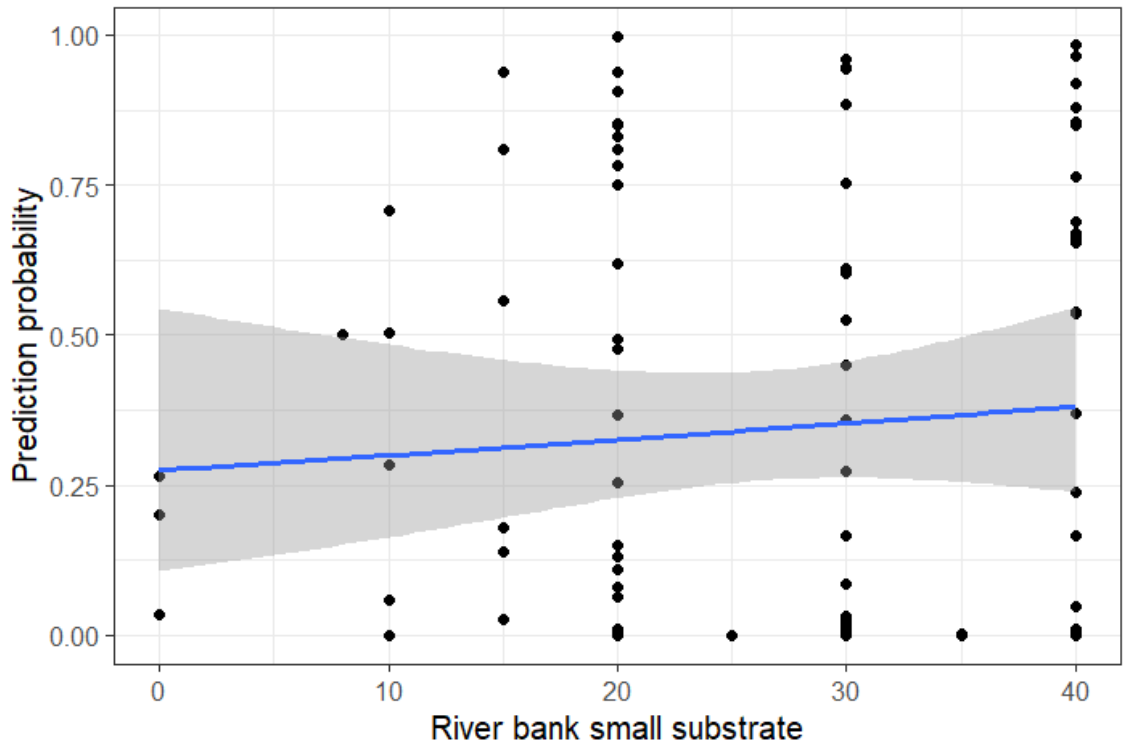

Figure 3. Prediction probability of otter relative to river bank small substrate

River width showed a significant negative relationship with otter occurrence (β = -2.50, CI -4.36–0.62, P < 0.05), suggesting that otters prefer narrower rivers that may provide better shelter and prey availability. Similarly, water current also had a significant negative effect (β = -1.21, CI = -2.35 to -0.8, P < 0.05), suggesting that otters prefer calmer waters (Table 1). Similarly, river width showed a significant negative relationship with otter occurrence (β = -2.50, CI -4.36 to -0.62, P = 0.01), suggesting otter prefer narrow river width (Table 1).

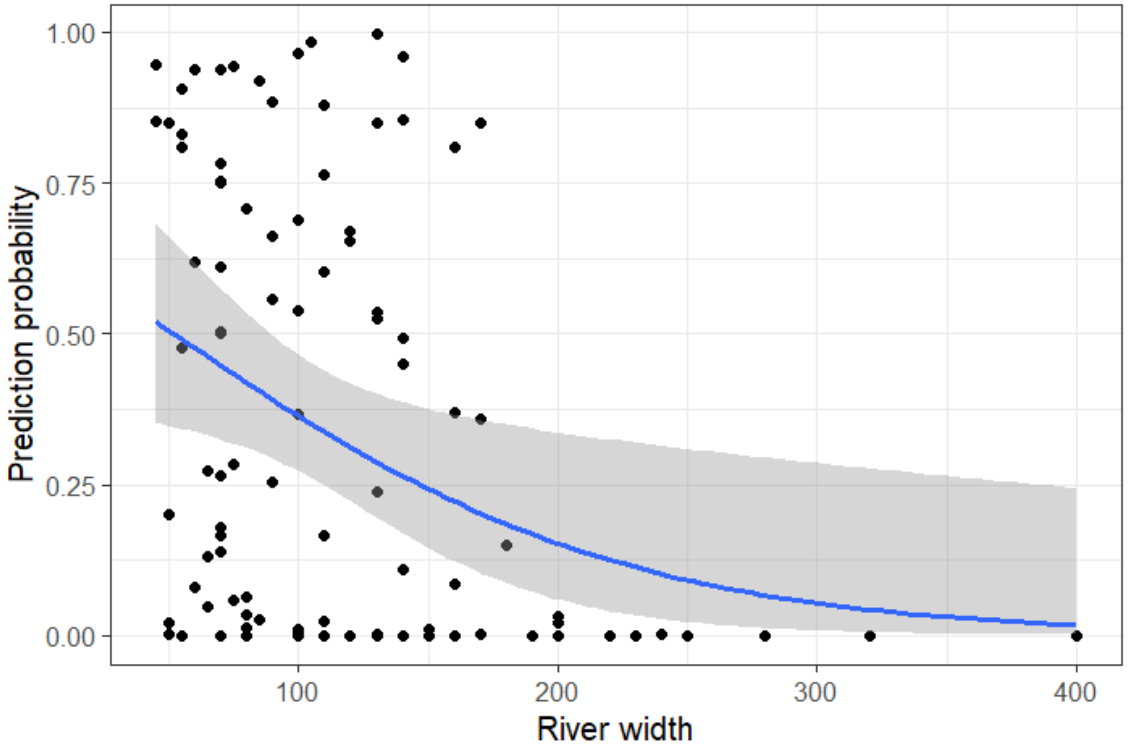

Figure 4. Prediction probability of otter relative to river width in the Western Bend of Karnali River

Vegetation cover at different levels (low, moderate, high, and dense) did not have significant effects on the otter presence, as indicated by high standard errors and non-significant P-values (P = 0.99 for all categories). Overall, these results indicate that otter occurrence is significantly influenced by bank substrate, river width, and water current, while vegetation cover appear to play an insignificant role. The findings suggest that otters prefer to use habitats with small stone substrates, minimal human presence avoiding areas with strong water currents and wider rivers.

Near house number was found to be a strong negative predictor of otter presence (β = -6.63, CI -10.15 to -3.12, P < 0.05), indicating avoidance of areas with high human activity as more the number of houses near riverbank will increase the human activity.

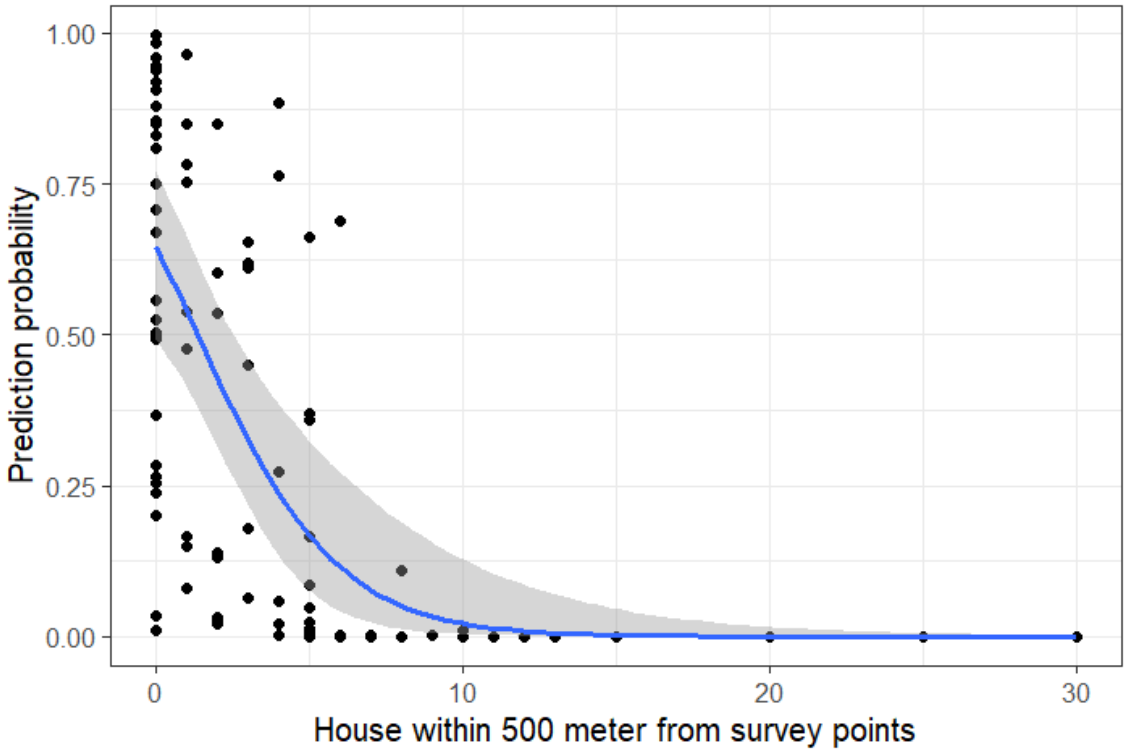

Figure 5. Prediction probability of otter relative to house number within 500 m radius of the transect.

4.2. Conservation threats to otters

Otters are highly sensitive to habitat disturbances and human-induced threats, which often lead to population declines and habitat displacement. Among the various conservation threats, the presence of feral and free-ranging domestic dogs has emerged as a significant factor influencing otter distribution and behavior. These dogs may compete with otters for resources, disturb resting sites, or even act as direct predators, particularly in riparian zones near human settlements. Understanding the extent to which dog abundance affects otter presence is therefore crucial for effective conservation planning.

Dog abundance had a significant influence on otter presence. In areas with no dogs, otter occurrence was positively associated (β = 2.94, CI 0.95–4.94, P < 0.05). However, moderate dog abundance did not have a statistically significant effect (β = 0.71, CI –3.13–4.55, P > 0.05) (Table 1).

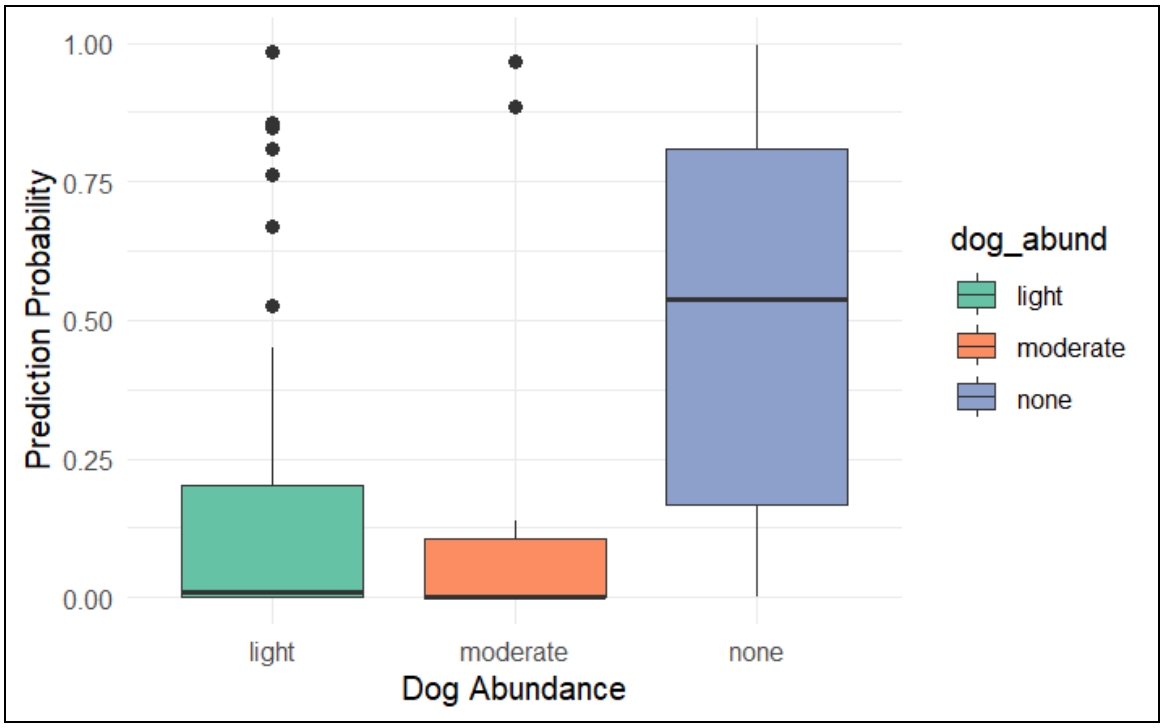

Figure 6. Prediction probability of otter relative to dog abundance in the Western Bend of Karnali River

The HDI was calculated by integrating conservation threats recorded throughout the field survey i.e. Infrastructure development, fishing activities, habitat use and human disturbance. HDI showed a negative, but non-significant effect on otter presence (β = –2.46, Std. Error = 1.91, CI 6.26–1.33, P >0.05). This suggests that while HDI may impact otter occurrence, its influence was not statistically significant in this analysis (Table 1).

5. Discussion

This study confirms the presence of otters in the Western Bend of the Karnali River in western Nepal, an area located outside the boundaries of protected zones. The occurrence of otters in this region is influenced by several key habitat variables, including bank substrate type, water current, river width, proximity to human settlements, and dog abundance. These findings provide valuable insights into the habitat preferences and conservation challenges faced by otters in a human-dominated landscape.

5.1. Habitat

This study found that a number of habitat characteristics, such as bank substrate, river width, water current, and proximity to human settlements, have a substantial impact on otter presence in Western Bend of the Karnali River. The preference for small stone surfaces is consistent with earlier studies showing that smooth-coated otters (*Lutrogale perspicillata*) and Eurasian otters (*Lutra lutra*) choose substrates that offer better denning and feeding options (Nawab & Hussain, 2012). In study conducted at Protection Island, British Columbia, Canada Lesage et al. (2025), stated that substrates like boulders and sandstone were preferred by otters. Large stone substrates, on the other hand, have a non-significant effect, which implies that otters might find these locations less conducive because there is less prey available or because burrowing places are less accessible (Anoop & Hussain, 2005). Study conducted by Giri et al. (2025) in major of Myagdi district, Nepal shows that otter occurrence was negatively correlated with greater altitudes, rock piles and large stones in the riverbed.

The finding that water currents have a major impact on otter occurrence is in line with research from other areas. Study conducted in river basin of Northern Spain by Tolrà et al. (2024), showed otter's preference for river reaches with high biological productivity, characterized by abundant aquatic vegetation, deeper waters, and slower flow velocities. In a study conducted in rivers of Eastern Bhutan, otters were observed in both fast-flowing and slow-moving river sections, indicating adaptability to various aquatic environments (Norbu et al., 2024).

Furthermore, otter avoidance of wide river sections and fast-flowing waters suggests a preference for narrower, slower-moving rivers, likely due to the availability of calm areas for resting and hunting, as documented in similar studies (Jayasurya et al., 2023; Jonah Dias et al., 2022; Nawab & Hussain, 2012; Shenoy et al., 2006).

The observation that vegetation cover did not significantly influence otter occurrence aligns with findings from various studies across different regions. For instance, Madsen and Prang (2001) investigated otter habitats in Denmark and concluded that vegetation cover was not a significant predictor of otter presence, suggesting that otters may tolerate certain levels of habitat alteration without it adversely affecting their distribution. Similarly, Romanowski et al. (2013) examined the recolonization of Eurasian otters in Central Poland and found that otters occupied areas with lower tree cover and more regulated river sections, indicating a shift in habitat tolerance during population expansion. In the context of Nepal, Shrestha et al. (2021) conducted a survey along the Sanibheri River and its tributaries, reporting a weak correlation between otter scat presence and bank vegetation cover, possibly due to the predominance of nearly bare riverbanks in the study area. Additionally, Pianzin et al. (2021) studied otter presence in oil palm-dominated landscapes of Sabah, Malaysia, and observed that streams with well-covered bank canopies and good forest quality did not significantly correlate with otter presence. These studies collectively suggest that while vegetation cover can provide essential resources for otters, its influence on their occurrence may vary depending on regional ecological contexts and the availability of other critical habitat features. Thought he insignificant effect of vegetation cover on otter occurrence contradicts findings from some previous studies, such as Medina-Vogel et al. (2003), which suggested that dense riparian vegetation provides essential shelter and breeding sites for otters. However, the lack of significance in this study may be due to regional variations in habitat use or differences in vegetation structure within the study area.

The study also discovered a strong negative correlation between the number of number of human residences near rivers and otter incidence, suggesting that otters avoid places with considerable human activity. This result is in line with research conducted by Dahal et al. (2020); Nawab and Hussain (2012); Raha and Hussain (2016), which reported that anthropogenic disturbances such as fishing, sand mining, and human settlements negatively impact otter populations by degrading habitat quality and reducing prey availability. Similar patterns have been noted by studies conducted in various regions of Asia, where otter populations continue to exist in protected or less disturbed habitats but decline in places with considerable human activity (Anoop & Hussain, 2004; Kruuk, 2006). A study conducted by Tolrà et al. (2024) in two heavily anthropized river basins of Spain, otters avoided places with significant human accessibility because their breeding grounds were extremely sensitive

to human disturbance. Nixon et al. (2024) concluded their study in North American river stating otters exclude areas with high road densities, which may lead to increased human disturbance or mortality.

5.2. Conservation threats to otters

Dog population size was found to be a major determinant of otter presence, with otters being more prevalent in dog-free areas. It's interesting to note that otter presence was less likely to be found in locations with a small or moderate population of dogs, which may indicate that dogs discourage otters from residing there. Similar to study by Prakash et al. (2014), regions where dog abundance is none, prediction probabilities are more widely distributed, suggesting increased variability in otter presence. Domestic and feral dogs pose a serious danger to wildlife populations through competition and predation, especially in areas where natural habitats are being encroached upon by human settlements (Weston & Stankowich, 2014).

Dogs cause significant harm to otters, since one of the males with good physical conditions who were examined died immediately from dog wounds (Fusillo et al., 2022). Dog attacks have been reported as cause of death in otter worldwide (Polednik et al., 2011). Study conducted by (Barros et al., 2022) at Southern Chile suggests otter prediction is negatively impacted by the dog abundance as dogs were found to be acting reservoirs of infectious diseases in otter, where Canine distemper virus was thought to be transmitted among individuals by direct contact.

Interestingly, the current study found no significant difference in the HDI between otter presence and absence sites, suggesting that otters may exhibit a certain degree of tolerance to human activity in the region. This finding aligns with Awasthi et al. (2024) who similarly reported that HDI did not significantly vary between sites inhabited by otters and those without otter presence in Far Western Nepal. Their study assessed multiple environmental parameters and concluded that otters were not strictly limited to areas with low human disturbance, highlighting a potential behavioral adaptability or habitat resilience. Such results indicate that while human disturbance remains a widely recognized threat to otter populations, its influence may not be uniformly critical across all landscapes or regions. Therefore, local ecological and social contexts must be considered when assessing otter vulnerability and planning conservation strategies.

The lack of significant influence of the HDI on otter occurrence observed in this study is further supported by findings from outside the South Asian region. Madsen and Prang (2001), in their study on otter habitats in Denmark, also found that human disturbance was not a significant predictor of otter presence. Despite variations in landscape and anthropogenic pressure, their results suggest that otters may be more adaptable to certain levels of human activity than previously assumed. This reinforces the idea that otters can persist in human-modified landscapes, provided that core habitat features such as food availability and water quality are maintained. Such observations underline the importance of evaluating species' tolerance thresholds contextually, rather than assuming uniform vulnerability to human disturbance.

6. Conclusions and recommendations

6.1. Conclusions

The study confirmed the presence of otters in the Western Bend of the Karnali River at western Nepal. The otter presence in the Western Bend of the Karnali River is strongly linked to specific habitat features: they prefer areas with small stone substrates, narrower rivers, and smoother water currents. Human disturbance, particularly proximity to houses and presence of dogs, significantly reduces otter occurrence. These findings have crucial implications for guiding conservation strategies to ensure the long-term survival of otters in the Karnali River basin.

6.2. Recommendations

Conservation recommendations:

i. Program to control the feral dog should be implemented with together with the concern authorities and the local communities.

ii. Human activities such as sand and rock extraction along riverbanks should be regulated, as these areas serve as vital habitats for wildlife.

Future research recommendations:

i. Study on seasonal change in habitat use is recommended as the season also plays vital role in habitat use as well as preference.

ii. Conduct a comprehensive study on the current population status and monitor the changes in otter populations over time.

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Appendices

Appendix 1. Research Permission from Department of Forest and Soil Conservation, Ministry of Forest and Soil Conservation, Government of Nepal

नेपाल सरकार
वन तथा वातावरण मन्त्रालय
वन तथा भू-संरक्षण विभाग

फोन नं.: ५३२७५७४

(कृपया पत्रोत्तरमा प्राप्त पत्र संख्या र मिति उल्लेख गर्नुहोला ।
बबरमहल, काठमाडौं, नेपाल

प्राप्त पत्र संख्या र मितिः-
पत्र संख्याः- ०८१/०८२
च. नं.:- ३६६

मिति : २०८१/०६/२२

विषयः अनुसन्धान अनुमति सम्बन्धमा ।

श्री मदन आचार्य,
सुर्खेत, नेपाल ।

प्रस्तुत विषयमा Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu मा M. Sc. मा अध्ययनरत तपाईले "Factors affecting distribution and people's perception towards Otter Conservation in the great bend of Karnali, Nepal" को विषयमा अध्ययन अनुसन्धानका लागि अध्ययन अनुमति उपलब्ध गराइदिनु हुन भनि मिति २०८१/०६/१३ गते यस विभागमा दिनु भएको निवेदन साथ प्रपोजल प्राप्त भयो। सो सम्बन्धमा कारवाही हुँदा उक्त अध्ययन अनुसन्धानबाट Factors affecting distribution and people's perception towards Otter Conservation लगायतका विषयमा जानकारी प्राप्त हुने भएकोले प्रपोजलमा उल्लेखित Methodology (Field Survey, Transect Survey, Scat Collection and Questionnaire Survey) अनुसार तपसिलको शर्तहरुको अधिनमा रही डिभिजन वन कार्यालयसँग समन्वय गरि सन् २०२४-१०-०१ देखि २०२५-०४-३० सम्मका लागि अनुसन्धान गर्नु हुन निर्देशानुसार अनुरोध छ।

शर्तहरु

१. अनुसन्धानकर्ताले वन ऐन २०७६ तथा वन नियमावली २०७९, राष्टिय निकुञ्ज तथा वन्यजन्तु संरक्षण ऐन, २०२९ र नियमावली २०३० तथा यस मातहतका नियमावलीहरुको पूर्ण पालना गर्नुपर्नेछ ।
२.अनुसन्धान कार्य डिभिजन वन कार्यालयसँगको समन्वयमा गर्नुपर्नेछ ।
३. संकलित नमूना (Scat only) को परिक्षण कार्य Tribhuvan University, Kirtipur को प्रयोगशालामा नै गर्नुपर्नेछ।
४.अनुसन्धानको क्रममा प्राप्त भएको जैविक विविधता संरक्षणसँग सम्बन्धित संवेदनशिल सूचनाहरु गोप्य राखु पर्नेछ अनाधिकृत रुपमा त्यस्ता सूचनाहरु कसैलाई पनि उपलब्ध गराउन पाइने छैन ।
५.अनुसन्धान कार्य समाप्त भए पश्चात एक प्रति रिपोर्ट/प्रतिवेदन (कागजी तथा विद्युतिय) यस विभागमा अनिवार्य रुपमा बुझाउनु पर्नेछ ।
६. तोकिएका शर्तहरुको पालना नगरिएमा विभागले कुनै पनि समयमा अनुसन्धान अनुमति रद्द गर्न सक्नेछ ।

(सबनम पाठक)
वन अधिकृत

बोधार्थ

श्री डिभिजन वन कार्यालय, भेरी, सुर्खेत। : प्रत्यक्ष निगरानीमा उल्लेखित कार्य गर्न आवश्यक सहयोग गर्नु हुन ।

Appendix 2. Datasheet used to record the variables while conducting the field study

Habitat Parameter and Potential Threats Study

Transect No: **Date:**

GPS: **Time:**

Otter/Otter Sign Observation					
Scat/s:					
Tracks:					
Feeding Remains:					
Habitat Parameters					
Width of River		**River Bank Slope**			
Water Current		**pH of Water**			
Bank Substrate Type	**Percentage**				
• Sand and Mud (< 1cm)					
• Small Stones (1-10cm)					
• Large Stones (>10cm-0.5m)					
• Rock/boulders (>0.5m)					
Vegetation Cover Percentage (✓)	**0-5%**	**5-25%**	**25-50%**	**50-75%**	**Above 75%**
Habitat Disturbance (within 100m)					
• Abundance of Dogs	None (0)	Light (1-3)	Moderate (4-6)	Severe (6+)	
• Cattle/Cattle Tracks	None (0)	Light (1-10)	Moderate (11-20)	Severe (20+)	
• Trash	None (0)	Light (5% within 100m)	Moderate (10% within 100m)	Severe (>10% within 100m)	
• No of House within 500 m					
Potential Threats to Otter Survival					
Distance to Human Settlement	_____ m / km				
Otter Sighting	Yes	No	If Yes, when:		
Which among the following is the prime threats to otter survival? Tick all those applied					
Threats	**None**	**Light**	**Moderate**	**Severe**	
• Poaching and hunting					
• Habitat loss/fragmentation					
• Infrastructure Development					
• Food Availability					
• Water Quality/Trash					
• Human Disturbance					
• Electrofishing					
• Overfishing					

Appendix 3. Corrplot of continuous variables

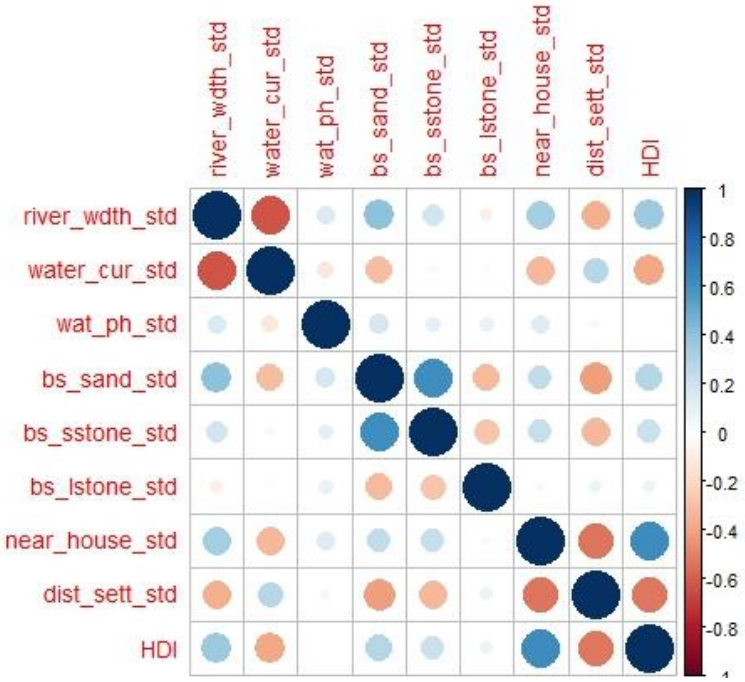
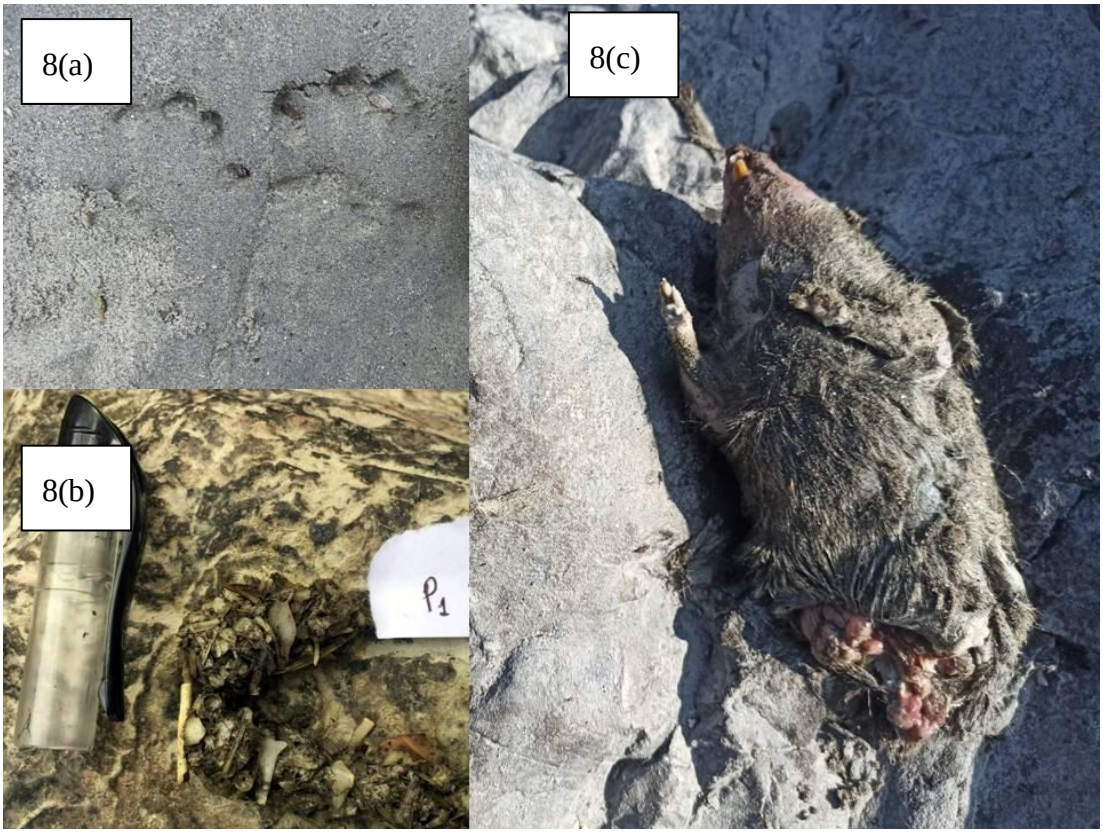


Figure 7. Corrplot showing pairwise correlation coefficients among the continuous variables

Appendix 4. Photographs from the field study

Photograph 1. Otter photographed while conducting the field survey



Photograph 2. Indirect signs of otter in study area while conducting the survey; 8(a) Pugmark, 8(b) Scat and 8(c) Food remain

Photograph 3. Fieldwork in the study area