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Research Article

Habitat status of the Smooth-coated Otter (*Lutrogale perspicillata*) in Geruwa-Khaurahi River, Bardia National Park, Nepal

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ABSTRACT
Smooth-coated Otter (SCO), a top predator and health indicator of the aquatic ecosystem is included as vulnerable on the IUCN red list and listed in Appendix I. Geruwa-Khaurahi River (GKR) was observed to determine the habitat status of SCO between Bardiya National Park (BNP) and Khata Corridor (KC), and to evaluate factors affecting the SCO habitat, data on habitat parameters and SCO signs were collected in each transect of 500 m. Principal component analysis was used for the most probable habitat parameter selection. An SCO group of eight was observed at Lalmati on the broad, shallow, and fast-flowing GKR with a sandy island and a flat stone bank with a vast escape distance. All signs were found on the sandy shoreline of the riverine forest with nearby tall *Saccharum* coverage over a narrow escape cover with a gentle bank slope. Diversions of water from the Geruwa River to the narrow and shallow Khaurahi River resulted in fast-flowing water where SCO pugmarks were found abundant. But at KC, human disturbances, over-fishing, river mining, and infrastructures have made the river unsuitable for SCO. SCO preferred dense riverine forests where the gentle riverbank has sand and/or tall *Saccharum* in between a narrow escape distance. Also, the narrow river with shallow depth and slow flow of good water quality was preferred by SCO. Lastly, with minimal human disturbance, further study on feeding ecology and population dynamics is requisite to conserve the suitable habitat of the SCO.

Keywords: Bardiya National Park, habitat, Khata Corridor, Smooth-coated Otter, spraints

Introduction
Otter, one of the top predators of aquatic ecosystems, is a semi-aquatic animal living in wetland habitats. Otters, the elusively nocturnal mammals feed on fish, amphibians, and crustaceans (mainly crabs) (Roos & Loy, 2015). They are also an important biological indicator of the health of aquatic ecosystems as mentioned by Acharya & Rajbhandari, (2014).

There are 13 species of otters in the world and 5 species in Asia, out of which 3 species are found in Nepal, Eurasian Otter, *Lutra lutra*; Smooth-coated Otter, *Lutrogale perspicillata* and Oriental Small-Clawed Otter, *Aonyx cinera* (Duplaix & Savage, 2018). Smooth-coated Otter (SCO) is in the Vulnerable (Vu) category of IUCN red list data 2021 and Appendix I of CITES (Khoo et al., 2021; CITES, 2019).

SCO are essentially lowland species (plains) that depend on the availability of prey species in water bodies (Acharya & Lamsal, 2010) like rivers and lakes along with swampy and mangrove forests for hiding along the coast and estuaries as playgrounds. They prefer suitable habitats having shallower water, moderate currents, sloppy sand, and clayey banks with good coverage of riparian vegetation (Acharya, 2006b).

Direct sighting of otters is hard due to their nocturnal habit (Acharya, 2012a, 2012b; Duplex & Savage 2018) so studies are done through signs like footprints and spraints of SCO. A sprainting site is a place with spraints lying at least 1 m from other spraints (Kruuk et al., 1986). Fresh spraints are cylindrical, black in color, and have a pleasant, sweet-musky smell, in comparison old spraints are grey to white (Acharya, 2017). Thus, in this study, the habitat of SCO in the Geruwa-Khaurahi River (GKR) was observed along with the evaluation of factors affecting SCO habitat in the GKR. At the same time, SCO habitat was compared between Bardiya National Park (BNP) and the Khata Corridor (KC) of the Geruwa-Khaurahi River.

Materials and Methods
Study Area
The main Karnali River (507 km long) is subdivided into the Karnali River and braided meandering Geruwa River from Lalmati, Bardiya. GKR is the eastern canal of the Geruwa River flowing from Lalmati (28.6041N 81.2724E) inside the BNP through the KC to Katarniyaghat Wildlife Sanctuary, India. GKR was chosen as a study area as a result of a preliminary visit in May 2019 and the field visit was done in January 2020. The river stretch studied was 28 km long.

Acharya, (2016) and BNP, (2021) have stated that BNP (IUCN Category: II) has a total area of 968 sq km with 507 sq. km of buffer zone. BNP is the largest undisturbed national park in Nepal as it is far from the capital, Kathmandu. While Geruwa River is the western border of BNP and the Khaurahi River is the eastern channel of the Geruwa River which lies inside BNP.

KC, a significant, important biological corridor, bridges BNP in the Churia foothills of Nepal to Katarniyaghat

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Wildlife Sanctuary in India. This transboundary corridor covers an area of 82.62 sq. km. with a forest area of 31.86 sq. km. with a human population of 18300 (WWF Nepal, 2011; Uprety et al., 2010). The study area in KC starts from Hattisar and ends at Patharbhoji near Kothiyaghat Bridge (the longest bridge in Nepal) (28.3734N 81.2135E).

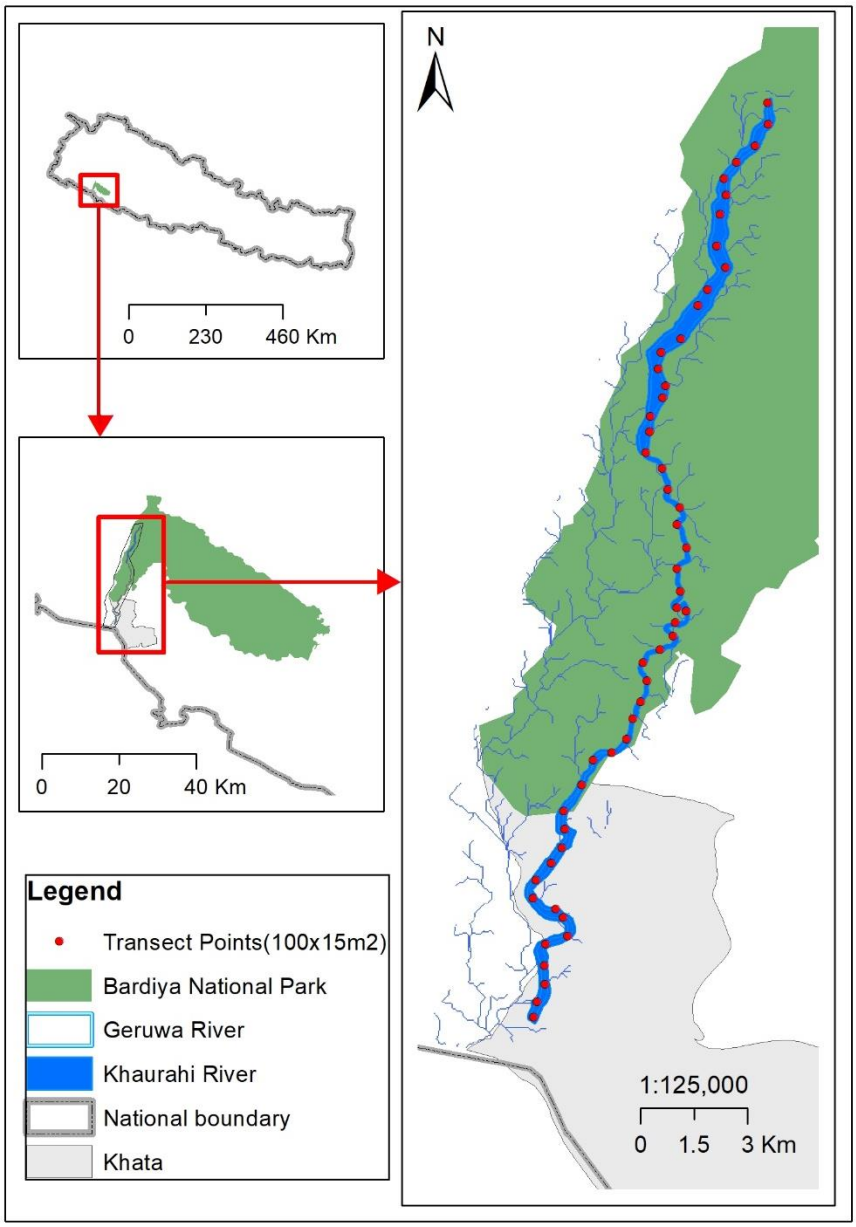

Figure 1 Map of Study area, GKR of Bardiya with transect plots

There were primarily nine vegetation classes identified which were dry Sal (*Shorea robusta*) forest, high-density sal forest, low-density sal forest, high-density mix forest, low-density mixed forest, riverine forest, short grass, tall grass, and degraded forest (BNP, 2021; Dinerstein, 1979; Joshi, 2003). Sharma (1999) found the area to be dominated by sal forests having grassland, savanna, and riverine forests. The Karnali River system has a shoreline with sand banks, small/large stones, and gravel and kans (*Saccharum spontaneum*, a wild sugarcane species) cover.

BNP along with KC supports a total of 53 species of mammals, about 400 species of avifauna, 25 species of reptiles and amphibians and 121 species of fishes (Nagarkoti, 2012). The protected species in BNP and KC included tiger (*Panthera tigris*), one-homed rhinoceros (*Rhinoceros unicornis*), Asiatic wild elephant (*Elephas maximus*), swamp deer (*Cervus duvauceli*), Giant Hornbill (*Buceros bicornis*), Black stork (*Ciconia nigra*), Gharial (*Gavialis gangeticus*) and Python (*Python molurus*) (Acharya, 2016; Gaire, 2006; Nagarkoti, 2012).

Methods

The field survey was done during winter in January 2020 following methods used by Macdonald and Mason (1983), Nawab and Hussain (2012), and Acharya, (2017).

The belt transect method was applied in which the sampling plot of 100m x 15 m was taken in every 500 m distance moving from one plot to the other. The sampling plot included both sides of the river resulting in 56 plots in total from a 28 km stretch of the river. There were 40 plots in BNP and 16 plots in KC. All plots were searched by walking.

Data on habitat parameters (Table 1), and GPS locations along with SCO's signs (spraints, footprints, dens, resting, grooming sites, etc.) were noted in each plot and every SCO sign sighting site. Habitat parameters also included the type of SCO sign, sign distance from the edge of river water to the sign, the freshness of signs, and the number of footprint sites, basking sites, grooming sites, and spraints marking sites (Acharya, 2017). For the identification of holts or dens and grooming sites; tracks of SCO and live SCO were followed along with past data, and literature. Habitat parameters were noted for all sign sites (Acharya, 2017).

The study area was classified into the riverine forest, sal forest, grassland, settlement, unoccupied rocky bank, and agriculture in habitat types. Among these habitats, all embankments, roads, bridges, and housing were classified as settlements while open areas at the banks which mostly consist of rocks without vegetation were classified as unoccupied rocky banks. Acharya, (2016, 2017) found SCO to be more related to *Saccharum* presence than other vegetation so, *Saccharum* was chosen as a variable along with its height.

Table 1 Variables used for the study of SCO in GKR with their measurement tools, and details modified (Nawab & Hussain, 2012; Acharya, 2017; CBS Nepal, 2019)

	Variables/Habitat parameters	Data type	Measurement tool	Description, and measurement details with a favorable range
	River channel width (m)	Scalar	Range finder	Distance between shorelines of the river.
	Shoreline substrate characteristics (%)	Categorical	Visually assigned	Approximate percentage of total area (100 m x 15 m) of the plot covered by boulders (diameter> 5 cm), gravel (diameter 0.2-5 cm), sand (diameter < 0.2 cm), and grass.
	Average river depth (m)	Scalar	Metered pole	River depth was measured at three points on a plot, and the mean depth was calculated.
	Water current	Categorical	Visually assigned	The most frequent flow velocity per plot is done as stagnant (1), slow (2), and fast (3).
	Riverbank slope types (degrees)	Scalar to categorical	Clinometers	Flat (0-15), Gentle (16-30), and steep (31^{+}) bank-slope (degrees). A slope <30 degrees is favorable.
	Distance of escape cover from the shoreline (m)	Scalar	Range finder	The nearest distance from the water's edge to shoreline vegetation provides cover for SCO. Distance less than 20m is favorable.
	The average height of kans (*Saccharum spontaneum*) (m)	Scalar	Metered pole	The height of the *Saccharum* (highly dominated as per Acharya, 2017) was measured, and the average height was calculated.
Water parameters	Temperature ℃	Scalar	DO meter	General water quality (Mortality increases with increasing temperature gradient point)
	pH	Scalar	pH probe	The favorable range is 6.5-8.5.
	DO mg/L	Scalar	DO meter	The favorable range is 5-9 mg/L
	TDS mg/L	Scalar	TDS probe	The favorable range is below 1000mg/L

Data analysis

The mean value of all variables was used as the habitat characteristics of SC to conduct Principal Component Analysis (PCA). PCA was done with factor analysis using Varimax rotation (Revelle, 2020) to reduce dimensionality and for the determination and decision-making of the factors influencing habitat parameters of SCO (Vincent, 2011; Wickham & Hester, 2020; Kassambara & Mundt, 2020; R Core Team, 2020; Wickham et al., 2021a; Eoloughlin., 2021). Principal components with an eigenvalue greater than one (e. v. > 1) were extracted and the first two principal components were plotted through a ggbiplot (Wickham, 2016) to show the relationship between variables and the principal components. Stepwise Logistic Regression was done to predict the occurrence of SCO and to find the accuracy (R^2) (Newman, 1998; Robin et al., 2011; RStudio Team, 2020; Leisch & Dimitriadou, 2021; Wickham et al, 2021b; Venables & Ripley, 2002) of observed variance explained by the model inputs (Nawab & Hussain, 2012). Data analysis was performed in RStudio version 1.3 (RStudio Team, 2020) and QGIS version 3.18.2 'Zurich' (QGIS Development Team, 2021).

Results and Discussion

Distribution

A total of 22 SCO signs were recorded in GKR. There was only one direct sighting of eight SCO in a group which was recorded in transect three, i.e., B3 (Photograph 1, Figure 2) i.e., at the Lalmati tent camp of BNP. While there was no SCO found at KC in the same river downstream. A low population of SCO in Nepal has been observed in past decades and was estimated to

be present only in undisturbed core habitats of protected areas (Acharya, 2016, 2017; Houghton, 1987; Thapa, 2002). This could be related to only one SCO group found during this study.

Photograph 1 A group of eight SCO sighted in Geruwa River.

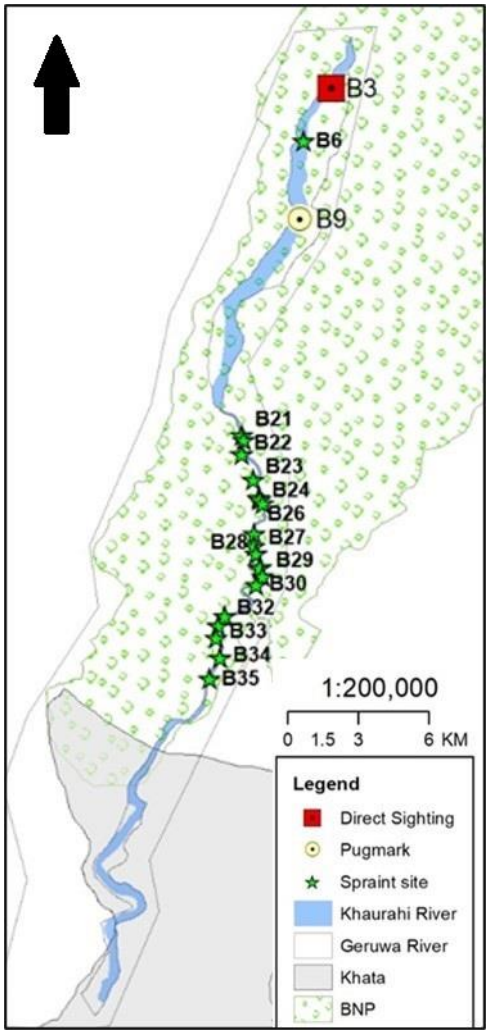

Figure 2 SCO sign observed sites in GKR

In Geruwa River, Paneru (2014) also observed a group of eight SCO but there was no record of the direct sighting by Acharya (2016, 2017). Thapa (2019) observed SCO at two sites of Babai, and three sites of Karnali River which are on the east and west of the Geruwa River, respectively. This shows that SCO inhabits all the rivers of the BNP, i.e., protected habitat.

The place SCO observed was flat having stone and boulders on the vast escape distance without any grass. While at the confluence of the sandy river island, fresh pugmarks, and spraints along with grooming marks (Photograph 2) of the group were recorded 0.1m from the river water line.

Photograph 2 A grooming site with footprints and body marks of a Smooth-coated Otter.

Likewise, there was no grooming site observed while only one pugmark was observed other than the direct otter-sighted area (Lalmati tent camp). This is because the winter rain and litter collection time during the field could have washed/erased pugmarks and grooming sites on the sand (JNCC, 2004). Grooming sites and pugmarks on the sands are the best for tracing the den location but due to lack of pugmarks in the field, no den was found around. Acharya (2017) found most of the footprints (Photograph 3) on sandy banks where the river depth was 0.6-2 m and river width was 30-110 m while grooming sites on sandy islands and banks with 0.6m to 3m far from water. He also recorded 2 dens in the Geruwa River in BNP.

Photograph 3 Footprints of SCO found at BNP headquarters during a preliminary visit.

There were 20 spraint sites observed within 11 plots. Spraints were mostly found three times in plots B21 and B24, so otter density in these two sections was found to be high. While spraints in B26, B28, and B32 occurred twice and spraints in B6, B23, B27, B29, B30, B33, B34, and B35 occurred once. Hence, from plot B21 to plot B32, this river stretch has the most occurrence of spraints.

Spraints were deposited mainly at sandy islands in between shallow channels with dense coverage of *Saccharum* as in Pandit, (2012). As Acharya (2017)

mentioned, fresh spraints were found to be cylindrical black and greenish with a pleasant, fishy, sweet-musky smell (Photograph 4) but old spraints found were washed and diffused. The spraints consist of scales and bones of fishes, frogs, and shells of crustaceans (Photographs 5). From Photograph 6, it can be seen that SCO's prey at Geruwa River is a type of fish (a freshwater eel in this case) that swims into 0.5m deep fast-flowing water.

Table 2 List of signs observed plots with the types of signs found in GKR

Sign Type	Freshness	Repeat	Plots	Total
Direct sighting	Fresh	Not repeated	1	1
Pugmark			1	1
Spraint			2	20
	Old		11	
		Repeated	7	
Total				22

Photograph 4 A fresh spraint cylindrical in shape and black-green in color

Photograph 5 An old whitish spraint consisting of scales of fishes and skeletons of crabs

Photograph 6 An SCO eating a freshwater eel at Lalmati tent camp in Geruwa River

No signs of SCO were found at KC in this study like in the study of Acharya (2017). This could be because of human disturbance, and threats to SCO like heavy fishing decreasing the prey density of SCO in huge gradient (Acharya, 2012a, 2012b, 2016, 2017; Jimenez & Lacomba, 1991); mining of sand and boulders, and heavy human movement for the collection of grass and fodder along with the farming at the riverbank.

A large number of signs recorded were mostly inside the protected habitat of BNP on the Khaurahi River (from transect B21 to B32, particularly from Bagaura to near the NTNC office). Fewer signs were recorded in the Geruwa River which is supported by Acharya (2016, 2017) because of the heavy water diversion at Gaida Machan toward the protected habitat of the Khaurahi River. Again, two small dams in the Khaurahi River have created an advantageous habitat for aquatic and semi-aquatic animals like SCO and their prey. Downstream was less favored (Jimenez & Lacomba, 1991; Mason, 1995) since the downstream of the river faced human disturbance and human-otter conflict due to the prey species overlapping (Acharya, 2012, 2017). So, no extent of signs was found downstream or KC.

Habitat parameters

The riverine forest was found to be dominant in the study area (62.5 %) (Foster-Truley et al., 1990; Thapa, 2002) followed by grassland (14.29 %), and Sal forest (5.36 %). BNP has nearly three times more riverine forest and grassland than KC along with Sal forest and the unoccupied rocky bank found in BNP. While KC consists of agricultural land along with a heavy settlement (Table 4). BNP is serene while KC is disturbed by human settlement (Acharya, 2012b, 2017; Nagarkoti, 2012; Thapa, 2002; WWF-Nepal, 2011). Because of the human disturbance, Acharya (2012) recorded the disappearance of the SCO from the Narayani River.

The river width of the GKR was found to be narrower at BNP (37.59 m) comprising the Khaurahi River and wider at KC (62.96 m) because of the mixing back of the Khaurahi River to the main Geruwa River. While the river width of the SCO sign presence area (33.3 m) was found to be medium. Since the study was carried out in winter, river depth was shallow (0.67 m), normally found within the one-meter depth, other than in some pools in the river. Thapa (2002) found SCO widely relocated from the Geruwa River into smaller channels and other wetlands in the BNP with shallow depths in the rainy season thus, the shallow depth of the GKR in this study is favored by SCO as a habitat. This shallow depth of the river is a very advantageous habitat preference for SCO as it reduces the energy needed when fishing in deeper water (Pandit, 2012) and stagnant conditions due to the high dam (Macdonald & Mason, 1985).

Water flow, categorized into pool (1), slow (2), and fast (3) was found to be moderately fast (2.39). Like the river depth, a slow flow is preferred to save energy against water currents while fishing. But SCO sign observation was done in fast-flowing water (2.8). This moderately fast flow of water contradicts the result of Thapa (2002), Nawab and Hussain (2012), Pandit (2012), Raha and Hussain (2016), and Acharya (2016, 2017) but when water flow and depth are considered along with the mild rainfall during the field study, it satisfies the result with them. Jimenez and Lacomba (1991) considered converting rivers to pools in dry seasons which concentrates fish and amphibians resulting in maximum otter activity.

Flat (0^{o} – 15^{o}) and gentle/moderate slopes (16^{o} – 30^{o}) were preferred by SCO while steep slopes (30^{o} +) were avoided by SCO as in Thapa (2002), Pandit (2012), Raha & Hussain (2016) and Acharya (2016, 2017) because, SCO needs more energy expenditure while foraging, grooming, and escaping on steep slopes (Khan, 2013). In this study, the bank slope was found to be moderate (21.83^{o}) while KC (14.36^{o}) seems to be flatter than the BNP (29.3^{o}) but no signs were found in Khata due to human disturbance and human-otter conflict.

Escape distances were found to be wider in BNP (30.7 m) and KC (49.34 m) but escape distance in the SCO sign presence area was found to be narrow i.e., 4.91 m (Thapa, 2002; Nawab & Hussain, 2012; Pandit, 2012; Raha & Hussain, 2016; Acharya, 2016, 2017) while in contrast SCO direct sight area had a very wider escape cover as they could pass through any point regardless of escape distance for fishing and foraging.

Table 3 Water parameters with bank slope and escape distance of the BNP and KC, and comparison with mean sign presence data

Variables	BNP mean	KC mean	Combined mean	Sign presence plots (mean)
pH	7.31	7.38	7.35	6.99
DO (mg/L)	7.98	6.26	7.12	7.62
Temperature (^{o}C)	14.33	18.41	16.37	15.0
TDS (mg/L)	190.8	369.3	280.05	210.9
Water Flow (m/s)	2.65	2.13	2.39	2.8
River Width (m)	37.59	62.96	50.28	33.3
River Depth (m)	0.73	0.63	0.68	0.78
Escape Distance (m)	30.71	49.34	40.03	4.91
Bank Slope (^{o})	29.3	14.36	21.83	26

All SCO signs were found on the sandy bank (Acharya, 2016, 2017; Thapa, 2002). The average shoreline composition of GKR was dominated by sand (66 %) and then grass (59 %). KC had a higher average percentage of boulders and gravel (5 % more) than BNP where there is no possibility of finding SCO signs like footprints and

grooming sites (Acharya & Lamsal, 2010). While areas with a sandy bank and *Saccharum* with 0.83 m in average height which provides a safe hide were found to be a potential habitat for SCO (Acharya, 2017).

Considering water parameters, the temperature was found to be 14.33 °C at BNP due to rain and 18.41 °C at KC with a mean of 16.37 °C at GKR. pH observed was near 7 which meets drinking water quality (CBS Nepal, 2019). The mean DO of GKR was found to be 7.12 mg/L. While the DO of BNP (7.98 mg/L) was found to be a bit greater than that of KC (6.26 mg/L). Less amount of TDS (< 2000) was preferred of which BNP (190.8 mg/L) had a lower amount of TDS than that KC (369.3 mg/L). If there is any unnaturally influenced huge gradient in water parameters, there will be the death of aquatic animals i.e. decreasing SCO prey ultimately causes a decrease in SCO number. From upstream to downstream there was no sign of water pollution because of fast-flowing water and BNP under the protection.

There were 16.68 % average and a total of 19 plots (33.28 %) of *Saccharum* observed with an average height of 0.54 m (Table 4). *Saccharum* (serving as escape cover) was only found inside BNP and the riverine forest dominated the presence of *Saccharum* with 13 plots (23.21 %) having an average height of 0.88 m while settlement and agricultural land had no *Saccharum* presence. A tolerable distance between SCO from humans was observed in the Alaknanda-Ganga Basin because of shoreline vegetation(Khan et al., 2014).

Table 4 Comparison of shoreline compositions (*Saccharum* presence and its height and percentage of boulder, gravel, sand, and grass) with habitat type (Unoccupied Rocky Bank (URB), Grassland (GL), Riverine Forest (RF), Sal Forest (SF), Settlement (ST), Agriculture (AG)) in GKR between BNP and KC along with presence and absence of SCO signs

Variables	Sites	URB	GL	RF	SF	ST	AG	Total	Mean
Count (plots)	BNP	4.00	6.00	26.00	3.00	1.00	-c	40.00	6.67
	KC	-	2.00	9.00	-	1.00	4.00	16.00	2.67
	Total	4.00	8.00	35.00	3.00	2.00	4.00	56.00	9.33
***Saccharum* (plots)**	BNP	2.00	2.00	13.00	2.00	-	-	19.00	3.17
	KC	-	-	-	-	-	-	-	-
	Total	2.00	2.00	13.00	2.00	-	-	19.00	3.17
***Saccharum height* (m)**	BNP	0.75	0.95	0.88	0.65	-	-	3.23	0.54
	Khata	-	-	-	-	-	-	-	-
	Total	0.75	0.95	0.88	0.65	-	-	3.23	0.54
Boulder (%)	BNP	0.25	0.17	0.12	0.37	0.00	0.00	0.90	0.15
	KC	0.00	0.00	0.03	0.00	0.00	0.17	0.20	0.03
	Total	0.25	0.17	0.15	0.37	0.00	0.17	1.11	0.18
Gravel (%)	BNP	0.00	0.21	0.05	0.10	0.00	0.00	0.36	0.06
	KC	0.00	0.49	0.30	0.00	0.00	0.58	1.36	0.23
	Total	0.00	0.70	0.35	0.10	0.00	0.58	1.72	0.29
Grass (%)	BNP	0.20	0.48	0.34	0.23	0.30	0.00	1.55	0.26
	KC	0.00	0.64	0.41	0.00	0.80	0.17	2.02	0.34
	Total	0.20	1.11	0.75	0.23	1.10	0.17	3.56	0.59
Sand (%)	BNP	0.23	0.15	0.27	0.30	0.70	0.00	1.64	0.27
	KC	0.00	0.38	0.41	0.00	1.20	0.33	2.32	0.39
	Total	0.23	0.53	0.68	0.30	1.90	0.33	3.96	0.66
Sign Presence (plots)	BNP	-	2.00	12.00	1.00	-	-	15.00	2.50
	KC	-	-	-	-	-	-	-	-
	Total	-	2.00	12.00	1.00	-	-	15.00	2.50

Factors affecting habitat selection of the river

In the PCA, the first three principal components or factors covered 50.5% of the variance with a p-value less than 0.01, i.e., P<0.01 in GKR. Five PCs had eigenvalue >1 but only two were taken for analysis through ggbiplot (Table 5). The first principal component (PC1) explained 25.3% of the variance. It was positively correlated with *Saccharum* presence (0.73), water flow (0.628), DO (0.583), and *Saccharum* height (0.536) but was negatively correlated with TDS (–0.784), temperature (-0.773), gravel (-0.663), and river width (-0.609).

The second principal component (PC2) explained 14.3% of the variance. It was positively correlated with the boulder (0.741) and escape distance (0.629) but was negatively correlated with sand (-0.495) and *Saccharum* height (-0.419). The third principal component (PC3) explained 11% of the variance. It was positively correlated with bank slope (0.56) but was negatively correlated with grass (-0.678), and pH (-0.587) (Table 5).

The ggbiplot of principle component analysis of habitat parameters (Figure 6) showed boulder, water flow, and dissolved oxygen was found to be positively related to both PC1 and PC2 while sand, temperature, and TDS were negatively related to both PC1 and PC2. Escape distance, gravel, and width of the river were found to be only positively related to PC1 while the depth of the river, grass, *Saccharum* presence, *Saccharum* height, and slope of the riverbank were found to be positively related only to PC2. Similarly, it could be seen that most of the data on habitat parameters of BNP were positively related to PC2 but all data on habitat parameters of KC were negatively related to PC2.

Table 5 Principal component analysis of the habitat correlates showing component loading on three principal components for winter in GKR (extraction method, principal component analysis; rotation method, varimax)

Habitat parameters	PC1	PC2	PC3
Bank Slope	0.264	-0.120	0.560
Boulder	0.118	0.741	0.114
Depth	0.103	-0.322	-0.258
DO	0.583	0.226	-0.089
Escape Distance	-0.292	0.629	0.259
Flow	0.628	0.293	0.116
Grass	0.120	-0.332	-0.678
Gravel	-0.663	0.325	-0.021
***Saccharum* Height**	0.536	-0.419	0.066
Saccharum	0.730	-0.227	0.228
pH	-0.086	0.103	-0.587
Sand	-0.108	-0.495	0.303
TDS	-0.784	-0.279	0.229
Temp.	-0.773	-0.386	0.286
Width	-0.609	0.117	-0.278
Eigenvalues	3.790	2.14	1.65
Proportion of Variance	0.253	0.143	0.11
Cumulative Proportion	0.253	0.395	0.505

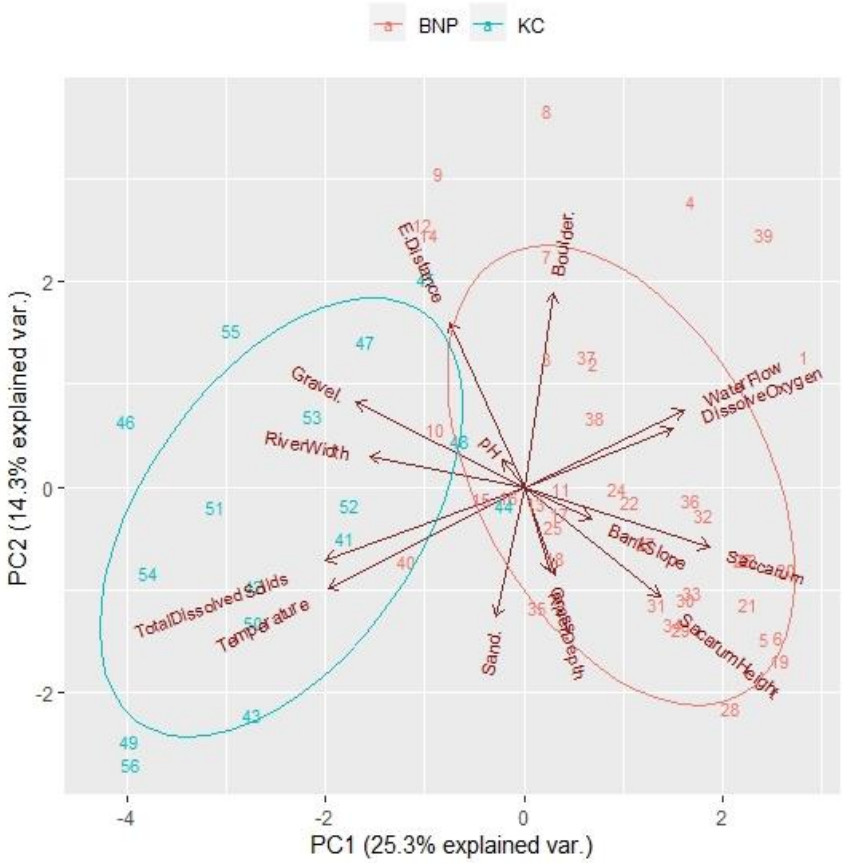

Figure 3 A ggbiplot for the first two principal components representing data of GKR in a grouping of BNP and KC

Table 6 Summary of logistic regression model for predicting the suitability of a river stretch for the presence of SCO in GKR

Variable	B	S.E.	Wald	P-value	Exp B	Mean
pH	-0.406	0.09	-4.531	0*	0.666	6.986
DO	-0.072	0.035	-2.065	0.044	0.930	7.621
Temperature	-0.063	0.024	-2.617	0.012	0.939	15.03
Escape Distance	-0.002	0.001	-1.712	0.093	0.998	4.914
Height	0.395	0.103	3.844	0*	1.484	0.659
(Intercept)	4.701	0.914	5.145	0*	-	-

B = Coefficient of constant (intercept); S.E. = Standard Error of B; Wald = Wald chi-square statistics (Z); Sig. = P value; Exp. (B) = Odds ratio; 0* ≠ 0

The logistic regression model ($R^2 = 1$, pseudo $R^2 = 1.47$, P-value = 0.0064 (i.e., $P < 0.01$)) had 85.71% accuracy in the precise classification of available SCO's sign habitat. The model suggests that the SCO in the Geruwa River preferred those spots with tall *Saccharum* height, and lower escape distance with good river water quality conditions, i.e., temperature, pH, and DO in the normal range (Table 6).

Conclusions

A group of eight SCOs was found fishing and crossing the river at Lalmati. The Khaurahi River in BNP was the best habitat for SCO because of the high sign density, the low disturbed riverine habitats, sandy banks and sandy islands, tall *Saccharum* cover, gentle slope, narrow escape distance, medium-width river, shallow depth water, and fast-flowing good water quality. But the human disturbances like agriculture, sand and boulder mining, heavy fishing and settlement, road construction, and embankments by the river along with human-otter conflict caused SCO to abandon KC. From PCA, factors affecting SCO were dense riverine forest, narrow river, shallow depth, sandy gentle sloped bank, tall *Saccharum,* narrow escape distances, low disturbance, and slow flowing normal quality. Further studies like feeding ecology, population dynamics, and occupancy of SCO are recommended. SCO could conserve and protect both aquatic as well as terrestrial habitats, so their conservations and protections are recommended for a better-balanced ecosystem.

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