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Management and Conservation Note

River Otter Latrine Site Selection in Arid Habitats of Western Colorado, USA

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ABSTRACT River otters (*Lontra canadensis*) select specific habitat features when establishing latrines, but no studies have described latrine features in arid and semiarid environments. We developed a model describing those habitat features that influence otter latrine site selection on rivers in arid and semiarid watersheds of western Colorado, USA. River otters selected latrine sites with the presence of beaver (*Castor canadensis*) activity, large prominent rocks, adjacent to deeper water, with shading over the site, and rock or cliff overstory. Our model provides a robust predictive tool for identifying river otter latrine sites in arid environments of southwestern North America.

KEY WORDS arid environments, habitat selection, latrines, logistic regression, *Lontra canadensis*, river otter.

River otters were endemic to many river systems in southwestern North America, but over-harvest and anthropogenic alterations of water quality contributed to their extirpation from much of this region by the early 1900s (Toweill and Tabor 1982, Melquist et al. 2003). Many states, including Colorado, Arizona, and Utah, USA, have reintroduced river otters over several years from the 1970s through 1990s (Colorado Division of Wildlife 2003, Maxfield et al. 2005, New Mexico Game and Fish 2006). These reintroductions have met with various degrees of success, and it is not entirely clear what factors influenced success of these efforts. Although prey availability may be the most important and potentially limiting factor for river otters, availability of suitable habitat also is likely to influence their distribution (Ruiz-Olmo et al. 2001, Melquist et al. 2003, Crait and Ben-David 2006). River otter latrine sites are terrestrial locations used in intraspecific communication through the deposition of urine, feces, and anal gland secretions and are indicative of habitat quality (Hutchings and White 2000, Rostain et al. 2004, Ben-David et al. 2005). In fact, presence or absence of otter latrines has been used to evaluate otter distribution, range expansion, and persistence of existing or reintroduced populations (Swimley et al. 1998, Hutchings and White 2000).

Latrine site selection by river otters has been described extensively for temperate environments (Melquist and Hornocker 1983, Dubuc et al. 1990, Ben-David et al. 1996, Swimley et al. 1998). However, to date no studies address river otter latrine site selection in semiarid and arid environments. We examined river otter latrine site selection in western Colorado. Our goal was to develop a predictive model of river otter latrine sites in that region that will improve efficiency and accuracy of sign surveys before and after reintroductions of otters projected to occur throughout southwestern North America.

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STUDY AREA

We conducted our study on 6 reaches of 5 rivers in western Colorado, which included the Green, Colorado, Piedra, Dolores, and Gunnison rivers. We selected rivers and sections based on the need to meet the river otter recovery objectives of the Colorado Division of Wildlife and in concert with a broader river otter DNA study (Colorado Division of Wildlife 2003, DePue 2007). Rivers included in our study represented the major drainages in western Colorado and included sites from northern Colorado (the Green River) south to the border with New Mexico (the Piedra River; Fig. 1). Distances between sampled river sections ranged from 45 km to >450 km (Fig. 1). Climate was semiarid to arid, with average temperatures ranging from 18° C in January to 38° C in July and average annual precipitation ranging from 254 mm to 381 mm (Birdsall and Florin 2007). River volume ranged from an annual average of 11.3–198.0 cubic meters per second (cms) and had spring runoff highs ranging from 51 cms to 510 cms (United States Geological Survey 2007). River characteristics ranged from calm-flat (class I) water to stretches of substantial pool-drop (class IV) whitewater and had gradients from 0.012 m/km to 12 m/km. Most of the river sections we surveyed were encompassed by large desert canyons surrounded by rock walls of sandstone and granite. River banks were vegetated with semiarid plant communities and riparian obligate species, predominantly eastern cottonwood (*Populus deltoides*), tamarisk (*Tamarix ramosissima*), willows (*Salix* spp.), Utah juniper (*Juniperus osteosperma*), and box elder (*Acer negundo*).

METHODS

In 2004, we surveyed 13 km of the Green River in Browns Park National Wildlife Refuge from 13 to 21 July; 45 km of the Colorado River between Grand Junction, Colorado, and the Colorado–Utah state line from 26 July to 21 August; and 42 km of the Green River through Dinosaur National Monument from 3 to 5 September. In 2005, we surveyed river otter habitat at 3 additional areas: 52 km of the Dolores River from 30 May to 10 June, 33 km of the Piedra River from 28 to 30 June, and 62 km of the Gunnison River from

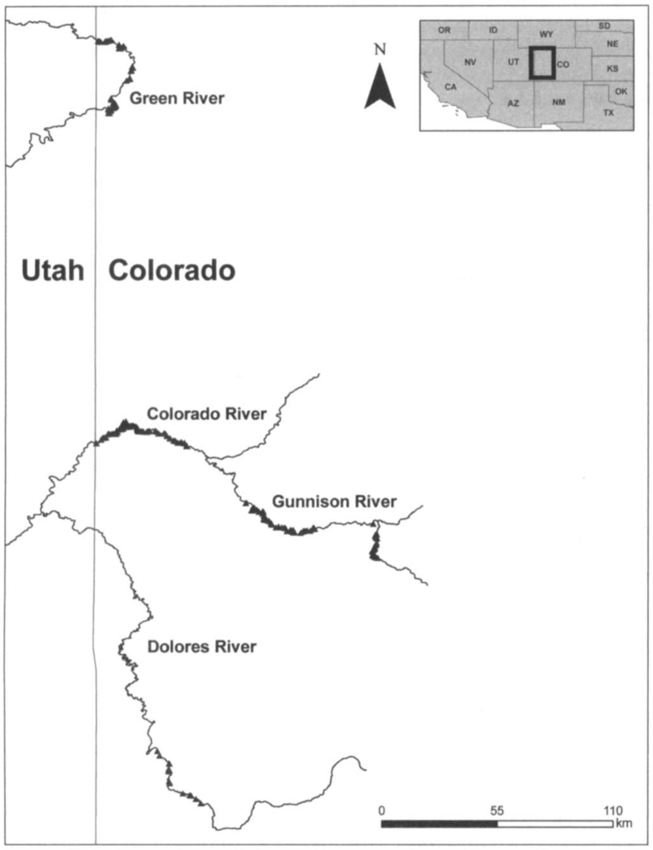

Figure 1. Map of study area, rivers, and locations of river otter latrine and random habitat locations we used to develop a latrine site selection model in western Colorado, USA, May–September 2004–2005.

10 July to 14 August. These survey dates represent the summer season for this region.

We measured habitat characteristics at river otter latrines and un-used sites selected at random in conjunction with a study to develop noninvasive DNA sampling techniques for otters (DePue and Ben-David 2007). We located latrine sites by surveying both river banks with raft or kayak and on foot within 30 m from the water's edge, because previous studies demonstrated that most otter latrines occur within this distance (Bowyer et al. 1995). We considered an otter activity site a latrine if the site had $\geq$3 feces. We chose random sites a priori using the 1:100,000 National Hydrography Data (United States Geological Survey 2004), with ArcView 3.2 (ESRI, Redlands, CA). We used a 10-m buffer to create shoreline polygons adjacent to river edges, within which we generated 30 sets of random coordinates for each of the 6 reaches, for a total of 180. In the field, we used a handheld Global Positioning System (GPS) unit to locate these random sites. When a random point landed on water or >10 m offshore, we moved the plot in a straight line to the nearest shore, unless it landed on inaccessible terrain.

We measured habitat features at each latrine site within a 10-m radius, pivoting around the point with the highest concentration of otter activity (Ben-David et al. 2005, Crait and Ben-David 2007). For random sites, we used predetermined coordinates as the focal point, or 1 m from the water's edge for sites that we moved, and we again described the habitat within a 10-m radius.

We measured habitat characteristics similar to those reported in previous river otter studies (Dubuc et al. 1990; Bowyer et al. 1995, 2003; Swimley et al. 1998). We visually estimated and ranked overstory and understory cover within the site in 20% intervals (coded 1–5) following protocols detailed by Higgins et al. (2005). We also evaluated overall overstory density with a spherical densiometer in each of the 4 cardinal directions at the focal point of each site. Overstory (objects taller than 1.5 m) categories included the following: cottonwood, willows, tamarisk, box elder, and rock cliff. Understory (vegetation shorter than 1.5 m) categories included the following: grass, unknown brush, willows, cottonwood, and tamarisk. Similarly, we visually estimated percentage of shading of the area within the 10-m radius at each site. We evaluated shading separately from trees and rock cliff because shade was often provided by features that existed outside the 10-m radius of sampling (usually by cliffs or the canyon wall). We categorized the substrate at each focal point as sand, grass, mud, rocks, or large prominent rock (coded as binary presence–absence). We also recorded presence of fresh beaver sign within 40 m of the site on either side of the river. In the first year of the study, we ranked water depth at 0.5 m from the water's edge as low if water was less than knee height, medium if water was less than waist deep, and high if it was deeper than the waist. In the second year, we recorded water depth at each site with a graduated measurement rod. In total, we measured habitat characteristics for 42 latrines and 119 random sites. The 42 latrines we described were dispersed across all 6 river sections on the 5 rivers that we studied. These sites occurred over a distance that ranged from 0.1 km in the same drainage to >450 km in separate drainages. These latrine sites were used by $\geq$21 different individual otters as determined from DNA fingerprinting of feces and hair collected at these sites (DePue 2007).

We used logistic regression to develop a model to predict latrine site selection by river otters with site type (latrine and random) as the dependent variable and habitat characteristics as predictor variables (Bowyer et al. 1995, 2003; Manly et al. 2002; Ben-David et al. 2005). Because we wanted to develop a robust model with wide application for the entire region, we pooled data from all rivers and reaches. To control for multicollinearity, we used a Pearson correlation matrix and excluded one variable from each pair with a significant correlation ($P < 0.05$, $r > |0.4|$; Zar 1999).

Because measurements of river depth were highly correlated with the ranking of river depth (Pearson correlation, $r = 0.845$, $P \leq 0.001$) for sites measured in both field seasons, we used ranks of river depth data in our analyses. Similarly, we used visual estimates of shading as input data in the logistic regression models because they were highly correlated with measurements using the densiometer (Pearson correlation, $r = 0.724$, $P \leq 0.001$).

We constructed 8 a priori models to determine habitat characteristics that would predict river otter latrine sites in

Table 1. Number of variables (K), Akaike's Information Criterion corrected for small sample size (AIC_c), ΔAIC_c, model likelihood, and model weights (w_i) for 8 a priori models describing differences between river otter latrines and un-used sites selected at random in western Colorado, USA, May–September 2004 and 2005.

Model	Model parameters	K	AIC_c	ΔAIC_c	Model likelihood	w_i
1	Beaver, sand, rocks, grass, prominent rock, cottonwood overstory, cliff, willow understory, river depth, shade	10	90.83	0.00	1.000	0.529
2	Beaver, prominent rock, river depth, shade, cliff	5	92.54	1.71	0.425	0.225
3	Beaver, prominent rock, river depth, cliff	4	94.66	3.83	0.147	0.078
4	Beaver, prominent rock, river depth, cottonwood overstory, shade	5	94.77	3.94	0.139	0.074
5	Beaver, prominent rock, river depth, shade	4	95.52	4.69	0.096	0.051
6	Beaver, sand, mud, rocks, grass, prominent rock, cottonwood overstory, willow overstory, tamarisk overstory, cliff, willow understory, river depth, shade	13	95.81	4.98	0.083	0.044
7	Beaver, prominent, river depth	3	105.32	14.49	0.001	0.000
8	Beaver, rocks, grass, cottonwood overstory, cliff, river depth, shade	7	113.1	22.27	0.000	0.000

arid environments. Models included variables we hypothesized would predict otter latrines based field observations and previous studies (Swimley et al. 1998, Bowyer et al. 2003, Ben-David et al. 2005, Crait and Ben-David 2007). We first determined that the data fit a logistic regression model with a Hosmer–Lemeshow goodness-of-fit test (Hosmer and Lemeshow 2000). We then used Akaike's Information Criterion corrected for small sample sizes (AIC_c) and Akaike weights (w_i) to select the most parsimonious model that best described otter latrine sites (Burnham and Anderson 2002). We selected the most parsimonious model with the lowest AIC_c score, highest w_i value, and the most biologically meaningful set of parameters. Because we were interested in developing a model that would help wildlife professionals locate river otter latrines in semiarid and arid environments, we also assessed prediction success for the 2 top candidate models (Boyce et al. 2002). We randomly selected 80% of the sites from both latrine and random sites (n = 34 and 95, respectively) to develop model coefficients. Using coefficients we obtained from 80% of the sites, we tested the ability of the model to correctly classify the remaining 20% (latrines n = 8, random sites n = 24) of the data. To determine prediction performance of our model, we generated a receiver operating characteristic curve and calculated the area under the curve (AUC) statistic (Hosmer and Lemeshow 2000). To ensure robust prediction success, and given our small sample size, we repeated the classification analyses 5 times and report the results of the mean prediction success from the 5 iterations (Boyce et al. 2002). We evaluated prediction success, specifically sensitivity (% of correctly classified latrine sites), at a cut point of 0.5. We also calculated odds ratios, which can be used to describe the change in probability of use for every incremental change in predictive variables (Hosmer and Lemeshow 2000). We performed all statistical analyses with SAS 9.1 (SAS Institute, Cary, NC).

Lastly, to determine which variables were selected for or against by otters, we calculated the frequency of occurrence and 95% confidence interval (Zar 1999) for each variable in the model that best described the data. In addition to odds ratios, this analysis provided a measure of effect size.

RESULTS

We surveyed 247 km of river along the Green, Colorado, Piedra, Dolores, and Gunnison rivers. Latrine site densities ranged from 0.03 latrines/km to 0.42 latrines/km. River otters established latrine sites in rivers with gradients that ranged from 0.012 m/km to 12 m/km and among sections of class IV whitewater.

Two models were within 2 AIC_c units. Nonetheless, although the top model had higher weight (w_i = 0.529, K = 10), the second model was more parsimonious (w_i = 0.225, K = 5; Table 1) and contained those variables that repeatedly occurred in the 5 top models. Several of the additional variables in model 1 (sand, rocks substrate, grass substrate, cottonwood overstory, cliff overstory, willow understory, and shade) were statistically insignificant at α = 0.05. Based on these observations, we concluded that the second ranking model containing presence of beaver, a prominent rock, deeper pool, shade, and a cliff was more representative of otter latrine site selection. The AUC value for this model was 0.95, indicating good predictive power (Boyce et al. 2002); and from 5 iterations, the average overall correct classification was 87% (SE = 0.025) and sensitivity 72% (SE = 0.073).

Variables identified by this model occurred at significantly higher frequencies on otter latrine sites than at random sites (Fig. 2). A 20% increase in overstory cover by cliff or rock overhangs increased probability of latrine presence by a factor of 2 (Table 2). Presence of a prominent rock increased probability of an otter latrine by a factor of 24 and occurred at 41% of latrine sites compared with only 5% of random sites. River depths $\geq$60 cm occurred at 61% of latrine sites, and an increase of 20 cm in river depth increased probability of latrine occurrence by a factor of 3. Finally, presence of beaver sign increased probability of latrine occurrence by a factor of 51 (Table 2).

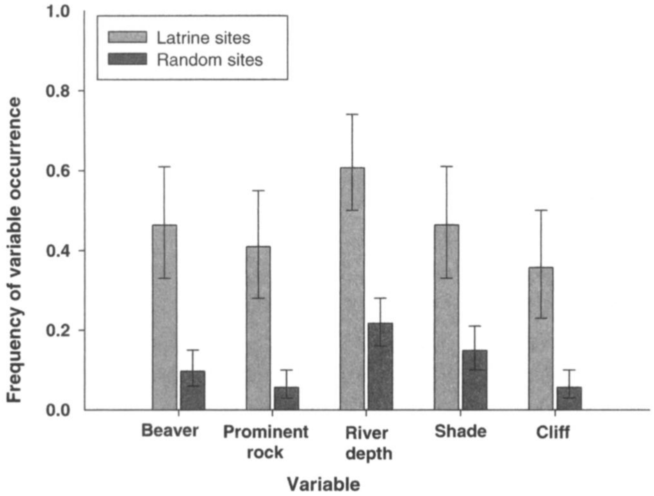

Figure 2. Frequency of occurrence of beaver sign within a 40-m reach, prominent rock, river depth ≥60 cm, cliff ≥20% of overstory, and shade ≥40% (±95% CI), at river otter latrine sites compared with random sites in western Colorado, USA, May–September 2004 and 2005.

Table 2. Coefficient of variation, standard error, and statistical significance of variables from the best logistic regression model explaining river otter latrine site selection in western Colorado, USA, May–September 2004 and 2005.

Variable	CV	SE	Significance	Odds ratio
Beaver	3.935	0.786	<0.001	51.166
Prominent rock	3.180	0.753	<0.001	24.051
River depth	1.124	0.317	≤0.001	3.076
Shade	0.023	0.011	0.039	1.023
Cliff	0.746	0.382	0.051	2.109

DISCUSSION

River otters in semiarid western Colorado selected a combination of biotic and abiotic features similar to habitat characteristics selected for by otters in temperate systems and that may be limited on the landscape we studied (Melquist and Hornocker 1983, Swimley et al. 1998, Crait and Ben-David 2007). However, we observed that in semiarid environments latrine sites were established under overhanging cliffs and rocks rather than trees. Although trees occurred sparsely along these watercourses, they were not important in predicting occurrence of otter latrines in our study. Otters probably choose latrine sites with rock cliffs or canyon walls as overhead cover for similar reasons reported in temperate habitats, such as protection from aerial predators and reduction in desiccation of their scent marks (Ben-David et al. 2005). Similarly, selection for large rocks as a platform for scent marking is consistent with other studies (Swimley et al. 1998, Ben-David et al 2005). Otters probably use these rocks because they are often higher than surrounding habitat, providing a visual advantage and enhanced scent dispersal.

Deep pools probably allow otters easy escape from predators and are important during seasonal low water flows as well as during drought because prey aggregate in deep pools during these times (Ruiz-Olmo et al. 2001). We were unable to note seasonal changes in latrine use during low water flow because it was not feasible to survey in canyons when the water was too low for floating. However, Ruiz-Olmo et al. (2001) showed that in years with extreme drought conditions mortality of Eurasian otters (*Lutra lutra*) in Spain increased dramatically. Sections of rivers with little water were abandoned, and otters exploited fish trapped in isolated pools. Because many rivers in the semiarid and arid southwest have extremely low flows from late summer to early spring, deep pools are probably important for persistence of otters in those systems.

Based on our results, surveys for river otter latrines in semiarid and arid environments should concentrate efforts in areas where beavers are present. Other studies suggested that beavers enhance habitat quality for otters by creating ponds and deepening stream channels (Reid et al. 1994*a*, *b*; Swimley et al. 1998; LeBlanc et al. 2007). In arid and semiarid habitats, beaver activity is probably important for maintaining and creating pools that enhance fish abundance during drought as well as creating den sites that can be used by river otters (Melquist and Hornocker 1983). Given the importance of beaver activity as a predictor of otter latrines along rivers in southwestern North America, future studies should evaluate the otter–beaver interactions in these river systems.

Management Implications

Habitat characteristics identified in our study as important features for river otter latrine sites in arid environments will provide researchers and managers with a robust predictive tool to effectively evaluate habitat use and monitor the success of reintroductions. Model variables are easily and efficiently identified in the field with little training and could be used to improve monitoring of river otter populations. Unfortunately, despite recent technological advances in digital mapping, it will be difficult to define features important to river otters remotely because variables that emerged in our analyses are difficult to measure with current remote sensing technologies, especially at broad scales. For example, rivers in the western United States are often at the bottom of large canyons, so large prominent rock formations will probably be hidden from above. Also, beaver activity may be ephemeral and variable through time. Therefore, evaluation of habitat for planning reintroductions or locating activity sites to assess otter presence will require surveys for river otter latrines in the field.

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