1   **Title: On the Edge: Identifying priority areas for conservation of Fishing Cat, a threatened**
2   **wetland felid, amidst rapidly altering freshwater landscapes**

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Abstract

1. Freshwater ecosystems have been most severely impacted in the Anthropocene with 27% of its species threatened with extinction. Fishing Cat is a globally threatened South and South-east Asian wetland felid that is also a highly rated Evolutionarily Distinct and Globally Endangered (EDGE) species, i.e., it is a global priority for conservation and research. Being an understudied species, knowledge gaps exist on its basic ecology, such as distribution and niche.

2. To address this, ensemble species distribution modeling (ESDM) was used to clarify doubts on its potential distribution and niche. To provide a relatable current context, loss of suitable habitat to urbanization (2010-2020) was estimated by analyzing range-wide survey data with environmental and anthropogenic variables (night-time lights and land surface temperature as proxies for urbanization).

3. Wetlands (18.36%) and elevation (17.15%) are the most important variables determining the ecological niche of Fishing Cat. It was predicted to be mainly restricted to low-elevation (<111 m) wetlands in river basins of South and South-east Asia. An estimated 23.74% suitable habitat was lost to urbanization.

4. Incrementally building on the ESDM outputs, high priority movement corridors and landscape conservation units were identified.

5. South Asia holds the core of the global Fishing Cat population with two very important regions - Ganges Brahmaputra Basin and Indus Basin - sharing transboundary areas with highly suitable habitat and many priority conservation units. The former is strategic to maintaining connectivity between South and South-east Asian Fishing Cat populations while isolation effects in the latter need investigation. Coastal wetlands of South-east Asia, though severely impacted, are crucial for the felid's persistence.

6. More than 90% of Fishing Cat's potential range lies outside the protected area network. Here, the felid can be adopted as a flagship species to conserve rapidly degrading low-elevation wetlands within a socio-ecological framework by involving multiple stakeholders.

Keywords: Ensemble Species Distribution Modeling (ESDM), Fishing Cat, freshwater, wetlands, landscape conservation prioritization, urbanization

1. Introduction

The alarming rates of species loss during the ongoing sixth mass extinction surpass pre-human background estimates and continue because of increasing anthropogenic threats (Barnosky et al., 2011; Tittensor et al., 2014; Burivalova, Butler & Wilcove, 2018). Freshwater ecosystems, which are lifelines to both society and diverse species assemblages, have been the most severely impacted by these unprecedented threats but remain under-prioritized in the conservation domain (Albert et al., 2020; Tickner et al., 2020). Occupying less than 1% of the Earth's surface, these ecosystems provide habitat to one-third of the world's vertebrate species and 10% of all species (Dudgeon 2019), yet freshwater biodiversity populations have experienced dramatic declines with wetlands being lost three times faster than forests (Gardner and Finlayson, 2018). Approximately 27% of freshwater species and 42% of the 70 wetland dependent mammals are threatened with extinction (Balian et al., 2008; Tickner et al., 2020). Increasing socio-economic development in productive lowland regions is a significant threat to freshwater ecosystems (Darwall and Freyhof, 2016). In clarion calls published recently, scientists have stressed on integrating modern technology with field based knowledge for tracking endangered species of high conservation value to develop global freshwater conservation strategies (Arthington, 2021).

Fishing Cat (*Prionailurus viverrinus*) is a member of the threatened freshwater mammalian guild (Veron et al., 2008). Moreover, it is a highly rated 'Evolutionarily Distinct and Globally Endangered' (EDGE) species (EDGE score > 4), i.e, a global priority for research and conservation, but remains understudied (Tensen, 2018). It is one among the only two felids to have morphological adaptations for a semi-aquatic hunting niche (MacDonald and Loveridge, 2010), despite modern felids being morphologically and ecologically similar due to their recent and rapid divergence (Johnson et al. 2006). These include a double-coated, water-resistant fur, partially webbed feet, a short and stubby tail that provides balance while hunting or navigating in water and half-sheathed claws that provide traction in mud and facilitates gripping of slippery prey like fish (Kitchener, 1991; Sunquist and Sunquist, 2014; Hunter, 2019). Further, fish is known to be an important prey species and the primary constituent of its eclectic dietary niche (Haque and Vijayan, 1993; Cutter, 2015; Mukherjee et al., 2016). Both its morphological adaptations and prey association therefore suggests a strong selection for thriving in wetland environments.

Confirmed records of its presence exist from Pakistan, India, Nepal, Bangladesh, Sri Lanka, Myanmar, Thailand, Cambodia, Vietnam and Java (Willcox, 2015; Mukherjee et al., 2016, Lin and Platt, 2019) while its presence in peninsular Malaysia, Sumatra, Lao PDR, Taiwan and China remains speculative at best (Duckworth et al., 2009; Sanderson, 2009; Jutzeler, 2010; Duckworth et al., 2010). Further, there is lack of clarity on its distribution even within range countries. For instance, was/is it present in India's western coast? Though there is anecdotal evidence and speculation of its occurrence there (Jerdon, 1874; Nowell and Jackson, 1996; Sunquist and Sunquist, 2014), recent surveys have failed to detect it (Janardhanan et al., 2014). Its actual distribution in South-east Asia still needs clarity with targeted research being conducted only in

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111   Thailand and Cambodia (Cutter, 2015; Thaung et al., 2018; Chutipong et al., 2019). Moreover,
112   recent records of its occurrence from relatively non-moist drier areas (Sadhu and Reddy, 2013;
113   Talegaonkar et al., 2018) and higher altitudes (>1800 m) (Thudugala, 2015) further create
114   confusion regarding limitations of the species' fundamental niche.

115   The tools and techniques offered by Geographical Information Systems (GIS) have immense
116   potential in combining large scale ground information with remotely sensed satellite data and
117   modeled spatial data layers to demarcate species' geographical ranges, identify its movement
118   corridors (Jalkanen et al., 2020; Xiao et al., 2020), and pinch points of connectivity (Yu et al.,
119   2021), leading to prioritization of regions for their conservation (Lin et al., 2020; Shrestha et al.,
120   2021). Species distribution modeling (SDM) approach has demonstrated the applicability of
121   machine learning in defining species-environment relationship and the geographic extent of
122   species distribution (Ahmed et al., 2021; De Simone et al., 2021; Lozano, 2021). SDMs combine
123   the theory of ecological niche (Hutchinson, 1957), with machine learning algorithms to estimate a
124   set of conditions appropriate for the species, and thereby estimate its potential spatial extent of
125   distribution. These predictive models combine species presence locations with environmental
126   variables (Araujo and Guisan, 2006; De Simone et al., 2021) to not only estimate species'
127   geographic extent but also identify the limiting environmental factors. However, performance of
128   these predictive models may vary from case to case (Hao et al., 2019). Instead of selecting an
129   individual algorithm, an ensemble of models harnesses better predictive power (Araujo and New,
130   2007; Hao et al., 2019; Lozano, 2021).

131   In the present study, we employed ensemble species distribution modeling (ESDM) to a) estimate
132   the potential global distribution of Fishing Cat and b) identify factors limiting its fundamental
133   niche. To understand the current extent of its distribution under the impact of urbanization, the
134   most prominent marker of socio-economic development, we further c) estimated loss of suitable
135   habitat to urbanization from 2010 to 2020. Incrementally building on the ESDM outputs, we
136   identified d) critical movement routes in urbanized landscapes and e) Landscape Conservation
137   Units (LCUs) to suggest conservation priority regions for maintaining global Fishing Cat habitat
138   populations and connectivity.

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140   **2.   Methods**

141   **2.1 Species Occurrences**

142   Fishing Cat occurrences collected through field surveys by teams in respective Fishing Cat
143   presence countries were collated (Appendix Data Sources). Only occurrences recorded through
144   camera traps, or photographic evidence were used, while evidences that were not collected through
145   systematic surveys (road kills, captures, dead specimens, museum specimens) were eliminated.
146   Spatial filtering of the occurrence points was performed using a buffer of 4.6 km, assuming 20

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147 km^2 (~4.6 km square grid) as the maximum home range for Fishing Cat (Sunquist and Sunquist
148 2014). The occurrences dataset was divided into temporal categories of those collected between
149 2010-2014 (T_1) and 2015-2020 (T_2). Here onwards we refer to the two time frames as T_1 and T_2.
150 Records indicating road kill and conflict or negative interaction with humans were also retained
151 for manual evaluation of model output.

2.2 Habitat Variables

153 Distribution models for Fishing Cat were developed accounting for two scenarios, an ecological
154 scenario and an urban impact scenario. A set of 37 variables for the ecological scenario and two
155 additional variables for the urban impact scenario were used (Appendix Data Sources). Values of
156 the habitat variables were attached to the species occurrence locations using QGIS 3.10.
157 Collinearity among the variables was computed using the R package 'caret' (Kuhn, 2008).
158 Variables left after removing collinear variables (Fig 1 and 2), were also tested for Variance
159 Inflation Factor (VIFs, Marquardit, 1970). The variables retained were – annual mean temperature
160 (bio_1), mean temperature of warmest quarter (bio_10), precipitation of driest month (bio_14),
161 precipitation of warmest quarter (bio_18), mean monthly Normalised Difference Vegetation Index
162 (NDVI) for February (NDVI_Feb), mean monthly NDVI for September (NDVI_Sept), elevation,
163 ecoregions and wetlands (CIFOR). For the urban impact scenario, night-time lights and land
164 surface temperature (LST) (Ariken et al., 2020) were used in addition to the ecological variables.
165 To compare between the ecological and urban impact scenarios, we retained all the variables from
166 the former in the latter scenario. The bioclimatic variables, elevation, eco-regions and wetlands
167 remained constant across the two time intervals. NDVI, LST and night-time lights were used for
168 the years 2012-13 and 2019 in order to represent the respective time intervals T_1 and T_2. Since the
169 maximum home range for the Fishing Cat (20 km^2) was considered, bioclimatic layers of spatial
170 resolution 2.5 minutes (~4.6 km) were selected and the other raster layers were resampled to 2.5
171 minutes spatial resolution. Considering the geographic scale of this study, all analyses were
172 performed using Asia Lambert Conformal Conic meter projection.

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2.3 Modeling Procedure

175 The ecological and urban impact scenarios were modeled for both T_1 and T_2. Hence, four different
176 distribution models were developed representing the ecological scenario for T_1 (EcoT$_1$), ecological
177 scenario for T_2 (EcoT$_2$); the urban scenario for T_1 (UrbT$_1$), and the urban scenario for T_2 (UrbT$_2$).

178 We used the ensemble modeling approach for developing the ensemble species distribution model
179 (ESDM) for FC, using r package 'SSDM' (Schmitt et al., 2017). 'SSDM' is a robust and user-
180 friendly platform for modeling ecological niche of the species, using mathematical representation
181 of the known occurrences of the species (Guissan and Thuiller, 2005; Schmitt et al., 2017). The
182 ensemble modeling approach has been proven to be useful in eliminating bias arising from single
183 models and predicting more precisely (Araujo and New, 2007; Hao et al., 2019).

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The model was supplied with a presence only occurrence records and calibrated to pick pseudo-absence/background points using the default strategy (Barbet-Massin et al., 2012) incorporated within the 'SSDM' package. Each algorithm was set for 15 replicate repetitions and 'leave-out-one' cross-validation strategy was used for evaluation of the ESDM. Receiver's Operating Curve (ROC) was used for model evaluation and binary map threshold computation. Algorithm selection in 'SSDM' is automated. The algorithms which have an evaluation above a specified threshold, are only used in the final ensemble projection. A threshold ROC of 0.75 was set for algorithm selection. The algorithms which passed this filter were Random forest (RF), Support vector machine (SVM), Multivariate adaptive regression splines (MARS) and Classification tree analysis (CTA). Based on the model evaluation scores (Table 1), we retained RF and SVM for the final model predictions. The metric used for computing the threshold for binary maps was sensitivity-specificity equality (Liu et al., 2005; Jiménez-Valverde and Lobo, 2007). Scenario $EcoT_2$ was first parameterised using this procedure. Thereafter, $EcoT_1$, $UrbT_1$ and $UrbT_2$ scenarios were computed, keeping the model parameters constant, for comparability and uniformity among model outcomes.

Variable importance scores computation is automated in the 'SSDM' package. However, for variable response curves, random points were generated over the geographic range and values of all the variables used in the models and the probability surfaces were extracted to the points. The variable values were plotted against the probability scores using R package 'ggplot2' (Wickham, 2011). The limiting range of important variables determining Fishing Cat was estimated based on the occurrence data as was adopted by Mukherjee et al., 2010.

2.4 Loss of suitable habitat due to urbanization

The binary maps for the two scenarios and respective time intervals were used for calculation of suitable ecological niche for FC in the respective scenarios and the difference in the maps was calculated using the MOLUSCE 3.0.13 plugin in QGIS v2.18.2.

2.5 Habitat Connectivity

The ESDM based probability raster for $UrbT_2$ was inverted to produce a friction layer for the movement of FC across its habitats. The 'Least Cost Corridors and Paths' module in the SDM toolbox (Brown, 2014; Brown et al., 2017) was used for identifying the corridors based on the least cost paths (LCPs) on a friction/cost layer. Due to processing limitations at the spatial resolution of 2.5 minutes (~ 4.6 km), the friction layer for the LCP analysis using SDM toolbox was resampled to a resolution of 5 minutes (~ 9.2 km). We used the 'percentage of LCP value' method for selecting the least cost corridors (LCCs) as this method selects corridors based on site-specific LCPs (Chan et al., 2011; Brown et al., 2017). Fishing Cat occurrences for T_2 were used as input points. Due to the absence of any physical connection between Sri Lanka and the rest of the land area in the study area, and to avoid computational errors, Fishing Cat occurrence points from Sri Lanka were omitted from the LCC analysis.

220   In addition, a circuit theory-based connectivity analysis was also performed using the tool
221   Circuitscape v4.0 (McRae et al., 2013), which implements the circuit and random walk theory
222   (McRae et al., 2009). This tool computes a resistance-based connectivity metric based on a series
223   of combinatorial and numerical analyses (Shah and McRae, 2008). The prime difference between
224   a circuit and an LCP is that the circuit corridor is identified after computation of multiple paths
225   between the population cores and the conductive probability of every raster cell is measured. In
226   contrast, the LCP is based on a single least-cost route (Bowman et al., 2020). The circuit theory
227   accommodates the assumption that animals may not have the knowledge of the perfect least-cost
228   route (Marrotte et al., 2017) and the most traversed paths could be a cumulative outcome of the
229   paths with minimum resistance. We used Protected Areas (PAs) where Fishing Cat occurrences
230   for T_2 were recorded as core areas indicating source populations. Pair-wise nodes and eight-cell
231   window were parameterised for estimation of current flow, using the inversed ESDM as the
232   resistance surface.

233   To pinpoint areas with very high density of both current flow and LCPs, i.e. the pinch points for
234   Fishing Cat movement in the study region, the 'Pinch Point Mapper' tool (McRae, 2012) from the
235   'Linkage Mapper' toolkit for ArcMap (McRae and Kavanagh, 2011) was used. The Pinch Point
236   mapper combines the frameworks of LCP and circuit theory and identifies pinch points having
237   high density of paths represented through both the LCPs and Circuitscape based current flows. The
238   pinch points are the bottlenecks in the corridor with considerable traffic of animal movement
239   (McRae, 2012). These are regions with degraded or semi-degraded adjacent cells and thus points
240   of significant importance for movement/dispersal from the landscape conservation perspective.
241   Being narrow sections in the corridor, removal of these regions might hamper the connectivity of
242   populations in a landscape (Liu et al., 2020). Linkage paths were constructed using the 'Linkage
243   Pathways' tool, which were further used as inputs to the Pinch Point Mapper tool. Pairwise
244   calculation was set for the Circuitscape mode and 4.6 km was set as the minimum cost-weighted
245   corridor width. Since, all raster data in this study were processed at a spatial resolution of 2.5
246   minutes (~ 4.6 km), this was the lowest possible corridor width that could be parameterised.

2.6 Priority Conservation Units

248   A conservation unit of 100 km^2 was assumed for prioritization of landscape conservation units
249   (LCUs) for Fishing Cat. The LCU prioritization was implemented through the R package
250   'prioritizr' (Hanson et al., 2018), using 'Lsymphony' open source solver. We used two different
251   scenarios for modelling the LCUs – (a) costs based on FC connectivity and (b) costs based on
252   urbanisation in the landscape. For the first scenario, the connectivity cost values from the LCP
253   output raster and the inversed current flow raster were added and attached to each grid, to designate
254   the costs that FC would incur in a given grid. These costs were calculated from the perspective of
255   identifying the most suitable units for FC. For the urbanization scenario, the raster values from
256   night-time lights and LST were combined and attached to the grids, representing the conservation
257   costs that would be incurred if a given 100 km^2 grid was to be selected for conservation. The raster
258   output from the ESDM for $UrbT_2$ and the CIFOR wetlands were used as feature layers.

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259 Optimization targets ranging from 10%-50% of the landscape, with increments of 5% were
260 implemented for each scenario resulting in nine solutions for each respective scenario.
261 Prioritization importance scores (PIS) were assigned to each solution in the inverse order of their
262 target optimization. A PIS of 50, 45, 40, 35, 30, 25, 20, 15 and 10 was assigned to solutions of
263 targets 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50% respectively (Rodewald et al., 2019).
264 Hereafter, the solutions from all the nine prioritized targets were added into a single solution and
265 units encompassing protected areas were selected.

3.   Results

3.1 Global distribution of Fishing Cat and limiting factors

268 Wetlands (18.36%) and elevation (17.15%) were the highest contributing variables determining
269 the ecological niche of Fishing Cat. The felid was predicted to be mainly restricted to low-elevation
270 (<111 m above sea level) wetlands. These wetlands are part of the floodplains and delta regions of
271 the Indus Basin, Ganges-Brahmaputra Basin (GBB), Ayeyarwaddy Basin, Salween Delta, Chao
272 Phraya river system, Mekong Basin and Red River Delta (Fig. 3). In peninsular India, Fishing Cat
273 was mainly predicted to occur in the Mahanadi Basin and the Godavari-Krishna Delta. The Lower
274 Indus Basin and Middle Indus Basin constituting the westernmost limit of Fishing Cat's
275 distribution is predicted to have very high quality Fishing Cat habitat. Our model predicted the
276 occurrence of Fishing Cat along the Indian western coast but the felid might have never occurred
277 there (see Janardhan et al., 2014). Apart from this, the island country of Sri Lanka was predicted
278 to have broad and continuous suitable areas for the cat along both the eastern and western coast.
279 A narrow zone fringing the northern coastline of Java, another island, was also found to be suitable.
280 Among these, the Indus Basin, parts of the Indo-Nepal Terai, Sunderbans delta along with low-
281 elevational wetlands of the Gangetic floodplains, parts of the Mahanadi basin including Chilika
282 lagoon, Bhitarkanika and Mahanadi mangroves and small portions of the Godavari- Krishna delta
283 are predicted to have very highly suitable habitat. In South East Asia, such high quality habitats
284 are sparingly present in the Ayeyarwady delta and coastlines of Thailand, Cambodia and Vietnam.
285 More than 90% of the predicted suitable range for Fishing Cat lies outside protected areas (see
286 Supplementary information, S1). To guide future surveys, we have provided detailed
287 biogeographical information of regions with >50% predicted presence of Fishing Cat in the
288 mainland and separately for the island country of Sri Lanka along with jurisdictional boundaries
289 to maximize relevance for management (see Supplementary information, S2).

290

3.2 Temporal loss of habitat

292 The ecological scenario (EcoT1) is a hypothetical one, useful in visualizing the extent of the
293 suitable habitat for Fishing Cat with only natural predictors and without anthropogenic pressures.
294 Since the bioclimatic and topographic factors remained constant over the two time points (T1 and

295   T2) in this study, a decline of 18% (Table 2) in the suitable habitat under the ecological change
296   scenario (EcoT1 to EcoT2) indicates a shrink in the vegetation cover/habitat, which indirectly
297   represents anthropogenic pressure. On the other hand, the urban impact scenario (UrbT1 to UrbT2)
298   includes proxies of anthropogenic structures as an influencing variable in the model and can better
299   emphasize the impact of urbanization on Fishing Cat habitat.

300   The ESDM probability maps that were generated using the selected algorithms, RF and SVM, had
301   the Receivers Operating Curve (ROC) evaluation score above 0.82 and Kappa evaluation score
302   above 0.64 for all the computed scenarios (Table 1). This indicates that we could successfully
303   implement the models in estimating the suitable habitat for Fishing Cat in the two scenarios
304   considered in this study. The binary ESDM maps were generated using the respective threshold
305   values for each scenario (Table 1).

306   Area of the model predicted suitable area for Fishing Cat in each scenario was calculated (Table
307   1) and the changes in the predicted presence between T_1 and T_2 in both the ecological and urban
308   impact scenarios were calculated (Table 2). The loss of predicted suitable area (Table 2) for Fishing
309   Cat, in the ecological scenario (EcoT$_1$ to EcoT$_2$) was estimated at 18.404% and 23.784% in the
310   urban scenario (UrbT$_1$ to UrbT$_2$) (see Fig 5 and 6). Simultaneously, percent gain in suitable habitat
311   was also estimated, 4.159% for EcoT$_1$ to EcoT$_2$ and 19.375% for UrbT$_1$ to UrbT$_2$ (Table 2).

312

3.3 Landscape connectivity

314   The raster values of connectivity outputs i.e., the LCC, LCC line density; the Circuitscape output
315   for cumulative current density and the Pinch-points were rescaled to 0-1. The lowest 30% of the
316   cost values in the LCC were used to depict the LCC for Fishing Cat, and the highest 30% of the
317   values to show the density of LCPs in the LCC (Fig. 7). Similarly, top 30% of the maximum flow
318   values (Jennings et al., 2020; Li et al., 2020) were considered to depict the conductivity-based
319   corridor for Fishing Cat movement (Fig. 8) and 5% of the highest values of the output from the
320   Pinch Point Mapper were used as thresholds for delineating the pinch points (Fig. 9).

321

3.4 Landscape Conservation Units

323   In both the Fishing Cat connectivity scenario and the least urban scenario, the Indus basin and
324   parts of GBB in South Asia figured as LCUs of very high priority.

325   According to the Fishing Cat connectivity scenario, 39 high to very high LCUs were found in
326   South Asia. No high priority LCU was present in South-east Asia. Six LCUs of moderate priority
327   were selected in South-east Asia. In the least urban scenario, 25 LCUs of high to very high priority
328   were selected in South Asia. Six LCUs of high to very high priority were present in South-east
329   Asia.

330   **4.   Discussion**

331   To the best of our knowledge, this study was the first attempt to model the global distribution of
332   Fishing Cat, an under-studied, globally endangered freshwater mammalian carnivore of high
333   conservation and research value (Veron et al., 2008; Tensen, 2018; Zanin and Neves, 2019). RF
334   and SVM, selected as the best performing algorithms for the SDM of Fishing Cat, have been found
335   to be powerful classifiers in other studies too (Fukuda et al. 2013; Thahn Noi and Kappas, 2018).
336   The felid was predicted to be mainly restricted to low-elevation (<111 m above sea level) wetlands
337   of South and South East Asian river basins (Fig 3). Low elevation was also estimated to be an
338   important predictor for Fishing Cat distribution in the Indian subcontinent (Silva et al., 2020).
339   South Asia holds the core of the global Fishing Cat population with India sharing two trans-
340   boundary regions in the GBB of high Fishing Cat occurrence probability (>80%) - a) wetlands of
341   the Terai region with Nepal, and, b) the Gangetic Delta (including the Sunderbans) with
342   Bangladesh. South Asia also has the highest numbers of LCUs in parts of the GBB and the Indus
343   Basin (Fig 9, Table 3). The situation in South-east Asia seems precarious and therefore worthy of
344   intensive research and conservation efforts. Along the coastline of Myanmar and Thailand, Fishing
345   Cat connectivity is predicted to face the highest resistance but some areas of the Mekong
346   floodplains and delta region provide lower resistance, higher habitat suitability including the
347   presence of LCUs and potentially important dispersal corridors.

348   **4.1 Flexibility/limitedness of its fundamental niche**

349   There are some departures from the hypothetical situation presented by our models as is expected,
350   discussing which might resolve doubts and strengthen our understanding of its ecology and
351   fundamental niche. For example, despite our predictions of the restriction of its niche to low-
352   elevation wetlands (>111 m above sea level), Fishing Cats were documented from an elevation of
353   1870 m from Sri Lanka's central hilly region. This is the only unit globally to colonize higher
354   elevations and thus constituted a small fraction of the occurrence points in comparison to the
355   regional species pool of the mainland. Therefore this was not chosen as a suitable habitat by our
356   model. A closer introspection of the Sri Lankan geography reveals that freshwater sources in the
357   island originate from the central hilly regions and flow out towards all directions, creating
358   numerous water-rich habitat/wetland complexes throughout the island. Thus, during sea-level rise
359   events, low-elevational populations might have been pushed to migrate up the hills due to
360   geometric constraints imposed by the island and would have been facilitated to colonize the higher
361   altitudes because of the presence of rivers. This could have caused a local adaptation in the Sri
362   Lankan population and effectively extended its fundamental niche. Theoretical predictions do
363   predict selection of broader niche breadth in species in variable environments (Levins, 1962;
364   Sultan and Spencer, 2002). Mainland populations situated in more predictable environments may
365   have been relaxed of such selection pressures. Additionally the presence of more competitors in
366   the mainland might have limited them to a narrower and specialized niche. In addition, Fishing
367   Cat was recorded from drier regions in Sri Lanka, also predicted to be unsuitable/sub-optimal by

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368 our model. The presence of man-made wetlands such as ancient hydrological tanks, reservoirs and
369 croplands simulating Fishing Cat habitat might have facilitated its occurrence in these drier regions
370 inland. Infact, annual rainfall was found to be the most important climatic variable determining
371 Fishing Cat distribution in a Sri Lanka specific modeling (Thudugala, *in litt.*) that might be playing
372 a critical role in maintaining these wetlands in the drier inland regions.

373 Fishing Cat has also been recorded recently from the much drier central and north-western Indian
374 landscapes (Sadhu and Reddy, 2013; Talegaonkar et al., 2018; Dey, 2018; Dutta et al., 2021) and
375 the arid Deserts and Xeric Shrublands terrestrial ecoregion of Pakistan (Roberts, 1997). Our model
376 predicts the presence of sup-optimal habitat in central and north-western India that has riverine
377 connections to the highly suitable Terai region. Therefore Fishing Cat populations here could be
378 an extension of the Terai population. However, these could be dead ends as they meet the Thar
379 Desert to the west and the highlands and plateau regions of Central India to the south. Nonetheless
380 they represent threatened freshwater ecosystems worthy of attention. In Pakistan, which is the
381 westernmost limit of global Fishing Cat distribution, it is the presence of the Lower and Middle
382 Indus freshwater ecoregions (see Abell et al., 2008), within the drier terrestrial ecoregion that has
383 made this region highly suitable for Fishing Cat with several priority conservation units. Thus
384 records of Fishing Cat from drier regions suggest that either these are marginal habitat or that
385 climatic and geographic factors have contributed to the formation and persistence of wetlands
386 within the drier regions which facilitated the cat to colonize these regions.

387 Thirdly, our model predicts Fishing Cat occurrence in the Indian western coast which is dominated
388 by the Western Ghats mountain range and associated streams. There are no confirmed reports of
389 the cat's occurrence here historically. Recent surveys have been unable to detect the cat in the
390 western coast, following which it was hypothesized that the salinity of the Arabian Sea could have
391 been the limiting factor (Janardhan et al., 2014). We suggest that rather than salinity, the absence
392 of river systems forming extensive floodplains and deltas in this region, is responsible for Fishing
393 Cat's inability to colonize it. Presence of such riverine systems can overcome limitations imposed
394 by salinity, as is found in the Indus delta region, which meets the Arabian Sea to the south.

395

396   Fourthly, our model predicted a gain of 19% habitat between 2010 to 2020 (Table 2). This
397   predicted gain is a result of the significant number of occurrence points in the proximity of urban
398   areas. Such landscapes, which are by-products of rapid urbanization replacing wetland habitat are
399   neither non-habitat, nor fully suitable ones, where the cat has no choice but to persist in remaining
400   small patches. Such landscapes thus exhibit an extremely complicated mosaic of available habitat
401   and built-up spaces, making it difficult for the model to distinguish between pure habitat and
402   mixed/non-habitat, leading to counter-intuitive predictions suggesting habitat gain. For instance,
403   in Colombo, Sri Lanka, GPS-collared adult females were found to use wetland areas more than
404   urban areas whereas a sub-adult male was found to exclusively use hyper-urban areas within the
405   city suggesting that it was pushed into marginal habitat by adults (Ratnayaka et al., 2021). These
406   hyper-urban areas, as observed by us, were characterized by abandoned colonial architectures
407   replete with anthropogenic food sources such as fish present in large courtyard ponds, commensal
408   rodents and birds present in the unkempt gardens. However, all urban spaces, especially upcoming
409   modern smart cities do not/will not have heritage buildings and their unmanicured open spaces,
410   which is why the gain shown by our model cannot be ecologically supported. Moreover, road kills
411   and negative interactions between humans and Fishing Cat are commonly occurring issues in
412   rapidly urbanizing landscapes (Adhya et al., 2011; Thudugala, 2015; Ganguly et al., 2020;
413   Thudugala *in litt*). In Sri Lanka alone, data from a citizen science program (2005 to 2021) shows
414   101 records of cat death/injury from vehicular collisions. This further suggests that urban spaces
415   might infact be ecological traps in the long term.

416   **4.2 Research and conservation efforts needed outside PA network**

417   According to model predictions, more than 90% of the predicted Fishing Cat distribution lies
418   outside protected areas. However, qualitative and/or quantitative assessments of populations and
419   their threats outside protected areas in range countries remain woefully scarce. The few studies
420   that have been conducted on the felid largely report sporadic occurrences and status reports that
421   either lacked rigor, comprehensiveness and/or placement within the larger biogeographic context
422   (Adhya and Dey, 2011; Mukherjee et al., 2012; Palei et al., 2018; Chutipong et al., 2019;
423   Kantimahanti et al. 2019; Kolipaka et al., 2019; Chakraborty et al., 2020). Population estimates on
424   the species are very scarce and restricted to a few protected areas (Nair, 2012; Das et al., 2017)
425   with the exception of Phosri et al., 2021. Across South Asia, it is the freshwater landscapes outside
426   protected areas that seem to be important for maintaining connectivity but are being subjected to
427   severe degradation. Large portions of the Indus, wetlands of the Gangetic Plains, particularly in
428   Bangladesh, the Terai-Dooars region, wetland complexes of the Brahmaputra and coastal wetlands
429   of the Indian eastern coast between Chilika lagoon and the southernmost Indian Fishing Cat
430   population in Godavari-Krishna delta need intensive surveys to not only determine current status
431   but also to examine present connectivity using advanced genetic tools. The Indus population
432   deserves special mention as a region that holds the westernmost population of Fishing Cat globally,
433   is predicted to have highly suitable areas important for conservation, but could well be suffering
434   from isolation effects. Roberts (1977), had reported occasional stragglers from the Middle Indus

435 Basin, and, along the floodplains of the rivers Sutlej, Beas and Ravi in the adjacent Indian Punjab
436 district. A thorough comprehensive current assessment is needed in the region.

437 The distribution of the species in most of South-east Asia has been extremely hampered in the
438 recent past. We recommend thorough investigations and rapid conservation efforts to stem the loss
439 of low-elevational wetlands like mangroves and marshes in the pinch points of connectivity. The
440 species has been detected in the Ayeyarwady region of Myanmar (Lin and Pratt, 2019). Targeted
441 surveys are required in the adjacent Salween Basin which has moderately suitable habitat. In
442 Thailand, Fishing Cat has been detected in the Chao Phraya river system region (Chutipong et al.,
443 2019) and from peninsular Thailand (Cutter, 2007). More investigations are recommended in the
444 inland and coastal wetlands present in the country's eastern and western coastal provinces (see
445 S1), especially around the Krabi estuary, even though Chutipong et al., (2019), failed to detect
446 them in this area. In Cambodia, Fishing Cat populations were found to be restricted to the
447 mangrove forests of Peam Krasop Wildlife Sanctuary and Ream National Park but not in Botum
448 Sakor National Park (Thaung et al., 2018). Longer, more intensive and targeted surveys focussed
449 in coastal wetlands of Cambodia as well as along shoreline mangrove patches, for example, in the
450 Koh Kong Krov island are needed. Inland wetlands along the Mekong river in Cambodia should
451 also be targeted for further surveys. A dead specimen retrieved from a roadside market in the Tonle
452 Sap area in 2018, indicates the possibility of an existing population there (Ministry of Agriculture
453 Forestry and Fisheries and Wildlife Alliance *pers. comm.*, 2018) as was previously assumed
454 (Davidson et al., 2006; Rainey and Kong, 2010), prompting surveys currently underway. In
455 Vietnam, where surveys have failed to detect Fishing Cat in recent decades, we recommend
456 targeted surveys in the Plain of Reeds, Red River Delta and U Minh wetlands. Part of U Minh
457 consists of peat swamps which might not be preferred by Fishing Cat but parts with swamps and
458 grasslands could be potentially important survey sites. In Java, there is evidence of the cat's
459 presence historically (Sody, 1936) and more recently (Duckworth *pers. comm.*, 2012)
460 corroborating model findings. However, surveys have failed to re-detect it since the last decade
461 suggesting that the species is critically endangered in the country (Willianto *pers. comm.*, 2021).
462 No suitable habitat for Fishing Cat was predicted to be present in Sumatra. This is backed by
463 absence of either historical or recent evidence of its presence in the country. How the Fishing Cat
464 came to occur in Java therefore is a mystery.

465

466 **4.3 Loss of critical wetland habitat**

467 Our models predict a contraction of more than 23.74% in suitable Fishing Cat habitat between the
468 two time periods TI and T2 due to urbanization. This is relatable given the continuing trend in
469 rapid wetland loss globally and especially in Asia (Davidson, 2018). Wetlands are predicted to
470 disappear much faster given the projected increase of urban population by 1.4 billion within 2050
471 (Hettiaracchi et al. 2015). Moreover, ephemeral or intermittently flooded wetlands are not well-
472 represented in global datasets (Davidson, 2014), which are known to be habitat preferred by

Fishing Cat, such as reed-building marshes, mangrove swamps and freshwater swamps (Sunquist and Sunquist, 2014; Mukherjee et al., 2016; Hunter et al., 2019). This further augments the threat to Fishing Cat as loss of their primary habitat due to urbanization is undoubtedly rapid but has remained undetected and therefore not foregrounded.

Human populations are known to be concentrated in productive lowland regions of the world and undoubtedly it is here that the impact of sustaining modern industrial human societies are most strongly felt (Darwall and Freyhof, 2016). Coastal wetlands have been more severely affected by urbanization and its indirect effects than inland natural wetlands (Wilkinson et al., 1994; Davidson, 2018). For instance, continuous development pressures have been degenerating the Indo-Malayan mangroves with several stretches in coastal South and South-east Asia annihilated to create megacities (Dasgupta and Shaw, 2013; Kumar and Ambastha, 2018). The loss has exacerbated in the last few decades rendering mangroves in the Indus, Ayeryarwady, Mekong and Red river basins critically degraded with the Lower Indus Basin losing 43% of its mangrove cover from 1990 to 2014 and Ayeyarwady delta losing 64% from 1978 to 2011 with predictions of complete deforestation by 2026 (Dasgupta and Shaw, 2013; Webb et al., 2014; Richard and Freiss, 2016; Qasim et al., 2016). Commercial shrimp culture is a particularly severe threat to the coastal wetlands of South-east Asia destroying 41% of Thailand's coastal mangroves and 50% of Mekong delta's mangroves since 1975 (Dasgupta and Shaw, 2013). Wetlands along the Indian east coast formed by Mahanadi, Godavari and Krishna have also been affected by hydrological fragmentation and dams with recent studies estimating a decline in the Godavari-Krishna delta by 42 km^2 between 1977 and 2008 (Kumar and Patnaik, 2018; Day et al., 2019). Mangroves in this region were found to be under high stress from intensive aquaculture and industrialization (Day et al., 2019; Bagaria et al., 2021). In addition, 42% riparian vegetation has also been lost in the Lower Indus Basin from 1990 to 2014 (Webb et al., 2014). In the Terai Arc Landscape shared between Nepal and India, much of the wet grasslands and swamps were converted during 1970-80 for agricultural expansion and human settlements with only patches of disjunct habitat persisting in protected areas (Chanchani et al., 2014). A further loss of natural grassland area by 24% was estimated from 1980-2000 across eight protected areas in India and Nepal (Banerjee et al., 2020). In this context, lowlands in GBB which were suggested to be a probable climate refugia for the species by Silva et al. 2020, maybe rendered unsuitable if the present rates and types of alteration continue. According to the Asian Wetland Directory (1989), 68% of Sri Lanka's 41 internationally significant wetland sites are under moderate to high threat. The Dry Zone's coastal lagoons, estuaries, and mangrove swamps are highly threatened due to various developmental activities. The Mahaweli Ganga Floodplain System has been recognized as a wetland site 'under significant threat of destruction', and is comparable with the Sundarbans and Mekong Delta, demanding immediate action (IUCN Sri Lanka, 2004). In the light of these recent and rapid changes, we further stress the criticality of the status of Fishing Cat worldwide. This is because range reduction is known to imply population declines (IUCN Standards and Petitions Subcommittee, 2017; Ceballos et al., 2017; Santini et al., 2019).

512   **4.4 Priority regions and threats**

513   While spatial prioritization for conservation research and action has foregrounded biodiversity in
514   the global context and eased the process of systematic planning and fund acquisition (Myers,
515   2003), it has also been substantially criticized for being bereft of 'situated knowledge' and its
516   failure to engage with locally obtained experience (Wyborn and Evans, 2021). In our study, we
517   attempted to interpret and discuss the findings of our model based on our collated local and
518   regional work experience. Most of the authors are members of Fishing Cat Conservation Alliance,
519   a global cohort of researchers and conservationists, working to facilitate change across the range
520   countries.

521   Our findings suggest that GBB, consisting of wetlands in the Terai region, Gangetic plains,
522   Gangetic Delta and valleys of the Brahmaputra along with its tributaries and distributaries, have
523   areas with high occurrence probabilities of Fishing Cat (>80%) and might be playing a critical role
524   in maintaining connectivity between populations within South Asia barring the island country of
525   Sri Lanka. The populations in the Terai and Sundarbans were in fact found to be genetically
526   connected in the past (Mukherjee et al., 2015). This implies that populations in GBB are integral
527   to maintaining connectivity between transboundary regions connecting Nepal, Bangladesh and
528   India. Due to its strategic position, GBB is probably indispensable in preventing isolation of
529   populations in the Lower and Middle Indus Basin and those that are located in the Indian East
530   coast populations. Secondly, the Gangetic Delta of GBB is critical in maintaining connectivity
531   between populations in South and South-east Asia, since it is contiguous to the coastal wetlands
532   of Myanmar. Additionally, GBB had the highest number of LCUs, many of which are contiguous,
533   suggesting that this region provides high permeability conducive for species dispersal and requires
534   lesser investments for conservation and restoration of the species' habitat (Table 3). The Lower
535   Indus Basin had the second highest number of LCUs (Table 3). Even though our connectivity
536   analysis shows that Beas, Ravi and Sutlej floodplains provide limited resistance, this is unlikely
537   given the uninhibited loss of wetlands in the Indian state of Punjab following the Green Revolution
538   and urbanization (Brar and Chandel, 2012). A limitation of our study is the use of only an
539   urbanization based resistance matrix for assessing connectivity, which under-represents the
540   accumulated resistance to dispersal from hostile land-use regimes such as extensively occurring
541   intensive agricultural landscapes and similar aquaculture waterscapes.

542   The river basins with predicted Fishing Cat occupancy are also among the biggest freshwater fish
543   producing regions with the Ganges, Brahmaputra and Mekong featuring among the top seven
544   basins to contribute to 50% of the global freshwater fish catch, supporting the livelihood of
545   millions locally and providing nutrition globally (WWF, 2021; Ainsworth et al., 2021). These
546   basins are prey-dense wet landscapes for Fishing Cat. Yet these are facing above-average stress
547   levels from the compounding effects of hydropower dams, pollution, overexploitation and climate
548   change resulting in catastrophic declines in wild freshwater fish populations (FAO, 2020; WWF
549   2021). A third of the world's freshwater fishes are threatened with extinction and 80 species are
550   already extinct (WWF, 2021). To state that freshwater fishes in the developing Asian economies

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551　are being similarly, if not more severely affected, will not be an overstatement. Throughout its
552　global distribution range, 90% of which lies outside the purview of protection, Fishing Cat faces
553　the dual challenge of severe habitat and prey loss. It is here that wetlands are being subjected to
554　diversion to meet development objectives. For instance, in India, these are categorized as
555　'wastelands' (National Remote Sensing Centre, 2010; National Strategic Development Plan, 2014;
556　Hettiaracchi et al. 2015), in contravention of the Ramsar convention and by contradicting national
557　wetlands protection laws (see Wetland Rules, 2020). In Cambodia, on the other hand, regulations
558　can be weakened to develop large swathes of protected areas including mangrove forests to meet
559　economic objectives. The felid was recently downlisted to Vulnerable in 2016 from Endangered
560　in 2010 with the change in the Red List category attributed to improved data quality and not an
561　improved conservation status (Mukherjee et al., 2010; Mukherjee et al., 2016). However, current
562　trends mandate a re-assessment in the light of the species' critical condition in Java and Vietnam
563　where it remains undetected for the last two decades. In addition, we have most certainly
564　underestimated its range contraction by not accounting for the compounding effects of
565　development-induced intensive resource uses such as agriculture and aquaculture, which as
566　regimes, add to the impacts of urbanization and climate change thereby escalating global threats
567　to its habitat, i.e., freshwater ecosystems.

568　**4.5 A flagship mammal to conserve highly threatened freshwater ecosystems**

569　With research and conservation action mostly having a terrestrial and marine focus, the perspective
570　of freshwater ecosystems have been grossly under-represented, impeding fund allocation and
571　contributing indirectly to their high rates of loss (Tickner et al., 2020). Dearth of basic information
572　such as the distribution and status of many freshwater species has resulted in a lack of focussed
573　broadscale conservation plans (Abell et al., 2008). Given the need to highlight the
574　disproportionately threatened and critical status of freshwater biodiversity, Rees et al., 2020,
575　prescribed the adoption of flagship species to promote and motivate public and political
576　engagement. In this context, Fishing Cat was found to have an above average appeal among the
577　general public despite being restricted in its distribution and niche (Macdonald et al., 2017).
578　Devising range-wide strategies to conserve this hypercarnivore and top predator may benefit the
579　ecological community it represents as well as the critical habitat it inhabits, such as ephemeral
580　wetlands (like marshes, mangroves and freshwater swamps) that are situated outside the purview
581　of protection and are highly abused owing to ill-awareness and apathy. We thus propose that
582　Fishing Cat be used as a flagship species to conserve rapidly degrading low-altitude wetlands and
583　their ecological communities in the major river basins of South and South-east Asia. We emphasize
584　that such conservation has to be socio-ecologically sensitive, inclusive of multiple stakeholders
585　and function within a wise-use operating space (see Kumar et al., 2020), knowing well that the
586　dominant terrestrial strategy of 'fortress conservation' is inadequate for freshwater biota
587　conservation (Dudgeon et al., 2006).

588

589 **Data accessibility**

590

591 All distributional data needed to evaluate the results and conclusions of the paper are available at
592 www.fishingcat.org.

593

594 **Declaration of competing interests**

595

596 The authors declare that they have no conflict of interest.

597

598 **Author contributions**

599

600 Conceptualization - Tiasa Adhya, Partha Dey; Data curation - Priyamvada Bagaria; Formal
601 analysis - Priyamvada Bagaria; Funding acquisition - N/A; Investigation - Tiasa Adhya, Partha
602 Dey, Priyamvada Bagaria; Methodology - Priyamvada Bagaria; Project administration - Tiasa
603 Adhya; Resources - Jim Sanderson; Software - Priyamvada Bagaria; Supervision - Tiasa Adhya,
604 Partha Dey; Validation - Tiasa Adhya, Partha Dey, Anya Ratnayaka, Ashan Thudugala, Vanessa
605 Herranz; Visualization - Tiasa Adhya, Partha Dey, Priyamvada Bagaria; Roles/Writing - original
606 draft - Tiasa Adhya, Priyamvada Bagaria, Partha Dey; Writing - review & editing - Tiasa Adhya,
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608

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	AUC	Kappa	Threshold	Presence (Area in km^2)	Absence (Area in km^2)
EcoT$_1$	0.821	0.642	0.521	1106360	8646851
EcoT$_2$	0.834	0.668	0.551	948753.2	8804458
UrbT$_1$	0.847	0.694	0.628	781283.3	8971928
UrbT$_2$	0.827	0.654	0.535	745619.1	9007592

Table 1: AUC values of all models along with threshold

	EcoT$_1$ to EcoT$_2$	UrbT$_1$ to UrbT$_2$
Habitat gain	46014.0267	151373.806
Habitat loss	203621.1354	185824.7738
Percent gain (%)	4.159	19.375
Percent loss (%)	18.404	23.784

1

Table 2: Changes in area of suitable habitat for FC in the two scenarios and time intervals. Note: Area in km². EcoT$_1$ - Ecological scenario for T$_1$; EcoT$_2$ - Ecological scenario for T$_2$; UrbT$_1$ - Urban scenario for T$_1$; UrbT$_2$ - Urban scenario for T$_2$.

River Basins	Location	Highest Priority	High Priority	Moderate Priority	Total no of LCUs
Fishing Cat connectivity scenario					
Indus Basin	South Asia	8	5	1	**14**
GBB	South Asia	15	10	10	**35**
Mahanadi basin	South Asia	1	-	-	**1**
Godavari-Krishna delta	South Asia	-	-	1	**1**
Ayeyarwady basin	South-east Asia	-	-	1	**1**
Salween delta	South-east Asia	-	-	1	**1**
Chao Phraya river system	South-east Asia	-	-	2	**2**
Mekong Basin	South-east Asia	-	-	2	**2**
Red River Delta	South-east Asia	-	-	-	0
Least urbanized unit scenario					
Indus Basin	South Asia	9	3	1	**13**
GBB	South Asia	6	7	4	**17**
Mahanadi basin	South Asia	-	-	-	**0**
Godavari-Krishna delta	South Asia	-	-	1	**1**
Ayeyarwady basin	South-east Asia	-	-	1	**1**
Salween delta	South-east Asia	-	-	-	**0**

Chao Phraya river system	South-east Asia	-	-	2	**2**
Mekong basin	South-east Asia	3	2	1	**6**
Red River Delta	South-east Asia	1	-	1	**2**

Table 4: Different LCUs selected in river basins of South and South-east Asia
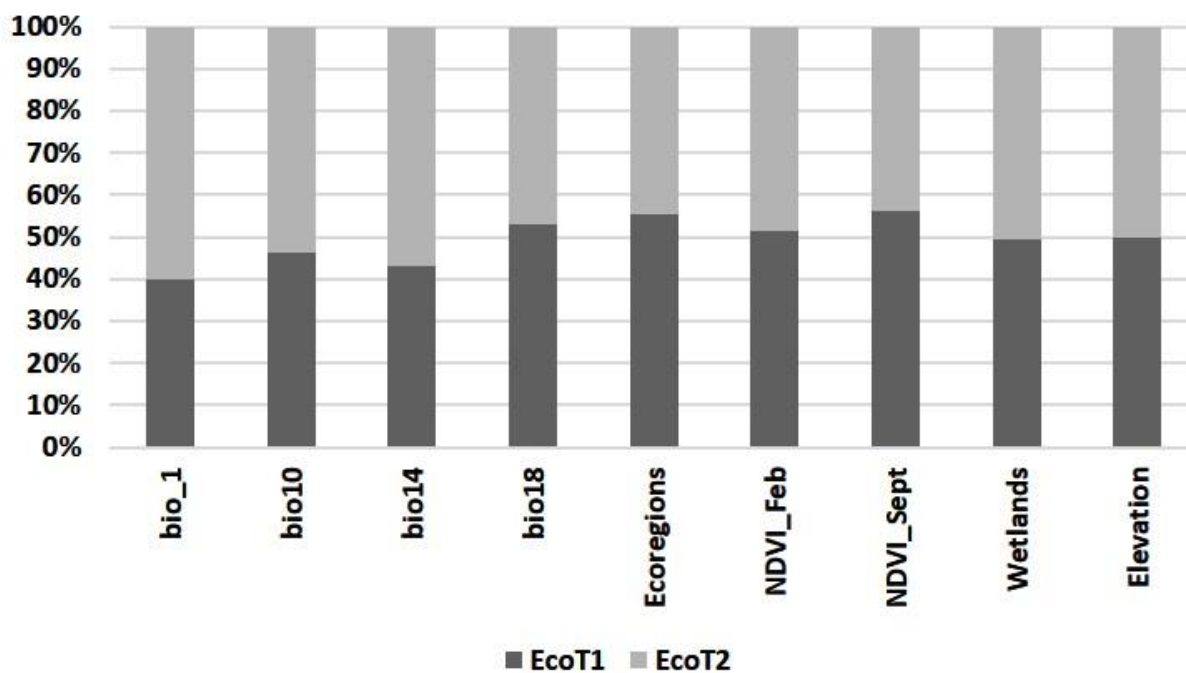
LIST OF FIGURES

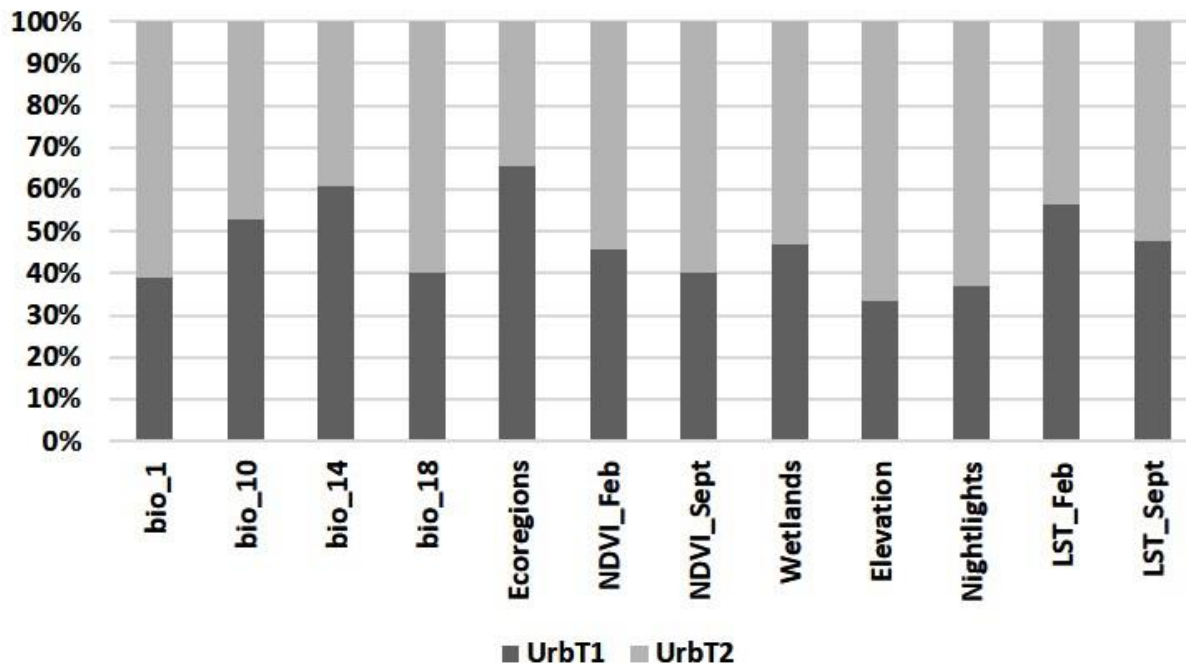**Fig 1: Variable Importance Scores for the ecological scenario**

Fig 2: Variable Importance Scores for the urban scenario

Bio 1 = Annual Mean Temperature

Bio 14 = Precipitation of Driest Month

Bio 18 = Precipitation of Warmest Quarter

Bio 10 = Mean Temperature of Warmest Quarter

CIFOR = global wetland maps

LST_Feb = Land Surface Temperature in February

LST_Sept = Land Surface Temperature in September

NDVI_Feb = Normalized Difference Vegetation Index for February

NDVI_Sept = Normalized Difference Vegetation Index for September

SRTM = global elevation data

4
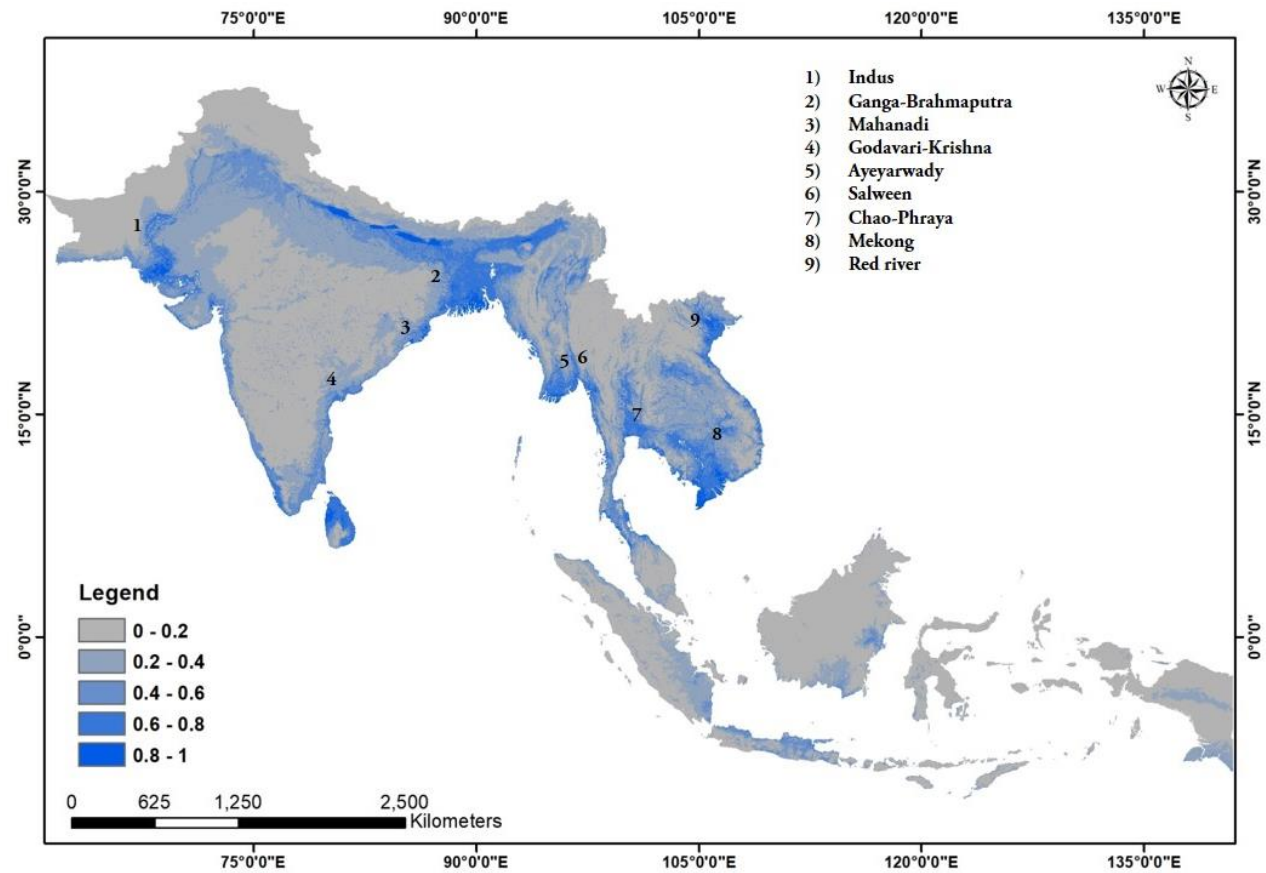
Fig 3: Predicted global distribution of Fishing Cat along river basins of South and Sout-east Asia with probabilities of occurrence
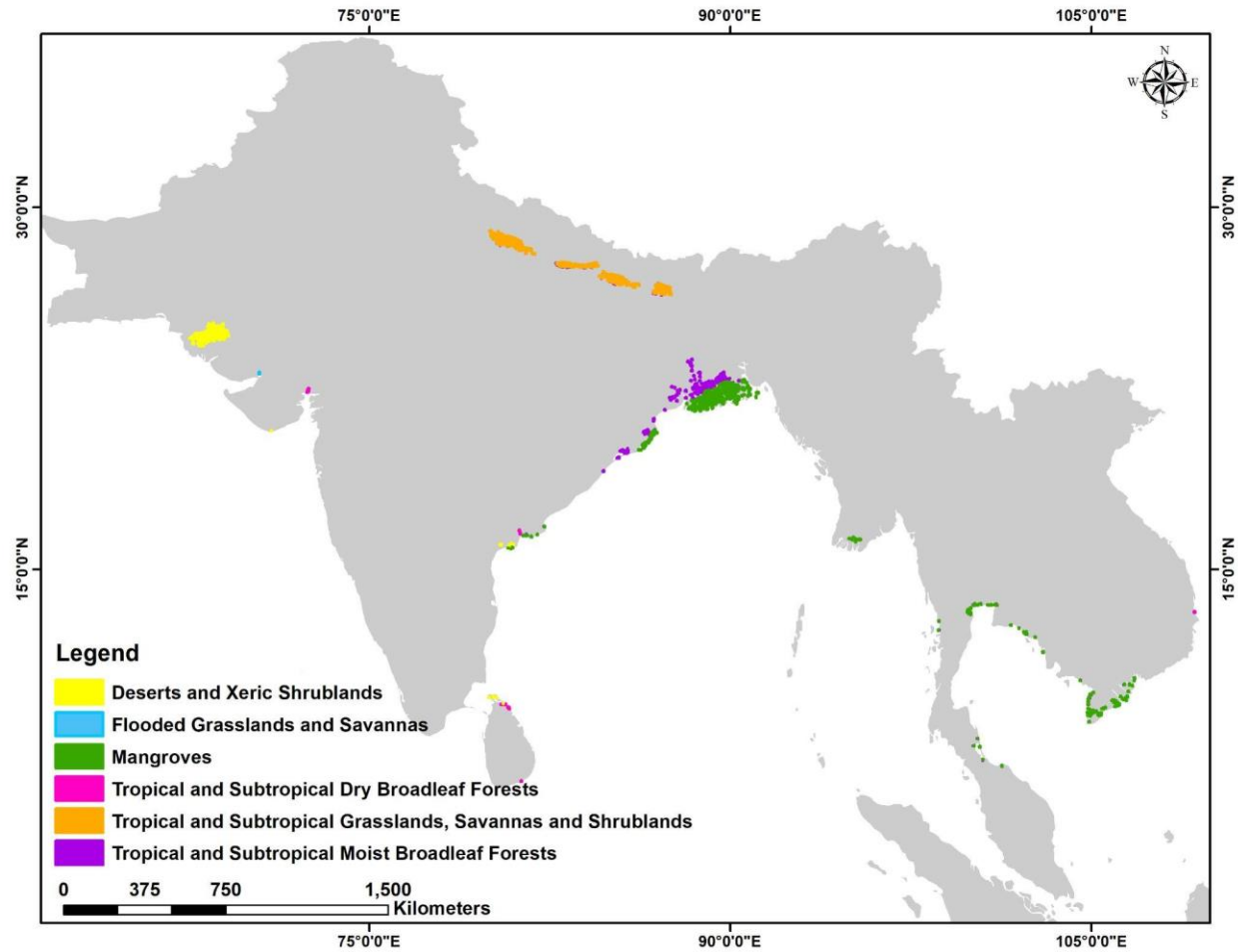
Fig 4: Ecoregions with Fishing Cat predicted to have more than 80% probability of occurrence. Note: Symbology inflated for better visualization.
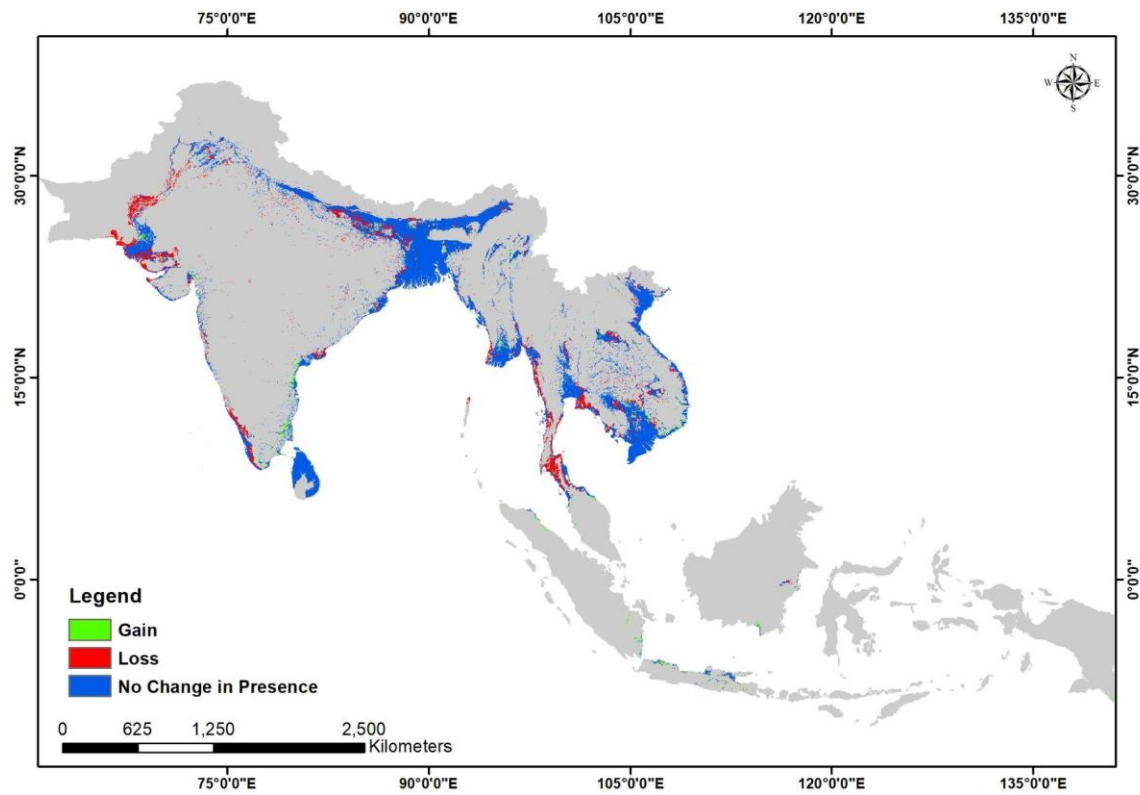
Fig 5: Change in the predicted distribution of Fishing Cat from 2010 to 2020, in an ecological change only scenario.
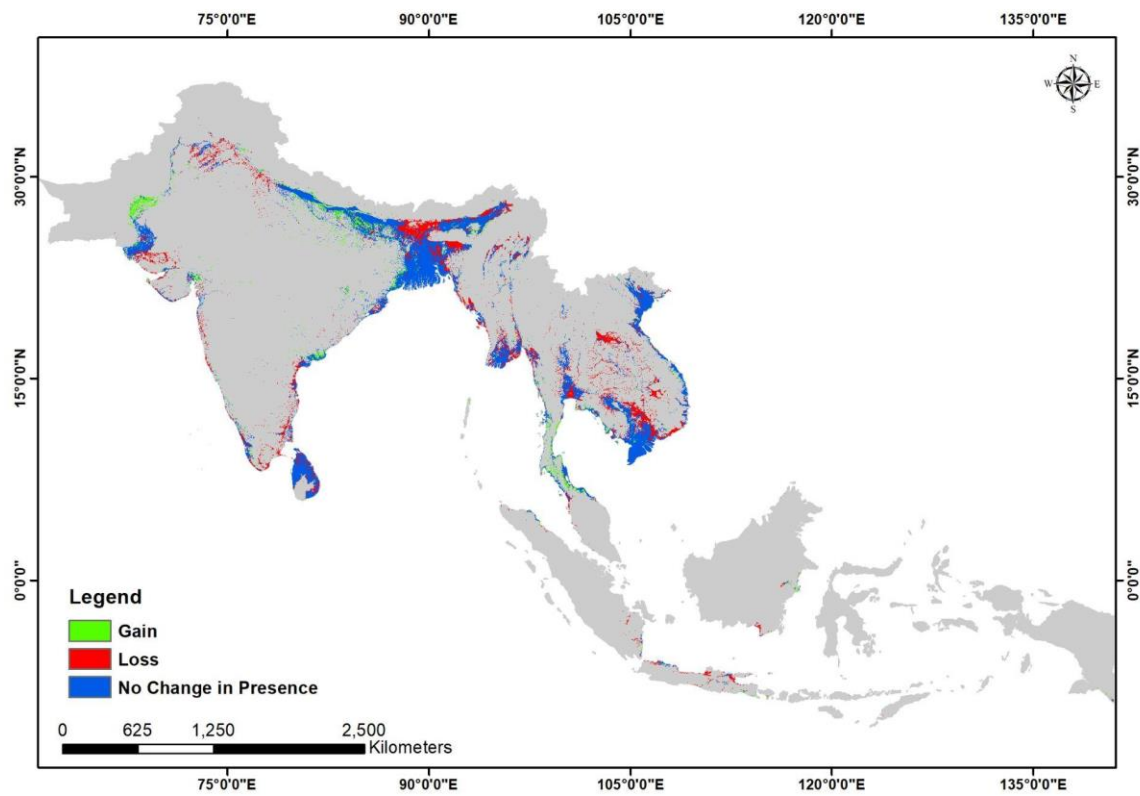
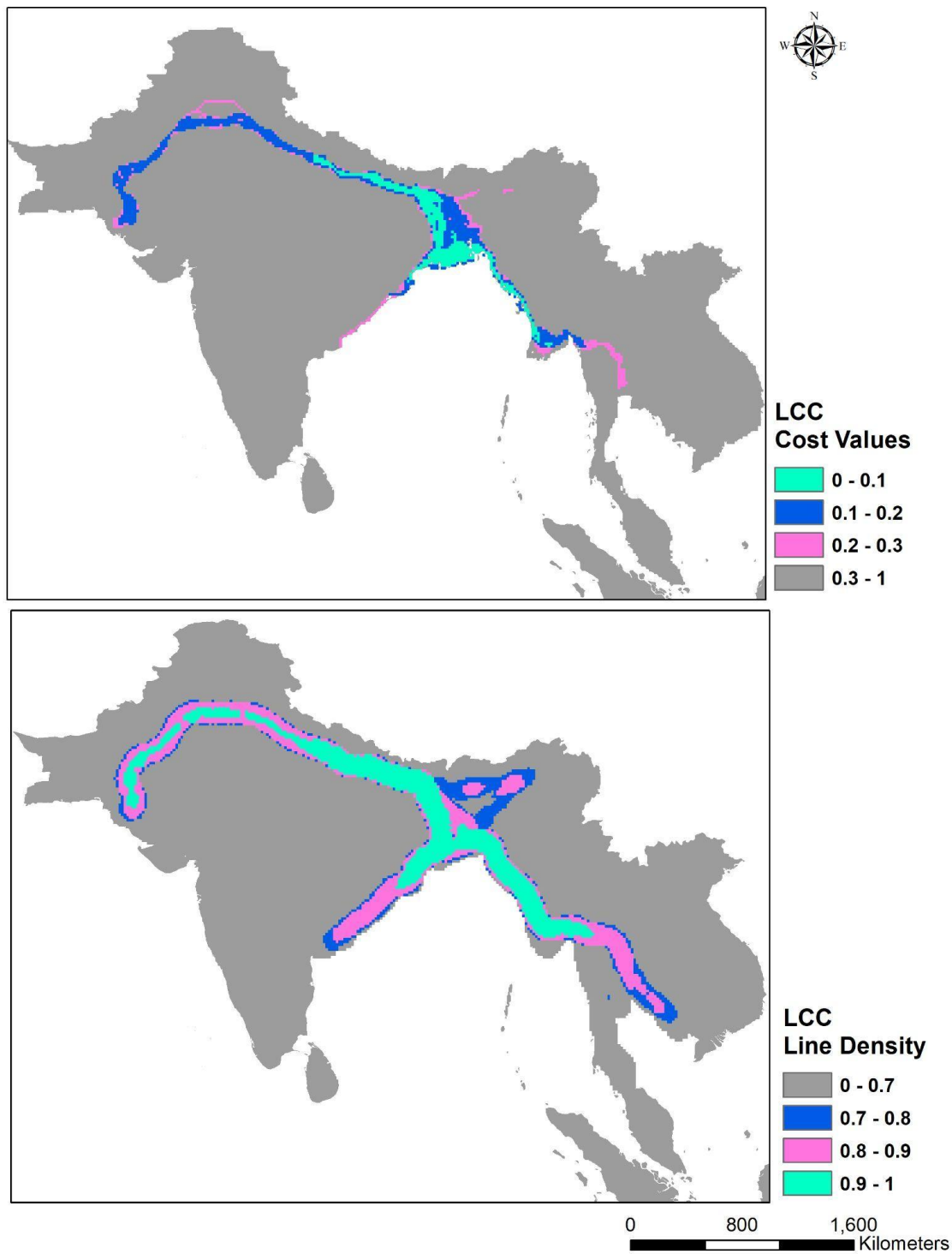**Fig 6: Change in predicted global distribution of Fishing Cat due to urbanisation between T1 and T2**

Fig 7: Least Cost Corridors (LCCs) and Line Densities of LCCs for global Fishing Cat connectivity. Note: Higher cost values in LCC denote higher friction in movement, while higher line density values denote most traveled LCCs.
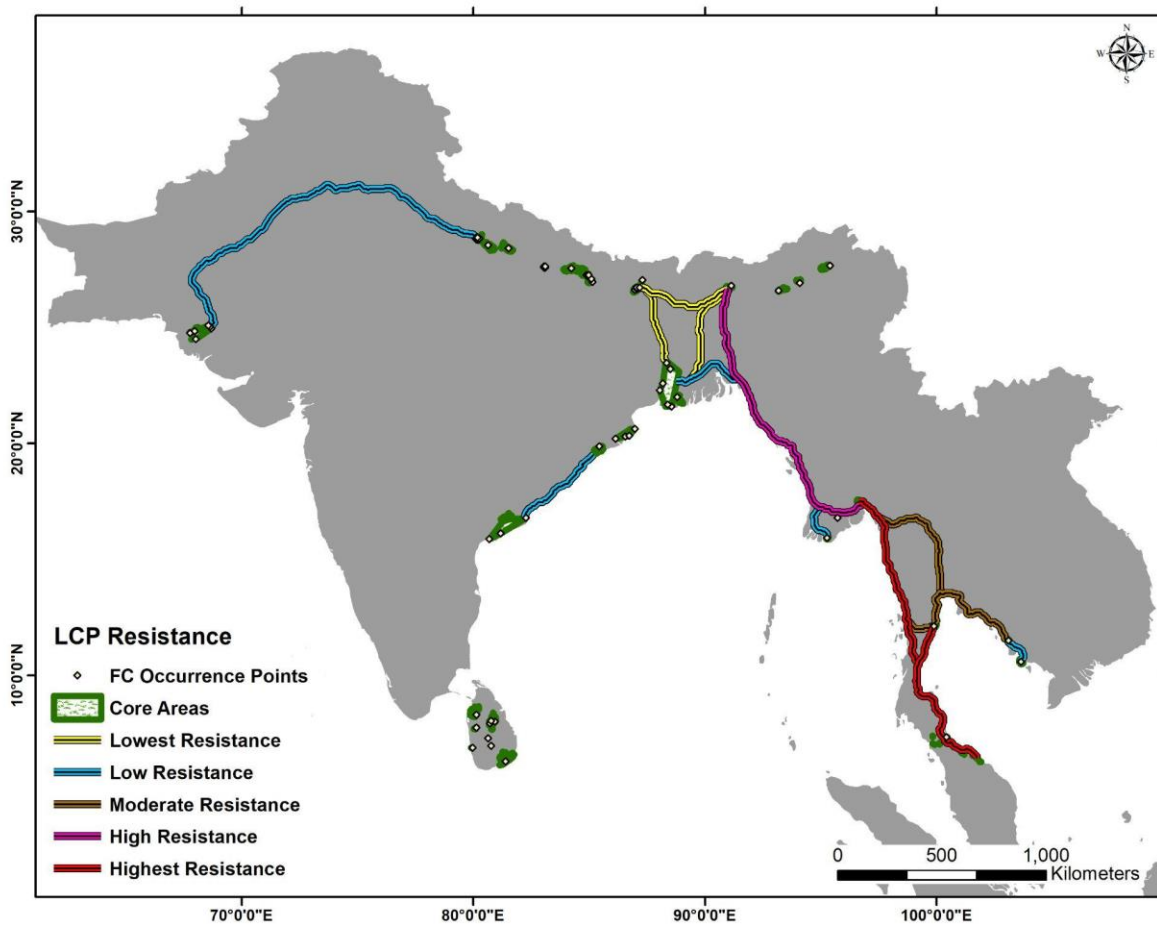

Fig 8: Least Cost Path (LCP) with varying levels of resistance to global Fishing Cat connectivity.
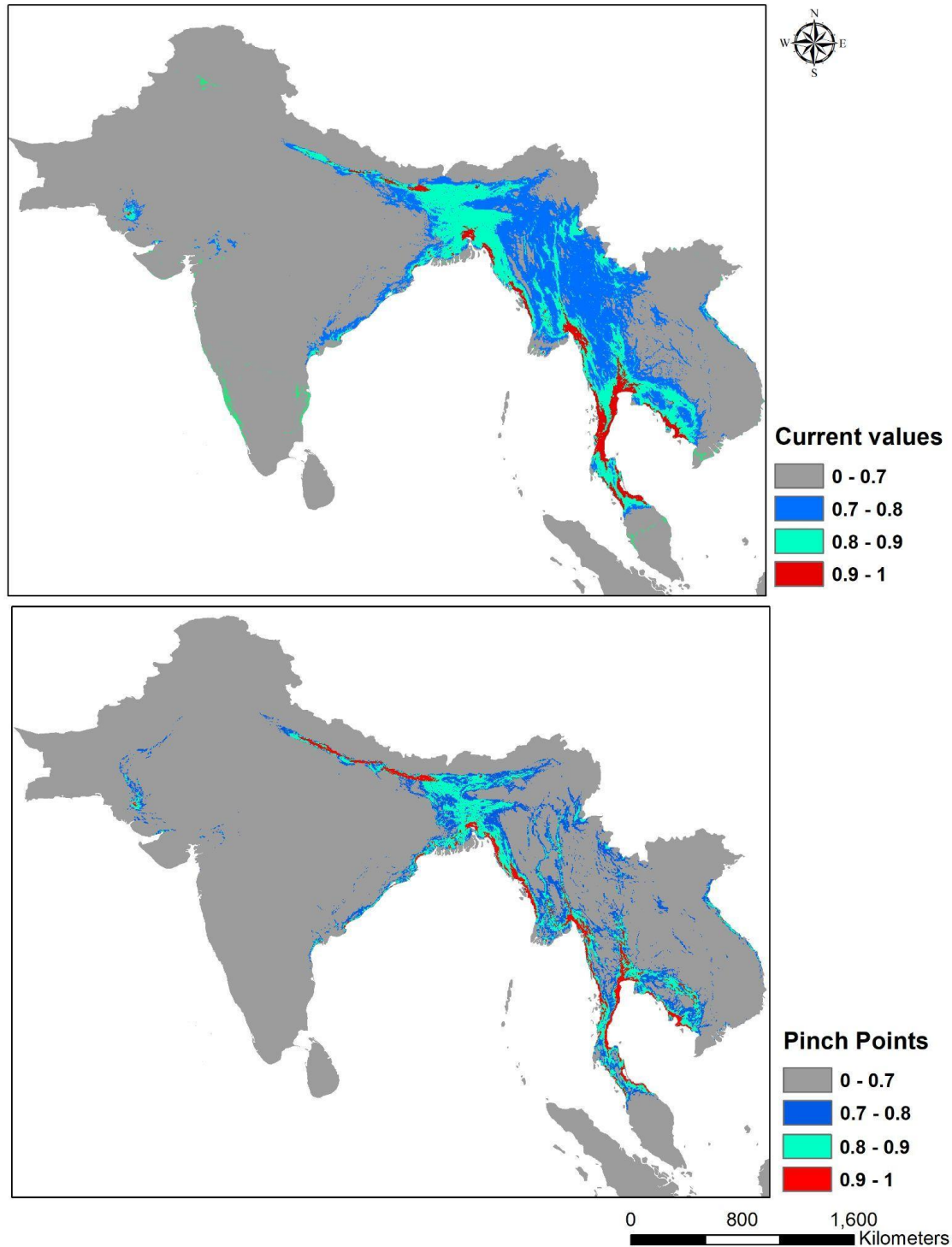
10

Fig 9: Circuitscape generated corridor showing higher current flow intensity in most suitable movement corridors (above). Corridors with a minimum width (4.6 km) and a high density of corridor path depict the pinch-points, i.e, bottlenecks in the corridor (below).
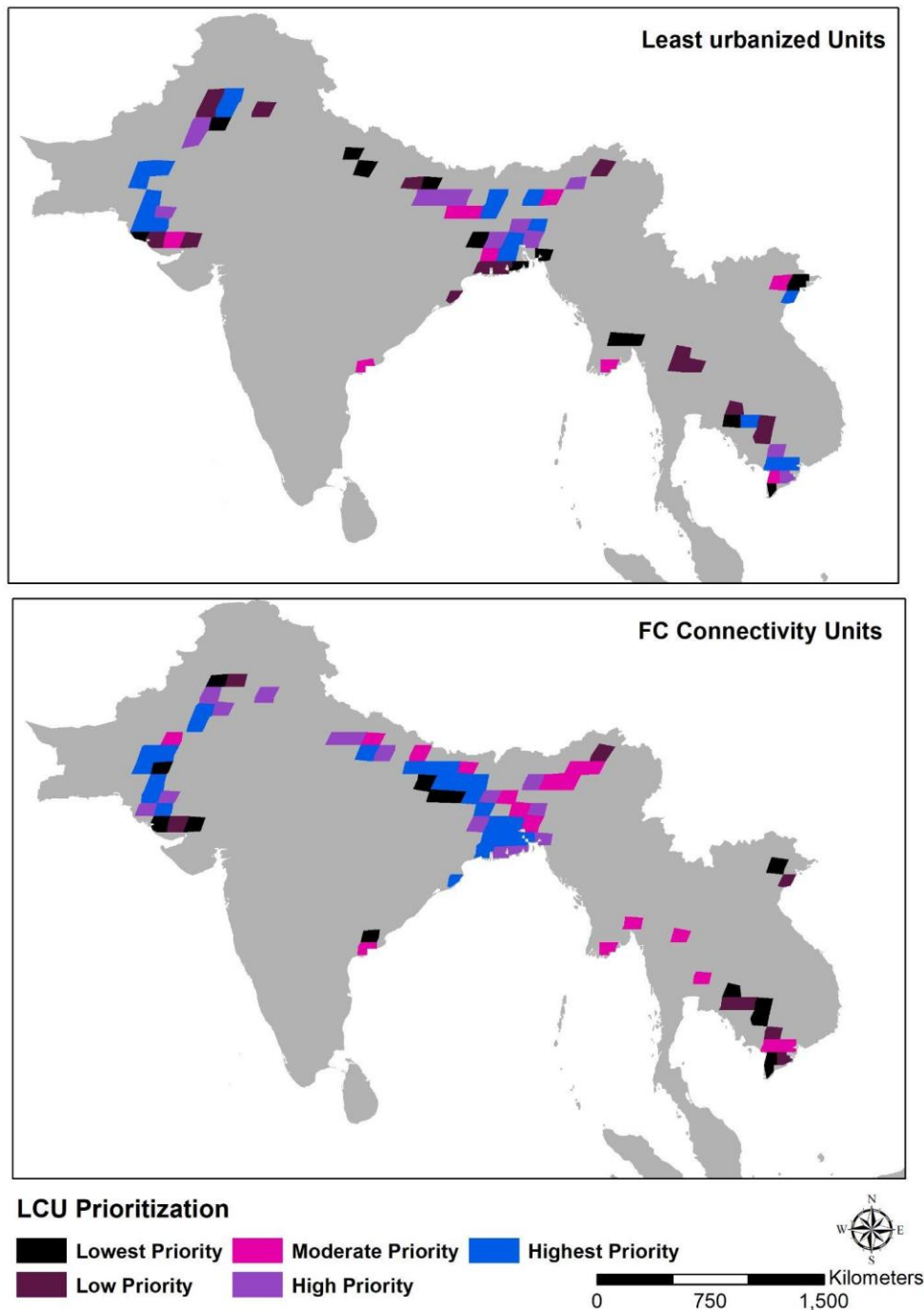
Fig 10: Landscape Conservation Units according to the least urbanized scenario (above) and most suitable habitat units that facilitate connectivity (below).

Appendix Data Sources

Habitat Variables	Spatial Resolution	Citation
Variables used in the Ecological Scenario		
Worldclim v.2.0 bioclimatic layers (n=19)	2.5 minute (~4.6 km)	Fick, S.E. and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302-4315.
Monthly mean of Normalised Difference Vegetation Index (NDVI) layers extracted from the 16-Day L3 Global 1 km – MOD13A2v006. Two NDVI layers from the same month were used for calculating the monthly means (n=12).	1 km raster layers resampled to 2.5 minute (~4.6 km)	Didan, K. (2015). MOD13A2 MODIS/Terra Vegetation Indices 16-Day L3 Global 1km SIN Grid V006 [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2020-02-20 from https://doi.org/10.5067/MODIS/MOD13A2.006
Elevation derived from SRTM GL3v003	90 m resampled to 2.5 minute (~4.6 km)	NASA JPL (2013). NASA Shuttle Radar Topography Mission Global 3 arc second [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2020-07-15 from https://doi.org/10.5067/MEaSUREs/SRTM/SRTMGL3.003
Terrestrial ecoregions of the World, The Nature Conservancy classification	Vector data, rasterised at 2.5 minute spatial resolution	Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., Kassem, K. R. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938.
Terrestrial ecoregions of the World, Worldwide Fund for Nature classification	Vector data, rasterised at 2.5 minute spatial resolution	Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., Kassem, K. R. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938.

Global Wetlands v3	236 m resampled to 2.5 minute (~4.6 km)	Gumbricht, T.; Román-Cuesta, R.M.; Verchot, L.V.; Herold, M.; Wittmann, F; Householder, E.; Herold, N.; Murdiyarso, D., 2017, "Tropical and Subtropical Wetlands Distribution version 2", https://doi.org/10.17528/CIFOR/DATA.00058, Center for International Forestry Research (CIFOR), V3, UNF:6:Bc9aFtBpam27aFOCMgW71Q== [fileUNF]
Digital Soil Map of the World	Vector data, rasterised at 2.5 minute spatial resolution	Land and Water Development Division, FAO, Rome
Euclidean Distance from water layer developed using – using the World Water Bodies data released by ESRI Data & Maps	Raster layer created in ArcGIS with 2.5 minute spatial resolution	ESRI Data & Maps, 2015
Additional variables for the Urban Impact Scenario		
Monthly Land Surface Temperature and Emissivity (LST&E) extracted from MOD11C3 Version 6 (n=12)	0.05 degree (~5.6 km) resampled to 2.5 minute (~4.6 km)	Wan, Z., Hook, S., Hulley, G. (2015). MOD11C3 MODIS/Terra Land Surface Temperature/Emissivity Monthly L3 Global 0.05Deg CMG V006 [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2020-07-16 from https://doi.org/10.5067/MODIS/MOD11C3.006
VIIRS Day/Night Band Nighttime Lights Version 1 Tiles with the ranges 00N60E and 75N0E for all the months of 2013 (T1) and 2019 (T2) were downloaded, resampled, rescaled and an annual mean was calculated.	15 second (~450 m) resampled to 2.5 minute (~4.6 km)	C. D. Elvidge, K. Baugh, M. Zhizhin, F. C. Hsu, and T. Ghosh, "VIIRS night-time lights," International Journal of Remote Sensing, vol. 38, pp. 5860–5879, 2017.

Supplementary Information

River basins	Countries	Wetland complexes	Provinces/ States/ Districts
Indus basin A. Lower Indus Basin B. Middle Indus Basin	A i) Pakistan B i) Pakistan	i) Wetland complexes (Haleji lake, Keenjhar lake, Chotiari reserve, Nara canal area, Qualandri creek in the Indus delta, Keti Bundar mangroves, the Karachi harbour area, Jubho lagoon and Nurri lagoon) ii) Areas around the Hub dam adjacent to Sindh province and Miani Hor mangroves i) Waterlogged and swampy areas formed by seepage from unlined canals	i) Sindh Province ii) Balochistan Province i) Punjab Province
Ganges Brahmaputra Basin (GBB) A. Wetlands of the Terai region	A i) India ii) Nepal	i) swamps, marshes and seasonally inundated grasslands in National Parks (Jim Corbett, Dudhwa, Katarniaghat, Kishanpur and Valmiki Tiger Reserve) ii) mudflats, reeds beds, freshwater marshes of Koshi Tappu Wildlife Reserve, Jagdishpur Ramsar site, Chitwan National Park, Parsa	i) State of Uttar Pradesh ii) Districts of Sunsari, Saptari, Udayapur, Kapilvastu, Kailali

B. Wetlands of Gangetic Plains		National Park, Ghodaghodi Tal Ramsar site	
	B i) India	i) shallow wetlands, riverine wetlands and floodplains of Yamuna and Ganga including Okhla Bird Sanctuary, Baghel Tal, Bakhira Lake, Surha Tal, Dahar Lake, Soor Sarovar Bird Sanctuary, Samaspur Lake ; Ramsar site with wetland stretch between Brijghat and Narora; shallow wetlands in Bihar like Kanwar Jheel, Kusheshwarsthan, Bariella, Vikramshila Dolphin Sanctuary, Moti Jheel and various wetland complexes in several districts of West Bengal.	i) States of Delhi, Agra, Uttar Pradesh, Bihar, West Bengal (including districts of Nadia, Murshidabad, Bardhaman, Howrah, Hooghly, East and West Midnapore)
C. Wetlands within the valley of Brahmaputra, its tributaries and distributar-ies	C i) India		i) State of Assam and West Bengal
D. Wetlands of Gangetic Delta	ii) Bangladesh	i) tall grassland wetland habitat, oxbow lakes and riverine wetlands including Deepor Beel Ramsar Site, Majauli island, Dhir-Dilpai-Dakra complex, Tamranga-Dalani complex, Urpod Beel, Chandubi Lake, Orang, Laokhowa, Kaziranga National Park, Jaldapara Wildlife Sanctuary and Gajoldoba wetland	ii) Districts of Sylhet, Mymensingh, Sunamganj, Moulvibazar
	D i) India	ii) seasonally flooded marshy wetlands and swamp forests of Haor basin of Sylhet and eastern Mymensingha, Tanguar Haor Ramsar Site, Hakaluki Haor	i) State of West Bengal
		i) seasonally flooded wetlands, depressed lands,	

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	ii) Bangladesh	river creeks, mangrove swamps and marshes including the East Kolkata Wetlands Ramsar Site; Sunderbans delta ii) deltaic wetlands including Marijat Haor, Atadanga Haor, Chanda-Bahgia Beel, Sowagram-Gopalpur Beel, Dakatia Beel, Naldanga Beel, Tarail Beel; Sunderbans delta	ii) Districts spanning most of Bangladesh, except for its hilly tracts
Mahanadi basin	i) India	i) depressions, floodplain wetlands and ephemeral wetlands including marshes and mangroves connected to Mahanadi, Brahmani and Baitarani rivers; Debi mouth; Bhitarkanika Ramsar site; Chilika lagoon	i) Districts of Kendrapada, Puri, Khordha; Ganjam
Godavari-Krishna delta	i) India	i) mangrove swamps, inland and coastal wetlands	i) Districts of Guntur, Krishna, East Godavari, West Godavari, Visakhapatnam, Vizianagaram, Srikakulum
A. Ayeyarwady basin B. Salween delta	i) Myanmar i) Myanmar	i) coastal mangroves and freshwater swamp forests i) floodplain wetlands and mangrove forests	i) States of Ayeyarwady, Bago, Rakhine, Yangon, Kachin, Sagaing i) States of Kayin and Mon
Chao Phraya river system	i) Thailand	i) riverine wetlands along the Mun, Chi and Songkhram like the Kut Ting Marshland, a Ramsar site; inland and coastal wetlands including Non Thung Thong wetland drained by Tapi river; Bung Khong Long Ramsar Site; Thale sap	i) Provinces of Nongkhai province, Nakohn si Thammarat, Pattani, Narathiwat, Surat Thani, Patthalung, Songkhla, Phang

		estuary, Laem Kham marshes; Nong Plak Phraya wetlands, Krabi estuary	Nga, Phuket, Trang, Satun
Lower Mekong Basin	i) Cambodia	i) flooded forests, swamps, marshes and grasslands including Stung Treng Ramsar site, Tonle Sap Ramsar Site, Boeing Chhmar Ramsar Site, Bassac marshes Ramsar Site	i) Provinces of Stung Treng, Battambang, Kampong Thom, Kandal
	ii) Vietnam	ii) Tram Chim National Park or Plain of Reeds Ramsar Site, Lang Sen Wetland Reserve, U Minh wetland complex	ii) Provinces of Dong Thap, Long An, Kien Giang, Ca Mau
Red River Delta	i) Vietnam	i) mangroves and intertidal habitats of Red River Delta Biosphere Reserve	i) Districts of Xuan Thuy and Tien Hai

S1: Mainland river basins along with transboundary freshwater units, wetland complexes and jurisdictional boundaries with predicted occurrence of Fishing Cat

Key Areas	Topographic zones (Coastal: 0-100m / Intermediate Plains: 100-500m / Central Highlands: >500m)	Wetland complexes	Provinces / States / Districts
Salt water wetlands (Estuaries)	Coastal plains	Estuaries around Sri Lanka including Kala Oya Estuary	Western Provinces
Salt water wetlands (Lagoons)	Coastal plains	Lagoons are found around the coast of Sri Lanka including the Chundikulam and Negamboo Lagoons	Northern and North-western Provinces
Salt water wetlands (Mangroves)	Coastal plains	Kala Oya Estuary, southern boundary of the Wilpattu National Park, mangroves associated with Negombo and Chilaw Lagoons	Northern, North-western, Western Provinces

Inland freshwater wetlands (Rivers, streams)	Coastal plains and intermediate plains	Rivers and streams associated habitats	Eastern Province
Inland freshwater wetlands (Swamp forest and villus)	Intermediate plains	Flood Plains National Park, Somawathiya	North- central and Western Provinces
Man-made wetlands (Tanks, reservoirs, and rice paddy fields)	Intermediate Plains	Man-made tanks and paddy fields simulating Fishing Cat habitat	North-central and Western, Provinces
Protected landscapes (national parks, sanctuaries, and protected areas through government sectors)	Coastal plains and Intermediate plains	Protected areas by Department of Wildlife Conservation, Forest Department,or other government bodies like Municipal Councils)	Wilpattu National Park,

S2: Key areas in Sri Lanka in wetland complexes with jurisdictional boundaries with predicted occurrence of Fishing Cat