Small-clawed otters (*Aonyx cinereus*) in Indonesian rice fields: latrine site characteristics and visitation frequency

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2 site characteristics and visitation frequency

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15 **Abstract**

16 Latrine sites, or areas where otters scent-mark and deposit feces, are a habitat feature
17 that serve an important role in communication for many otter species. The small-clawed
18 otter (*Aonyx cinereus*) inhabits both natural and rice field landscapes in Southeast Asia.
19 However, latrine site use by small-clawed otters in rice field landscapes is largely
20 unknown. Based on a 53-week field survey and landscape analyses, we investigated
21 latrine site use by small-clawed otters in rice field landscapes in West Sumatra,
22 Indonesia. Using land use and/or local environmental variables as predictors, we
23 performed generalized linear model analyses to explain the spatial patterns of latrine site
24 occurrence and otter visitation frequency to latrine sites. We determined that small-
25 clawed otters use some latrine sites repeatedly over time; 10 latrine sites were still in
26 use more than 7 years after their initial discovery. Generalized linear model analyses
27 revealed that an intermediate number of rice field huts was the single most important
28 predictor of latrine site occurrence, whereas distance to the nearest settlement, distance
29 to the river, and mean water depth of the rice field adjacent to the latrine site were
30 important predictors of otter visitation frequency to latrine sites. These results indicate
31 that the latrine site preferences of small-clawed otters in rice field landscapes are
32 strongly associated with intermediate levels of rice farming activities. Indonesian rice
33 fields are being degraded or disappearing at an accelerated rate because of land
34 conversion and modernization of agriculture. We emphasize an urgent need for design
35 and implementation of otter-friendly rice farming to conserve small-clawed otters.

36

37 Keywords: scent marking, otter spraint, habitat preference, Satoyama, rice paddy field

38 **Introduction**

39 Many mammals use scent marking for communication (reviewed in Ralls 1971;
40 Johnson 1973), and areas where mammals scent mark with feces are called latrine sites.
41 Latrine communication is common among many mustelid species such as polecats,
42 minks, martens, badgers, and otters (reviewed in Hutchings and White 2000).

43 Despite their semi-aquatic nature, otters use latrine sites on dry land (Kruuk
44 1992). Otter latrine sites serve multiple functions, including territorial marking, sexual
45 attraction, and communication among conspecific individuals or small groups
46 (Hutchings and White 2000). Otters also use latrines for activities other than scent
47 marking; for example, the latrine sites of North American river otters (*Lontra*
48 *canadensis*) are used to delineate territories and serve as meeting places or social
49 information hubs among small groups (e.g., Melquist et al. 2003; Green et al. 2015;
50 Barocas et al. 2016). Therefore, latrine site surveys have become a standard method for
51 assessing occurrence, identifying habitat preference, and/or constructing species
52 distribution models of otters (Swimley et al. 1998; Reuther et al. 2000; Stevens et al.
53 2011).

54 Unlike other mustelid carnivores, which frequently visit and defend territorial
55 boundaries, otters intensively use and defecate in core areas that are important for
56 foraging, grooming, and constructing holts (dens) (Kruuk 1992; Hutchings and White
57 2000). Therefore, frequently used latrine sites provide a relative measure of the intensity
58 of use of different latrine sites and their associated habitat characteristics (Hutchings
59 and White 2000). For this reason, researchers have studied otter visitation at latrine sites
60 to assess habitat quality (Prenda and Granado-Lorencio 1996) and fish prey availability

61 (Crait et al. 2015), and to determine the locations of latrine sites relative to the home
62 range of otters (Barocas et al. 2016).

63 The small-clawed otter (*Aonyx cinereus*) is distributed in South and Southeast
64 Asia, and has been designated a vulnerable species by the International Union for
65 Conservation of Nature (IUCN) (Wright et al. 2015). Although small-clawed otters are
66 common in zoos, their basic ecology is largely unknown in the wild (Wright 2003).
67 Small-clawed otters are carnivores that primarily prey on aquatic animals, such as crabs,
68 fish, frogs, arthropods, mammals, and snails (Kruuk et al. 1994; Aadrean et al. 2010;
69 Hon et al. 2010). Small-clawed otters use a variety of natural and human-altered
70 habitats, including rivers, streams, peat swamps, mangrove forests, rice fields, ditches,
71 and fish ponds (Hussain et al. 2011).

72 In a protected wetland area in India, small-clawed otters prefer shallow, narrow
73 streams and high-elevation areas rather than deep, large rivers and low-elevation areas
74 (Perinchery et al. 2011; Raha and Hussain 2016). When small-clawed otters use human-
75 altered landscapes, such as coffee and tea plantations adjacent to protected areas, latrine
76 site occurrence is associated with riparian vegetation and the availability of potential
77 refuges (e.g., boulders and fallen logs) (Prakash et al. 2012). Although environmental
78 characteristics of the small-clawed otter latrine sites have been reported for human-
79 altered landscapes (e.g., Prakash et al. 2012), such characteristics have yet to be
80 investigated based on visitation frequency.

81 In rice field landscapes of some Southeast Asian countries, such as Malaysia,
82 Thailand, the Philippines, and Indonesia, small-clawed otters use rice fields as foraging
83 and latrine sites (Foster-Turley 1992; Aadrean et al. 2010; Gonzales 2010;
84 Kanchanasaka and Duplaix 2011). A previous study in the Malay Peninsula

demonstrated that the latrine sites of small-clawed otters occurred in rice fields adjacent to a mangrove mudflat (Foster-Turley 1992). In addition, a preliminary descriptive study in Indonesian rice fields reported that the latrine sites of small-clawed otters were located near rice field huts or trees (Aadrean et al. 2010). However, these previous reports were primarily descriptive studies that only highlighted the potential importance of specific landscape components to latrine site occurrence. Furthermore, these studies did not assess the relative importance of such landscape features relative to other environmental factors. Even though small-clawed otters are a common inhabitant of Satoyama landscapes (a landscape mosaic of secondary forests, grassland, rice fields, cropland, and streams surrounding villages) in Southeast Asia, little information exists concerning their latrine site characteristics in such landscapes.

In this study, we sought to determine which land use factors are important for explaining the occurrence of latrine sites of small-clawed otters in Indonesian rice fields. Because the frequency of visitation to latrine sites may differ depending on local environmental conditions, such as prey availability (Crait et al. 2015), we subsequently investigated which land use and local environmental factors best explain the visitation frequency of small-clawed otters to latrine sites. This study is the first to document the visitation frequency of small-clawed otters to latrine sites. Rice fields differ from natural wetlands in that landscape components and local physicochemical environments are influenced by farming activities. We hypothesized that the occurrence and visitation frequency of latrine sites are related to land use and local environmental factors specific to rice field landscapes. Based on the results, we discuss the importance of developing otter-friendly farming in the face of agricultural modernization and land use changes, which in turn lead to loss of potential otter habitats.

109

110 **Methods**111 *Study area*

112 The study site was located in rice field landscapes along the Batang Anai River
113 drainage in the Padang Pariaman Regency, West Sumatra, Indonesia (longitude
114 0°38'00"S–0°40'40"S, latitude 100°17'10"E–100°20'20"E, altitude 25–50 m; Fig. 1;
115 Fig. S1). Climate data from BPS-Statistics Indonesia (2010–2013) indicated that the
116 Padang Pariaman Regency has an average temperature of 25.4°C (range 22.7–27.3°C),
117 average humidity of 87.0% (range 82.3–91.2%), and average monthly rainfall of 372.3
118 mm (range 138.0–853.2 mm), all of which are characteristic of the tropical climate in
119 this region. The substrate of the Batang Anai River adjacent to the study site is
120 dominated by gravel, whereas that of downstream areas is dominated by sand. Gravel
121 and sand mining is regularly conducted along the Batang Anai River by local people.
122 High precipitation and steep slopes, which are typical characteristics of West Sumatra,
123 contribute to high water level fluctuations of the river.

124 The rice fields included in this study are irrigated by the Anai Dam, which
125 irrigates 13,640 ha of farmland along the river drainage. Prior to construction of the
126 Anai Dam, farmland in this area was irrigated by the Batang Anai River and rainwater
127 via earthen canals and ditches. After the dam and concrete canals were constructed in
128 1996, both the area of farmland and cropping intensity increased in the entire drainage
129 area. In this study, we only used data from an upper area of the irrigated farmland (Fig.
130 S2), because this area has been surveyed since 2008 (Aadrean et al. 2010). In recent
131 years, many rice fields in the lower areas have been drained and converted to dry
132 farmland (i.e., corn fields and palm oil plantations) or human settlements. Potential otter

133 habitats have presumably been eliminated because such land use changes are associated
134 with the draining of wetland habitats.

135 In the Batang Anai River drainage, rice fields are planted 2–3 times a year.
136 Farmers can start a new planting cycle any time of year at their discretion.
137 Consequently, different planting phases can be found across the entire landscape
138 throughout the year. Owners of rice fields are smallholder farmers. Most farmers use
139 chemical pesticides and fertilizers, although a few use a mixture of organic and
140 chemical fertilizers. For plowing, farmers use fuel-operated hand tractors. Planting,
141 harvesting, pesticide and fertilizer application, and other farming activities are
142 conducted manually.

143 Among the four otter species (*Lutra lutra*, *L. sumatrana*, *Lutrogale perspicillata*,
144 and *Aonyx cinereus*) that occur in Sumatra, only small-clawed otters inhabit the study
145 area (Aadrean et al. 2010). Potential food items of small-clawed otters in the rice fields
146 include fish (e.g., *Anabas testudineus*, *Puntius binotatus*, *Clarias batrachus*), mollusks
147 (e.g., *Melanoides tuberculata*, *Tryonia clathrata*, *Pomacea canaliculata*), and frogs
148 (e.g., *Fejervarya cancrivora*, *F. limnocharis*). Although small-clawed otters reportedly
149 feed heavily on *Potamon* and other unidentified crabs (Kruuk et al. 1994; Hon et al.
150 2010), crabs are absent from earthen ditches and rice fields in the study area. In the
151 Batang Anai River drainage, non-indigenous golden apple snails (*Pomacea*
152 *canaliculata*) provide an important food source for small-clawed otters (Aadrean et al.
153 2011).

154

155 *Field surveys*

156 The occurrence of latrine sites of small-clawed otters was first studied in 2008
157 and 2010 by walking along ditches and levees adjacent to rice fields (Aadrean et al.
158 2010). Otter footprints left in the mud of the rice fields also provided guidance to the
159 latrine sites. Owing to the conspicuous smell of spraints (otter scat) and damage to the
160 vegetation of levees or occasionally the rice plants adjacent to latrine sites, local farmers
161 are often aware of latrine site locations; thus, information regarding latrine site locations
162 was also provided by farmers encountered during the field surveys.

163 The first preliminary survey was performed over a 17-day period between July
164 and December 2008. In 2010, a second preliminary survey was performed over a 19-day
165 period between April and September. These preliminary surveys were only conducted
166 along main levees throughout a wide geographical area in the upper Batang Anai River
167 drainage. In 2015, a thorough, systematic survey was performed over a 32-day period
168 from February–April and August–September throughout the rice fields within a subset
169 of the preliminary survey areas (Fig. 1). In the 2015 survey, we surveyed every
170 individual rice field in the study area along one side of the levee at least once. Because
171 rice fields are arranged in blocks, this procedure allowed us to check, on average, two or
172 more sides (levees) of each rice field. We were also careful to re-survey the old latrine
173 sites. Some of the old latrine sites had been converted to shrubland or roads; thus, we
174 were only able to re-survey 16 of the 19 old latrine sites in 2015.

175 During the latrine site survey in 2015, we ground-checked land use
176 classifications with the aid of printed satellite images (see subsection “Land use
177 analysis”). We also used the satellite images to confirm that every individual rice field
178 was surveyed at least once. In addition, we recorded the locations of rice field huts

179 (called “dangau” in the Minangkabau and Bahasa languages) during the field survey
180 because a preliminary study identified several latrine sites adjacent to a rice field hut
181 (Aadrean et al. 2010).

182 To record the visitation frequency to latrine sites by small-clawed otters, we
183 monitored latrine sites weekly over the 53 weeks from April 12, 2015 to April 10, 2016.
184 Of 29 latrine sites, we removed four newly discovered latrine sites from the visitation
185 frequency analysis, as these four latrines were discovered after August 2015, and
186 therefore could not be monitored all 53 times; these four latrine sites were only used in
187 the occurrence analysis. At each visit, two trained field crews recorded the presence of
188 new spraints. We considered spraints that were located at a certain site in a given week
189 to be one otter visit regardless of the size and number of spraints. To verify that the
190 spraints were new, we collected and removed old spraints when each latrine site was
191 surveyed. The spraints of small-clawed otters are slimy and sticky, and otters smear
192 their spraints when they defecate (Aadrean et al. 2010). When removing spraints, we
193 attempted to avoid removing substrate to retain spraint slime, thereby minimizing
194 artificial disturbances to latrine site use by small-clawed otters.

195 In the rice field adjacent to each latrine site, we also recorded the mean water
196 depth and golden apple snail biomass as measures of local environmental conditions.
197 All latrine sites were located within 2 m of the nearest rice field. Water depth (cm) was
198 measured from the levee using a ruler at one location along the first row of rice plants
199 near the latrine site. If the bottom of the rice field was uneven, we measured water depth
200 at several points along the levee, and the average value was used to represent water
201 depth. Golden apple snails were collected by first placing a 2-m long rope along the
202 levee and then placing two 20-cm sticks perpendicular to the levee to delineate a

quadrat (20×200 cm). Wet weights of golden apple snails were determined using a digital scale to the nearest 0.1 g. Local environments of the rice fields fluctuate along with planting cycles. To infer average annual environmental conditions, water depth and snail weight from the rice field adjacent to each latrine site were each averaged over the 53-week period.

Land use analysis

Before starting the field survey in 2015, we digitized and classified Google Earth satellite images (Google Inc., California, USA) into the following land use types: rice fields, dry farmland, settlement, tree patches, irrigation canals, roads, and other. Although the satellite images allowed us to delineate farmland borders, we could not differentiate rice fields and dry farmland. Therefore, we printed the images and subsequently verified the land use classifications in the field during the latrine site surveys in 2015.

In the land use dataset, we only included areas with tree patches and settlements that were $> 225 \text{ m}^2$. We considered roads (width ≥ 3 m; either gravel or paved) to be those that could be driven by cars. For irrigation canals, we only digitized primary and secondary concrete channels (width > 4 m). For logistical reasons, we were unable to digitize the complex network of earthen ditches and small tributaries of the Batang Anai River. In this paper, we only use maps that were verified in the field.

We conducted geographical information system (GIS) analysis using QGIS ver. 2.6.1 (QGIS Development Team 2014). To calculate the nearest distance from each latrine site to the respective land use, we used the plugin NNJoin ver. 1.2.2 (Tveite 2015).

227

228 *Data analysis*

229 We constructed statistical models of latrine site characteristics in two steps. First,
230 we modeled the occurrence of latrine sites along the Batang Anai River using grid-based
231 analysis (hereafter, the “occurrence model”). Prior to analysis, we divided the map of
232 the study area into 200×200 -m grids. We determined grid size based on the average
233 distance to the nearest latrine sites ($230.9 \text{ m} \pm 142.7 \text{ SD}$). Only grids that contained
234 surveyed rice fields were selected; consequently, 189 grids were selected for further
235 analysis. Although the grids were added to maps after the field survey was performed,
236 we were able to determine the presence or absence of latrine sites in each grid based on
237 the individual rice field survey data from 2015. We used a generalized linear model
238 (GLM) to model the occurrence of latrine sites (response variable) with seven land use
239 variables as predictors (Table 1). We treated the response variable as having a binomial
240 distribution with logit link. Because we used the satellite map from 2015, we only used
241 the latrine site occurrence data from the 2015 field survey in the occurrence model.

242 Second, we modeled the visitation frequency of small-clawed otters to the latrine
243 sites using a point-based analysis (hereafter, the “frequency model”). We defined otter
244 visitation frequency to latrine sites as the number of times spraints were found in a
245 certain location during the 53-week period. We used the number of visitations as the
246 response variable and the land use and local environmental variables as predictors
247 (Table 1). We treated the response variable as having a negative binomial distribution
248 and a log link.

249 In both models, we initially checked the normality assumption for each predictor
250 using the Shapiro–Wilk normality test. When the normality assumption could not be

met, we performed arcsine-square-root, log, fourth-root, square-root, or multiplicative inverse transformations (Table 1). Appropriate data transformations for predictors used in the visitation model were determined based on Box–Cox log-likelihoods (Dormann 2011). The predictors of the visitation model were subsequently standardized by scaling and centering. We checked for collinearity among predictors in all models; no predictors were highly inter-correlated (Pearson correlation analyses: all $r < 0.7$). When necessary, we included polynomial degrees of a predictor variable based on scatter plots.

We selected the best model using backward stepwise selection based on Akaike’s Information Criterion correction for small samples (AIC_c). The model with the smallest AIC_c was considered the best model. When two or more models had small differences in AIC_c values from the model with the smallest AIC_c ($\Delta AIC_c < 2$), we selected the most parsimonious model (i.e., fewest parameters) (Burnham and Anderson 2004).

We performed Moran’s I-test to examine whether spatial autocorrelation existed in the residuals of the respective best models (Dormann et al. 2007). For all cases, there was no evidence of spatial autocorrelation (Moran’s I: $P > 0.1$)

We assessed model performance using explained deviance (D^2), calculated as $1 - (\text{residual deviance} / \text{null deviance})$ (Guisan and Zimmerman 2000). When more than one predictor was retained in the refined model, we compared D^2 for the models that excluded each predictor to that of the full model to infer the relative contributions of predictors to the response variable (expressed as ΔD^2).

We conducted all statistical analyses using R freeware (R Core Team 2016). We used the MASS package to compute and plot profile log-likelihoods for the parameters of the Box–Cox power transformation, and to fit the negative binomial GLM (Venables and Ripley 2002). We also used the spdep package to compute Moran’s I statistics to

test for spatial autocorrelation (Bivand and Piras 2015) and the MuMIn package to calculate AIC_c values (Bartoń 2016).

Results

Latrine sites

Of the 29 latrine sites, 13 were newly discovered in 2015, and 16 were old latrine sites from the 2008 or 2010 surveys (10 sites from 2008 and six from 2010). The average number of visitations by small-clawed otters to the latrine sites was 11.9 ± 10.0 SD (range 0–29, N = 25). One old latrine site was no longer used, and four old latrine sites were only visited once each during the 53 weeks. The visitation frequency to the latrine sites did not significantly vary with the year of first discovery of the latrine sites (Kruskal–Wallis rank sum test: $\chi^2 = 0.72$, $P = 0.70$; Fig. S3).

Occurrence model

We found latrine sites of small-clawed otters in 25 of 189 grids (Fig. 1). Based on model selection among nine candidate models using AIC_c in the GLM, the number of rice field huts was the sole variable that explained the occurrence of small-clawed otter latrine sites (Table 2; Table S1). Latrine site occurrence exhibited a non-linear relationship with the number of huts; occurrence was positively associated with the number of huts, but negatively associated with the squared number of huts. Consequently, latrine sites had the highest probability of occurring with an intermediate number of huts (two or three) (Fig. 2). D^2 of the best model was 0.09.

298 *Frequency model*

299 Based on model selection among 10 candidate models, distance to the nearest
 300 settlement, distance to the Batang Anai River, and mean water depth of the rice field
 301 adjacent to a latrine site were the most important predictors that explained the visitation
 302 frequency of small-clawed otters to the latrine sites (Table 2; Table S2). The visitation
 303 frequency to the latrine sites was positively associated with distance to the nearest
 304 settlement and mean water depth, but negatively associated with distance to the Batang
 305 Anai River (Fig. 3). D^2 of the best model was 0.41. Among the three predictors, distance
 306 to the nearest settlement exhibited the highest contribution to D^2 ($\Delta D^2 = 0.31$), followed
 307 by mean water depth (0.16) and distance to the Batang Anai River (0.14).

308

309 **Discussion**

310 *Effects of land use and local environmental factors on latrine site occurrence and*
 311 *visitation frequency of small-clawed otters*

312 We found that the small-clawed otter latrine sites were related to both landscape-
 313 and local-level environmental characteristics of rice fields. According to the occurrence
 314 model, the number of rice field huts was non-linearly related to latrine site occurrence,
 315 with latrine sites occurring with the highest probability in the presence of an
 316 intermediate number of huts. The number of rice field huts was the sole important
 317 variable that explained latrine site occurrence. Furthermore, nine of 25 (36%) latrine
 318 sites were located near a rice field hut (distance < 3 m). In Sumatra, rice field huts are
 319 used by farmers as shelters; to guard rice from wildlife; to rest or have lunch; and/or to
 320 temporarily store fertilizers, pesticides, and farming equipment (Kato 1978). rice field
 321 huts are usually built near earthen irrigation ditches, which may provide foraging sites

for small-clawed otters. Moreover, the raised floors of rice field huts may provide temporary refuge for otters against sudden encounters with humans, and serve as an equivalent to fallen log refuges in natural habitats (Swimley et al. 1998; Anoop and Hussain 2004; Prakash et al. 2012). In addition, open grassland areas around rice field huts may provide suitable locations for grooming sites (Shenoy et al. 2006). Therefore, rice field huts may serve as important foraging, refuge, and grooming sites for small-clawed otters. However, a trade-off exists between larger numbers of huts and the intensity of human activities; that is, large numbers of rice field huts indicate intense human activities in these landscapes. Therefore, a landscape containing that contains an intermediate number of rice field huts may be an ideal location for small-clawed otter latrine sites.

Bridges are another land use feature that serve as important latrine sites for small-clawed otters (Reuther et al. 2000). Therefore, bridge surveys have become a standard survey method for otters (Gallant et al. 2008; Stevens et al. 2011; Just et al. 2012). A hut survey could also serve as a standard survey method for assessing the occurrence of small-clawed otters in rice field landscapes where large bridges are absent or rare.

The frequency model revealed a positive relationship between the visitation frequency of small-clawed otters to the latrine sites and mean water depth of the adjacent rice field. Annual mean water depth is an indicator of water availability in the rice field. Because small-clawed otters generally feed on aquatic animals (Kruuk et al. 1994), dry rice fields may be unsuitable as foraging sites. These results are consistent with the findings of Prenda et al. (2001), who reported that Eurasian otters in

345 Mediterranean streams are usually found at sites inundated by water during the dry
346 season.

347 The visitation frequency of small-clawed otters to the latrine sites was also
348 positively associated with distance to the nearest settlement. In Eurasian otters (*Lutra*
349 *lutra*), sprainting activities, which were assessed by the number of spraints found along
350 a transect, tend to be low in urban areas where land conversion or other human activities
351 are intense (Prenda and Granado-Lorencio 1996). Although our study was conducted in
352 human-altered landscapes, small-clawed otters appear to use sites that are relatively
353 distant (approximately 300 m) from settlements frequently to avoid direct encounters
354 with humans (Fig. 3). Light emitted by settlements may also disturb otter behavior, as
355 these animals are generally crepuscular or nocturnal (Hussain et al. 2011).

356 Another landscape factor that was strongly associated with latrine visitation
357 frequency by small-clawed otters was distance to the river. Because small-clawed otters
358 typically prefer narrow streams to wide rivers (Perinchery et al. 2011; Raha and Hussain
359 2016), we hypothesize that small-clawed otters use the river as a corridor to travel
360 across rice field landscapes rather than as a primary habitat. Because we have no
361 information about the home range of small-clawed otters, this hypothesis should be
362 tested in the field using telemetry.

363 A limitation of this study was the predictive performance of the occurrence model.
364 Although various land use factors were included in the occurrence model, the D^2 of the
365 best model was only 0.09. However, both linear and squared terms for the number of
366 huts showed significant associations with latrine site occurrence ($P < 0.05$) in the GLM
367 (Table 2). We hypothesize that the occurrence of latrine sites might be more
368 significantly associated with finer-scale land use factors, such as the network of earthen

ditches, small tributaries of the Batang Anai River, small patches of native shrubs, or the presence of swamps or abandoned fish ponds; none of these features could be quantified using the current coarse resolution maps. Choosing an appropriate spatial scale to determine latrine site occurrence may also be important, as species responses to landscape or land use factors are scale-dependent (e.g., Usio et al. 2017). These points warrant further exploration in future studies using finer-scale satellite or aerial maps, along with field evaluations and multi-scale land use analysis. Furthermore, although we ensured that we surveyed each grid, we cannot eliminate the possibility of pseudo-absence, because new latrine sites might have appeared after the one-time survey took place. To minimize or avoid the influence of pseudo-absence, presence–absence surveys should ideally be performed multiple times at each sampling unit (grid) (MacKenzie et al. 2006), or a presence-only modeling technique, such as Maximum Entropy Modeling (MaxEnt; Phillips et al. 2006), should be used.

Latrine site fidelity of small-clawed otters

We revealed that small-clawed otters tend to use some latrine sites over long periods of time, as 10 latrine sites were used for more than 7 years. This was rather surprising, because landscape features change dramatically over the year based on rice cultivation cycles.

In captivity, latrine sites of small-clawed otters are first chosen by the alpha male (Alana Dewar, *pers. comm.*). After the alpha male dies, the group continues to use the latrine site, and his position is filled by another male in the group. Even though spraints are regularly removed and cleaned, the group still uses a similar location as the latrine site, but the exact location changes gradually over time. The otter latrine sites are even

likely passed on to the next generation, as several latrine sites of African clawless otters (*Aonyx capensis*) discovered in 1972 were still used after more than 40 years (Rowe-Rowe 1992; Kubheka et al. 2013). Therefore, records of the exact locations of latrine sites may be useful for future monitoring of latrine site use by small-clawed otters in rice field landscapes, unless drastic environmental changes take place.

Implications for otter conservation

Rice fields may serve as an alternative wetland habitat for various types of aquatic and semi-aquatic wildlife, including endangered species (Bambaradeniya and Amarasinghe 2002; Usio and Miyashita 2014). Our study indicates that rice fields provide important latrine sites for small-clawed otters. Nevertheless, how and to what extent modernization of agriculture, such as intensive use of agrochemicals and large machinery, affects small-clawed otters remains unknown. Modernization of agriculture in paddy-dominated landscapes has dramatically increased agricultural production (Food and Agriculture Organization of the United Nations 2000); however, such agricultural intensification has caused severe declines in biodiversity in rice field landscapes (Natuhara 2013). For example, in Japanese Satoyama, overuse of agrochemicals, farmland consolidation, and cementing of the bottom and sides of irrigation ditches have led to losses of aquatic biota from rice field landscapes and accelerated biological magnification of toxic chemicals (Miyashita et al. 2014). Such combinations of multiple stressors, in turn, have led to extinctions of the crested ibis (*Nipponia nippon*) and Oriental white stork (*Ciconia boyciana*), which were once widely distributed throughout Japan (Usio and Miyashita 2014).

Indonesia is currently experiencing human overpopulation; hence, increased food production through agricultural modernization is unavoidable. Natural wetlands have been disappearing at an accelerated rate because of their conversion to palm oil plantations (Margono et al. 2014). In addition, changes in land use or farming practices have led to losses of aquatic and semi-aquatic organisms that use rice fields as foraging or refuge sites. Furthermore, the System of Rice Intensification (SRI), in which less water is used during rice cultivation, is being promoted in Indonesia (Wardana et al. 2015). Although the SRI protocol encourages the use of organic pesticides and fertilizers, shallow-flooding practices may produce detrimental effects on aquatic biodiversity, including small-clawed otters. Given these threats, we emphasize the need for the design of otter-friendly rice-farming practices before small-clawed otters completely disappear from the region.

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438 **References**

- 439 Aadrean, Novarino W, Jabang (2011) A record of small-clawed otters (*Aonyx cinereus*)
440 foraging on an invasive pest species, golden apple snails (*Pomacea canaliculata*)
441 in a West Sumatra rice field. IUCN Otter Spec Gr Bull 28:34–38
- 442 Aadrean, Salmah S, Salsabila A, Rizaldi, Janra MN (2010) Tracks and other signs of
443 otters in rice fields in Padang Pariaman, West Sumatra: a preliminary study. IUCN
444 Otter Spec Gr Bull 27:6–11
- 445 Anoop KR, Hussain SA (2004) Factors affecting habitat selection by smooth-coated
446 otters (*Lutra perspicillata*) in Kerala, India. J Zool 263:417–423. doi:
447 10.1017/S0952836904005461
- 448 Bambaradeniya CNB, Amarasinghe FP (2002) Biodiversity associated with the rice
449 field agro-ecosystem in Asian countries: A brief review. International Water
450 Management Institute, Colombo, Sri Lanka
- 451 Barocas A, Golden HN, Harrington MW, McDonald DB, Ben-David M (2016) Coastal
452 latrine sites as social information hubs and drivers of river otter fission–fusion
453 dynamics. Anim Behav 120:103–114. doi: 10.1016/j.anbehav.2016.07.016
- 454 Bartoń K (2016) MuMIn: Multi-Model Inference. R Package version 1.15.6
- 455 Burnham KP, Anderson DR (2004) Multimodel inference understanding AIC and BIC
456 in model selection. Sociol Methods Res 33:261–304
- 457 Bivand R, Piras G (2015) Comparing Implementations of Estimation Methods for
458 Spatial Econometrics. J Stat Softw 63:1–36
- 459 Crait JR, Regehr E V, Ben-david M (2015) Indirect effects of bioinvasions in
460 Yellowstone Lake: The response of river otters to declines in native cutthroat trout.
461 Biol Conserv 191:596–605. doi: 10.1016/j.biocon.2015.07.042

- 462 Dormann CF (2011) Modelling Species' Distributions. In: Jopp F, Reuter H, Breckling
 463 B (eds) Modelling Complex Ecological Dynamics: An Introduction into Ecological
 464 Modelling for Students, Teachers & Scientists. Springer Berlin Heidelberg, Berlin,
 465 Heidelberg, pp 179–196
- 466 Dormann CF, McPherson JM, Araújo MB, Bivand R, Bolliger J, Carl G, Davies RG,
 467 Hirzel A, Jetz W, Kissling WD, Kühn I, Ohlemüller R, Peres-Neto PR, Reineking
 468 B, Schröder B, Schurr FM, Wilson R (2007) Methods to account for spatial
 469 autocorrelation in the analysis of species distributional data: A review. *Ecography*
 470 30:609–628. doi: 10.1111/j.2007.0906-7590.05171.x
- 471 Food and Agriculture Organization of the United Nations (2000) The State of Food and
 472 Agriculture. Food and Agriculture Organization of the United Nations, Rome
- 473 Foster-Turley P (1992) Conservation aspects of the ecology of Asian small-clawed and
 474 smooth otters on the Malay Peninsula. *IUCN Otter Spec Gr Bull* 7:26–29
- 475 Gallant D, Vasseur L, Bérubé CH (2008) Evaluating bridge survey ability to detect river
 476 otter *Lontra canadensis* presence: a comparative study. *Wildlife Biol* 14:61–69.
 477 doi: 10.2981/0909-6396(2008)14[61:EBSATD]2.0.CO;2
- 478 Gonzales JB (2010) Distribution, exploitation and trade dynamics of Asian small-
 479 clawed otter (*Amblonyx cinereus*) Illiger 1815 in Mainland Palawan, Philippines.
 480 Bachelor's thesis. Western Philippines University, Palawan, Philippines
- 481 Green ML, Monick K, Manjerovic MB, Novakofski J, Mateus-Pinilla N (2015)
 482 Communication stations: cameras reveal river otter (*Lontra canadensis*) behavior
 483 and activity patterns at latrines. *J Ethol* 33:225–234. doi: 10.1007/s10164-015-
 484 0435-7

- 485 Guisan A, Zimmermann NE (2000) Predictive habitat distribution models in ecology.
 486 Ecol Modell 135:147–186. doi: 10.1016/S0304-3800(00)00354-9
- 487 Hon N, Neak P, Khov V, Cheat V (2010) Food and habitat of Asian small-clawed otter
 488 in northeastern Cambodia. IUCN Otter Spec Group Bull 21:12–23.
- 489 Hussain SA, Gupta SK, DeSilva PK (2011) Biology and ecology of Asian small-clawed
 490 otter *Aonyx cinereus* (Illiger, 1815): A review. IUCN Otter Spec Gr Bull 28:63–75
- 491 Hutchings MR, White PCL (2000) Mustelid scent-marking in managed ecosystems:
 492 Implications for population management. Mamm Rev 30:157–169. doi:
 493 10.1046/j.1365-2907.2000.00065.x
- 494 Johnson RP (1973) Scent marking in mammals. Anim Behav 21:521–535. doi:
 495 10.1016/S0003-3472(73)80012-0
- 496 Johnson CJ, Hodder DP, Crowley S (2013) Assessing noninvasive hair and fecal
 497 sampling for monitoring the distribution and abundance of river otter. Ecol Res
 498 28:881–892. doi: 10.1007/s11284-013-1071-8
- 499 Just EH, Stevens SS, Spinola RM, Serfass TL (2012) Detecting river otter *Lontra*
 500 *canadensis* latrines near bridges: does habitat and season influence survey success?
 501 Wildlife Biol 18:264–271. doi: 10.2981/11-042
- 502 Kanchanasaka B, Duplaix N (2011) Food Habits of the Hairy-nosed otter (*Lutra*
 503 *sumatrana*) and the Small-clawed otter (*Aonyx cinereus*) in Pru Toa Daeng Peat
 504 Swamp Forest, Southern Thailand. IUCN Otter Spec Gr Bull 28A:139–149
- 505 Kato T (1978) Change and Continuity in the Minangkabau Matrilineal System.
 506 Indonesia 25:1–16
- 507 Kruuk H (1992) Scent marking by otters (*Lutra lutra*): signaling the use of resources.
 508 Behav Ecol 3:133–140

- 509 Kruuk H, Kanchanasaka B, O'Sullivan S, Wanghongsa S (1994) Niche separation in
 510 three sympatric otters *Lutra perspicillata*, *L. lutra* and *Aonyx cinerea* in Huai Kha
 511 Khaeng, Thailand. Biol Conserv 69:115–120. doi: 10.1016/0006-3207(94)90334-4
- 512 Kubheka SP, Rowe-Rowe DT, Alletson JD, Perrin MR (2013) Possible influence of
 513 increased riparian activity (stream modification and agricultural intensification) on
 514 abundance of South African otters. Afr J Ecol 51:288–294. doi: 10.1111/aje.12033
- 515 MacKenzie DI, Nichols JD, Royle JA, Pollock KH, Bailey LL, Hines, JE (2006)
 516 Occupancy estimation and modeling: inferring patterns and dynamics of species
 517 occurrence. Academic Press
- 518 Margono BA, Potapov P V, Turubanova S, Stolle F, Hansen MC (2014) Primary forest
 519 cover loss in Indonesia over 2000–2012. Nat Clim Chang 4:1–6. doi:
 520 10.1038/NCLIMATE2277
- 521 Melquist WE, Polechla PJ, Chapman JA (2003) River Otter. In: Feldhamer GA,
 522 Thompson BC, Chapman JA (eds) Wild mammals of North America: Biology,
 523 management, and conservation, 2nd edn. The Johns Hopkins University Press,
 524 Baltimore and London, pp 708–734
- 525 Miyashita T, Yamanaka M, Tsutsui MH (2014) Distribution and abundance of organisms
 526 in paddy-dominated landscapes with implications for wildlife-friendly farming. In:
 527 Usio N & Miyashita T (eds) Social-ecological restoration in paddy-dominated
 528 landscapes, Springer Japan, Tokyo, pp 45-65
- 529 Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands
 530 in Japan. Ecol Eng 56:97–106. doi: 10.1016/j.ecoleng.2012.04.026

- 531 Perinchery A, Jathanna D, Kumar A (2011) Factors determining occupancy and habitat
 532 use by Asian small-clawed otters in the Western Ghats, India. J Mammal 92:796–
 533 802. doi: 10.1644/10-MAMM-A-323.1
- 534 Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species
 535 geographic distributions. Ecol Model 190:231–259. doi:
 536 10.1016/j.ecolmodel.2005.03.026
- 537 Prakash N, Mudappa D, Raman TRS, Kumar A (2012) Conservation of the Asian small-
 538 clawed otter (*Aonyx cinereus*) in human-modified landscapes, Western Ghats,
 539 India. Trop Conserv Sci 5:67–78
- 540 Prenda J, Lopez-Nieves P, Bravo R (2001) Conservation of otter (*Lutra lutra*) in a
 541 Mediterranean area: the importance of habitat quality and temporal variation in
 542 water availability. Aquat Conserv Mar Freshw Ecosyst 11:343–355. doi:
 543 10.1002/aqc.454
- 544 Prenda J, Granado-Lorencio C (1996) The relative influence of riparian habitat structure
 545 and fish availability on otter *Lutra lutra* L. sprainting activity in a small
 546 Mediterranean catchment. Biol Conserv 76:9–15. doi: 10.1016/0006-
 547 3207(95)00080-1
- 548 QGIS Development Team (2014) QGIS Geographic Information System. Open Source
 549 Geospatial Foundation Project. <http://www.qgis.org/>
- 550 R Core Team (2016) R: A Language and Environment for Statistical Computing. R
 551 Foundation for Statistical Computing, Vienna, Austria. <http://www.r-project.org/>
- 552 Raha A, Hussain SA (2016) Factors affecting habitat selection by three sympatric otter
 553 species in the southern Western Ghats, India. Acta Ecol Sin 36:45–49. doi:
 554 10.1016/j.chnaes.2015.12.002

- 555 Ralls K (1971) Mammalian Scent Marking. *Science* 171:443–449. doi:
 556 10.1126/science.171.3970.443
- 557 Reuther C, Dolch D, Green R, Jahrl J, Jefferies D, Krekemeyer A, Kucerova M, Madsen
 558 AB, Romanowski J, Roche K, Ruiz-Olmo J, Teubner J, Trindade A (2000)
 559 Surveying and monitoring distribution and population trends of the Eurasian otter
 560 (*Lutra lutra*). *Habitat* 12:148
- 561 Rowe-Rowe DT (1992) Survey of South African otters in a freshwater habitat, using
 562 sign. *South African J Wildl Res* 22:49–55
- 563 Shenoy K, Varma S, Prasad KVD (2006) Factors determining habitat choice of the
 564 smooth-coated otter, *Lutra perspicillata* in a South Indian river system. *Curr Sci*
 565 91:637–643
- 566 Stevens SS, Just EH, Cordes RC, Brook RP, Serfass TL (2011) The influence of habitat
 567 quality on the detection of river otter (*Lontra canadensis*) latrines near bridges. *Am*
 568 *Midl Nat* 166:435–445. doi: 10.1674/0003-0031-166.2.435
- 569 Swimley TJ, Serfass TL, Brooks RP, Tzilkowski WM (1998) Predicting river otter
 570 latrine sites in Pennsylvania. *Wildl Soc Bull* 26:836–845
- 571 Tveite H (2015) The QGIS NNJoin Plugin. <https://plugins.qgis.org/plugins/NNJoin/>
- 572 Usio N, Miyashita T (2014) Social-ecological restoration in paddy-dominated
 573 landscape. Springer Japan, Tokyo
- 574 Usio N, Nakagawa M, Aoki T, Higuchi S, Kadono Y, Akasaka M, Takamura N (2017)
 575 Effects of land use on trophic states and multi-taxonomic diversity in Japanese
 576 farm ponds. *Agric Ecosyst Environ* 247:205–215. doi: 10.1016/j.agee.2017.06.043
- 577 Venables WN, Ripley BD (2002) *Modern Applied Statistics with S*, 4th edn, Springer,
 578 New York

- 579 Wardana P, Widyanoro, Rahmini, Abdulrachman S, Zaini Z, Jamil A, Mejaya MJ,
580 Sasmita P, Suhartatik SE, Abdullah B, Margaret S, Baliadi Y, Dhalimi A, Hasmi I,
581 Suharna (2015) Panduan Teknologi Budidaya Padi SRI (System of Rice
582 Intensification). Indonesian Center for Rice Research, Ministry of Agriculture
583 Indonesia, Jakarta, Indonesia
- 584 Wright LC (2003) Assessing the welfare of captive Asian small-clawed otters
585 (*Amblonyx cinereus*): Can inductive methods play a part? IUCN Otter Spec Gr
586 Bull 20:35–41
- 587 Wright L, de Silva P, Chan B, Lubis IR (2015) *Aonyx cinereus*. The IUCN Red List of
588 Threatened Species 2015: e.T44166A21939068. doi: 10.2305/IUCN.UK.2015-
589 2.RLTS.T44166A21939068.en
- 590

591 Figures

593 **Fig. 1** Study site in the Batang Anai River drainage area in West Sumatra, Indonesia.

594 Each grid is 200 × 200 m. Filled grids represent areas where latrine sites of small-
 595 clawed otters were found in the 2015 survey (conducted over 53 weeks from April 12,
 596 2015 to April 10, 2016). Small effluent ditches flowing from the rice fields to the river
 597 are not shown

598

599

600 **Fig. 2** Relationship between the number of huts and latrine site occurrence of small-
 601 clawed otters. The solid line indicates the predicted value. Grey dashed lines indicate
 602 approximate 95% confidence limits (± 2 standard errors of the generalized linear model
 603 fit). Open circles indicate the distributions of raw data. Circle size is proportional to
 604 sample size (number of grids)

605

Fig. 3 Relationships between small-clawed otter visitation frequency to latrine sites and mean water depth of the rice field adjacent to the latrine site (a), distance to a settlement (b), and distance to the Batang Anai River (c). The solid lines indicate predicted values. Grey dashed lines indicate approximate 95% confidence limits (± 2 standard errors of the generalized linear model fit). The predicted value and confidence limits for each predictor were calculated from the parameter estimates of the best model when the remaining predictors were set to the mean values. Note that the predictors were back-transformed to show the actual associations with the response variables. Open circles indicate raw data

617 **Table 1** Predictor variables used in two generalized linear models to investigate the
 618 occurrence of small-clawed otter latrine sites (the occurrence model) and visitation
 619 frequency of small-clawed otters to the latrine sites (the frequency model).
 620 Transformation refers to the type of data transformation used to normalize the predictor
 621 variable

Variable	Description	Mean	SD	Range	Transformation
<u>Occurrence model</u>					
ricefieldprop	Proportion of rice field area in the grid	0.45	0.30	0.00–1.00	$\arcsin(\sqrt{x})$
treeprop	Proportion of tree patch area in the grid	0.09	0.10	0.00–0.42	$\arcsin(\sqrt{x})$
streetsettleprop	Proportion of street and settlement areas in the grid	0.13	0.19	0.00–1.00	$\arcsin(\sqrt{x})$
canalprop	Proportion of canal area in the grid	0.02	0.04	0.00–0.16	$\arcsin(\sqrt{x})$
dryfarmprop	Proportion of dry farmland area in the grid	0.04	0.06	0.00–0.32	$\arcsin(\sqrt{x})$
hutnumber	Number of rice field huts in the grid	0.75	1.10	0–6	None
gridriverdist	Nearest distance (m) from the centroids of the grids to Batang Anai River	1141	564.1	15.6–2377.0	None
<u>Frequency model</u>					
Landscape factors					
dryfarmdist	Linear distance (m) to the nearest dry farmland	132.5	95.5	32.8–421.2	$\log(x)$
treedist	Linear distance (m) to the nearest tree patch	74.8	68.0	0.0–257.8	$\sqrt[4]{x}$

streetdist	Linear distance (m) to the nearest street	170.3	77.7	52.4–304.4	None
riverdist	Linear distance (m) to the Batang Anai River	1204.0	595.5	82.2–2258.0	None
canaldist	Linear distance (m) to the nearest irrigation canal	162.0	142.5	9.3–555.0	$\sqrt[4]{x}$
settlementdist	Linear distance (m) to the nearest settlement	97.1	77.1	0.0–292.6	$\sqrt{x}$
hutdist	Linear distance (m) to the nearest rice field hut	73.2	79.6	0.0–243.1	$\sqrt[4]{x}$
Local environmental factors					
watermean	Mean water depth (cm) of an adjacent rice field (over 53 weeks)	1.66	0.80	0.79–4.51	$\frac{1}{x}$
snailweightmean	Mean weights (g) of golden apple snails in an adjacent rice field (over 53 weeks)	8.06	6.77	0.63–21.32	$\sqrt[4]{x}$

Table 2 Parameter estimates of the best occurrence models and frequency models. Bold-faced font indicates the best model based on the lowest ΔAIC_c (Akaike's Information Criterion correction for small samples) and the most parsimonious model (fewest variables among models with $\Delta AIC_c < 2$). Note that the watermean was inverse-transformed ($1/x$) using Box–Cox transformation; a negative value in the estimate represents a positive value in the actual relationship. See Table 1 for abbreviations of the predictors

Model	covariate	Estimate	SE	z value	P value	K ¹	AIC _c	ΔAIC_c	Weights
Occurrence model									
Occurrence ~ canalprop + hutnumber – hutnumber ²						3	139.43	0	0.3405
	Intercept	–3.0196	0.4359	–6.927	< 0.0001				
	canalprop	2.6434	1.5319	1.726	0.0844				
	hutnumber	1.7100	0.5601	3.053	0.0023				
	hutnumber ²	–0.3507	0.1646	–2.131	0.0331				
Occurrence ~ hutnumber – hutnumber²						2	140.16	0.73	0.236
	Intercept	–2.7612	0.3899	–7.082	< 0.0001				
	hutnumber	1.7100	0.5563	3.074	0.0021				
	hutnumber ²	–0.3636	0.1639	–2.219	0.0265				
Occurrence ~ canalprop + treeprop + hutnumber – hutnumber ²						4	140.26	0.83	0.2245
	Intercept	–3.4852	0.6285	–5.545	< 0.0001				
	canalprop	2.9589	1.5666	1.889	0.0589				
	treeprop	1.3812	1.2244	1.128	0.2593				
	hutnumber	1.9210	0.6095	3.152	0.0016				
	hutnumber ²	–0.3999	0.1781	–2.246	0.0247				
Frequency model									
Frequency ~ settlementdist – watermean – riverdist						3	174.85	0	0.4649
	Intercept	2.2309	0.1643	13.578	< 0.0001				

settlementdist	1.0690	0.2559	4.178	< 0.0001
watermean	−0.4438	0.1708	−2.598	0.0094
riverdist	−0.5639	0.2308	−2.444	0.0145

Frequency ~ settlementdist − watermean + hutdist − riverdist					4	176.51	1.66	0.2032
Intercept	2.1992	0.1590	13.835	< 0.0001				
settlementdist	1.1558	0.2673	4.324	< 0.0001				
watermean	−0.4683	0.1645	−2.847	0.0044				
hutdist	0.2207	0.1611	1.370	0.1706				
riverdist	−0.6534	0.2330	−2.804	0.0050				

630 ¹ Number of parameters

Ecological Research

Supplementary data

Small-clawed otters (*Aonyx cinereus*) in Indonesian rice fields: latrine-site characteristics and visitation frequency

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Fig. S1 Photo of a rice field landscape in the Batang Anai River drainage in Sumatra, Indonesia
(Photo by Evan Ananta)

Fig. S2 Map of irrigated farmland in the Batang Anai River drainage in Sumatra, Indonesia. The dashed rectangle indicates the study site of the 2015 field survey (conducted over 53 weeks from April 12, 2015 to April 10, 2016)

Fig. S3 Box plots of visitation frequency over 53 weeks for small-clawed otters during the year of first discovery. Thick lines indicate the medians, boxes show inter-quartile ranges (IQR), and whiskers denote 1.5 times the IQR. Visitation frequency did not significantly vary with the year of first discovery (Kruskal–Wallis rank sum test, $\chi^2 = 0.72$, $P = 0.70$)

Table S1 Summary of the model selection results for the occurrence of small-clawed otter latrine sites (occurrence model) in the Batang Anai River drainage area in West Sumatra, Indonesia. Bold-faced font indicates the best model based on the lowest ΔAIC_c (Akaike's Information Criterion correction for small samples) and the most parsimonious model (fewest variables among models with $\Delta AIC_c < 2$). See Table 1 for abbreviations of the predictors

Model	K ¹	AIC _c	ΔAIC_c	Weights
Occurrence ~ canalprop + treeprop + ricefieldprop + hutnumber – hutnumber ² – dryfarmprop – streetsettleprop – riverdist	8	147.29	7.86	0.0067
Occurrence ~ canalprop + treeprop + ricefieldprop + hutnumber – hutnumber ² – dryfarmprop – streetsettleprop	7	145.26	5.83	0.0184
Occurrence ~ canalprop + treeprop + ricefieldprop + hutnumber – hutnumber ² – dryfarmprop	6	143.36	3.93	0.0476
Occurrence ~ canalprop + treeprop + ricefieldprop + hutnumber – hutnumber ²	5	141.65	2.22	0.1118
Occurrence ~ canalprop + treeprop + hutnumber – hutnumber ²	4	140.26	0.83	0.2245
Occurrence ~ canalprop + hutnumber – hutnumber ²	3	139.43	0	0.3405
Occurrence ~ hutnumber – hutnumber²	2	140.16	0.73	0.2360
Occurrence ~ hutnumber	1	146.02	6.59	0.0126
Occurrence ~ 1	0	149.70	10.27	0.0020

¹ Number of parameters

Table S2 Summary of model selection results for visitation frequency of small-clawed otters to latrine sites (frequency model) in the Batang Anai River drainage area in West Sumatra, Indonesia. Bold-faced font indicates the best model based on the lowest AIC_c (Akaike's Information Criterion correction for small samples) and the most parsimonious model (fewest variables among models with $\Delta\text{AIC}_c < 2$). Note that watermean was inverse-transformed ($1/x$) using Box–Cox transformation: a negative value in the estimate represents a positive value in the actual relationship. See Table 1 for abbreviations of the predictors

Model	K ¹	AIC _c	ΔAIC_c	Weights
Frequency ~ settlementdist – watermean + hutdist + snailweightmean + treedist + streetdist – riverdist – dryfarmdist – canaldist	9	198.04	23.19	0
Frequency ~ settlementdist – watermean + hutdist + snailweightmean + treedist + streetdist – riverdist – dryfarmdist	8	191.46	16.61	0.0001
Frequency ~ settlementdist – watermean + hutdist + snailweightmean + treedist – riverdist – dryfarmdist	7	186.28	11.43	0.0015
Frequency ~ settlementdist – watermean + hutdist + snailweightmean + treedist – riverdist	6	181.90	7.05	0.0138
Frequency ~ settlementdist – watermean + hutdist + snailweightmean – riverdist	5	178.42	3.57	0.0782
Frequency ~ settlementdist – watermean + hutdist – riverdist	4	176.51	1.66	0.2032
Frequency ~ settlementdist – watermean – riverdist	3	174.85	0	0.4649
Frequency ~ settlementdist – watermean	2	177.17	2.32	0.1464
Frequency ~ settlementdist	1	178.89	4.04	0.0617
Frequency ~ 1	0	180.33	5.48	0.0301

¹ Number of parameters