DIURNAL REST SITE SELECTION BY RINGTAILS (*BASSARISCUS ASTUTUS*) IN NORTHWESTERN CALIFORNIA

by

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ABSTRACT

Diurnal rest site selection by ringtails (*Bassariscus astutus*) in northwestern California

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The ringtail (*Bassariscus astutus*) is a fully protected species in California. Understanding diurnal rest site selection is an important component of developing management plans for the species. Ringtail rest site selection was examined in a managed forest of northwestern California. Nineteen ringtails (11 males, 8 females) were radio-collared and located in diurnal rest sites on 441 occasions; however, only 16 individuals (8 males, 8 females) were located enough times to be included in the analysis. Ringtails were found in 158 unique sites and re-visited sites on 283 occasions. Of the 158 unique sites, 75 (47.5 %) were in cavities in live trees and of 111 rest sites located in trees, 25 (22.5 %) were in live black oaks (*Quercus kelloggii)*. Of the 283 occasions when ringtails were found re-visiting a rest site, 144 (50.9 %) were in live trees. Ringtails re-visited rest sites located in trees on 240 occasions; Douglas-firs (*Pseudotsuga menziesii*) were re-visited on 127 (52.9 %) of these occasions.

A resource selection function (RSF) providing an index of ringtail rest site use indicated that rest site use was positively associated with distance from water and steep slopes. The RSF also indicated that rest site use was positively associated with hardwood, sapling, brushy pole, and seedling vegetation types, relative to young forest vegetation. The top model had high predictive capacity, suggesting that the model can be used to develop land management strategies that incorporate conservation needs of

ringtails on the Hoopa Valley Indian Reservation, and may be useful in development of land management practices aimed at providing habitat for ringtails in other areas of northwestern California.

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INTRODUCTION

Little is known about the ecology of ringtails (*Bassariscus astutus*) despite their listing as a fully protected species in California and as a sensitive species in Oregon (Belluomini 1980, Alexander et al. 1994). Habitat alteration and destruction have negatively affected some ringtail populations in California (Williams 1986, Orloff 1988). However, neither California nor Oregon directly manages for the species, and their conservation needs are uncertain (Buskirk and Zielinski 2003).

Rest sites are important to forest carnivores because they provide shelter during inhospitable weather conditions, protection from predators, and sites to raise young (Dalke 1948, Callas 1987, Lariviere 2004, Hwang et al. 2007). Ringtails are nocturnal (Callas 1987, Poglayen-Neuwall and Toweill 1988, Zeiner et al. 1990), and the availability of diurnal rest sites may be a limiting factor for other procyonids (Lariviere 2004).

Ringtails have been studied in arid environments (Trapp 1978, Belluomini and Trapp 1984, Orloff 1988, Chevalier 1989), and within forests of northern California and southern Oregon (Callas 1987, Alexander et al. 1994, Dark 1997). Management recommendations for conservation of ringtail habitat vary. Both Callas (1987) and Alexander et al. (1994) reported that tall and large diameter Douglas-fir (*Pseudotsuga menziesii*) snags provided important rest sites for ringtails. However, Campbell (2004) found a negative relationship between ringtail detections and large snags and a positive relationship between ringtail detections and hardwood trees. Habitat selection by an animal occurs as a multi-scale process (Johnson 1980, Lawler and Edwards 2006), and the goal of this study was to evaluate ringtail rest site selection at the landscape scale (2nd order habitat selection; Johnson 1980) on the Hoopa Valley Indian Reservation (HVIR) in northwestern California, USA. Ringtails are important to tribal cultural integrity on the HVIR; their hides have traditionally been used as regalia and continue to be used in cultural dances by the Hupa people (N. Colegrove, Hoopa Valley Tribal Forest Manager, personal communication). Timber harvest on the reservation has resulted in a mosaic of different forest types and age classes interspersed throughout the landscape, providing an opportunity to evaluate ringtail rest site selection in a forest actively managed for timber harvest. While studies at other sites have investigated habitat selection by ringtails, they have not predicted where ringtail rest sites were expected to be located based on habitat features. I used a resource selection function (RSF; Manly et al. 1993, Carroll et al. 2000, Manly et al. 2002), along with remote sensed habitat components, to predict where ringtail rest sites were expected to be located on the HVIR.

Several studies have suggested that habitat components such as water presence, tree species and size, slope, and aspect may influence rest site selection by the species (Trapp 1978, Callas 1987, Chevalier 1989, Alexander et al. 1994, Dark 1997, Campbell 2004). To investigate the hypothesis that specific habitat components are important to ringtail rest site selection, I tested the prediction that remote sensed habitat components (such as aspect, elevation, roads, vegetation edges, vegetation type and water) would accurately predict rest site use by ringtails.

STUDY AREA

My study area (Figure 1) ranged in elevations from 97 m to 1100 m (Singer and Begg 1975, Hoopa Valley Indian Reservation 2006), and could be characterized as a diverse forest dominated by Douglas-fir and tan oak (*Lithocarpus densiflorus*). The climate of Hoopa can be characterized by hot, dry summers and cool, wet winters. At an elevation of 107 m, the annual mean temperature is 7.3 degrees Celsius during the winter and 21.6 degrees Celsius during the summer, with mean annual precipitation of 1.48 m (Hoopa Valley Indian Tribe 2010).

The topography was highly variable, ranging from areas characterized by rocky canyons, to areas characterized by dense forest, to areas characterized by open prairies. Rocky outcroppings and snags were found throughout most of the study area. In other studies on ringtails (Callas 1987), clear cut and shrub stage vegetation lacked trees and snags. However, Hoopa Valley Tribal Forestry has retained residual legacy trees and snags (Wilson and Carey 2000) in clear cut and shrub stage vegetation within my study area.

Conifers other than Douglas-fir were rare, but consisted of Jeffrey pine (*Pinus jeffreyii*), ponderosa pine (*Pinus ponderosa*), and incense cedar (*Calocedrus decurrens*). In addition to tan oak, other hardwoods consisted of madrone (*Arbutus menziesii*), chinquapin (Q*uercus muehlenbergii*), canyon live oak (*Quercus chrysolepis*), black oak (*Quercus kelloggii*), big-leaf maple (*Acer macrophyllum*), alder (*Alnus glutinosa*), and Pacific dogwood (*Cornus nuttallii*). Common shrubs included manzanita (*Arctostaphylos* *spp*.), huckleberry (*Vaccinium scoparium*), California blackberry (*Rubus ursinus*), Himalayan blackberry (*Rubus discolor*), and annual grasses (Matthews 2002).

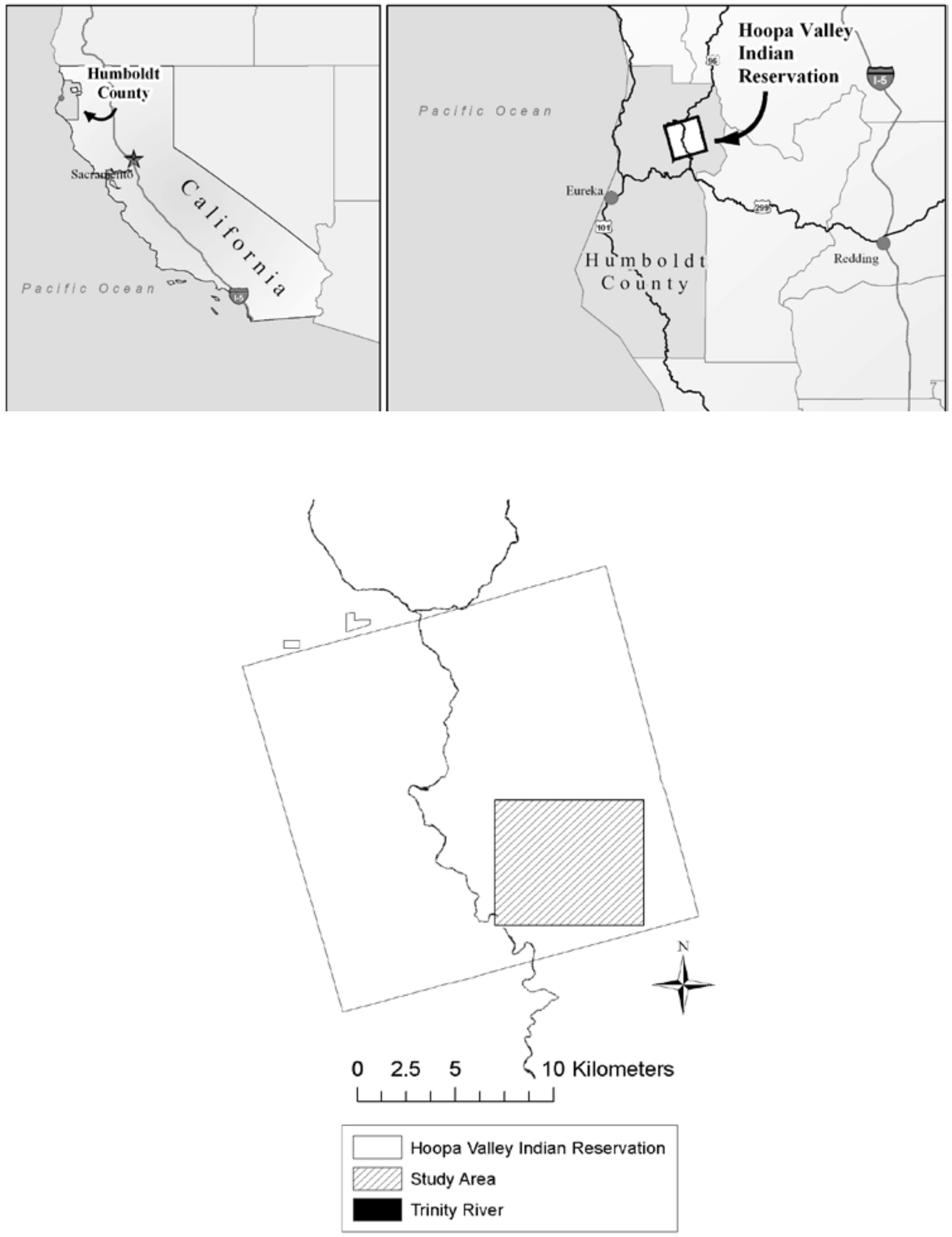

Figure 1. Diurnal rest site selection by ringtails was studied on the Hoopa Valley Indian Reservation, in northwestern California, USA. The study area on the reservation is drawn approximately; however, actual dimensions vary slightly.

METHODS

Trapping and Handling

Wire mesh live traps ranging in size from 13 x 13 x 41 cm to 25 x 31 x 81 cm (Tomahawk Live Trap Company, Tomahawk, Wisconsin, USA) were set in Winter 2008 using an assortment of baits (apples, chicken, peanuts, raisins, combination of apples and peanuts, or combination of jelly and peanuts). Although the objective of the study was to evaluate ringtail rest site selection at the landscape scale (2^{nd} order habitat selection; Johnson 1980), budget and time constraints made it impossible to place traps across the entire landscape of the HVIR. Traps were placed over several different drainages in order to distribute captures over a fairly large area (approximately 12 km^2) that would be representative of landscape scale habitat selection by the species. Within the drainages, traps were usually placed within 100 m of a drivable road.

Insulated wooden nest boxes were attached to traps in order to provide security, reduce environmental stress, and facilitate handling of trapped animals (Fowler and Golightly 1994, Gabriel and Wengert 2005). Mesh-handling cones were used to handle and weigh ringtails (± 10g). Each ringtail was anesthetized with ketamine (25 mg/kg) delivered by intramuscular injection. One first upper premolar was extracted using a "cat-size" dental extractor and aged by cementum annuli (Matson Laboratory, Milltown, Montana, USA).

Radio transmitters weighing approximately 20 g (Supply Two-Stage Transmitter, Sirtack Wildlife Tracking Solutions, Havelock North, New Zealand) attached to 1 cmwide collars were placed on adult ringtails; female ringtails weighing more than 700 g and males weighing more than 900 g were classified as adults upon capture (Callas 1987). Animal handling and techniques were approved by the Humboldt State University Institutional Animal Care and Use Committee (06/07.W.123-A).

Animal Locations

Radio-collared ringtails were located during the period of January 2008 through August 2008 using a hand-held 2-element Yagi antenna and a receiver (RA-14, Telonics Inc., Mesa, Arizona, USA). Radio transmitters were equipped with an activity processor and used to determine activity, inactivity, and mortality. Inactive signals were followed to diurnal rest sites where ringtails were located. To ensure that locations were independent of one another, each was separated by a period of at least 18 hours for each animal. Separating locations over a period of at least 18 hours allowed ringtails to become active during the night and make a new decision about which rest site to occupy on the following day. A minimum of one rest site per week was obtained for each individual ringtail to distribute locations evenly across the period of January 2008 through August 2008. Locations of ringtail rest sites were recorded with a Global Positioning System (GPS; Rhino 120, Garmin International Inc., Olathe, Kansas, USA), using a 12 m accuracy, and incorporated into a Geographical Information System (GIS) layer using ArcGIS software (ver. 9.3, Environmental Research Systems Institute, Inc., Redlands, California, USA).

Habitat Sampling

I used Hoopa Valley Tribal Forestry's GIS data, which was developed from aerial photographs, timber cruises and timber harvest data (Higley and Carlson 2008). The Tribe's GIS data allowed me to generate digital maps of slope, elevation, aspect, roads, water, and vegetation characteristics in my study area (Table 1). Habitat at ringtail rest sites were compared to available habitat. Vegetation type and type of vegetation edge were categorical variables. I chose to use young forest as a reference category. All associations of vegetation use were made in comparison with the use of young forest vegetation. Because aspect is a circular statistic, it was linearized using the equation:

[1 – Cosine (aspect in radians)] + [1 – sine (aspect in radians)]

so that mesic, northeasterly aspects had low values and xeric, southwesterly aspects had high values (Ford et al. 2002).

Thomas and Taylor (2006) identified 4 designs for analysis of habitat selection related to resource use and availability. I used a Design 1 analysis, where pooled use-data for all individuals were compared with availability-data for the study area. Using an RSF is not the ideal approach for a Design 1 analysis, as the mathematical requirements of the analysis may not be satisfied due to the lack of independence of locations of used units (McDonald et al. 2005). Additionally, a few animals might contribute disproportionately to the dataset (Thomas and Taylor 2006). In order to address these concerns, locations were weighted for equal sample sizes among individual animals, following an approach used by Ciarniello et al. (2007). Not all radio-collars persisted

Table 1. Classification of habitat components at the Hoopa Valley Indian Reservation (HVIR) in northwestern California, USA, that were measured using remote sensed Geographic Information Systems (GIS) coverages at ringtail (*Bassariscus astutus*) rest sites and at random available sites. All data used in the models came from the Hoopa Valley Tribal Forestry geodatabase (J.M. Higley, Hoopa Valley Department of Natural Resources, personal communication).

Habitat component	Description	Categorical classifications	Description of categorical classifications
Aspect [a]	Aspect of slope at site. (linearized using the equation: [1 – cosine (aspect in radians)] + [1 – sine (aspect in radians)])	Continuous	
Distance from road	Distance (m) to nearest road from site.	Continuous	
Distance from vegetation edge	Distance (m) to nearest vegetation edge from site.	Continuous	
Distance from water	Distance (m) to nearest perennial stream from site.	Continuous	
Elevation [a]	Elevation (m) at site.	Continuous	
Slope [a]	Percent slope at site.	Continuous	

Table 1 (continued). Classification of habitat components at the Hoopa Valley Indian Reservation (HVIR) in northwestern California, USA, that were measured using remote sensed Geographic Information Systems (GIS) coverages at ringtail (*Bassariscus astutus*) rest sites and at random available sites. All data used in the models came from the Hoopa Valley Tribal Forestry geodatabase (J.M. Higley, Hoopa Valley Department of Natural Resources, personal communication).

Habitat component	Description	Categorical classifications	Description of categorical classifications
Vegetation Type	\ Forest type based on age	Non-forested	Non-forested areas.
		Seedling	< 10 years of age
		Sapling, brushy pole	10 - 29 years of age.
		Young forest	30 – 80 years of age.
		Mature forest	> 80 years of age.
		Hardwood	Forest where hardwoods were the dominant tree species.

Table 1 (continued). Classification of habitat components at the Hoopa Valley Indian Reservation (HVIR) in northwestern California, USA, that were measured using remote sensed Geographic Information Systems (GIS) coverages at ringtail (*Bassariscus astutus*) rest sites and at random available sites. All data used in the models came from the Hoopa Valley Tribal Forestry geodatabase (J.M. Higley, Hoopa Valley Department of Natural Resources, personal communication).

Habitat component	Description	Categorical classifications	Description of categorical classifications
Type of vegetation edge	The closest type of vegetation edge.	Same categories as listed in the vegetation types on the previous page.	

[a]All topographic datasets were derived from 10 meter digital elevation models that were obtained from the Cal-Atlas Geospatial Clearinghouse (2008). Aspect and slope were calculated following the algorithm used by Burrough and McDonnell (1998).
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through the duration of the study, so only ringtails with at least 17 locations were used to build the RSF. If more than 17 locations were collected for an individual, locations were randomly eliminated until only 17 locations remained for that individual. This approach prevented an individual from contributing disproportionately to the analysis.

The largest area considered available to an animal, or population, is often designated as the study area (Buskirk and Millspaugh 2006). When examining landscape scale habitat selection, the study area has been determined by the researcher, and has been usually based upon a political boundary or upon animal movements (Thomas and Taylor 2006). The boundaries of the HVIR were much larger than the area where ringtails were trapped on the HVIR, and designating the entire reservation as the study area was inappropriate. Many studies investigating landscape scale habitat selection have combined the outer boundaries of animals' home ranges in order to designate a study area (Thomas and Taylor 2006). However, I collected only diurnal locations of ringtails and true home ranges could not be calculated. Thus, the study area was designated by the smallest rectangle that included all of the used ringtail rest site locations (Figure 1).

A common misconception is that the number of samples of used and random points must be equal. However, random points were used solely to obtain the RSF and were not treated as independent samples (Buskirk and Millspaugh 2006). The number of random points needed to sample resource distribution and abundance depends on the heterogeneity of the area to be sampled, with more heterogeneous environments requiring more points (Buskirk and Millspaugh 2006). Logistic regression is particularly robust to differences between the number of used and available points (Hosmer and Lemeshow 2000) and can cope with rather dissimilar use and availability samples (Buskirk and Millspaugh 2006). Using GIS, a large number of available points can be obtained to essentially produce a census of the available area (Buskirk and Millspaugh 2006). Thus, 1,000 available sites from within the study area were chosen at random in order to represent availability for ringtails in this study. When available sites overlapped used rest sites, they were sampled with replacement in order to produce an RSF that was robust to sample overlap (Johnson et al. 2006). An available site was considered overlapping when it came within a 25 m buffer of a used rest site.

Model Selection and Evaluation

The program NCSS (Version 2.0, NCSS Products, Kaysville, Utah, USA) was used to create a correlation matrix (Yeager 2005) to test for correlation among habitat components from used and available locations. Likewise, the Pearson correlation coefficient in NCSS was used to determine correlations between nominal variables (Yeager 2005). Highly correlated components ($r^2 \geq 0.60$; Meyer 2007) were eliminated from the analysis. A stepwise procedure was used as a variable reduction technique (Hosmer and Lemeshow 2000), and information-theoretic models (Burnham and Anderson 2002) with Akaike's Information Criteria (*AICc*; Akaike 1973) were used to rank habitat models in terms of parsimony and prediction (Apps et al. 2004). The deviance of each habitat model was compared to the deviance of the null model in order to determine how much variation in the data could be accounted for by each different model (Guisan and Zimmerman 2000).

Resource selection functions are frequently used to predict the probability of occurrence for many wildlife species (Ciarniello et al. 2007); however, it is important to evaluate their predictive capacity before use as a tool in a management situation (Johnson et al. 2006). In order to evaluate predictive power of the best model, *K*-fold cross validation of the data (Boyce et al. 2002, Johnson et al. 2006) was used. Cross validation can be used to evaluate spatially explicit RSF models by partitioning *K* random subsets from the original data. I randomly divided the animal locations into 5 equal-sized subsets, using Huberty's rule of thumb (Huberty 1994, Boyce et al. 2002) as a guideline. Four of these segments were used as training data in order to build the best model, and the remaining segment was used to test the model (Boyce et al. 2002, Fielding 2002).

A Spearman-rank correlation was calculated for each cross-validated observation to compare the relationship between the area-adjusted frequencies of cross-validation points within bins and their bin ranks (Boyce et al. 2002). As suggested by Boyce et al. (2002), predictions were divided into 20 equal-interval bins scaled between the minimum and maximum scores, and then simplified into 10 similar sized bins. I divided the frequency of cross-validated rest sites within a bin, by the number of available points that predicted values within the range of values in the bin in order to create area-adjusted frequencies (Boyce et al. 2002).

One advantage of cross validation was that it allowed for being able to examine how well model predictions were related to the index of probability of occurrence (Pearce and Boyce 2006). Area-adjusted frequencies were expected to be highly correlated with the predicted values when a model performed well and had high predictive power (Boyce et al. 2002). After the best model was selected, the Raster Calculator tool in the Spatial Analyst Extension of ArcGIS 9.3 (Environmental Research Systems Institute, Inc., Redlands, California, USA) was used to create a raster layer displaying an index of expected rest site use by ringtails throughout the HVIR.

RESULTS

Rest Site Use

The 19 ringtails (11 males, 8 females) were found in rest sites on 441 occasions. However, only 16 individuals (8 males, 8 females) had enough locations to be included in the analysis. There were 158 unique sites and ringtails were found re-visiting previous sites on 283 occasions. Rest sites were re-visited from 1 to 22 different times, and each site was re-visited a mean of 4.2 ± 0.6 ($\bar{x}$ ± *SE*) times. Males re-visited rest sites an average of 2.7 ± 0.5 times and females re-visited rest sites an average of 5.4 ± 1.0 times. Among 13 ringtails with 20 or more independent locations, the mean number of different rest sites was 12.8 ± 1.4 for males and 10.3 ± 1.5 for females. Ten sites were shared by 2 or more ringtails that used the same site, but at different times; and 8 sites were used concurrently, where 2 or more ringtails were located in the same site and at the same time (as defined in Callas 1987). Although these sites were used by more than one ringtail, every visit to the site after the first visit was considered a re-visit.

Of the 158 unique sites, 69 (43.7 %) were in cavities in live hardwood trees (Table 2) and from 111 of these unique rest sites located in trees, 25 (22.5 %) were in live black oaks (Table 3). Of the 283 occasions when ringtails were found re-visiting a rest site, 108 (38.2 %) of these re-visits were in live trees (Table 4). Ringtails re-visited rest sites located in trees on 240 occasions; Douglas-firs were re-visited on 127 (52.9 %) of these occasions (Table 5).

Table 2. Rest site type, number of times used (*n*), and percentage (%) of times used from 158 unique rest sites used by ringtails at the Hoopa Valley Indian Reservation in northwestern California, USA.

Rest site type	*n*	%
Cavity in live hardwood	69	43.7
Cavity in conifer snag	22	13.9
Rocky outcropping	16	10.1
Cavity in hardwood snag	13	8.2
Woodrat (*Neotoma fuscipes*) nest	11	7.0
Brush cover	8	5.1
Slash piles	8	5.1
Cavity in live conifer	7	4.4
Logs	3	1.9
Buildings	1	< 1.0

Table 3. Tree species, number of times used (*n*), percentage (%) of times used, and the mean ($\bar{x}$) and standard error (*SE*) of diameter at breast height (dbh) for each tree species from 111 unique ringtail rest sites that were located in trees, at the Hoopa Valley Indian Reservation in northwestern California, USA.

Tree species	*n*	%	$\bar{x}$ ± *SE* of dbh
Live black oak (*Quercus kelloggii)*	25	22.5	57.8 ± 3.6 cm
Douglas fir snag	22	19.8	132.1 ± 6.9 cm
Live tan oak (*Lithocarpus densiflorus*)	20	18.0	85.0 ± 5.6 cm
Live madrone (*Arbutus menziesii*)	17	15.3	103.4 ± 7.4 cm
Live Douglas-fir (*Pseudotsuga menziesii*)	7	6.3	112.2 ± 22.3 cm
Black oak snag	5	4.5	45.1 ± 6.2 cm
Live canyon live oak (*Quercus chrysolepis*)	5	4.5	106.7 ± 15.0 cm
Tan oak snag	4	3.6	81.9 ± 11.9 cm
Madrone snag	4	3.6	109.3 ± 25.6 cm
Live alder (*Alnus glutinosa*)	2	1.8	62.5 ± 1.3 cm

Table 4. Rest site type, number of times used (*n*), and percentage (%) of times used from 283 occasions when ringtails re-visited a rest site, at the Hoopa Valley Indian Reservation in northwestern California, USA.

Rest site type	*n*	%
Cavity in live tree	108	38.2
Cavity in conifer snag	91	32.2
Cavity in live conifer	36	12.7
Buildings	22	7.8
Cavity in hardwood snag	15	5.3
Rocky outcroppings	9	3.2
Slash piles, woodrat (*Neotoma fuscipes*) nests, or logs	2	< 1.0

Table 5. Tree species, number of times used (*n*), percentage (%) of times used, and the mean ($\bar{x}$) and standard error (*SE*) of diameter at breast height (dbh) for each tree species from 240 occasions when ringtails re-visited rest sites that were located in trees, at the Hoopa Valley Indian Reservation in northwestern California, USA.

Tree species	*n*	%	$\bar{x} \pm SE$ of DBH
Douglas-fir (*Pseudotsuga menziesii*)	127	52.9	147.7 ± 2.9 cm
Black oak (*Quercus kelloggii)*	42	17.5	57.8 ± 2.3 cm
Canyon live oak (*Quercus chrysolepis*)	31	12.9	92.2 ± 8.1 cm
Tan oak (*Lithocarpus densiflorus*)	22	9.2	83.5 ± 4.5 cm
Madrone (*Arbutus menziesii*)	16	6.7	112.8 ± 8.9 cm
Alder (*Alnus glutinosa*)	2	<1.0	62.5 ± 1.3 cm

Model Selection and Evaluation

The best model predicting ringtail rest site use was comprised of aspect, distance from vegetation edge, distance from water, elevation, slope, and vegetation type (Table 6; Table 7). This model was selected as the best model because it accounted for approximately 68 % of the *AICc* weights, while the next most competitive model accounted for only 20 % of the total *AICc* weights, and was 2.46 *AICc* points lower than the best model (Table 8). The best model explained 21.8 % of the deviance in the data, and the components elevation and vegetation type explained more than twice as much of the explained deviance as other components in the best model (Table 9).

Coefficients from the best model indicated that rest site use was positively associated with southwesterly aspects, distance from water, and steep slopes. Coefficients also indicated that rest site use was positively associated with hardwood (forest dominated by hardwood trees), sapling, brushy pole (forest between 10-29 years of age), and seedling vegetation types (forest younger than 10 years of age), relative to young forest vegetation (Table 10). Likewise, coefficients from the best model indicated that rest site use was negatively associated with non-forested vegetation (non-forested areas) distance from vegetation edge, and elevation (Table 10). Cross-validation suggested good predictive performance by the best model (Table 11), and provided evidence of good predictive power by the model (Boyce et al. 2002). A raster layer displaying an index of expected rest site use by ringtails was created for the HVIR (Figure 2).

Table 6. The mean ($\bar{x}$) and standard error (*SE*) of continuous habitat components for 272 rest site locations, and 1000 random available sites, that were used to build a resource selection function (RSF) generating an index of ringtail rest site use at the Hoopa Valley Indian Reservation in northwestern California, USA.

Variable	$\bar{x}$ ± *SE* of used sites	$\bar{x}$ ± *SE* of available sites
Aspect [a] of slope at site (linearized using the equation: [1 – cosine (aspect in radians)] + [1 – sine (aspect in radians)]	2.62 ± 0.04	1.89 ± 0.03
Distance to nearest road from site [a] (m)	157.19 ± 9.73	145.46 ± 4.43
Distance to nearest vegetation edge from site [a] (m)	66.68 ± 4.39	115.86 ± 3.79
Distance to nearest stream from site [a] (m)	142.53 ± 7.58	119.22 ± 3.45
Elevation at site [a] (m)	416.97 ± 12.68	497.11 ± 8.78
Percent slope at site [a] (%)	51.76 ± 0.94	42.64 ± 0.67

[a] See Table 1 for a description of each variable

Table 7. Number of times used (*n*), and percentage (%) of times used for 272 rest site locations, and 1000 random available sites, that were used to build a resource selection function (RSF) generating an index of ringtail rest site use at the Hoopa Valley Indian Reservation in northwestern California, USA, for categorical habitat components that were used to build the RSF.

Variable	*n*	% of used sites	*n*	% of available sites
Vegetation type [a]				
Hardwood	139	31.6	138	13.8
Mature forest	161	36.5	352	35.2
Non-forested	5	1.1	112	11.2
Sapling, brushy pole	63	14.3	99	9.9
Seedling	45	10.2	58	5.8
Young forest	28	6.3	241	24.1
Closest type [a] of vegetation edge				
Hardwood	89	20.1	178	17.8
Mature forest	160	36.3	334	33.4
Non-forested	62	14.1	59	5.9
Sapling, brushy pole	59	13.4	189	18.9
Seedling	20	4.5	59	5.9
Young forest	51	11.6	181	18.1

[a] See Table 1 for a description of each variable

Table 8. The best five candidate models, and the null model, predicting ringtail rest site use at the Hoopa Valley Indian Reservation in northwestern California, USA.

Model Parameter [a]	No. of parameters (K)	Akaike's criterion value (AICc)	Difference between AICc and the lowest-scoring model (Δ_i)	AICc weight (w_i)
Aspect, distance from vegetation edge, distance from water, elevation, slope, vegetation type	11	388.21	0.00	0.68
Aspect, distance from water, elevation, slope, vegetation type	10	390.67	2.46	0.20
Aspect, distance from road, distance from water, elevation, slope, vegetation type	11	392.66	4.45	0.07
Aspect, distance from water, elevation, slope, type of vegetation edge, vegetation type	15	396.05	7.85	0.01
Aspect, distance from vegetation edge, distance from water, elevation, vegetation type	10	396.30	8.09	0.01
Null	1	467.60	79.39	< 0.01

[a] See Table 1 for a description of habitat components used in the model structure.

Table 9. Residual deviance and its change when individual variables are removed from the best model predicting ringtail rest site use at the Hoopa Valley Indian Reservation in northwestern California, USA.

Component removed[a]	Residual deviance	Change in residual deviance
All (Null model)	935. 20	203.45
Elevation	802.07	70.32
Vegetation type	784.93	53.18
Aspect	756.47	24.72
Distance from water	755.34	23.59
Slope	752.03	20.28
Distance from vegetation edge	740.79	9.04
none (Best model)	731.75	0.00

[a] See Table 1 for a description of habitat components used in the model structure.

Table 10. Estimated coefficients and standard errors (*SE* ±) for habitat components used in the best model predicting ringtail rest site use at the Hoopa Valley Indian Reservation in northwestern California, USA.

Habitat Component[a]	Coefficient	*SE*	*P*
Aspect (radians)	0.5646	0.1182	< 0.01
Distance from vegetation edge (m)	-0.0039	0.0013	< 0.01
Distance from water (m)	0.0049	0.0010	< 0.01
Elevation (m)	-0.0044	0.0006	< 0.01
Slope (%)	0.0246	0.0056	< 0.01
Vegetation type			
Young forest	0.0000	0.0000	
Hardwood	0.4855	0.3120	0.12
Mature Forest	0.4802	0.3404	0.16
Non-forested	- 1.7098	0.6912	0.01
Sapling, brushy pole	1.6496	0.3673	< 0.01
Seedling	2.0912	0.4438	< 0.01

[a] See Table 1 for a description of habitat components used in the model structure.

Table 11. Cross-validated Spearman-rank correlations (r_S) between resource selection function (RSF) bin ranks and area-adjusted frequencies for individual data segments (Boyce et al. 2002) predicting ringtail rest site use at the Hoopa Valley Indian Reservation in northwestern California, USA ($df = 8$ for all data segments). Each segment contained 20 % of the data, and was reserved for testing against the remaining 80 % that was used to build the model. The bin rank and area-adjusted frequency were positively correlated for all individual data segments, suggesting good predictive performance by the best model (Boyce et al. 2002).

Segment	r_s	P
1	0.83	0.01
2	0.78	0.02
3	0.95	< 0.01
4	0.81	0.02
5	0.98	< 0.01

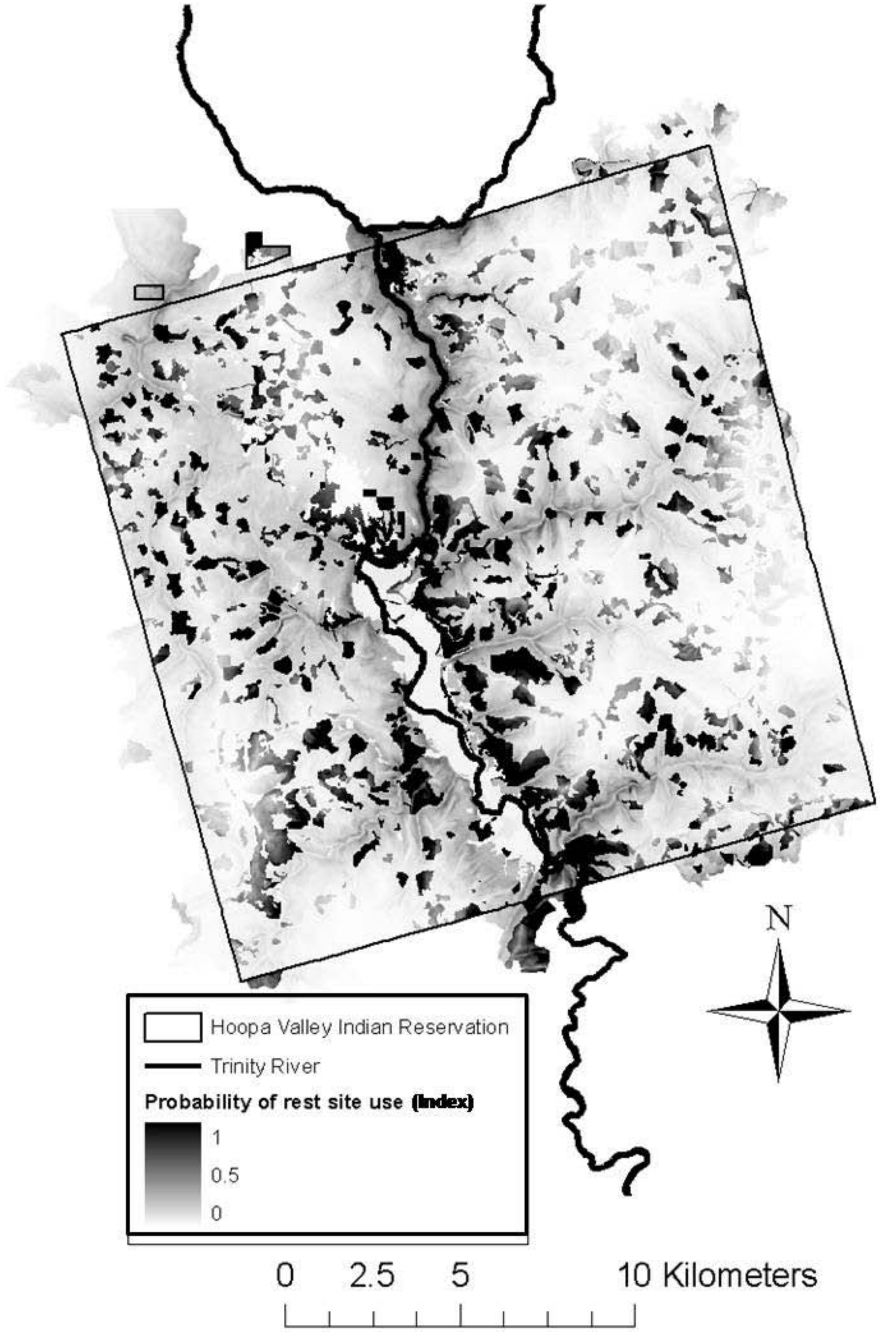

Figure 2. Map of the Hoopa Valley Indian Reservation in northwestern California, USA, displaying an index of probabilities of ringtail rest site use on the HVIR. Probabilities were generated through a Resource Selection Function (RSF) evaluating ringtail rest site selection at the landscape scale.

DISCUSSION

Rest Site Use

Ringtails used live trees, snags, rocky outcroppings, woodrat nests, brush cover, slash piles, logs, and buildings as rest sites. Similar structures have been used as rest sites by ringtails in other areas (Trapp 1978, Toweill and Teer 1981, Callas 1987, Chevalier 1989, Alexander et al. 1994). However, rocky outcroppings were the most commonly used type of rest site in arid areas (Trapp 1978, Chevalier 1989), whereas trees were the most commonly used type of rest site in forested areas (Callas 1987, Alexander et al. 1994). These patterns could be a result of the availability of these structures within a landscape. Alternatively, rocky sites may be used in arid areas because they offer favorable thermal conditions that aid in water economy (Chevalier 1989), or avoidance of predation.

Ringtails were found sharing rest sites, as documented previously (Toweill and Teer 1981, Callas 1987), and concurrent use was recorded between the same male and female ringtail on 8 occasions (7 occasions in the same tree and 1 occasion in a rocky outcropping). Callas (1987) recorded concurrent use by the same male and female ringtail on 4 occasions, as well as concurrent use between radio-collared and unmarked ringtails on 4 occasions. Female ringtails only appear to be receptive to males for a 24-hour period (Poglayen-Neuwall 1980), so a male may repeatedly share a rest site with a female in order to assess her condition in advance and ensure his presence during the time period when conception can occur (Callas 1987). Another explanation is that kin will use sites concurrently with each other. Alternatively, rest site sharing may occur because suitable rest sites are limiting (Lariviere 2004).

Model Selection and Evaluation

Evidence strongly suggested that elevation and vegetation type were the most important habitat components affecting rest site use by ringtails. Ringtails were positively associated with lower elevation sites as reported in northern California by Callas (1987) and the southern and central Sierras by Campbell (2004). Southern Oregon is the northern extent of the distribution of ringtails, and it appears they may be unable to tolerate extremely cold climates (Mugass et al. 1993). During the winter, lower elevations that receive less snowfall would remain warmer than high elevations that receive abundant snowfall, and may explain why ringtails use rest sites in lower elevations. Additionally, snow at higher elevations may limit access to food resources and may be another explanation for the use of lower elevation rest sites.

Sapling, brushy pole (forest between 10-29 years of age) and seedling vegetation (forest younger than 10 years of age) had the strongest positive association with rest site use, relative to young forest vegetation (forest between 30-80 years of age). Callas (1987) suggested that ringtails avoided clear-cut and shrub stage vegetation lacking trees and snags. Hoopa Valley Tribal Forestry has practiced silvicultural techniques retaining residual legacy trees and snags (Wilson and Carey 2000) in shrub stage vegetation used by ringtails in this study, and this may have been one of the reasons for the positive association with this vegetation type. Additionally, sapling, brushy pole and seedling vegetation offer an abundance of food resources for ringtails. Alexander et al. (1994) found that the diet of ringtails in southwestern Oregon was omnivorous, and comprised of high proportions of plant matter (*Abies* and *Rubus spp*.) and small rodents. In sapling, brushy pole and seedling vegetation these resources are abundant (Vergara and Simonetti 2004). Retaining suitable legacy trees and snags in recently harvested vegetation may increase rest site availability for ringtails because of the combination of cover and food that these areas offer.

Mature forest vegetation (forest older than 80 years of age) would seem to offer more potential rest sites in large trees compared to sapling, brushy pole and seedling vegetation. Mature forest vegetation was observed being used by ringtails in this study, but relative to young forest vegetation, did not have as strong of a positive association with rest site use as did sapling, brushy pole, or seedling vegetation. At the HVIR, mature forest vegetation is frequently used by fishers (Yeager 2005), and ringtails may be pushed into sapling, brushy pole and seedling vegetation due to the presence of fishers, or other predators, in forest vegetation with larger trees (Dark 1997, Campbell 2004). Another explanation is that food resources are not as abundant in mature forest vegetation as in other vegetation types.

Sympatric carnivores including bobcats (*Lynx rufus*), gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), and spotted skunks (*Spilogale gracilis*) may also influence rest site selection by ringtails. Limited study of interactions between ringtails and other carnivores has occurred (Trapp 1978, Dark 1997, Campbell 2004), but the effect of the presence of these carnivores on ringtail habitat selection is unknown. In a comparative study of ringtails and gray foxes in Utah, Trapp (1978) suggested that ringtails may require larger areas than gray foxes to satisfy their energetic requirements. Campbell (2004) found that ringtail presence was modeled more accurately at a 10 km^2 scale while gray fox presence was modeled more accurately at a 5 km^2 scale. Future studies examining ringtail rest site selection in relation to the presence of sympatric carnivores would add valuable insight into the effect of these influences on rest site selection.

Non-forested vegetation had the strongest negative association with rest site use relative to young forest vegetation. This association could be a function of rest site availability within non-forested vegetation, as non-forested vegetation offers few potential rest sites for ringtails. Predators of ringtails may also reside in non-forested vegetation and ringtails may avoid non-forested vegetation due to their presence. It is also possible that non-forested vegetation lacks food resources needed by ringtails. Another possibility is that proximity to human development and domestic animals negatively affects rest site use. Therefore, conversion of forested vegetation to non-forested vegetation is expected to decrease rest site availability (and presumably habitat in general) for ringtails.

Although elevation and vegetation type predicted ringtail rest site use better than any other habitat components, other habitat components may also affect rest site use. Rest site use was positively associated with xeric, southwesterly facing aspects, as also found by Poglayen-Neuwall and Toweill (1988) and Campbell (2004). Southwesterly facing slopes are generally warmer and drier than northeasterly facing slopes (Murphy and Weiss 1988), and using rest sites on these slopes may help ringtails tolerate the cooler temperatures of northern California and southern Oregon.

Probability of ringtail rest site use decreased as distance from vegetation edge increased. Similar results were observed by Dark (1997) who reported that ringtails were detected more often in areas near vegetation edges. Dark (1997) utilized track-plate detections to make inferences about ringtail habitat selection, and this could be expected to characterize foraging selection better than rest site selection. Ringtails may forage near vegetation edges because of a greater diversity of food items in these areas (Dark 1997), and use rest sites near vegetation edges in order to minimize the costs associated with searching for these food items.

As distance from water increased, so did probability of rest site use. In arid areas, ringtails are restricted to riparian areas due to limited water availability (Trapp 1978, Lacy 1983, Belluomini and Trapp 1984, Chevalier 1989). However, ringtails were positively associated with riparian areas in fine-scale analyses in northwestern California (Callas 1987). Conversely, in a landscape-scale analysis in northern California, Campbell (2004) did not detect an association between ringtails and riparian areas. Water is more readily available in northern California than in more arid areas, and proximity to water may have less of an influence on ringtail rest site use in this region. Alternatively, these patterns could be a result of a lack of consistency in definitions of riparian areas among studies. In this study, perennial streams were considered riparian areas, but intermittent and ephemeral streams were also present on the reservation, and were likely flowing at times.

Rest site use was positively associated with steep slopes, as was previously reported by Campbell (2004). It is unknown why ringtails would select rest sites in these areas; however, steep slopes seem to pose little problem for ringtails since they are excellent climbers (Trapp 1972). It is also possible that steeper slopes contain more available rest sites, as these areas are less likely to be influenced by human development.

By weighting locations for equal sample sizes among individual animals, individuals did not contribute disproportionately to the dataset. It is possible that individual preferences influenced the dataset; however, my approach built a model that characterized rest site use by the population, rather than the individual, on the HVIR.

When evaluating the best model, it is important to realize that trap placement provided an inherent bias in the model. Traps were usually placed within 100 m of a road in order to increase efficiency when checking traps. In addition, if a systematic grid of traps over the entire reservation could have been implemented, this bias might have been avoided.

The percent deviance explained by the best model (21.8 %) was fairly low, indicating that habitat components other than those measured here probably influence rest site selection by ringtails. These components could include such things as conspecifics, potential competitors, predators, and food resources. Future studies designed to directly measure these types of components in habitat models may provide for a better understanding of ringtail rest site selection. Habitat selection is a multi-scale process, and ringtails may also cue in on habitat components at finer spatial scales (Lawler and Edwards 2006). Future studies providing a multi-scale approach to rest site selection might provide a better overall understanding of habitat use by ringtails.

RECOMMENDATIONS

Cross-validation indicated good predictive performance by the best model (Table 11), suggesting that this model could be used to develop land management strategies that incorporate the needs of ringtails on the HVIR. Similar habitat models have been created for many federally listed endangered species (Fielding and Bell 1997, Boyce et al. 2002); however, no such model has been reported previously for ringtails.

Currently, there is only limited knowledge of ringtail population size on the HVIR, or in California (Williams 1986). Ringtail conservation needs have not been incorporated into management plans on public or private lands. The advantage of my model is that it gives managers the flexibility to evaluate different types of land management strategies. The model provides an indication of how different land management strategies would affect ringtail habitat on the HVIR, and could be used in developing forest management plans that consider ringtail conservation needs.

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PERSONAL COMMUNICATIONS

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