Research Article

Conservation of the Asian small-clawed otter (*Aonyx cinereus*) in human-modified landscapes, Western Ghats, India

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Abstract

Conservation in human-modified landscapes is important for riparian animals as their habitats extend linearly beyond adjoining protected areas. We examined occupancy and intensity of habitat use of Asian small-clawed otters in coffee and tea plantations and an adjoining protected area in the Western Ghats. We sampled 66 stream segments of 500 m length, using spraints as an indicator of habitat use. Several variables characterising the stream and shoreline were also measured. Occupancy, corrected for detection of spraints, was >0.75 in all three land use types, indicating widespread use of the riparian ecosystem in human-modified landscapes. Intensity of habitat use, however, was much lower in tea (2.08 spraints/500 m) and coffee (2.42) plantations than in the protected area (3.86). Using GLMs we identified the abundance of potential refuges (such as boulders and fallen trees), which was greater in the protected area, as the major factor influencing intensity of habitat use. Shoreline diversity, which was lowest in the tea plantation, might also be another factor. The retention of much of the riparian vegetation and the presence of forest fragments which provide refuges have led to wide occupancy of the tea and coffee plantations although with less intensive use. Sand mining, fishing and infrequent poaching might be other reasons for the relatively low use of human-modified landscape. This study highlights the need to retain remnant forests and riparian vegetation, and to control some human activities for integrated management of species like the small-clawed otter in both protected areas and adjoining human-modified habitats.

Keywords: plantations, hill streams, land-use, occupancy, protected area.

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Introduction

Addressing conservation issues in human-modified landscapes is becoming increasingly pertinent, as protected areas cover less than 10% of tropical forests worldwide and the conversion to agriculture, plantations and other modified land-uses proceeds at an unprecedented scale [1-3]. Most tropical forests are now highly fragmented and form a heterogeneous matrix with human-modified land uses [4]. The human-modified habitats that occur within and around most protected areas in the tropics harbour a significant, albeit non-random, subset of biodiversity [5-7]. This subset includes animal species that are residents and transients, the latter using the human-modified habitat as feeding or breeding grounds [1-2,6]. Thus it is important to integrate the management of such modified land-uses with the management of protected areas in the landscape [3,8].

Research on conservation in human-modified landscape has focused on the terrestrial fauna, and reveals the pervasive influence of remnant forests and proximity to protected areas on the persistence of native biodiversity in such landscapes [3,7,9-10]. Life-history characteristics of the species also influence their survival in such modified landscapes [11-13]. The persistence of fauna associated with aquatic habitats in human-modified landscapes has received very little research attention, although aquatic habitats in such landscapes often get significantly modified due to several factors such as dams, deforestation, human settlements and agriculture [14-16]. Aquatic and semi-aquatic fauna, therefore, might have a lower persistence in the human-modified landscape. Moreover, riparian species may require maintenance of both aquatic and terrestrial habitats or might be resilient to change in one habitat. Given the paucity of studies exploring this aspect, it is safe to presume that both terrestrial and aquatic habitats are important. This is especially so for animals such as otters that are closely associated with riparian ecosystems and therefore have long and linear home ranges [17-18]. The intrusion of such linear home ranges into human-modified landscapes may make otters especially vulnerable. However, in Europe and North America, the occurrence of otters outside protected areas varies widely and is influenced by properties of the water bodies as well as human disturbance and land cover in the watershed [19-24].

In this study, we attempted to identify the key habitat features that influence the occupancy and habitat use of the Asian small-clawed otter (*Aonyx cinereus*) in a landscape that consisted of protected areas and adjoining coffee and tea plantations. We use the results to highlight implications for conservation of such riparian species. Our study area in the Anamalai Hills is a part of the Western Ghats, one of the most densely populated and human-modified biodiversity hotspots in the tropics [25]. Land-use modification in the form of tea and coffee plantations dates back more than a hundred years [26]. Several studies have examined the factors that influence the occurrence of terrestrial animals in the human-modified landscapes in the Western Ghats [see 7 for a review]. Three species of otters—Eurasian (*Lutra lutra*), smooth-coated (*Lutrogale perspicillata*) and Asian small-clawed —are known to occur in these mountain ranges [27]. While little is known about the distribution of Eurasian otter in India, the smooth-coated otter occurs in large water bodies [28]. The Asian small-clawed otter is the smallest and most restricted in distribution, being confined only to the higher elevations where they seem to prefer lower order streams [29]. This species, widely distributed in Southeast Asia with a disjunct population in the Western Ghats, is considered Vulnerable in conservation status [30].

Methods

Study area

The 958 km² Anamalai Tiger Reserve in the Western Ghats in peninsular India and the adjoining private tea and coffee plantations on the 220 km² Valparai plateau formed the study area (Fig. 1).

The dominant natural vegetation in the area is mid-elevation (600 m – 1400 m) tropical rainforest of the *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum* type [31]. The area receives an average annual rainfall of 3500 mm, spread over two monsoon seasons between June and December. The mammalian fauna is typical of the Western Ghats [6]. Two species of otters occur in the Reserve: the smooth-coated otter restricted to reservoirs within the Reserve, and the Asian small-clawed otter restricted to hill streams and rivers. The Valparai plateau, dominated by plantations of tea, coffee and cardamom, is surrounded by the Anamalai Tiger Reserve and other reserved forests and wildlife sanctuaries to the south and west. The plateau is also home to nearly 100,000 people, mostly estate workers, living in the Valparai town and settlements in the tea and coffee estates.

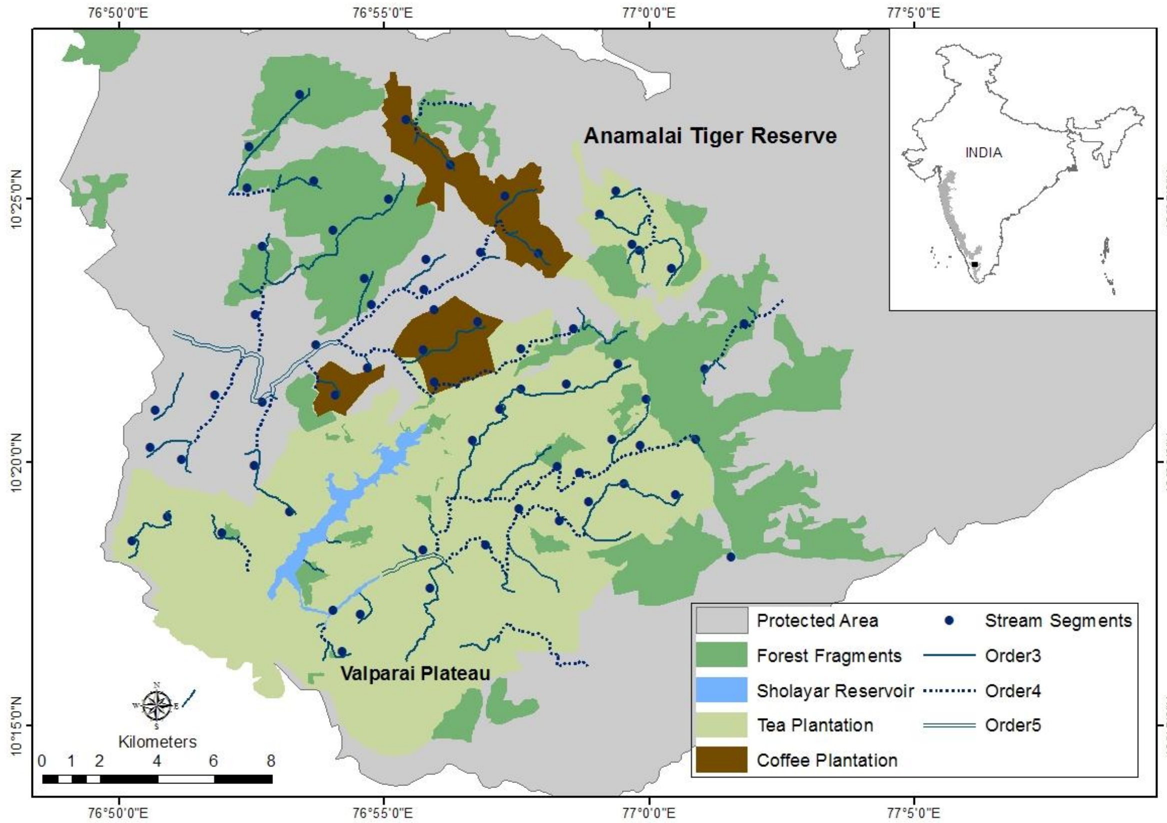

Fig. 1. The human-modified landscape in Valparai plateau and the surrounding protected area in which we sampled 66 stream segments for otter spraints. Note that there are several rainforest fragments embedded in the tea and coffee plantations.

Tea plantations are extensive monocultures with a sparse canopy of alien silver oak (*Grevillea robusta*) and represent the most extreme land-use modification in the landscape. Coffee plantations are mostly under native shade trees or under the shade of the alien *Maesopsis eminii* and *Grevillea robusta*, mixed with native species. These represent an intermediate level of land-use modification between the highly modified tea and the relatively undisturbed tropical rainforests within the protected area.

Field methods

We examined the occurrence of otters in the three land-use types in an occupancy framework [32] and intensity of use of habitat in a generalized linear model (GLM) framework, using the number of spraints as the indicator [33]. Although the use of spraint abundance as an indicator of relative abundance of otters has been widely debated (e.g. 33,34-35), recent research on the Eurasian otter shows a very close correlation between spraint abundance and population density, estimated from fecal DNA [36].

The field sampling was carried out from January to early May, 2010, the driest period in the Western Ghats, and an ideal time to sample for otter spraints [37]. We surveyed 66 segments, each of 500 m length, along perennial streams, each segment further subdivided into 100 m sub-segments as the spatial replicates. The stream segments for sampling were selected from a digitized map of the study area based on the proportion of area under protected area, coffee and tea land cover. The selected segments were at least 2 km apart in order to avoid spatial dependence across segments, in the absence of home range data for the study species. The selected segments were located in the field using a GPS receiver (Garmin Etrex). Both banks were thoroughly searched by the same two observers over the entire period to record otter spraints, footprints and denning sites. Sprains of the species could be identified due to the presence of a high proportion of crustacean remains in them [17]. We also set up passive infrared camera traps along few streams, but only to confirm identity of the species and not to record habitat use.

At 20 m intervals along each stream segment, we measured stream and shoreline attributes that could possibly influence otter presence. The stream attributes included stream type, width, depth and substratum. Stream type was classified as a run (smooth and non-turbulent flow), riffle (turbulent flow over rocks), pool (no flow) or cascade (vertical drop in the flow). Stream substratum was visually assessed to be rocky, muddy or a combination of both. The shoreline attributes measured were canopy cover (using a canopy densiometer), number of trees within two meters from the stream edge and shoreline substratum (rock, sand, vegetation or leaf litter). In each segment, we also recorded all refuges, which were natural and artificial structures close to the water's edge and above the waterline, such as large boulders with cavities, large fallen logs and burrows, which otters could use for denning and resting. Other variables that we recorded were dominant land use around the stream segment, human modifications (such as culverts) within 10 m from the stream, and disturbance (grazing, sand mining and other signs of human activity, but not including human tracks). Straight line distance to protected area was measured from a digitised toposheet (1:50,000) using ArcView 3.2 GIS. For each 500 m segment, means were estimated for continuous variables (e.g., stream width, canopy cover, number of trees and ground cover). Stream diversity and shoreline diversity were estimated by Simpson's index, from data on stream and shoreline substrata, respectively, converting the categories into proportions per 500 m segment.

Data analysis

We constructed otter detection histories for each stream segment depending on whether a spraint was detected or not in each of the five sub-segments. This was then analysed in the occupancy framework [21] using PRESENCE version 2.4 [38], for each land-use type separately and pooled together. We used analysis of variance (ANOVA) to examine differences among three land-use types in various stream and bank characteristics. Based on a correlation matrix of all measured or derived variables, we eliminated those that were highly correlated (p < 0.05) with one or more other variables. The retained variables were used as covariates in a GLM framework to model otter habitat-use, taking the number of spraints as the response variable with Poisson distributed errors. A global model was constructed incorporating all the retained variables to examine the overall fit. The competing models included individual covariates and select combinations and interaction terms with land use. We compared the models using ΔAIC_C and Akaike weight (w_i) to assess model fit. We also estimated weighted averages of the parameter values of the variables along with 95% CI, and considered as important only those variables whose 95% CI did not include zero [39]. We calculated the relative importance of variables following Burnham and Anderson [40]. All analysis was carried out using R statistical and programming environment [41-42].

Results

Occupancy

Camera trap pictures and sightings in the field showed the presence of only the small-clawed otters in the sampled areas. We recorded 174 spraints of this species from 66 stream segments that we surveyed from January 2010 to May 2010. Spraints were detected in 51 segments resulting in a naive occupancy (occupancy without accounting for probability of detection) estimate of 0.77. With occupancy (ψ) and detection probability (p) fixed across land-use types, otter occupancy for the surveyed landscape was 0.81 ± 0.06 (SE) with an estimated overall p of 0.96.

Spraints were detected in 22 out of 30 (naive estimate of occupancy=0.73) segments in tea plantations, 9 out of 12 (0.75) segments in coffee-cardamom plantations, and 20 out of 24 (0.83) segments in the protected area. When corrected for detection probability, ψ in the three land-uses were only slightly higher than naive estimates at 0.77 ± 0.09 (SE), 0.81 ± 0.14, and 0.86 ± 0.08, respectively, due to the high p of 0.95, 0.93 and 0.97, respectively. Since the p and ψ were high and similar for all three land-uses, we did not explore the influence of habitat covariates on them.

We also estimated ψ and p for the three land-use types using only fresh spraints. Occupancy ψ was 0.64 ± 0.14, 0.25 ± 0.13, and 0.52 ± 0.17 and p was 0.78, 0.99, and 0.72 for tea, coffee and protected area, respectively. Overall ψ for the surveyed landscape using only fresh spraint was 0.50 ± 0.08 and overall p was 0.82.

Table 1. Comparison of stream habitat attributes measured along stream segments of 500 m length in tea plantation (n=30 segments), coffee plantation (n=12 segments) and protected area (n=24 segments).

Habitat variable	**Tea** (mean±SE)	**Coffee** (mean±SE)	**Protected Area** (mean±SE)	**ANOVA $F_{2,63}$**	***p***
Stream width (m)	5.73±1.12	3.65±0.54	6.45±0.79	1.37	0.262
Pool (proportion)	0.14±0.03	0.14±0.04	0.36±0.05	8.32	<0.001
Riffle (proportion)	0.33±0.05	0.22±0.05	0.05±0.01	12.35	<0.001
Refuges (n/500m)	1.40±0.37	2.08±1.10	4.42±0.72	7.01	<0.01
Shoreline diversity	0.42±0.04	0.62±0.03	0.52±0.04	4.84	0.011
Canopy cover (%)	25.04±4.62	51.21±5.74	77.28±4.79	32.75	<0.001
Altitude (m)	1151.06±24.5	1064±61.7	863.4±4.0	17.24	<0.001
Distance to PA (m)	1647.60±229.8	609±141.5	N.A.	24.06	<0.001

Habitat use

Stream segments varied significantly ($p < 0.01$) in several attributes among the three land-use types (Table 1). Plantations, especially tea, had low canopy cover, low shoreline diversity and fewer refuges per segment, and fewer pools and more riffles as compared to the protected area. The encounter rates were 2.08 ± 0.66, 2.44 ± 0.37, and 3.17 ± 0.48 spraints per 500 m, in tea, coffee and protected area, respectively. The variables used in the generalized linear models of habitat use selected after screening for collinearity included land-use, distance to the protected area, altitude, number of refuges, proportion of pools, and shoreline diversity. The global model (Model 1 in Table 2) with all selected covariates had an AICc (289.51) much higher than the best fit model (Model 2), which had the number of refuges, land use, shoreline diversity and an interaction term for land-use and shoreline diversity as terms. However, Model 3 (which had only the number of refuges) and Model 4 (which had number of refuges and shoreline diversity) were indistinguishable from Model 2, with $\Delta AIC_C < 2$. Both these models had evidence ratios (0.49/0.20 and 0.49/0.21) of < 2.3 indicating high uncertainty in choosing among these three models. Other models had $\Delta AIC_C > 2$ compared to Model 2, and thus provided relatively poor fit. We examined model-averaged estimates of parameters of covariates in Models 2 to 4 and only the number of refuges had parameter estimate whose 95% CI did not include zero (Table 3).

Table 2. Akaike Information Criterion (AICc) and associated measures for candidate models. Model 1 is the global model which had all six covariates with no interaction terms. Other models are arranged in order of increasing AICc values. Models 2 and 6 have interaction terms with Land-use category.

Model ID	Model	AICc	ΔAICc	Akaike Weight (w_i)
1	Global model	289.51	8.08	0.01
2	Refuges + Land-use + Shoreline diversity + Land-use:Shoreline diversity	281.43	0	0.49
3	Refuges	283.11	1.68	0.21
4	Refuges + Shoreline diversity	283.2	1.77	0.2
5	Refuges + Land-use + Shoreline diversity	285.23	3.8	0.07
6	Refuges + Land-use + Shoreline diversity + Land-use:Refuges	288.71	7.28	0.01
7	Land use	295.33	13.9	0
8	Proportion of pools	296.3	14.87	0
9	Distance to Protected Area	297.07	15.64	0
10	Altitude	297.09	15.66	0
11	Shoreline diversity	297.15	15.72	0

Discussion

Due to high detection probability of spraints, estimates of occupancy were close to naive estimates of occupancy at the landscape scale as well as within each land-use type. Occupancy estimated from fresh spraints was, as expected, lower than that estimated using all spraints, the difference being highest in coffee plantations. Sampling was conducted during the dry season which partly coincided with coffee pulping season, when most streams flowing through coffee plantations were polluted with effluent from the pulp houses. Occupancy in tea and protected area did not show major differences between using all and only fresh spraints, indicating the continued use of the landscape during the dry season. While the small-clawed otter has been shown to have a high occupancy in streams in protected areas [29], the present study demonstrates a similarly high occupancy in human-modified landscape adjoining protected areas. This is consistent with reports for other species of otters whose occupancy seems to be fairly insensitive to human-modified landscapes [21,23,43-48]. A major reason for this is perhaps the linear nature of their habitats, which enables otters to travel over longer distances to meet their requirements in comparison to land mammals of similar body size. The factors that positively influence occupancy of otters seem to differ with species: increasing woody vegetation and stream density, decreasing cropland, grassland and shoreline diversity in the case of North American river otter *Lontra canadensis* [21]; increasing riparian vegetation in Southern river otter *Lontra provocax* [49-50], Cape clawless otter *Aonyx capensis* [47-48] and Eurasian otter *Lutra lutra* [17,20].

Table 3. Model averaged estimates of parameters, unconditional SE and 95% confidence intervals (CI) for variables in Models 2, 3 & 4 given in Table 2.

Covariate	Coefficient	Adjusted SE	Lower CI	Upper CI
Refuges	0.10	0.03	0.04	0.12
Land-use PA	1.88	2.11	-2.25	6.02
Land-use Tea	1.90	2.14	-2.30	6.10
Shoreline diversity	3.61	3.7	-3.65	10.9

The GLM analysis identified three models that seemed to explain equally the encounter rates of spraints in the sampled segments. Among the covariates in these models, the number of refuges was identified as the most significant. This was also a term in all three best models. Refuges included sites with boulders, large fallen logs and burrows. Such refuges are also heavily used by otters elsewhere [18,47-48,50]. The greater abundance of refuges in the protected area, one of the reasons for more intensive use of streams there as indicated by a higher spraint encounter rate, was primarily due to the more rugged topography in the Reserve. The tea and coffee plantations were mostly in the undulating and modified terrain of the Valparai plateau and therefore had fewer streams with large boulders.

For shoreline diversity, although the 95% CI of its model-averaged parameter estimate included zero, we believe it is an important variable that influences habitat use by small-clawed otter, as has been reported for Cape clawless otter [47-48] and Southern river otter [50], which spend considerable time feeding among shoreline vegetation. A higher diversity of shoreline habitat provides feeding and resting grounds and cover for otters. However, this is an attribute that has been considerably modified by human use in much of the Western Ghats.

Coffee and cardamom are grown in the Western Ghats frequently under natural shade and harbour a relatively high diversity of animal taxa including birds [51-52], mammals [6,53] and butterflies [54], both resident species and visitors from adjoining protected areas. The streams passing through coffee estates are also structurally more similar to the streams in the adjoining protected area. In contrast, in tea plantations natural vegetation is often cleared completely; only patches of forests and strips of riparian vegetation are left intact. This is clear from the low canopy cover and shoreline diversity along streams in the tea plantations (Table 1). It is these patches of forests that are responsible also for much of avian and mammalian diversity that occur in the tea plantations [6,52], and their continued retention may partly explain the use of tea plantations by small-clawed otter, although at relatively lower intensity.

Distance to the protected area did not seem to have any influence on spraint encounter rate, at least within 7 km from the protected area (the farthest distance of any point in the plantations from protected area boundary). In contrast, the species richness of butterflies, birds and many mammals in coffee plantations is known to decline sharply with increasing distance from the adjoining protected area [51,53-54]. A major reason might be the linear nature of the habitat of otters, which allows them to move farther into the human-modified landscape. Although spraint encounter rate differed across land-use types, much of the landscape irrespective of land-use was used by the otters, as indicated by the high occupancy rates. The presence of remnant forest patches with unmodified streams and the retention of riparian vegetation in some stretches in the human-modified landscape are major reasons for this. Proximity to protected areas may also be a contributory factor. Our sightings of a few holts in plantations indicates that there might be resident populations in the human-modified landscape and that not all otters using these streams are transient animals.

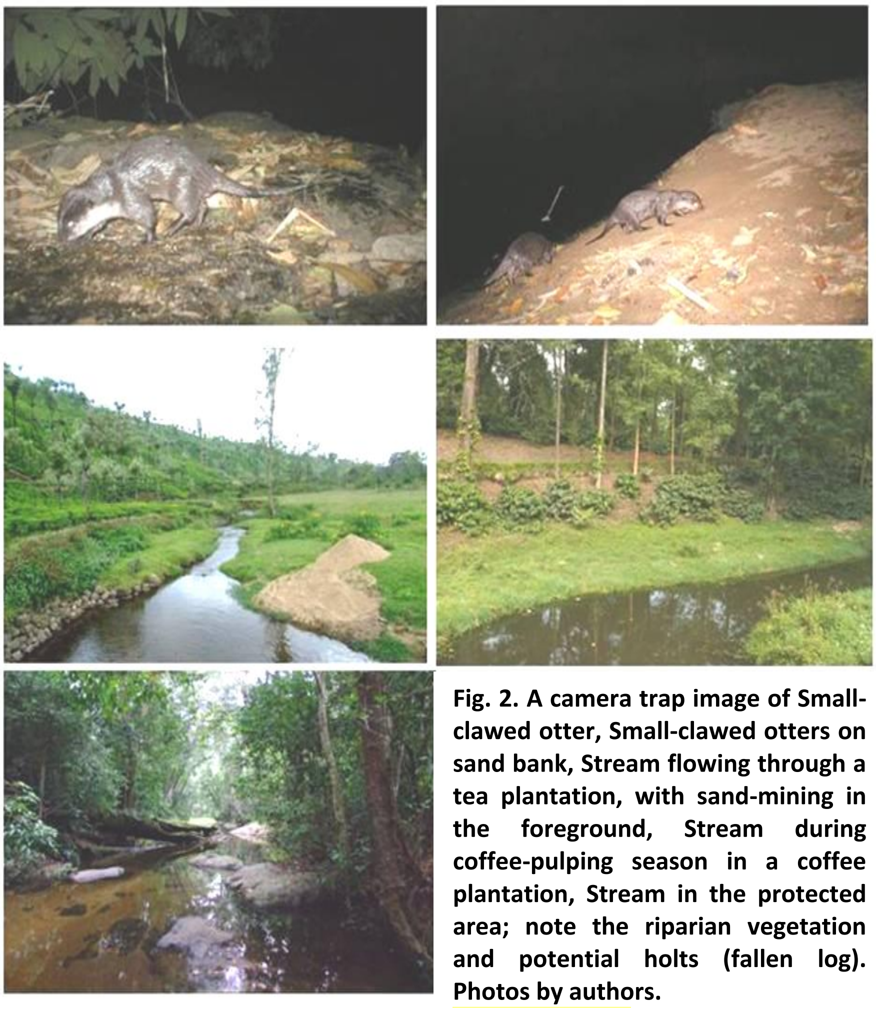

Fig. 2. A camera trap image of Small-clawed otter, Small-clawed otters on sand bank, Stream flowing through a tea plantation, with sand-mining in the foreground, Stream during coffee-pulping season in a coffee plantation, Stream in the protected area; note the riparian vegetation and potential holts (fallen log). Photos by authors.

Implications for conservation

This study shows that otters have a relatively high occupancy in protected areas and adjoining human-modified landscapes. Their use of the latter depends primarily on the availability of refuges for resting and denning, partly provided by shoreline vegetation. It is therefore important to retain riparian vegetation and forest patches that have streams in the human-modified landscape. The lower intensity of use of human-modified habitats may be due to human activities such as fishing, sand mining and removal of boulders and deadwood along streams. Although instances of poaching of otters in the landscape and neighbouring hill ranges [55] were recorded in the past, the area has been relatively free of poaching for the last few years. Pollution of streams during the short coffee-pulping season needs to be tackled with the co-operation and participation of local plantation companies. A step in this direction has been made with the introduction of certification of coffee and tea plantations [56]. Retention and restoration of riparian vegetation, coupled with control over extractive human activities, are especially important to facilitate persistence of otters in human-modified landscapes adjoining protected areas, given the linear nature of their habitat. Engagement with corporate bodies who own large tea and coffee plantations, which enclose riparian forests, is necessary in order to achieve this [9].

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References

[1] Bhagwat, S.A., Willis, K.J., Birks, H.J. and Whittaker, R.J. 2008. Agroforestry: a refuge for tropical biodiversity. *Trends in Ecology and Evolution* 23: 261–267.

[2] Gardner, T.A., Barlow, J., Chazdon, R., Ewers, R.M., Harvey, C.A., Peres, C.A. and Sodhi N.S. 2009. Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters* 12: 561–582.

[3] Gardner, T.A., Barlow, J., Sodhi, N.S. and Peres, C.A. 2010. A multi-region assessment of tropical forest biodiversity in a human-modified world. *Biological Conservation* 143: 2293–2300.

[4] Bennett, A., Radford, J. and Haslem, A. 2006. Properties of land mosaics: Implications for nature conservation in agricultural environments. *Biological Conservation* 133: 250–264.

[5] Perfecto, I. and Vandermeer, J. 2008. Biodiversity conservation in tropical agroecosystems – A new conservation paradigm. *Annals of the New York Academy of Science* 1134: 173–200.

[6] Sridhar, H., Raman, T.R.S. and Mudappa, D. 2008. Mammal persistence and abundance in tropical rainforest remnants in the southern Western Ghats, India. *Current Science* 94: 748–757.

[7] Anand, M.O., Krishnaswamy, J., Kumar, A. And Bali, A. 2010. Sustaining biodiversity conservation in human-modified landscapes in the Western Ghats: Remnant forests matter. *Biological Conservation* 143: 2363–2374.

[8] DeFries, R., Karanth, K.K. and Pareeth, S.J. 2010. Interactions between protected areas and their surroundings in human-dominated tropical landscapes. *Biological Conservation* 143: 2870-2880.

[9] Mudappa, D. and Raman, T.R.S. 2007. Rainforest restoration and wildlife conservation on private lands in the Western Ghats. In: *Making Conservation Work*. Shahabuddin, G. and Rangarajan, M. (Eds.), pp 210 – 240. Permanent Black, Ranikhet.

[10]Chazdon, R.L., Harvey, C.A., Komar, O., Griffith, D.M., Ferguson, B.G., Martínez-Ramos, M., Morales, H., Nigh, R., Soto-Pinto, L*., Van Breugel, M. and P*hilpott, S.M. 2009. Beyond Reserves: A research agenda for conserving biodiversity in human-modified tropical landscapes. *Biotropica* 41: 142–153.

[11]Laurance, W.F. 1990. Comparative responses of five arboreal marsupials to tropical forest fragmentation. *Journal of Mammalogy* 71: 641–653.

[12]Fimbel, C. 1994. Ecological correlates of species success in modified habitats may be disturbance- and site-specific: The primates of Tiwai Island. *Conservation Biology* 8: 106–113.

[13]Onderdonk, D.A. and Chapman, C.A. 2000. Coping with forest fragmentation: The primates of Kibale National Park, Uganda*. International Journal of Primatology* 21: 587–611.

[14]Dudgeon, D. 2000. Conservation of freshwater biodiversity in Oriental Asia: constraints, conflicts, and challenges to science and sustainability. *Limnology* 1: 237–243.

[15]Saunders, D.L., Meeuwig, J.J. and Vincent, A.C. 2002. Freshwater protected areas: Strategies for conservation. *Conservation Biology* 16: 30–41.

[16]Strayer, D.L., Beighley, E.R., Thompson, L.C., Brooks, S., Nilsson, C., Pinay, G. and Naiman, R. J. 2003. Effects of land cover on stream ecosystems: roles of empirical models and scaling issues. *Ecosystems* 6: 407–423.

[17]Kruuk, H. 2006. *Otters: ecology, behaviour and conservation*. Oxford University Press, Oxford.

[18]Melquist, E.W. and Hornocker, G.M. 1983. Ecology of River Otters in West Central Idaho. *Wildlife Monographs* 83: 3–60.

[19]Dubuc, L.J., Krohn, W.B. and Owen Jr, R.B. 1990. Predicting occurrence of river otters by habitat on Mount Desert Island, Maine. *Journal of Wildlife Management* 54: 594–599.

[20]Lundy, M.G. and Montgomery, M.I. 2010. A multi-scale analysis of the habitat associations of European otter and American mink and the implications for farm scale conservation schemes. *Biodiversity and Conservation* 19:3849–3859.

[21]MacKenzie, R.S. 2009. *Factors affecting the detectability and distribution of the North American River Otter*. M.S. thesis, Kansas State University, Manhattan, Kansas, USA.

[22]Prenda, J. and Granado-Lorencio, C. 1996. The relative influence of riparian habitat structure and fish availability on Otter *(Lutra lutra L.)* sprainting activity in a small Mediterranean catchment. *Biological Conservation* 76: 9–15.

[23]Robitaille, J.F. and Laurence, S. 2002. Otter, *Lutra lutra*, occurrence in Europe and in France in relation to landscape characteristics. *Animal Conservation* 5: 377–344.

[24]White, P.C.L., McClean, C.J. and Woodroffe, G.L. 2003. Factors affecting the success of an otter (*Lutra lutra*) reinforcement programme, as identified by post-translocation monitoring. *Biological Conservation* 112: 363–371.

[25]Cincotta, R.P., Wisnewski, J., Engelman, R. 2000. Human population in the biodiversity hotspots. *Nature* 404: 990–992.

[26]Muthiah, S. 1993. *The planting century: The first hundred years of the United Planters' Association of Southern India.* Affiliated East-West Press Pvt Ltd, Madras.

[27]Hussain, S.A. 1999. Status of otter conservation in India. *Environmental Information System Bulletin: Wildlife and Protected Areas, Mustelids, Viverrids and Herpestids of India* 2: 92–97.

[28]Anoop, K.R. and Hussain, S.A. 2005. Food and feeding habits of smooth coated otters (*Lutra perspicillata*) and their significance to the fish population of Kerala, India. *Journal of Zoology* 266:15–23.

[29]Perinchery, A., Jathanna, D. and Kumar, A. 2011. Factors determining occupancy and habitat use by Asian small-clawed otters in the Western Ghats, India*. Journal of Mammalogy* 92: 796-802.

[30]IUCN. 2011. *IUCN Red List of Threatened Species*. www.iucnredlist.org. Version 2011.2. Downloaded on 1 December 2011.

[31]Pascal, J.P. 1988. *Wet evergreen forests of the Western Ghats of India: Ecology, structure, floristic composition and succession*. French Institute of Pondicherry, India.

[32]MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Andrew Royle, J. and Langtimm, C.A. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83: 2248–2255.

[33]Mason, C.F. and Macdonald, S.M. 1987. The use of spraints for surveying otter (*Lutra lutra)* populations: An evaluation. *Biological Conservation* 41: 167–177.

[34]Conroy, J.W.H. and French, D.D. 1987. The use of spraints to monitor populations of otters (*Lutra lutra* L). *Symposia of the Zoological Society of London* 58, 247–262.

[35]Kruuk, H. and Conroy, J.W.H. 1987. Surveying otter *Lutra lutra* populations: a discussion of problems with spraints. *Biological Conservation* 41, 179–183.

[36]Lanszkia, J., Hidasb, A., Szentesb, K., Re´vayb, T., Lehoczkyc, I. and Weiss, S. 2008. Relative spraint density and genetic structure of otter (*Lutra lutra*) along the Drava River in Hungary. *Mammalian biology* 73: 40-47.

[37]Fusillo, R., Marcelli, M. and Boitani, L. 2007. Survey of an otter *Lutra lutra* population in Southern Italy: site occupancy and influence of sampling season on species detection. *Acta Theriologica* 52: 251–260.

[38]Hines, J.E. 2006. *PRESENCE2—Software to estimate patch occupancy and related parameters. USGS-PWRC*. http://www.mbr-pwrc.usgs.gov/software/presence.html.

[39]Arnold, T.W. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. *Journal of Wildlife Management* 74:1175-1178

[40]Burnham, K.P. and Anderson, D.R. 2002. *Model-selection and multi-model inference: a practical information-theoretic approach*. Springer-Verlag, New York.

[41]R Development Core Team. 2010. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

[42]Crawley, M.J. 2005. *Statistics: An Introduction using R*. John Wiley & Sons, Ltd. New York.

[43]Cho, H., Choi, K. and Lee S, Park Y 2009. Characterizing habitat preference of Eurasian river otter (*Lutra lutra*) in streams using a self-organizing map. *Limnology* 10: 203–213.

[44]Foster-Turley, P. 1992. Conservation aspects of the ecology of Asian small-clawed and smooth-coated otters on the Malay Peninsula. *IUCN Otter Specialist Group Bulletin* 7: 26–29.

[45]Durbin, L.S. 1998. Habitat selection by five otters *Lutra lutra* in rivers of northern Scotland. *Journal of Zoology* 242: 85–92.

[46]Sepúlveda, M.A., Bartheld, J.L., Monsalve, R., Gomez, V. and Medina-Vogel, G. 2007. Habitat use and spatial behaviour by Southern river otters (*Lontra provocax*) in riparian habitats of Chile: Conservation implications. *Biological Conservation* 140: 329–338.

[47]Somers, M.J. and Nel, J.A.J. 2004a. Habitat selection by the Cape clawless otter (*Aonyx capensis*) in rivers in the Western Cape Province, South Africa. *African Journal of Ecology* 42: 298–305.

[48]Somers, M.J. and Nel, J.A.J. 2004b. Movements and home range of Cape clawless otters (*Aonyx capensis*), affected by high food density patches. *Journal of Zoology* 262: 91–98.

[49]Aued, M.B., Chehebar, C., Porro, G., Macdonald, D.W. and Cassini, M.H. 2003. Environmental correlates of the distribution of Southern River Otters *Lontra provocax*. *Oryx* 37: 413–421.

[50]Medina-Vogel, G., Kaufman, V., Monsalve, R. and Gomez, V. 2003. The influence of riparian vegetation, woody debris, stream morphology and human activity on the use of rivers by Southern river otters *Lontra provocax* in Chile. *Oryx* 37: 422–430.

[51]Anand, M.O., Krishnaswamy, J. and Das, A., 2008. Proximity to forests drives bird conservation value of coffee plantations: implications for certification. *Ecological Applications* 18: 1754–1763.

[52]Raman, T.R.S. 2006. Effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats, India. *Biodiversity and Conservation* 15: 1577–1607.

[53]Bali, A., Kumar, A. and Krishnaswamy, J. 2007. The mammalian communities in coffee plantations around a protected area in the Western Ghats, India. *Biological Conservation* 139: 93–102.

[54]Dolia, J., Devy, M.S., Aravind, N.A. and Kumar, A. 2008. Adult butterfly communities in coffee plantations around a protected area in the Western Ghats. *Animal Conservation* 11: 26–34.

[55]Meena, V. 2001. Otter poaching in Palni Hills. *Zoo's Print Journal* 17: 696-698.

[56]Aerts, J., Mudappa, D. and Raman, T.R.S. 2010. Coffee, Conservation, and Rainforest Alliance Certification: Opportunities for Indian coffee. *Planters Chronicle*, December 2010: 15-26.