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MUIR WOODS INVENTORY OF SENSITIVE SPECIES IN OLD GROWTH FOREST: MAMMALIAN INVENTORY, SUMMER 1997, WINTER 1998

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Introduction

In 1989 the Superintendent of Golden Gate National Recreation Area (GGNRA) set two new objectives for natural resource management in the park. First, the park ecologist would begin inventorying wildlife resources. This objective recognized the need to manage dynamic processes and ecosystems for the conservation of biological diversity (Western and Pearl 1989). Second, the park would establish natural resource monitoring programs similar to programs at Channel Islands National Park (Davis and Halvorson 1988, Fellers et al. 1988). The GGNRA monitoring programs will be designed to detect changes in important natural resources and potential resource losses as a result of management actions (Cooperrider et al. 1986, Howell 1982, Howell 1985, Howell 1987, Thomas 1994), succession (McBride and Heady 1968), animal influences (Naiman 1988), fire (Thomas 1985) or global climate change (Smith and Tarpik 1989, USDI 1989, Burke and Kiester 1990).

This study is the first systematic inventory of mammals in the 90 year history of Muir Woods National Monument (NM). The study findings will be used to add wildlife presence and habitat use information to the quantitative baseline of park wide natural resources. Interpreters at Muir Woods NM will have the latest information about the species utilizing the park. Park managers can use the data for planning prescribed burns. We will attempt to make the data available through our GIS laboratory's on-line partnership with Silicon Graphics, Inc.

Study Site

Muir Woods National Monument is an old growth redwood and Douglas fir habitat that was isolated from other stands when coastal California habitat changed from forest to oak savanna during the last glacial retreat. This old growth grove was further isolated in the mid to late 1800's because its remote location was inaccessible to logging operations which provided lumber to San Francisco and the Bay Area. On January 9, 1908, President Theodore Roosevelt signed an Executive Order to create Muir Woods NM to protect one of the last old growth forests in the San Francisco Bay Area. Muir Woods was the sixth national monument created before the establishment of the National Park Service in 1916. Muir Woods NM encompasses 559 acres in the upper canyon of Redwood Creek which drains the south face of Mount Tamalpais, Marin County, California (Figure 1).

The climate of the area is Mediterranean, with summer droughts softened by coastal fog drip typical of forested north coastal California (SWA Group 1975). Annual precipitation for 1997 was 947 mm, and 1140 mm from January to April 1998. Muir Woods NM has a weather station on site. Elevation ranges from 37 m to 430 m (Martin and McBride 1979). The soil type is Centissima-Barnabe, derived from a complex of radiolarian chert, basalt, and sandstones of the Franciscan Formation (SWA Group 1975).

Muir Woods NM is dominated by a mosaic of old growth redwood, *Sequoia sempervirens*, and Douglas fir, *Pseudotsuga menziesii* (Howell 1970, Barbour and Major 1988). Additional tree species include California bay, *Umbellularia californica*, coast live oak, *Quercus agrifolia*, and tan oak, *Lithocarpus densiflora* (Howell 1970, Barbour and Major 1988). Under story vegetation includes huckleberry, *Vaccinium ovatum*, wild rose, *Rosa gymnocarpa*, redwood sorrel, *Oxalis oregana*, poison oak, *Toxicodendron diversilobum*, sword fern, *Polystichum munitum*, and lady fern, *Athyrium Filix-femina* (Howell 1970). Adjacent vegetation on the southwest side of Muir Woods NM was a mosaic of coastal scrub, consisting of coyote brush, *Baccharis pilularis* var. *consanguinea*, bush lupine, *Lupinus arboreus*, bush monkeyflower, *Mimulus aurantiacus*, poison oak, and a mixture of annual and perennial grasses including *Avena barbata* and *Festuca rubra* (Barbour and Major 1988). Adjacent vegetation on the northeast side of Muir Woods NM is a mosaic of coast live oak, California bay, and chaparral, *Adenostoma fasciculatum* (Barbour and Major 1988).

Methods

Study Plot Layout and Design

Ten transects with a total of 70 plots were established within Muir Woods NM in May, 1997. We stratified the habitats using an ArcView 3.0a version of Martin and McBride's (1979) vegetation map of Muir Woods. We used a 50 m grid overlay to randomly select starting points for the transects within habitats. Each point corresponded to the center of a grid cell. Two transects were placed in valley floor alluvial redwood stands. Four transects were placed in mid-slope habitats, two in redwood and two in Douglas fir. Each valley floor and mid-slope transect had five plots at 30 m intervals along the same elevation contour. Four transects were established on the ecotone of the redwood forest. Two ecotone transects were randomly placed on the east side of the canyon, the other two ecotone transects were randomly placed on the west side of the canyon. Each ecotone transect had ten plots at 30 m intervals. The ecotone transects began 30 m from the line of the ecotone with five plots projecting into the forest and five plots projecting into the adjacent habitat (Fig. 1).

Each plot was sampled for ten consecutive days, weather permitting. Study plot habitat is in the process of being sampled and characterized for vegetation and location using the modified protocol established for the fire monitoring program (Howell and Barrett 1998). The study plots were sampled for wildlife twice each year, in late winter and summer, and once for vegetation and location.

Data sheets were developed for trapping and track plate observations and incidental observations. At the end of each sampling day, data were entered into a computer database by either Earthwatch volunteers or by the wildlife technician. Data entered by volunteers were reviewed by the wildlife technician and edited by the principal investigator.

Mammal Inventory

Small mammal trapping was accomplished using 20-cm Sherman live traps (H.J. Spencer & Sons, P.O. Box 131, Gainesville, FL 32602) baited with peanut butter and rolled oats (Davis 1982, Dedon and Barrett 1982, Cooperrider et al. 1986). In 1998, a smaller (5x6x15 cm) live trap was used in addition to the 20-cm live trap to assess the capture success of each trap. Captured mammals were marked with metal ear tags (size 1005-1, National Band and Tag Co., P.O. Box 430, Newport, KY 41072) for later identification.

Searches were conducted around each plot for evidence of red tree vole, *Phenacomys longicaudus*, forag-

ing, although Muir Woods is outside this species' reported range (Zeiner et al. 1990). Carnivorous mammals were sampled using sooted track plates (Barrett 1983, Taylor and Raphael 1988) baited with canned cat food. Cat food cans were punctured and left for the 10-day sampling period. When cans disappeared they were replaced with new cans. Track plates (40 x 80 cm aluminum sheets) were laid out for the 10-day inventory period, checked daily and recovered at the end of the period. Tracks were circled daily to avoid double counting tracks.

Remote Cameras

In 1998, remote cameras were set near four transects during the spring sampling periods. The first camera set was operated in the valley floor (March 4 through March 11, 1998); the second camera set was operated above the Ocean View Trail. The third and fourth camera sets were operated along the Dipsea Trail in Douglas fir forest, and along the Deer Park Fire Road in mixed oak/grassland habitat during the second trapping session (March 26 through April 2, 1998). The fourth camera set on the Deer Park Fire Road remains in place and is checked weekly. Cameras on designated trails were programmed to take pictures between dusk and dawn to avoid taking pictures of people during the day. All cameras were checked daily and the number of animals detected and pictures taken were recorded. Film and batteries were replaced as necessary.

Incidental Observations

Incidental wildlife observations were recorded as the study teams walked to and from the plots.

Species Identification

Species were identified using standard field guides (Stebbins 1985, Jameson and Peeters 1988) and reference specimens obtained from the California Academy of Sciences.

Collections

Specimens were collected when animals died in traps and are currently being stored at the USGS-BRD Golden Gate Field Station. Suitable specimens will be prepared as museum skins and skulls, accessioned into the National Park collection, and housed at the California Academy of Sciences, San Francisco, or the Museum of Vertebrate Zoology, University of California, Berkeley.

Special Considerations

Handling of live animals followed the Center for Disease Control guidelines for sampling small mammals in the field that may be infected with Hantavirus. Workers wore latex gloves, eye protection, and half-face mask-respirator with canister filters for dust, fumes, mist, asbestos, and radionuclides. After handling animals, workers washed with detergent and cleaned the face mask with spray disinfectant. At the end of sampling, traps were soaked and washed in 10 percent bleach solution. Rabies was a very minimal risk since carnivores were not handled.

Facilities and Equipment

This project utilized the field equipment and geographic information system facilities of the Golden Gate Field Station at Ft. Cronkhite, Bldg. 1063, Marin Headlands, Golden Gate NRA.

Permits

An addendum to the USGS-BRD Golden Gate Field Station NPS research and collecting permit issued by MUWO/GOGA was obtained prior to beginning the inventory. We followed the animal use protocol (no. R90-0105-1290) and procedures approved by U.C. Berkeley on February 14, 1990.

Results

The 1997 summer sampling occurred in two intervals, June 20 through June 27 and July 16 through July 23. Thirty plots were sampled along the Deer Park Fire Road in June, consisting of 20 plots on redwood ecotone transects and 10 plots on mid-slope redwood transects. In July, the remaining 40 plots were sampled, including 20 valley floor plots and 20 ecotonal plots. The 1998 late winter sampling occurred March 3 through March 12 and March 26 through April 2. The latter sampling period was cut short due to unusually cold and rainy weather that endangered animals caught in traps. The sessions were reversed from 1997, with the Deer Park Fire Road transects sampled after the valley floor transects.

Mammal Inventory

Eighteen species of mammals were detected at Muir Woods NM (Table 1). The two forest types, redwood

and Douglas fir, had the greatest numbers of detection, 13 mammal species each. The grassland sites had 10 detections of mammal species. Coast live oak and California bay had three and six mammal detections, respectively. Striped skunk was detected only in California bay stands.

We observed a significant difference between seasons in mean detection for two species (Table 2). The opossum had a lower winter mean detection per plot while the raccoon had a higher winter mean detection per plot.

We used a Kruskal-Wallis (K-W) non-parametric analysis of variance (ANOVA) to determine if species had a preference for the valley floor, mid-slope or the upper slope ecotonal sites. Three species were detected more frequently on the valley floor, while the opossum was detected more frequently on the valley floor and mid-slope (Table 3). K-W ANOVA showed six species with a significantly higher detection frequency by habitats along the ecotonal transects (Table 4). Four of these species were detected exclusively in the grassland (Table 4). Raccoon detection was highest in redwood, and dusky-footed woodrat detection was highest in Douglas fir. We used K-W ANOVA to analyze habitat preferences for species at mid-slope plots. The raccoon had a significant selection for redwood and gray squirrel and spotted skunk preferred Douglas fir (Table 5). Valley floor transects are exclusively within redwood habitat, so habitat selection along these transects was not analyzed.

We conducted paired T-tests, given unequal variance, to determine habitat preferences for mammal species between the two forest types and between the two forest types and grassland. As with the K-W ANOVA, raccoon preferred redwood and dusky-footed woodrat preferred Douglas fir (Table 6). Five had a preference for redwood over grassland: opossum, Trowbridge's shrew, gray squirrel, gray fox and raccoon. Five species had a preference for Douglas fir over grassland: opossum, gray squirrel, dusky-footed woodrat, raccoon, and spotted skunk.

Table 1. Average number of individuals detected per plot, by species and habitat.
Muir Woods National Monument, California, 1997-1998.

Species ^a	Redwood	Douglas Fir	Coast Live Oak	California Bay	Annual grasses
California newt	0.0000	0.0000	0.0000	0.0000	0.0500
Opossum	0.1100	0.0938	0.0000	0.0000	0.0000
Trowbridge's shrew	0.1400	0.0625	0.2500	0.5000	0.0000
Shrew sp.	0.0250	0.0000	0.0000	0.5000	0.0000
Sonoma chipmunk	0.0375	0.0625	0.0000	0.0000	0.0000
Western gray squirrel	0.0500	0.1300	0.0000	0.0000	0.0000
Western harvest mouse	0.0000	0.0000	0.0000	0.0000	0.5000
Deer mouse	1.7000	1.6300	0.2500	3.0000	1.2500
Dusky-footed woodrat	0.0125	0.1600	0.0000	0.5000	0.0000
Meadow vole	0.0000	0.0000	0.0000	0.0000	0.1000
Coyote	0.0125	0.0313	0.0000	0.0000	0.0000
Domestic dog	0.0000	0.0000	0.0000	0.0000	0.0500
Gray fox	0.2100	0.1300	0.0000	0.0000	0.0500
Raccoon	0.4800	0.1900	0.7500	0.5000	0.0000
Striped skunk	0.0000	0.0000	0.0000	0.5000	0.0000
Spotted skunk	0.2400	0.2800	0.0000	0.0000	0.1000
Domestic cat	0.0000	0.0313	0.0000	0.0000	0.0500
Bobcat	0.0125	0.0000	0.0000	0.0000	0.0000
Total Species	13	13	3	6	10

^aspecies' scientific names are given in Appendix A.

Table 2. Seasonal differences in species detections (t-test).
Muir Woods National Monument, California, 1997-1998.

	Mean Detections		Significance	Unequal Variance
	Summer (n=69)	Winter (n=70)	2-tailed	
Opossum	0.1600	0.0143	0.0200	yes
Raccoon	0.1000	0.6000	0.0000	yes

There were no seasonal differences for the remainder of species.

Table 3. Species detected more frequently based on transect location (Kruskal-Wallis Test), n = 138.
Muir Woods National Monument, California, 1997-1998.

Species	Transect location	Significance
Opossum	valley, mid-slope	0.001
Trowbridge's shrew	valley	0.012
Sonoma chipmunk	valley	0.026
Deer mouse	valley	0.001

Table 4. Species detected more frequently based on habitat along ecotonal transects (Kruskal-Wallis Test), n=80. Muir Woods National Monument, California, 1997-1998.

Species	Habitat type	Significance
California newt	Annual grasses	0.061
Western Harvest Mouse	Annual grasses	0.000
Dusky-footed woodrat	Douglas fir	0.012
Meadow vole	Annual grasses	0.061
Domestic dog	Annual grasses	0.061
Raccoon	Redwood	0.006

Table 5. Species detected more frequently based on habitat along mid-slope transects (Kruskal-Wallis Test), n=40. Muir Woods National Monument, California, 1997-1998.

Species	Habitat type	Significance
Western gray squirrel	Douglas fir	0.076
Spotted skunk	Douglas fir	0.009
Raccoon	Redwood	0.002

Only 2 habitats were sampled: Redwood and Douglas fir.

Table 6. Species detection differences between selected habitats (t-test). Muir Woods National Monument, California, 1997-1998.

Species	Average number of individuals detected per plot					
	Redwood/Douglas Fir		Redwood/Grassland		Douglas Fir/Grassland	
	n = 80/32	Sig.	n = 80/20	Sig.	n = 32/20	Sig.
Opossum			0.11/0.00	0.028	0.09/0.00	0.083
Trowbridge's shrew			0.14/0.00	0.002		
Western gray squirrel			0.05/0.00	0.045	0.13/0.00	0.103
Dusky-footed woodrat	0.01/0.16	0.082			0.16/0.00	0.057
Spotted skunk					0.28/0.10	0.094
Gray fox			0.21/0.05	0.038		
Raccoon	0.48/0.19	0.022	0.48/0.00	0.000	0.19/0.00	0.032

Incidental Observations

Ten direct and indirect observations of mammals and one bird were recorded during the summer inventory (Table 7). Twenty-four direct and indirect observations of mammals and one reptile were recorded during the late winter inventory (Table 8).

Table 7. Incidental Observation Results, Muir Woods National Monument, California, Summer, 1997.

Species	Observations	Evidence	Habitat(s)
Northern spotted owl	1	Pellet	Redwood
Sonoma chipmunk	3	Sightings	Redwood
Black-tailed deer	7	Sightings, scats	Redwood

Table 8. Incidental Observation results, Muir Woods National Monument, California, Winter, 1998.

Species	Observations	Evidence	Habitat(s)
Western fence lizard	1	Sighting	Chaparral
Gray squirrel	1	Tracks	Redwood
Coyote	4	Tracks	Douglas fir, Oak, Grassland
Domestic dog	1	Tracks	Douglas fir
Gray fox	3	Tracks, scats	Redwood, Oak
Raccoon	3	Tracks, scats	Redwood, Oak
Bobcat	3	Tracks, scats	Redwood, Oak
Black-tailed deer	9	Sightings, tracks, scats	Redwood, Douglas fir

Remote Cameras

Six species were photographed using remote cameras (Table 9). There were no observations with Camera 2 which was placed in Douglas Fir forest, March 4 - March 11.

Table 9. Mammals photographed by remote cameras, Muir Woods National Monument, California, 1998.

Species	Number of Individuals Photographed		
	Camera 1 / Redwood March 4-11	Camera 3 / Douglas fir March 26-April 2	Camera 4 / Oak, grassland March 26-April 9, May 4-29
Coyote		1	2
Gray fox			1
Raccoon	2		1
Striped Skunk			1
Black-tailed deer	2		9
Human		14	47

Discussion

The raccoon was the only species with higher preference for redwoods at Muir Woods. This may be due to this species' large home range, foraging habits and ability to learn to take bait along a trap line. More species had greater habitat preference for Douglas fir and grassland. Species detections in coast live oak and California bay were higher than expected because of extremely low numbers of plots in each habitat type ($n = 2$, $n = 1$ respectively). We excluded both habitat types from further analyses.

Seasonal differences in species detections may be due to habitat selection differences between seasons or may be a by-product of only two seasons of data. The high winter detection rate for the raccoon is most likely due to auto-correlation between transect plots caused by raccoons raiding plots in sequence.

It seems likely that Muir Woods mammal composition is influenced in large part by the fact that it is a small island of habitat in a mosaic of other habitats. Examples are the prevalence of gray squirrel at Douglas fir sites and spotted skunk foraging in a forest when it is normally regarded as a grassland species. The most often detected mammal was the deer mouse which is ubiquitous in habitats of West Marin County (Howell and Barrett, 1997). Habitat preference was clear for four grassland species. Sonoma chipmunks were readily observed in association with the food concession, although we did detect them in redwood and Douglas fir. Trowbridge's shrew was present in both forest types.

The remote cameras confirmed the presence of coyotes in or near the park. The Deer Park fire road adjacent to the southwest boundary does have domestic dogs, probably associated with joggers, even though they are not permitted. We also detected domestic cat tracks above the State park residences in Kent Canyon.

In closing, this was our first year of sampling and these results are preliminary. We know that shrew-moles, *Neurotrichus gibbsii*, and the broad footed moles, *Scapanus latimanus*, were also present on the valley floor. (Howell, J. A., personal observation).

We thank the NPS staff for assisting in obtaining a research and collecting permit from the park for this project. Muir Woods natural resource staff assisted with day-to-day management of the project. The NPS also provided the assistance of part-time interns and volunteers to help with field work.

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Appendix A. Terrestrial species observed during 1997-1998 inventory, Muir Woods National Monument, California.

Class	Order / Family	Common name	Species name
AMPHIBIANS			
	Salamandridae	California newt	<i>Taricha torosa</i> 173677
REPTILES			
	Iguanidae	Western fence lizard	<i>Sceloporus occidentalis</i>
MAMMALS			
	Marsupialia	Opossum	<i>Didelphis virginiana</i>
	Insectivora	Vagrant shrew	<i>Sorex vagrans</i>
		Trowbridge's shrew	<i>Sorex trowbridgii</i>
		Shrew mole	<i>Neurotrichus gibbsii</i>
		Broad-footed mole	<i>Scapanus latimanus</i>
	Rodentia	Sonoma chipmunk	<i>Tamias sonomae</i>
		Western gray squirrel	<i>Sciurus griseus</i>
		Western harvest mouse	<i>Reithrodontomys megalotis</i> 180
		Deer mouse	<i>Peromyscus maniculatus</i>
		Dusky-footed wood rat	<i>Neotoma fuscipes</i>
		Meadow vole	<i>Microtus californicus</i>
	Carnivora	Coyote	<i>Canis latrans</i>
		Domestic dog	<i>Canis familiaris</i> 10001
		Gray fox	<i>Urocyon cinereoargenteus</i>
		Raccoon	<i>Procyon lotor</i>
		Striped skunk	<i>Mephitis mephitis</i>
		Spotted skunk	<i>Spilogale gracilis</i> 500000
		Domestic cat	<i>Felis catus</i>
		Bobcat	<i>Felis rufus</i>
	Artiodactyla	Black-tailed deer	<i>Odocoileus hemionus</i> 10000