

Fisher Diet in the Klamath/North Coast Bioregion

By

Richard T. Golightly, Talitha F. Penland, William J. Zielinski, and J. Mark Higley.

FINAL REPORT TO

U.S. Fish and Wildlife Service Contract #113334J025
and
Scotia Pacific Contract # 8355

SUBMITTED BY

Humboldt State Sponsored Programs Foundation
Arcata, California 95521

Principal Investigator: Richard T. Golightly

June 2006

Suggested citation: Golightly, R. T., T. F. Penland, W. J. Zielinski, and J. M. Higley. 2006. Fisher diet in the Klamath/North Coast Bioregion. Unpublished report, Department of Wildlife, Humboldt State University, Arcata, California.

Abstract: We characterized the diet of fisher in the Klamath/North Coast Bioregion of northern California by collecting 388 fecal remains at four distinct study areas within the Klamath Bioregion and analyzing differences between the warmer and drier interior sites and the marine influenced coastal sites. Mammals, especially Sciuridae, were the most frequent food items (98.0% and 26.8% frequency of occurrence, respectively), which differed from previous reports of fisher diet from outside of California. Also, unlike fishers in other parts of their range, reptiles (24.5%), amphibians (2.1%) and insects (55.2%) were found in the diet. The diet was relatively diverse compared to other fisher diet studies, both within California and elsewhere in their continental range. Interior areas had more use of lizards, members of the family Talpidae, and deer (probably from carrion). On coastal sites, tree squirrels were used less, but woodrats (*Neotoma* sp.) were used more. Foodstuffs varied with season at interior sites, which was coincidental with more extreme weather change between seasons. Coastal areas had the greatest overall diversity. Fisher in the Klamath/North Coast Bioregion, and probably elsewhere in California, did not extensively use porcupines or members of the Leporidae family as reported elsewhere in their continental range. Fishers in the Klamath/North Coast Bioregion appeared to forage opportunistically, but mostly used prey within an optimal body-size range (woodrats and tree-squirrels). This body size selection probably resulted from the inability to make prolonged use of larger prey items and the inefficient energetic acquisition associated with smaller prey.

Dietary issues may influence wildlife management decisions. Consideration of fisher reintroductions into regions where they have been extirpated may have an affect on

other medium to small body-sized carnivores. Further, forest management practices, such as wildfire and fuels reduction, or vegetative changes at stand or landscape scales may impact prey populations, and consequently produce changes in fisher populations.

Introduction

The quality of habitat and subsequent population effects on fishers is in part dependent on adequate food resources (Bulmer 1975, Powell and Zielinski 1994, Bowman et al. 2006). Fishers in the western United States are missing from former portions of their range, especially in California and the Pacific Northwest (Zielinski et al. 1995, Aubry and Lewis 2003). In 2004, fishers in the 3 west-coast states were identified as potentially needing protection provided by the Federal Endangered Species Act (see Federal Register 69 FR 18770). Strategies to conserve fishers require knowledge of diet and nutrition as a part of habitat assessment and protection.

Fishers have been described as generalist predators (Powell 1981, Zielinski et al. 1999, Bowman et al. 2006), yet they have also been specifically associated with snowshoe hare (*Lepus americanus*; Bulmer 1975, Powell 1981, Kuehn 1989) and porcupine as prey (*Erethizon dorsatum*; Schoonmaker 1938, Powell 1981, Arthur et al. 1989). Bowman et al. (2006) reported a positive numerical response of fisher populations to these two prey items, but noted that alternative prey may have been important in years when hare populations were reduced. Fishers may be true generalists (eat everything they encounter) or simply have the ability to subsist by switching prey when primary or desirable food sources are not abundant. Implicit in prey switching is that the nutritional returns are better for some prey types (Powell 1979), consequently we would predict population level responses to availability of these more profitable prey items (see Bulmer 1975, Krivan and Sikder 1999). Thus it is important to distinguish between being a true-generalist and switching from favored prey.

Season may be expected to influence predation patterns. Prey use may differ between seasons with seasonal variations in prey availability, changing capture effort, or changes in energy demand of fishers. Many studies (Arthur et al. 1989, Kuehn 1989) of diet have not had adequate samples to investigate seasonal effects, while others (Zielinski et al. 1999) have made some seasonal inferences.

Fisher diet in the southern Sierra Nevada Mountains of California differed from fishers elsewhere in their continental range (Zielinski et al. 1999). The southern Sierra Nevada are at the most southern extent of the fisher's range. Diet in California should be expected to differ given that prey availability, prey distribution, weather and habitat also differ. Although still near the southern extent of the fisher's range, our study areas in northwestern California are approximately 600 km north of the southern Sierra Nevada (where Zielinski et al. [1999] studied diet) and represents a different ecological region (see Mayer and Laudenslayer 1988).

Habitat use by fishers in northwestern California differed with distance from the ocean (up to 150 km; Beyer and Golightly 1996, Dark 1997) and potential prey may also vary coincidentally with habitat changes. We had an opportunity to assess diet coincidental with 4 spatially explicit studies of fisher habitat in northwestern California. By using 4 separate sites within the same eco-region and at different distances from the coast, we examined variation in diet at a very fine scale within the region, but could also amalgamate our samples for a courser scale than most studies at a single site. We divided the eco-region into two areas that differed in habitat characteristics: one subject to marine influence and a second more mesic area inland from the coast (hereafter interior). Combined with the previous work of Zielinski et al.(1999) this regional scale comparison

may be useful for understanding the influence of prey on the absence of fishers where they previously existed (Grinnell et al. 1937, Zielinski et al. 1995), and to evaluate management actions to return fishers to these areas (see Lewis and Hayes 2004). Although detailed prey availability across the region was not known, the variation in diet across the sites within the region could also allow inferences as to whether fishers appeared to forage as opportunistic generalists, prey specialists, foraged consistent with optimal foraging theory, or a combination of these characteristics.

Methods

Our investigation of fisher diet was conducted at 4 areas within a region of northwestern California known broadly as the Klamath/North Coast Bioregion (as defined by the California Biodiversity Council; hereafter Klamath Bioregion). Each of the four sites was separated by 24 to 70 km from its nearest neighbor site. Fisher fecal samples were collected from 1992 to 1997 on private timberland near the coast in Humboldt County (hereafter Green Diamond lands), the Coffee Creek and Castle Crags areas of Shasta-Trinity National Forest in Shasta and Trinity Counties (hereafter Shasta-Trinity), the Pilot Creek and Cedar Gap areas of Six Rivers National Forest in Humboldt and Trinity Counties (hereafter Six Rivers), and the Hoopa Indian Reservation in Humboldt County. We collected scats between June 1994 and May 1997 at the Shasta-Trinity study area, between March 1994 and March 1997 at the Hoopa Indian Reservation, between July 1993 and April 1996 at the Six Rivers study area, and only during April and May of 1994 and March and May of 1996 on Green Diamond lands.

The Shasta-Trinity site (40°55'N 122°54'W) was furthest from the ocean (110 to 150 km), on lands managed by the U.S. Forest Service and Sierra Pacific Industries.

Predominant vegetation was conifer forests dominated by Douglas-fir (*Pseudotsuga menziesii*) and incense cedar (*Libocedrus decurrens*), and woodland communities dominated by oaks (*Quercus* spp.), big leaf maple (*Acer macrophyllum*), and gray pine (*Pinus sabiniana*; Dark 1997). The Trinity Mountains were between this site and the Pacific Ocean, blocking marine-coastal weather influences. The elevation ranged from 610-1500 m, temperature ranged between -6° C in the winter to 40° C in the summer (Dark 1997), and annual rainfall varied between 60 – 170 cm (Seglund 1995).

The Six Rivers site (40°39'N 123°46'W) was closer to the ocean, at 69 to 100 km from the coast. This site ranged in elevation from 600 to 1800 m (Zielinski et al. 2004). The Six Rivers study area was vegetated by Douglas-fir, white fir (*Abies concolor*), Oregon white oak (*Quercus garryana*), tanoak (*Lithocarpus densiflora*) and red fir (*A. magnifica*) along with some dry grasslands (Zielinski et al. 2004). Temperatures at this site ranged from -7° in the winter to 41° in the summer, and precipitation ranged from 150-200 cm/year (unpublished data, National Weather Service).

The Hoopa site (41°5'N 123°45'W) was approximately 42 km from the coast and ranged in elevation from 100-1075 m (Yaeger 2005). Temperature in Hoopa averaged 7° C in the winter and 21° C in the summer, and yearly average rainfall was 156 cm (Yaeger 2005).

Green Diamond lands (40°50'N 123°40'W) extended from the coast to 30 km inland and were subject to marine influences (Klug 1997). Coast redwood (*Sequoia sempervirens*) and Douglas-fir characterized the vegetation (Klug 1997). Elevation ranged from near sea level to 1400 m (Klug 1997). Average temperatures ranged between 8° C in the winter and 15° C in the summer (Klug 1997) and annual rainfall

averaged 95 cm and 150 cm on the coast and coastal mountains respectively (Thompson pers. comm.).

Shasta-Trinity and Six Rivers were distant from marine influences and for some analyses were combined to describe more xeric areas of the Klamath Bioregion. Both Hoopa and Green Diamond were closer to the coast, more subject to marine influences, and were combined for some analyses to represent coastal portions of the bioregion.

Fecal remains (hereafter scat) were collected opportunistically at den and rest sites, at occupied traps coincidental with other studies, or were encountered when following radio-marked fishers (Table 1). All 4 studies used radio telemetry, which enhanced our opportunity for finding scats and associating scats with known individual fishers (e.g. at rest sites). Individual scats were assessed in the field based on shape, cooberating evidence, and odor for inclusion in analyses. Scats from traps, at capture sites, rest sites or den sites were not blindly accepted as fisher scat, although their likelihood as being classified as originating from a fisher was great. Scats were also reassessed for correct taxon upon arrival in the lab and evaluated consistently by the same two personnel. Only scat that could reasonably be identified as fisher were included in the analyses. The scats were stored individually in sealed and labeled plastic bags in a freezer until they were processed.

Each scat was assigned a unique lab-identification number. Each scat was weighed (± 0.1 g) and placed into a knee-high nylon stocking into which unique combinations of colored plastic beads were used as identifying markers. To separate compacted fecal material, the stockings containing scats were soaked overnight in a dilute bleach solution (5 ml of bleach / 3 l of water) and then agitated in a mechanical

Table 1. Fisher fecal remains were collected from five sources within the four study sites in the Klamath Bioregion in northern California.

Site	n	Source (%)				
		Rest or Den Site ^a	Capture or Trap Site ^b	Telemetered Individual ^c	Road or Path ^d	Unknown
Shasta-Trinity	148	50	17	24	4	5
Six Rivers	152	61	33	2	0	4
Hoopa	64	25	73	0	0	2
Green Diamond	23	70	30	0	0	0

^a Scat collected at rest or den sites of known fishers that were radio-marked. Although synchrony between use of the site by the marked fisher and the scat deposition were uncertain, these co-occurred within a period as short as a few hours or as long as a few days.

^b Scat from inside or on traps visited by fisher, or from sooted track plates coincidental with identified fisher tracks.

^c Scat was obtained while following individuals with radio transmitters and were usually very fresh. These scat may have been associated with an undetected rest site.

^d Scat collected on roads or paths within the study area coincidental with searches for fisher with radio-transmitters.

washing machine for approximately 10 min (Johnson and Hansen 1977). The washed contents of each stocking were placed into aluminum pie tins and oven-dried at 70° C for 24 hours in a gravity convection oven (Precision Scientific Inc., Chicago Illinois). After oven drying, the samples were stored in glass desiccators until analyzed. Beginning with large items, the contents of the washed and dried scats were sorted into categories (e.g., bones, hair, and plant material). Using a dissecting microscope (Baush and Lomb Stereozoom 5; 0.8x-4x magnification), the remaining material was searched for a maximum of two hours to remove smaller fragments that could be categorized (Southern and Watson 1941, Golightly et al. 1994). All categorized items, as well as items that were not initially identifiable, were stored in airtight glass vials, labeled and reserved for later identification.

Identification of Fecal Contents

Items removed from scats were identified using reference collections at the Humboldt State University (Arcata, California) Vertebrate and Wildlife Museums. Additionally, we had local collections of skeletons, seeds, hair, and feather samples gathered from within the study areas. Reference carcasses were cleaned in total with dermestid beetles (*Dermestes* sp.). Reference texts (Hall and Kelson 1959, Ingles 1965, Stebbins 1966, Borror and White 1970, Goin et al. 1978, Milne and Milne 1980, Proctor and Lynch 1993) and identification keys (Mayer 1952, Day 1966, Adorjan and Kolenosky 1969, Brunner and Coman 1974, Moore et al. 1974, Schopmeyer 1974, Hickman 1993) were used to confirm identification. With the exception of mammalian hair, a dissecting microscope was sufficient to aid in the identification of items removed from scats.

In addition to macroscopic characteristics (e.g., length, color, overall shape), positive identification of mammalian hair often required the examination of a hair's microscopic features. These features included the hair core or medulla and the outer sheath of scales comprising the cuticle (Mayer 1952, Day 1966, Adorjan and Kolenosky 1969, Moore 1974). To observe patterns formed by cuticular scales, we used clear fingernail polish applied to 50-mm cover slips to make an impression of the hair's surface. First, a single coat of polish was allowed to dry at room temperature until no longer "tacky" when touched. A sample of hair removed from a scat was then placed on the polished surface of the cover slip. Turning the cover slip over so that the polished surface was in contact with the top of the microscope slide and examining it under a compound microscope yielded a positive impression of the hair's cuticular scale pattern. Impressions made from hairs found in scats were compared to a collection of impressions we made using the same technique from known specimens and photographs and keys in Mayer (1952), Adorjan and Kolenosky (1969), and Moore (1974).

Mammals were identified primarily by the presence of bone, hair, and teeth. As investigators gained knowledge of identified parts and digits with associated nails, mammalian nails could be distinguished from bird feet. Birds were identified primarily by the presence of feather and bone and, to a lesser extent, by toes and skin from the foot region. When eggshell was encountered in a scat, it was included as a single category. Reptiles and amphibians were primarily identified by the presence of bones, teeth, and/or scales. Vertebrae were used to distinguish between reptile and amphibian when scales were not also present in a scat. Both scales and vertebrae were used to distinguish between lizard and snake. Intact lizard feet or toes were also commonly encountered.

Insects and other arthropods were identified from undigested exoskeleton. Mollusks (Gastropoda) were identified from the presence of a spiral shell, which was readily distinguishable from that of avian eggshell. Identifiable plant material encountered in scats was separated into two categories: seed and vegetative material. Whenever possible, all items found in scats were identified to species.

Analyses

Species-level identification was not always possible. We amalgamated counts of all identifiable material at each taxonomic level. For example, a scat containing a tree squirrel identified to species would be included in the count of scats contributing to the appropriate species, family, order, and class. Consequently, sample sizes of scats for identified items would be larger at higher levels of taxonomy. For each identified species or taxonomic level, we counted all scats containing the item and reported frequency of occurrence. Frequency of occurrence was reported as a percentage (number of scats containing a food item divided by the total number of available scats in the sample strata and then multiplied by 100).

Statistical analyses were conducted between study sites and seasons, but not between consumed taxa. Cross-taxa comparisons were not possible due to problems with differential digestibility, variation in body parts consumed, and animal mass (Lockie 1959, Golightly et al. 1994). Further, not all taxa or taxonomic levels had adequate counts to allow statistical analysis. Using counts of scats, we used Chi-square to compare between seasons or sites (expected values were adjusted to reflect the appropriate number of available scats within a site or season for all categories, but not for categories with empty cells). Chi-square was used to compare between coastal and interior areas for

selected prey. We also ranked taxa at similar levels to identify most frequently used foods. We chose the 4 most frequently observed families to characterize each site. When we ranked families to determine the 4 most frequently used, we excluded insects and plant material and required the item be among the 4 most frequent taxa in at least 3 of the sites. Finally, we graphically plotted prey use in the families Leporidae (hereafter leporid), Canidae (hereafter canid), and Mustelidae (hereafter mustelid) across season and site in order to compare these items to important foods elsewhere in the range of the fisher, or because of special management considerations regarding these taxa. Seasons were defined as spring for 21 March - 20 June, as summer for 21 June - 20 September, as autumn for 21 September - 20 December, and as winter for 21 December - 20 March.

For comparison of diet diversity to the southern Sierra Nevada we computed a niche-breadth index (Levins index; Colwell and Futuyma 1971). Zielinski and Duncan (2004) provided their raw data so that we could recalculate their estimates of Levins index using criteria and assumptions consistent with our investigation. Calculations were based on the number of occurrences of each food item (Serafini and Lovari 1993). One difference between the data from the southern Sierra Nevada and our investigation was the older classification of Cricetidae used in Zielinski et al. (1999). We restructured their classifications within Muridae and ensured that occurrences were not double counted in any case. Additionally, we removed items in the scats that were probably incidentally ingested (vegetation associated with Pinaceae). Finally we provided separate calculations of niche breadth when all vegetative matter was removed from the calculations.

Results

Of the 388 fisher scats examined, 39% came from the Shasta-Trinity area, 39% were from Six Rivers, 17% were from the Hoopa Indian Reservation and 6% were from Green Diamond lands. The four most common classes of animal matter found in the scats were Mammalia (hereafter mammal), Aves (hereafter bird), Reptilia (hereafter reptile), and Insecta (hereafter insect). Of these four, remains of mammals and insects were more consistently found in scats throughout all seasons at all sites than were remains of reptiles and birds (Figure 1). Mammals were present in 88-98% of all scats at all sites (Table 2). Vegetation, especially the family Pinaceae (Table 2), was common at all sites.

The four families that we used for comparisons between seasons and between sites (determined by ranking of food items; Appendix A) were Sciuridae (hereafter sciurids), Cervidae (hereafter cervids), Muridae (hereafter murids), and Talpidae (hereafter talpids) (Figure 2). Family frequencies were less than class frequencies due to fewer identifications to family than to class (Table 2). Leporids, canids, and mustelids were less consistently found in scats at all sites during all seasons than the 4 highest ranked families (Figure 3). Leporids were consumed at all sites during the spring, and only scats from Six River contained small amounts of leporids in all seasons. Canids and mustelids were found in scats from the Shasta-Trinity, Six Rivers and Hoopa study areas.

The Shasta-Trinity study area had the greatest number of significant differences in diet across seasons for class and family (Table 3). Birds, reptiles and insects were consumed at significantly different frequencies between seasons at Shasta-Trinity, but

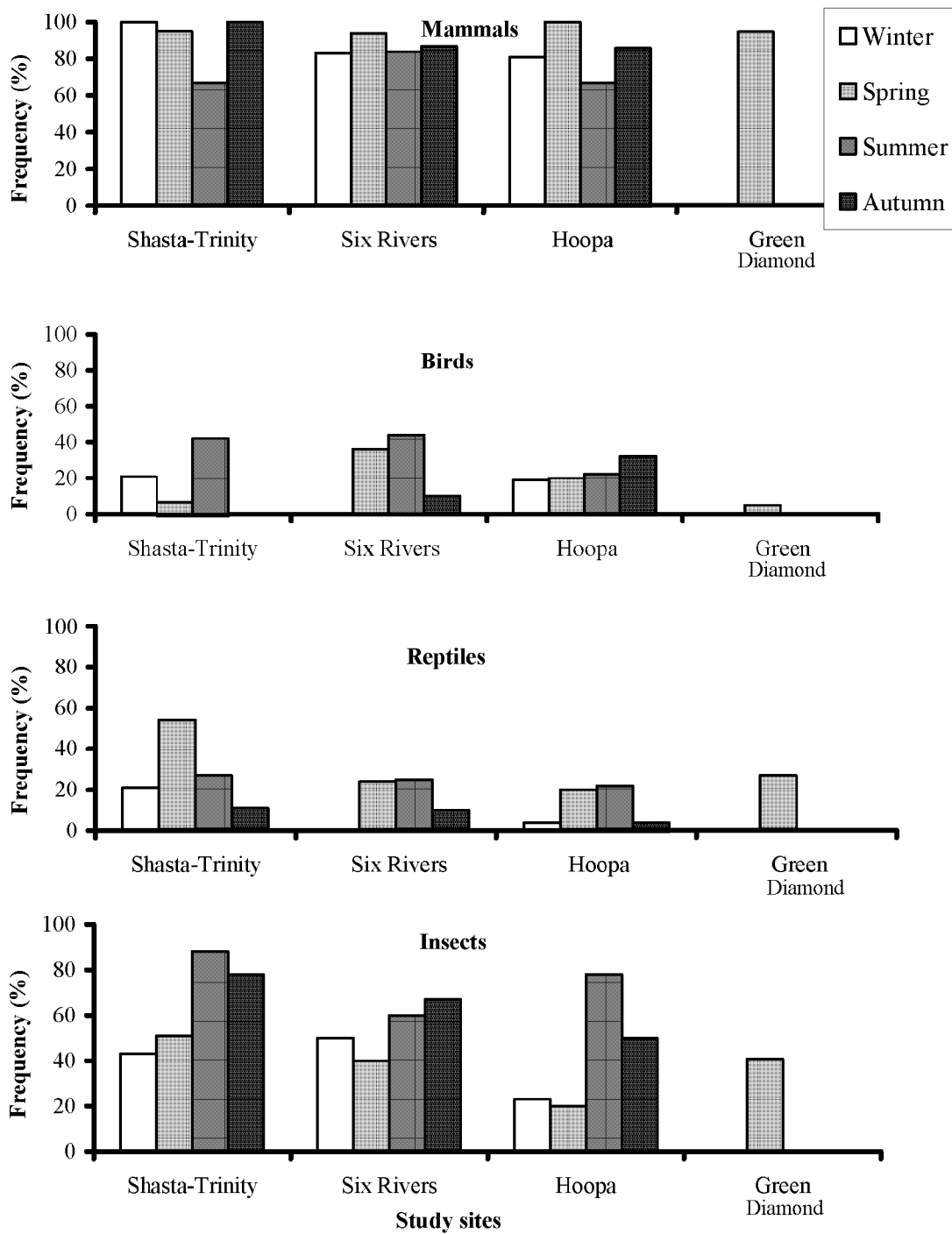


Figure 1. Relative frequency of major taxonomic groups in the diet of fisher from 4 study areas in the Klamath Bioregion of northern California varied across study sites. Mammals were consistently important in the diet across season and site. Only spring data was collected at the Green Diamond study area.

Table 2. Components of fecal remains were identified to the lowest taxonomic group possible. The total number of scats that contained the taxonomic group and the frequency of this taxonomic group were calculated for each study area. The frequency was calculated by taking the number of scats (n) containing the taxonomic component in each study area and dividing it by the total number of scats within that study area.

Taxa	Shasta-Trinity (n=148)		Six Rivers (n=152)		Hoopa (n=64)		Green Diamond (n=23)		Total (n=388)	
	n	%	n	%	n	%	n	%	n	%
Mammalia	131	88.5	149	98.0	59	92.2	22	95.7	361	93.0
Rodentia	61	41.2	83	54.6	33	51.6	16	69.6	193	49.7
Sciuridae	42	28.4	43	28.3	12	18.8	7	30.4	104	26.8
Sciurinae	35	23.6	39	25.7	10	15.6	1	4.3	85	21.9
<i>Sciurus griseus</i>	12	8.1	5	3.3	1	1.6	1	4.3	19	4.9
<i>Tamiasciurus douglasii</i>	1	0.7	6	3.9	6	9.4	0	0.0	13	3.4
<i>Eutamias sp.</i>	20	13.5	21	13.8	3	4.7	0	0.0	44	11.3
<i>Spermophilus sp.</i>	3	2.0	1	0.7	0	0.0	0	0.0	4	1.0
Pteromyinae (<i>Glaucomys sabrinus</i>)	5	3.4	5	3.3	2	3.1	4	17.4	16	4.1

Table 2 cont.

Muridae	15	10.1	36	23.7	17	26.6	10	43.5	78	20.1
Sigmodontinae	7	4.7	6	3.9	11	17.2	7	30.4	31	8.0
<i>Peromyscus sp.</i>	4	2.7	1	0.7	6	9.4	0	0.0	11	2.8
<i>Neotoma sp.</i>	2	1.4	4	2.6	7	10.9	7	30.4	20	5.2
Arvicolinae	3	2.0	23	15.1	6	9.4	4	17.4	36	9.3
<i>Clethrionomys sp.</i>	1	0.7	0	0.0	1	1.6	0	0.0	2	0.5
<i>Microtus sp.</i>	2	1.4	5	3.3	4	6.3	2	8.7	13	3.4
<i>Arborimus sp.</i>	0	0.0	14	9.2	1	1.6	0	0.0	15	3.9
Geomyidae (<i>Thomomys sp.</i>)	1	0.7	4	2.6	0	0.0	0	0.0	5	1.3
Insectivora	38	25.7	31	20.4	6	9.4	6	26.1	81	20.9
Talpidae	36	24.3	31	20.4	4	6.3	6	26.1	77	19.8
<i>Scapanus sp.</i>	28	18.9	22	14.5	3	4.7	4	17.4	57	14.7
<i>Neurotrichus gibbsii</i>	11	7.4	8	5.3	1	1.6	2	8.7	22	5.7
Soricidae (<i>Sorex sp.</i>)	4	2.7	0	0.0	2	3.1	0	0.0	6	1.5

Table 2 cont.

Artiodactyla (Cervidae)	28	18.9	45	29.6	8	12.5	0	0.0	81	20.9
Carnivora ^a	34	23.0	52	34.2	1	1.6	0	0.0	87	22.4
Canidae (<i>Urocyon cinereoargenteus</i>)	4	2.7	3	2.0	1	1.6	0	0.0	8	2.1
Mustelidae ^a	14	9.5	2	1.3	0	0.0	0	0.0	30	7.7
Mephitinae	14	9.5	1	0.7	0	0.0	0	0.0	15	3.9
<i>Mephitis mephitis</i>	3	2.0	1	0.7	0	0.0	0	0.0	4	1.0
Procyonidae (<i>Procyon lotor</i>)	0	0.0	4	2.6	0	0.0	0	0.0	4	1.0
Lagomorpha (Leporidae)	4	2.7	9	5.9	1	1.6	2	8.7	16	4.1
Chiroptera	3	2.0	0	0.0	0	0.0	0	0.0	3	0.8
Vespertilionidae (<i>Myotis sp.</i>)	2	1.4	0	0.0	0	0.0	0	0.0	2	0.5
Aves	36	24.3	47	30.9	17	26.6	1	4.3	101	26.0
Piciformes (<i>Colaptes auratus</i>)	2	1.4	1	0.7	1	1.6	0	0.0	4	1.0
Passeriformes	0	0.0	0	0.0	1	1.6	0	0.0	1	0.3

Table 2 cont.

Reptilia	53	35.8	30	19.7	6	9.4	6	26.1	95	24.5
Squamata	52	35.1	30	19.7	6	9.4	6	26.1	94	24.2
Sauria	30	20.3	21	13.8	3	4.7	2	8.7	56	14.4
Serpentes	5	3.4	4	2.6	1	1.6	4	17.4	14	3.6
Amphibia (Caudata)	2	1.4	2	1.3	3	4.7	1	4.3	8	2.1
Unknown Vertebrate	7	4.7	21	13.8	10	15.6	2	8.7	40	10.3
Insecta	97	65.5	82	53.9	26	40.6	9	39.1	214	55.2
Hymenoptera	64	43.2	54	35.5	10	15.6	0	0.0	128	33.0
Vespidae (<i>Vespula</i> sp.)	29	19.6	31	20.4	4	6.3	0	0.0	64	16.5
Formicidae	46	31.1	24	15.8	4	6.3	0	0.0	74	19.1

Table 2 cont.

Orthoptera	13	8.8	6	3.9	0	0.0	0	0.0	19	4.9
Gryllacrididae (<i>Stenopelmatus fuscus</i>)	11	7.4	1	0.7	0	0.0	0	0.0	12	3.1
Acrididae	1	0.7	5	3.3	0	0.0	0	0.0	6	1.5
Coleoptera	38	25.7	23	15.1	17	26.6	3	13.0	81	20.9
Mallophaga	1	0.7	3	2.0	0	0.0	0	0.0	4	1.0
Diptera	0	0.0	0	0.0	0	0.0	1	4.3	1	0.3
Other Invertebrates	3	2.0	7	4.6	3	4.7	4	17.4	17	4.4
Acarina (tick)	1	0.7	2	1.3	3	4.7	2	8.7	8	2.1
Araneida (spider)	1	0.7	1	0.7	0	0.0	0	0.0	2	0.5
(snail)	1	0.7	3	2.0	0	0.0	0	0.0	4	1.0

Table 2 cont.

Seed:	26	17.6	51	33.6	51	79.7	3	13.0	131	33.8
Ericaceae	4	2.7	5	3.3	10	15.6	0	0.0	19	4.9
<i>Vaccinium sp.</i>	0	0.0	4	2.6	10	15.6	0	0.0	14	3.6
<i>Arctostaphylos sp.</i>	4	2.7	1	0.7	0	0.0	0	0.0	5	1.3
Rosaceae (<i>Rubus sp.</i>)	6	4.1	10	6.6	5	7.8	0	0.0	21	5.4
Vitaceae (<i>Vitis sp.</i>)	0	0.0	0	0.0	2	3.1	0	0.0	2	0.5
Poaceae	0	0.0	0	0.0	0	0.0	1	4.3	1	0.3
Unk. Tiny, oblong seed	9	6.1	0	0.0	20	31.3	2	8.7	31	8.0
Misc. unknown seed	5	3.4	0	0.0	1	1.6	0	0.0	6	1.5
Vegetation (e.g., leaves):	133	89.9	129	84.9	41	64.1	17	73.9	320	82.5
Pinaceae	126	85.1	125	82.2	32	50.0	13	56.5	296	76.3
Cupressaceae	19	12.8	6	3.9	0	0.0	0	0.0	25	6.4
Poaceae	13	8.8	8	5.3	1	1.6	0	0.0	22	5.7

Table 2 cont.

Other Materials:

Eggshell	7	4.7	8	5.3	0	0.0	0	0.0	15	3.9
Rock	64	43.2	34	22.4	30	46.9	1	4.3	129	33.2
Artificial	16	10.8	20	13.2	17	26.6	2	8.7	55	14.2

^a Does not include fisher (*Martes pennanti*). Fisher guard hairs were often found in fisher scats. It was assumed that their presence in the scats resulted from the animal grooming itself. Only one scat from the Pilot Creek sample contained identifiable fisher remains other than hair (a lower jaw fragment and teeth from an adult animal). It was assumed that the presence of these remains resulted from one fisher scavenging on the carcass of another fisher.

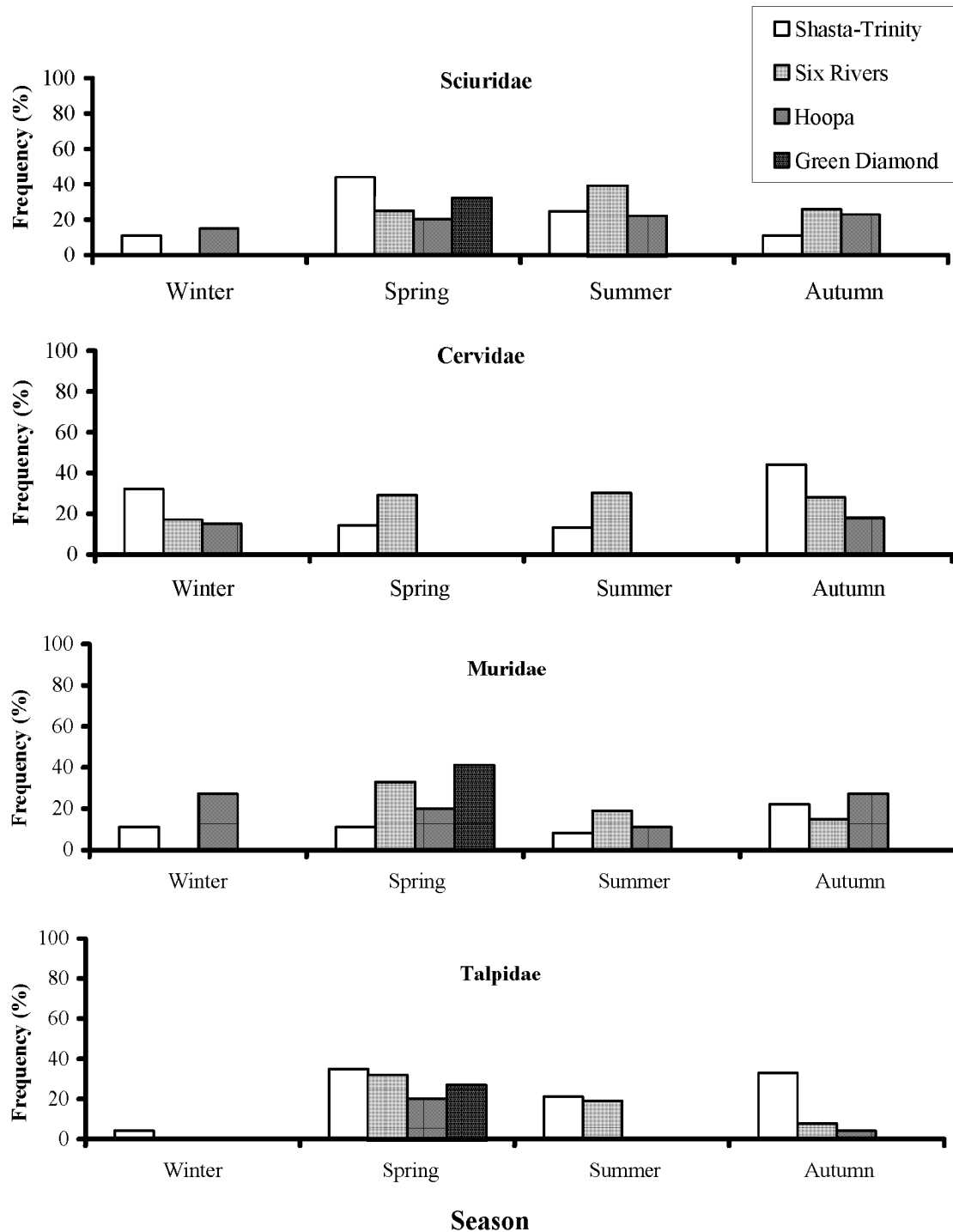


Figure 2. The four most frequent family level diet components of fishers from four study areas in the Klamath Bioregion of northern California were compared across seasons. Only spring data was collected at the Green Diamond study area.

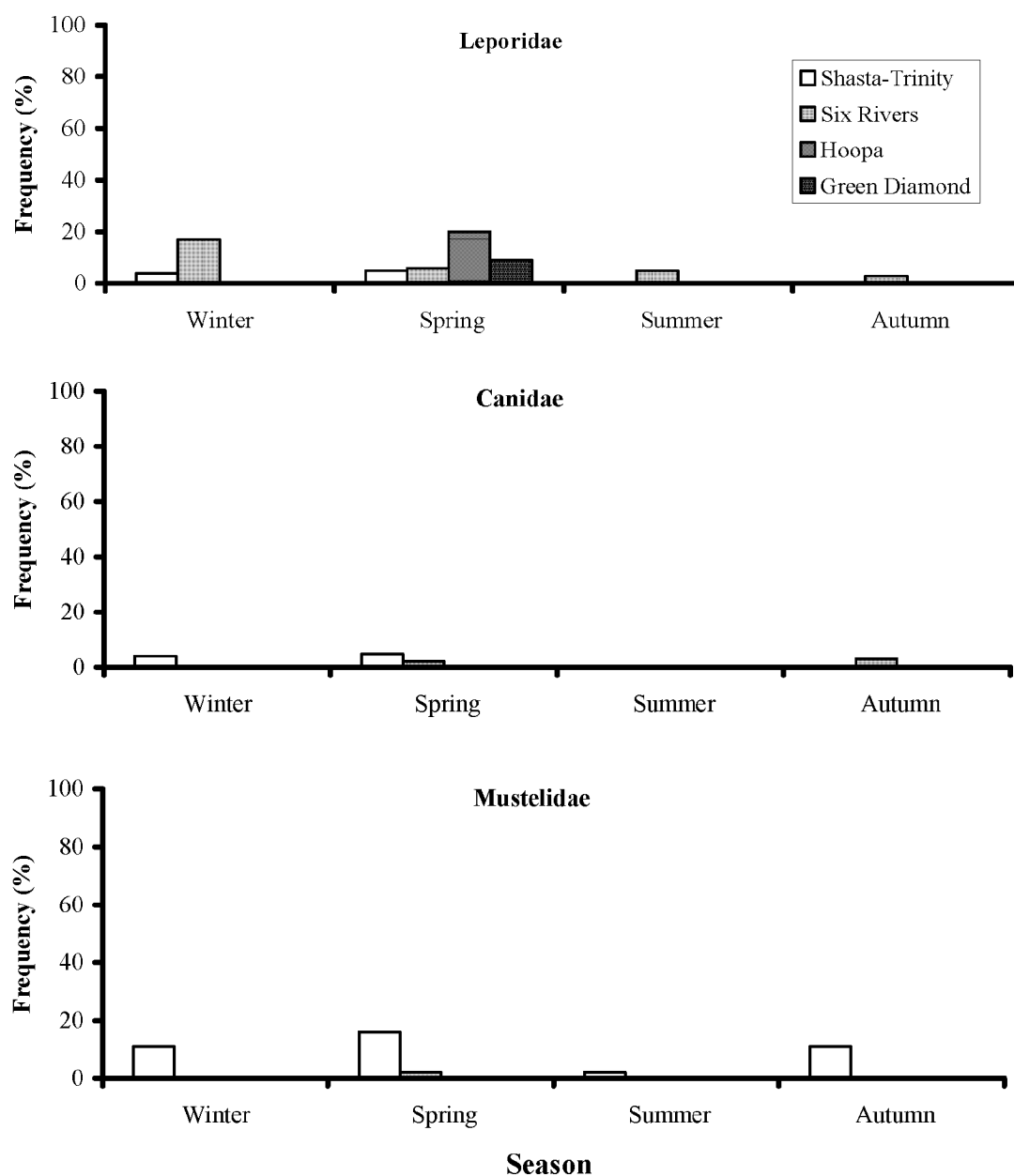


Figure 3. Three taxonomic groups of low frequency in the diet of fishers in the Klamath Bioregion were examined because of their significance to management or for comparison to other fisher populations. Only spring data was collected at the Green Diamond study area.

Table 3. Fisher diet was analyzed seasonally within taxa (chi-square tests) at each of three sites within the Klamath Bioregion in northwestern California. P values ≤ 0.10 are bolded.

	Shasta-Trinity			Hoopa			Six Rivers		
	χ^2	<i>P</i>	n	χ^2	<i>P</i>	n	χ^2	<i>P</i>	n
Class									
Mammalia	2.58	0.46	126	0.35	0.95	57	0.19	0.98	146
Aves	10.65	0.01	34 ^a	0.85	0.84	15	8.48	0.01	46 ^a
Reptilia	9.80	0.02	51	4.02	0.26	5	2.94	0.23	30 ^a
Insecta	9.01	0.03	92	6.07	0.11	25	3.85	0.28	79
Family									
Sciuridae	9.60	0.02	42	0.38	0.94	12	1.62	0.44	42 ^a
Cervidae	6.85	0.08	28	0.06	0.82	8 ^b	0.38	0.94	43
Muridae	1.70	0.64	14	0.84	0.84	15	3.87	0.14	35 ^a
Talpidae	8.76	0.03	35	1.32	0.25	2 ^b	6.65	0.04	31 ^a

^a Only 3 seasons were analyzed due to zeros in the data set.

^b Only 2 seasons were analyzed due to zeros in the data set.

frequency of mammals did not significantly vary between seasons (Table 3). Seasonal effects were also apparent in the sciurid and talpid frequencies at Shasta-Trinity (Figure 4). The Hoopa site did not have any apparent significant seasonal variations in diet. No seasonal differences occurred for cervid consumption at any site based on statistical analyses. However, only autumn and winter seasons could be compared statistically because zeros were present in the dataset for spring and summer. When considering seasons that had zeros for cervid presence in scats (spring and summer at Hoopa), it was apparent that cervids were used more in the autumn and winter seasons (Figure 4).

Mammals were the most consistently used food item at all sites (Figure 1). Birds were less consistently used. Although found at all sites, birds were used significantly more at Six Rivers in the spring than at other sites in spring, and tended to be used more at Hoopa in the autumn. Reptiles were used at all sites, but were most prevalent in spring and summer, with the greatest use occurring at Shasta-Trinity in spring (Table 4). Insects were prevalent across sites, but more in the summer and autumn.

Among mammals, there was no difference in the use of sciurids across sites (Table 4), but the species of sciurid did appear to vary across sites (Table 2). There was a tendency for greater cervid use at Shasta-Trinity in the summer (Table 3, Figure 4), and cervids were absent from Hoopa in both spring and summer (Figures 2, 4). Murids were consumed most on Green Diamond lands, and least at Shasta-Trinity (Table 4, Figure 2). Talpids tended to be consumed most at Shasta-Trinity in the autumn (Table 4), but were consumed at all sites in the spring, and were absent from Hoopa in summer (Figure 2).

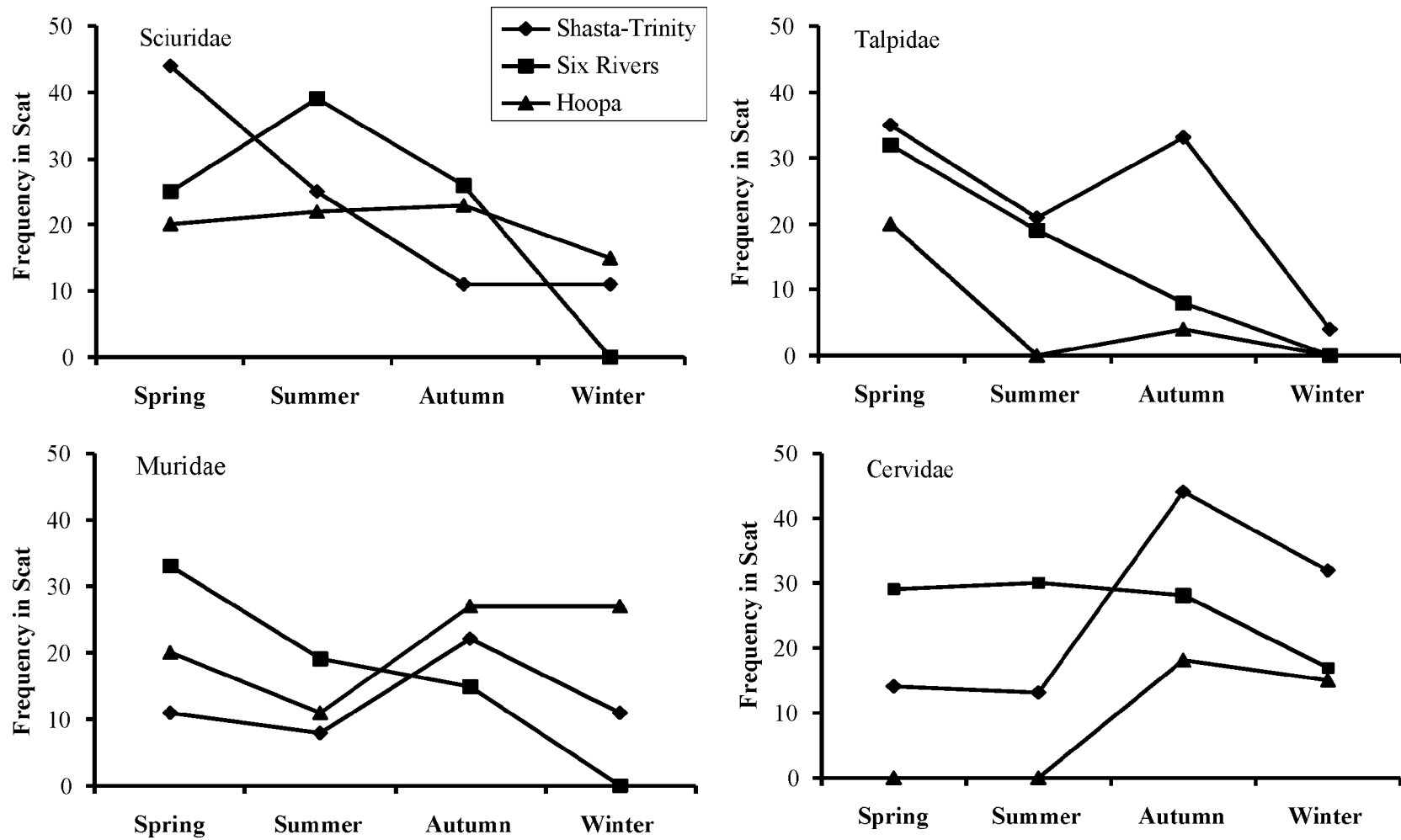


Figure 4. Four selected taxa of fisher prey varied seasonally at 3 sites in the Klamath Bioregion of northern California.

Table 4. Four sites were compared to determine regional differences in fisher diet within each season. Spring comparisons included the Green Diamond site as well as Six Rivers, Shasta-Trinity, and Hoopa. Summer, autumn and winter seasons included all sites except Green Diamond.

	Spring			Summer			Autumn			Winter		
	χ^2	<i>P</i>	n	χ^2	<i>P</i>	n	χ^2	<i>P</i>	n	χ^2	<i>P</i>	n
Class												
Mammalia	0.10	0.99	141	1.98	0.37	86	0.05	0.98	68	0.40	0.82	55
Aves	12.48	0.01	31	0.95	0.62	43	3.62	0.06	11	0.03	0.86	11
Reptilia	8.71	0.03	52	0.07	0.97	27	0.62	0.73	6	3.21	0.07	7
Insecta	1.28	0.73	62	2.58	0.28	78	0.99	0.61	44	1.94	0.38	21
Family												
Sciuridae	4.15	0.25	48	1.53	0.47	31	0.68	0.71	16	0.23	0.63	7
Cervidae	2.62	0.11	26	3.33	0.07	20	1.66	0.44	19	1.75	0.42	14
Muridae	9.67	0.02	36	2.39	0.30	13	1.02	0.60	14	1.92	0.17	10
Talpidae	0.69	0.88	47	0.05	0.82	19	5.76	0.06	7	-	-	-

Table 5. Fisher diet was compared within selected taxa between interior and coastal study areas using chi-square analysis.

	Interior		Coastal		χ^2	$P \leq$
	Observed	Expected	Observed	Expected		
Mammals	280	280.1	81	80.9	0.001	0.994
Sciurids	85	80.7	19	23.3	1.03	0.310
Sciurinae	74	65.9	11	19.1	4.39	0.036
Cervids	73	62.8	8	18.2	7.33	0.007
Murids	51	60.5	27	17.5	6.67	0.010
Sigmodontinae	13	24.1	18	7.0	22.6	0.001
<i>Neotoma</i> sp.	6	15.5	14	4.5	26.1	0.001
Talpids	67	59.7	10	17.3	3.95	0.047
Birds	83	78.4	18	22.7	1.23	0.267
Reptiles	83	73.7	12	21.3	5.23	0.022
Squamata	82	72.9	12	21.1	5.04	0.025
Sauria	51	43.4	5	12.6	5.87	0.015
Insects	179	166.0	35	48.0	4.53	0.033
Hymenoptera	118	99.3	10	28.7	15.7	0.001
Vespids	60	49.7	4	14.0	9.62	0.002
Formicids	70	57.4	4	16.6	12.3	0.001

When we compared the two coastal sites with the two interior sites, insects and reptiles were used more than expected (Table 5) at the interior sites and less than expected at the coastal sites. At more specific levels of taxonomic resolution sciurids differed between coastal and interior sites. Sciurids were used less than expected at coastal sites. Cervids and talpids were used more at interior sites. Conversely murids, and specifically Sigmodontinae and woodrats (*Neotoma* sp.), were used more than expected on the coastal sites when compared to interior sites. Among reptiles, Sauria (lizards) were used more than expected at interior sites. Among insects, Hymenoptera, Vespidae, and Formicidae were used more than expected at interior sites.

At interior sites, insects and reptiles were used most in the spring ($\chi^2 = 10.9$, $p = 0.012$; $\chi^2 = 11.1$, $p = 0.011$; respectively) while birds were used most in summer ($\chi^2 = 17$, $p = 0.001$). Cervids were used less than expected in the spring ($\chi^2 = 11.1$, $p = 0.011$). Sciurids and talpids were used as expected across seasons.

At coastal sites there were no statistically significant differences between seasons. However, we could not statistically test cervids due to the small sample. Cervids were absent at coastal sites in the fall and winter, unlike the interior sites.

The recalculated niche breadth (Levins index) for the southern Sierra Nevada was 0.26. The interior area of the Klamath Bioregion was 0.38, while the coastal area was 0.55. Overall niche breadth for the Klamath Bioregion was 0.39. We used 30 food categories for the southern Sierra Nevada and 41 food categories for the Klamath Bioregion. When the coastal and interior areas were considered separately, there were 37 and 29 categories respectively. When all vegetation was removed, the diversity in the

niche breadth for animal matter was 0.40 in the Klamath Bioregion (0.38 interior, 0.54 coastal) and 0.29 in the southern Sierra Nevada.

Discussion

The 388 scats from 4 sites provided adequate numeric and spatial separation to characterize the entire Klamath Bioregion. Adequate numbers (see Hanson and Graybill 1956 for discussion) of positively identified scats were analyzed to characterize the diet of fishers at Shasta-Trinity and Six Rivers sites in all seasons, in the spring on the Green Diamond site, and to strongly suggest patterns of diet at the Hoopa site in autumn and winter. The stratification by site and season sometimes resulted in small and unequal sample sizes, so we made inferences based upon sample sizes and statistics, but not from percentages alone. Further, non-fisher scat was probably excluded before analysis, and each sample was carefully scrutinized and were from relatively certain sources (traps and rest sites on short temporal scale).

Fishers in the Klamath Bioregion consumed a wide variety of prey that varied between seasons and specific sites. Mammals were the most frequent diet item at all sites and all seasons. Mammals that were consumed varied from small rodents and moles to cervids. Sciurids were a dominant and consistent taxa. Other small carnivores (e.g. spotted skunks, *Spilogale gracilis*; gray fox, *Urocyon cinereoargenteus*), although not consumed at great frequency, were found in samples from all 4 seasons and 3 of the sites; we assumed these were likely the result of predation by fishers.

Surprisingly, there was a relatively low occurrence of lagomorphs in the diet of fishers in the Klamath Bioregion. The distribution of snowshoe hare in California was not coincidental with our study sites or elevations. However, the brush rabbit (*Sylvilagus*

bachmani) and California black-tailed jackrabbit (*Lepus californicus*) were distributed across the region. Brush rabbits have been found in brushy areas with edible grasses (Chapman 1974). Black-tailed jackrabbits are more common in open areas (Best 1996) and this habitat would not have provided the overhead cover necessary for fisher habitat (Seglund 1995, Dark 1997, Zielinski et al. 2004). Mullis (1985) reported that a fisher took a brush rabbit (0.5 – 0.9 kg body weight, Chapman 1974), which was substantially smaller than a snowshoe hare (1.3 kg; Murray 2003). Also notable by its absence was the porcupine. The porcupine's distribution overlapped all 4 sites (see Ingles 1965), but porcupine was not detected in a single scat. Across the range of fishers, porcupine frequency in the diet has ranged from very low (Giuliano et al. 1989) to 12-34% (deVos 1952, Powell 1981, Rego 1984). Absence of porcupine in the scats was reflective of very little consumption.

Fishers in the Klamath Bioregion also regularly consumed birds, but less consistently than mammals. It was not generally possible to identify species of bird. Blue grouse (*Dendragapus obscurus*) are found throughout the bioregion and ruffed grouse (*Bonasa umbellus*) were present at two of the collection sites (Leopold et al. 1981). Both mountain quail (*Oreortyx pictus*) and California quail (*Callipepla californica*) are present in the Klamath Bioregion. Elsewhere (Zielenski et al. 1999), fishers have been reported to consume passerines as well. Additionally fishers regularly consumed snakes, lizards, and amphibians at all sites. Insects were also frequent in the scats. Although some insects (e.g.: Coleoptera and Formicidae) may have been inadvertently consumed with older carrion, others appeared to be actively consumed

(e.g.: Vespidae and Orthoptera) and we had anecdotal observations of insect nests being consumed.

Some vegetation was probably consumed incidentally with carrion (especially Pinaceae) or in stomachs, cheek pouches, and crops of prey. However, at sites with huckleberry (*Vaccinium* spp.), fishers may have actively consumed the fruits. Rocks were found in many scats and may have been consumed with decomposing carrion. Anthropogenic material was also common across sites and probably represented use of human refuse and possibly packaging associated with bait used for trapping. Interestingly, the greatest encounter of anthropogenic materials was in Hoopa scats where illegal dumping of human trash was considered a problem (Higley et al. 2005). Although Zielinski et al. (1999) reported spores of fungi in fisher scats, we did not do this lab analysis and cannot exclude possible fungi consumption by fishers at our sites.

Fisher Diet Comparison Across Scale

Comparisons between Klamath Bioregion and other regions. Diet of fishers in the southern Sierra Nevada (Zielinski et al. 1999) had several similarities to the Klamath Bioregion. In the southern Sierra Nevada, mammals were the most common diet item (especially sciurids), but included birds and reptiles as additional vertebrate prey (Zielinski et al. 1999). Deer were apparently available to fishers in the Sierra Nevada, primarily in winter. Large portions of the Sierra Nevada study site (Zielinski et al. 1999) were adjacent to National Parks (which may provide refuge), and deer migrate to higher elevations in spring. The deer in the Klamath Bioregion could neither move into the protection of parks nor seasonally move off the study area to higher elevations. Similar to our results, fishers in the southern Sierra Nevada did not consume many leporids. Like

the Klamath Bioregion, birds were used most in summer in the southern Sierra Nevada, but variation may have been detected if samples had been stratified by elevation just as bird use varied across sites in the Klamath Bioregion. Similar to the southern Sierra Nevada, insects were consumed year round in the Klamath Bioregion, including during winter. Rocks were detected in the feces more frequently in the Klamath Bioregion than in the southern Sierra Nevada; we speculate that greater scavenging (e.g. use of deer) may have caused earthen substrate to be contributed to the fecal remains.

Like other regions in the continental range of the fisher (Martin 1994), deer, birds, and vegetation were similarly consumed by fishers in the Klamath Bioregion and in the southern Sierra Nevada. Unlike fishers elsewhere, reptiles were a regular part of the diet in both the Klamath Bioregion and in the southern Sierra Nevada (Brown and Will 1979, Giuliano et al. 1989, Kuehn 1989). All other investigations of diet have included some tree-squirrel sized or larger prey including flying squirrels, gray squirrels and red squirrels (Brown and Will 1979, Arthur et al. 1989), and leporids, (especially snowshoe hare; Clem 1977, Raine 1987, Powell 1997) or porcupines (Clem 1977, Powell 1981, Powell 1993). Compared to other sites in the continental range of the fisher, both California investigations had low occurrences of lagomorphs and lacked porcupine in the diet.

Zielinski and Duncan (2004) reported that fisher diet in the southern Sierra Nevada was more diverse than elsewhere in the continental range of the fisher (see deVos 1952, Rego 1984, Arthur et al. 1989, Giuliano et al. 1989, Kuehn 1989, Powell et al. 1997). Using laboratory methods that were similar to our methods, Zielinski et al. (1999) identified at least 30 food categories from the 201 scats collected in the southern Sierra

Nevada. We identified at least 40 food categories as well as anthropogenic foodstuffs among the 388 scats from the Klamath Bioregion. Our recalculation of the niche breadth based on occurrences in the southern Sierra Nevada was 0.26 (B-standard as defined in Colwell and Futuyma 1971). The difference between the original reported value (Zielinski and Duncan 2004) and our recalculation resulted from the control of potentially double counted taxa and removal of items in the scats that were probably ingested incidentally to the foodstuffs. The niche breadth for the interior area of the Klamath Bioregion was 44% greater than the southern Sierra Nevada. The coastal area was even more diverse than the southern Sierra Nevada (more than double). Some of these differences may have resulted from the wider scale and larger sample sizes from the Klamath Bioregion. However, it also appears that the diet of fishers in California is very diverse, and relatively more so in the Klamath Bioregion, especially in the coastal areas. Interestingly, fisher abundance has been described as being greater in the coastal areas (Truex et al. 1998, Thompson in prep; see coastal surveys by Beyer and Golightly 1996 and Klug 1997; in contrast to the interior surveys reported in Dark 1997).

In calculation of niche-breadth when only animal matter was considered as food, the relative estimates were very similar to those containing all food categories. Although fishers can eat berries and other vegetative matter, most of the diversity of food was animal matter.

Martin (1994) speculated that there was a negative relationship between diet diversity and the use of large prey. It could be argued that large prey in a small sample could by itself decrease the apparent diet diversity. However, with 388 scats from 4 sites, and 201 scats with similar finding from the southern Sierra Nevada, the absence of

porcupine and leporids in California cannot be simply a sampling artifact. Further, some larger prey (e.g.: deer and other carnivores) did occur in our samples while the diversity in the diet was also high.

Zielinski and Duncan (2004) proposed that the diversity of prey in the diet of fishers in California could possibly be explained by the variety of prey that was available to fishers in the southern Sierra Nevada. This would suggest that these fishers were opportunistic. However, habitat and energetics also affect prey selection (see below) and these complicated the categorization of fisher as simply opportunistic. Regardless, fishers in California and probably the Pacific States have a more diverse diet than reported elsewhere in the continental range of the fisher (see Martin 1994).

Comparisons of fisher diet between coastal and interior regions of the Klamath Bioregion. At a smaller spatial scale within the Klamath Bioregion, we could stratify the diet of fishers from the drier interior sites (Shasta-Trinity and Six Rivers) and those sites influenced by marine conditions (Hoopa and Green Diamond). These two broad habitats contained different plant species (e.g.: redwood, tanoak, and huckleberry in the coastal forests and more pines with less understory in the drier sites; see contrasting description between Hoopa and Shasta-Trinity in Yaeger 2005). Diet in coastal areas included more woodrats and amphibians and less deer, other carnivores, and insects (especially Orthoptera, primarily Jerusalem crickets). Sciurids appeared to replace the woodrats in the diet of fishers at interior sites. In spite of temperature and vegetative differences, reptile use occurred across both habitat types although significantly more on the interior sites. Again, this suggests that fishers were opportunistic while being influenced by habitat and energetic issues.

Seasons appeared to affect the interior sites, but not the coastal sites. There were seasonal patterns for birds, reptiles, and deer at interior sites, but not at coastal sites. This would be consistent with the stronger seasonal variation at the interior sites and more moderating effect of the marine climate on the coastal areas. One exception was the consistent use of sciurids throughout the year at interior sites.

Fisher diet comparisons between sites within the Klamath Bioregion. At class and order levels of taxonomy, the overall characterization of the Klamath Bioregion did not differ from the general pattern obtained at any of the 4 sites. However, at lower levels of taxonomy, such as sciurid rodents, the species of consumed prey was not the same. Sciurids were consumed at all sites, but the prevalent sciurid species consumed differed between sites. Moreover, while there was relatively high use of sciurids at Shasta-Trinity and Six Rivers, there was a higher relative use of woodrats (similar mass) at Hoopa and Green Diamond (11 and 30%, respectively) and less use of sciurids. Woodrats were probably more available at Hoopa and Green Diamond due to the greater understory complexity in the coastal study area and the greater aridity at the interior sites (see Carraway and Verts 1991). Thus, this pattern of use probably reflected species availability (density), predominant habitat, site differences in weather, and abundance of other prey types of similar mass.

Cervids (probably black-tailed deer; *Odocoileus hemionus*) were common in all seasons at Six Rivers and most common in autumn and winter at Hoopa and Shasta-Trinity. Autumn use of cervids coincided with the state hunting-season at Shasta-Trinity (which was the site nearest to a large human population center). Although spring use of deer at Six Rivers and Shasta-Trinity may have included fawns, it is reasonable to assume

that summer, autumn, and winter use was scavenged from carrion. In autumn, carrion may have been enhanced by hunters who failed to recover killed deer (see Miller et al. 2003) and in winter by kills associated with inclement weather (Unsworth et al. 1999). Notably, the occurrence of cervids in the winter diet at Shasta-Trinity was coincidental with greatest distance from the moderating effects of the coastal climate.

Birds were used at all sites, but the season of most frequent use varied by site. Fishers at Hoopa used birds in all seasons. Fishers at Six Rivers used birds in spring and summer, and fishers at Shasta-Trinity used birds in summer only. Sample sizes for birds were adequate to ensure that assignment of absence to a season at a site was probably a result of little to no use during that season. Bird migratory patterns and seasonal vulnerability due to migration may explain these site variations. Fishers also consumed eggs from nests in the spring.

Prey Preference or Generalist

Based on the variety of prey items (at least 20 species of mammals plus birds, reptiles, insects, and fruits) and the changes in use with changes in availability (e.g.: seasons, carrion, etc.), we concluded that fishers in the Klamath Bioregion and in California probably consumed all potential prey they encountered, and appeared to do so opportunistically. As seasons changed, those potential prey items were included or excluded in the diet. In our investigation we did not detect any apparent species-level specialization in the diet.

In our investigation in the Klamath Bioregion, fishers probably consumed porcupine only infrequently. Although porcupine range extends through the southern Sierra Nevada (Ingles 1965), porcupine was absent in the data from Zielinski et al. (1999)

as well. Conversely, Powell (1981, 1993) suggested that fishers specifically sought porcupine as prey. Consistent with Powell's (1981, 1993) description of porcupine, Bulmer (1975) and Bowman et al. (2006) suggested that fishers were able to switch prey when snowshoe hare populations were reduced.

Our description of a highly diverse diet was in contrast to the described specialization on porcupine and snowshoe hare elsewhere in the range. The apparent low use of leporids and porcupine in our investigation provided uncertainty as to foraging strategies used by fishers. Some selection did appear to occur (sciurids on the interior sites through all seasons and woodrats at coastal sites) and the characterization of fisher diet as simply opportunistic may be inadequate to describe how fishers forage, nor does simple opportunism explain that high use of porcupine and hare elsewhere. Křivan and Sikder (1999) modeled a 1-predator 2-prey system and suggested three possible scenarios for predator foraging behavior: 1) predators specialize on the more profitable prey, 2) predators are generalists and feed on every encountered prey item, and 3) predators forage adaptively following rules of optimal foraging theory (adaptive generalists). Martin (1994) speculated that fishers might select larger prey types (e.g.: simply characterized by porcupine or snowshoe hares when available). In diverse ecosystems there may be different prey that would be consistent with the optimal body size that could be captured and were profitable to hunt. If fishers are adaptive generalists, they would eat what they encountered, but where possible select more profitable prey (presumably larger body size when available in adequate numbers). If fishers did exhibit selection for that profitability, prey or prey body size should be consistent across sites. Such selection

may be more generic than a specific species as was suggested by Martin (1994) (e.g.: body size).

By examining energetic return based upon body size, we can infer which species fishers might select. Powell (1979) estimated the daily caloric needs of fishers in Michigan in winter. Estimated daily energy expended based on field measurements was 862 kJ/day for a 2.4 kg female and averaged 1471 kJ/day for males weighing 5 kg. We used Powell's (1979) figures to estimate the number of kills necessary to sustain a fisher. We assumed that a small to medium sized mammal had a metabolizable energy of 86% (Litvaitis and Mautz 1980, Ball and Golightly 1992), and that energy content of mammalian prey in summer is about 21.8 kJ/g dry weight (Petrusewicz and MacFadyen 1970). The lean dry matter for lab mice was 42% (Ball and Golightly 1992) and 28% for jackrabbits (Nagy et al. 1976). Using these estimates, a gm wet-weight of prey (assume 30% dry matter) that was 86% metabolizable would provide 5.6 kJ/g (21.8 kJ/g multiplied by 0.3 multiplied by 0.86). At this rate of energy return, 263g and 154g of prey/day wet-weight would be needed for the male and female fishers respectively. Fishers in the Klamath Bioregion have been reported to weigh slightly less (Seglund 1995, Dark 1997) than those observed by Powell (1979), and consequently, daily energy needs may be slightly less. An average-weight Douglas squirrel (approximately 250g; Hall 1981) would supply a female fisher with a 1.6-day supply of energy, or a male with almost a 1-day supply. Similarly a woodrat (*N. fuscipes* males averaged 315 g; Hamm 1995) could supply 2 days of energy for a female and more than one day for a male. At warm ambient temperatures in summer, a large-bodied kill would not be useable beyond a few days. Scavengers and decomposers would degrade a carcass. Conversely, if

consuming small rodents (e.g. *Peromyscus maniculatus*, 15-25 g; Chappell et al. 2003) or lizards (e.g. western fence lizard, *Sceloporus occidentalis*, 3.65-19.02 g; Roe et al. 2005), the fisher would need to find and consume 10-26 mice or lizards (assuming each individual weighed 10 g) per day for male or female fisher, respectively. Consequently, we argue that although fishers can consume a variety of prey to meet their daily energy demand, larger prey may be more profitable than smaller prey when available (250g-1kg size in summer; in winter larger sizes may persist longer after killed if fishers can defend their kill). It is important to note that there may be inherent risk associated with prey such as porcupine and that fishers consuming porcupine have been reported to have porcupine quills imbedded in their faces and elsewhere (see Kuehn 1989). Further, as noted by Powell (1979), competition with other predators may reduce the available energy in kills that are consumed over days. It should be noted that carrion in the form of deer would be more efficient because they could forage almost exclusively on flesh, and the profitability would be high, so long as they were not damaged by other predators.

The idea that fishers may select prey of tree squirrel or bigger size when available is consistent with inferences of selection for porcupine or hare. However, rather than switching prey we argue that they use what they encounter, but satisfy their caloric need quickest with larger items. Consistent with this hypothesis, the regular ingestion of sciurids at interior sites could be replaced with more numerous woodrats at coastal sites, in spite of sciurids still being available. Additionally, gray fox, spotted skunk, or other small/medium-sized carnivores could be energetically profitable and potentially be selected if they could be acquired at low risk.

Management Conclusions

Fishers can utilize a variety of prey, but adequate energy is most efficiently gathered when consuming tree squirrels, woodrats or larger prey (0.250-1kg) in California. Consequently highly productive habitats with available prey in this size class may produce numerical responses (Bowman et al. 2006) in fisher abundance. Where a diversity of prey types in this size class exists, apparent switching may occur when one of these prey types declines. This could occur without an apparent change in fisher numbers, which would be consistent with the models of Křivan and Sikder (1999).

It is important to recognize that many small mammalian carnivores are also in the prey size class used by fisher in California (e.g.: marten, *Martes americana*, 0.85 kg, Hall 1981; gray fox, 3.0-7.0 kg, Ball and Golightly 1992, Cypher 2003; spotted skunk, 0.5-1.8 kg, Rosatte and Larivière 2003) and we found the latter two among the prey. Because many small carnivores are at relatively low density (e.g. marten, Buskirk et al. 1994) and because fishers will opportunistically consume what they encounter, there is a potential for fishers to influence populations of these other carnivores. This influence may occur because of direct interaction (being consumed) or due to competition for overlapping food resources (see Zielinski and Duncan 2004). Other forest carnivores consume many of the same small mammals, birds, and reptiles that fishers may consume.

Reintroduction of fishers has been considered in areas of its range where it has been extirpated (see Lewis and Hayes 2004). It would be overly simplistic to consider only that fishers were once a component of that ecosystem and that their reintroduction will have only positive consequences. The status of other small carnivores in these ecosystems has also changed and the relationship to reintroduced fishers may differ from

the conditions when they previously occurred at the site. Thus, care must be taken to consider potential impacts on sympatric carnivores that have similar or smaller body size, or consume similar prey. Conversely, the broad character of the diet of fishers suggests that they may readily find food when introduced onto productive lands with a variety of small mammals, especially with tree squirrels or woodrats.

Anthropogenic influences may also affect fishers (especially over winter).

Grenfell and Fasenfest (1979) reported that fishers would consume bovid carrion. The availability of carrion would also be related to deer management. The effect of carrion from any source on reproduction and survival of fishers is unknown. Although illegal since 1972, carrion was historically used in “meat baits” to attract and poison other predators in some regions within the fisher range (U.S. Fish and Wildlife Service 1979), and we caution that where fishers are present, such use of a predacide may have the potential to negatively affect fishers.

The productivity of a habitat, especially as it affects small mammal abundance, may influence fisher persistence and abundance. Fisher habitats in California do not experience the prolonged winters characteristic of more northern parts of the fisher’s range. Thus the role of large-bodied prey was less important in California (it does not persist), and consisted mostly of scavenged deer when available.

Timber management activities in California forests may change the existing availability and type of prey. As these altered forests proceed through succession, there will be dynamic alterations of fisher food. Some of our observed differences in diet between sites may be reflective of different seral stages. Fishers often use large trees as rest sites and areas with relatively closed canopies (Seglund 1995, Dark 1997, Zielinski et

al. 2004, Yaeger 2005), which explains why some research has associated fishers with late seral forest (see Rosenberg and Raphael 1984). However, some important prey species increase in numbers in logged forests (Hamm 1995, Waters and Zabel 1998). Although cover and good resting or denning sites will ultimately constrain which forest-habitats support fishers, prey may be more associated with conifer-forest openings and edges with greater productivity (Murcia 1995). Examples would include woodrats, which are more abundant in areas post timber harvest (Hamm 1995) or tree squirrels in areas of abundant oak mast. Anecdotally, fisher abundance in the Klamath Bioregion seems to be correlated with the highly productive coastal forests (Beyer and Golightly 1996, Klug 1997, Truex et al. 1998, Yaeger 2005, Thompson et al. in prep.). Although California ground squirrels (*Spermophilus beecheyi*) can be very abundant in clear-cut and early seral forests (pers. obs.), they were not prevalent in diet (these seral stages were available in the study area); their absence probably resulted from them occupying areas that also lacked cover for fishers. Conversely, tree squirrels and chipmunks (*Tamias* sp.) were abundant in the diet and are associated with forest cover.

There are several forest practices in managed timber lands that have the potential to influence prey populations and availability. Concern about wildfire has initiated programs to control fuel (removal of downed woody materials and under story vegetation). Within forests, numerous small mammals use the downed woody material (Loeb 1999, Menszel et al. 1999, Ucitel et al. 2003). Removal of these materials has potential to reduce prey abundance that may cause fishers to hunt elsewhere, or reduce overall abundance of fishers if the fuel treatments are on a wide scale. Assessments of

fuel-reduction planning should consider potential changes in small mammal abundance that may affect food supply for fishers.

Another forest practice that has potential to change the fisher's prey base is the conversion of vegetation from one habitat type or vegetative composition to another. Sometimes this is intentional through planting new seedlings, selective removal (e.g.: hardwoods), or vegetation manipulation to improve forest growth (e.g.: thinning and herbicide treatment; see Whitaker 2003). At other times this conversion of habitat or vegetation change is an inadvertent consequence of forest management considerations (e.g.: stream-side protection zones). It is important to recognize that these practices may alter which prey is available, and although fishers can switch prey, they may not always be able to use the new habitat in the converted landscape. For example, most sciurids use conifers and oaks as a food base, and the riparian habitat associated with stream protection zones may not provide this food without addition of uplands containing the appropriate tree species.

Acknowledgments

We thank S. Elliot for detailed hours of sorting and identifying fecal remains. We thank S. Dark, J. Dayton, N. Duncan, P. Hapmann, R. Klug, A. Pole, R. Schlexer, G. Schmidt, K. Schmidt, A. Seglund, R. Truex and S. Yaeger for collecting scat. Several fecal remains used from the Shasta-Trinity site were provided by Sierra Pacific Industries. Early support for analyses were provided by the California Department of Fish and Game. Funding for the completion of this report came from U.S. Fish and Wildlife Service and Pacific Lumber Company.

Literature Cited

- Adjoran, A. S. and G. B. Kolenosky. 1969. A manual for the identification of hairs of selected Ontario mammals. Research Report (Wildlife) 90, Department of Lands and Forests, Ontario, Canada.
- Arthur, S. M., W. B. Krohn, J. R. Gilbert. 1989. Habitat use and diet of fishers. *Journal of Wildlife Management* 53: 680-688.
- Aubry, K. B., and J. C. Lewis. 2003. Extirpation and reintroduction of fishers (*Martes pennanti*) in Oregon: implications for their conservation in the Pacific states. *Biological Conservation* 114: 79-90.
- Ball, L. C., and R. T. Golightly Jr. 1992. Energy and nutrient assimilation by gray foxes on diets of mice and Himalaya berries. *Journal of Mammalogy* 73: 840-846.
- Best, T. L. 1996. *Lepus californicus*. *Mammalian Species* 530: 1-10.
- Beyer, K. M. and R. T. Golightly 1996. Distribution of pacific fisher and other forest carnivores in coastal northwestern California. Unpublished report, Wildlife Department, Humboldt State University, Arcata, California, USA.
- Boror, D. J. and R. E. White. 1970. A field guide to insects. Houghton Mifflin, Boston, Massachussetts, USA.
- Bowman, J., D. Donovan, and R. C. Rosatte. 2006. Numerical response of fishers to synchronous prey dynamics. *Journal of Mammalogy* 87: 480-484.
- Brown, M. K., and G. Will. 1979. Food habits of the fisher in northern New York. *New York Fish and Game* 26: 87-92.

- Brunner, H. and B. J. Coman. 1974. The identification of mammalian hair. Inkata Press, Melbourne, Australia.
- Bulmer, M. G. 1975. Phase relations in the ten-year cycle. *Journal of Animal Ecology* 44: 609-621.
- Buskirk, S. W., and L. F. Ruggiero. 1994. American Marten. Pages 7-37 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the Western United States. U. S. Forest Service General Technical Report RM 254.
- Carraway, L. N., and B. J. Verts. 1991. *Neotoma fuscipes*. *Mammalian Species* 386: 1-10.
- Chapman, J. A. 1974. *Sylvilagus bachmani*. *Mammalian Species* 34: 1-4.
- Chappell, M. A., E. L. Rezende, and K. A. Hammond. 2003. Age and aerobic performance in deer mice. *Journal of Experimental Biology* 206: 1221-1231.
- Clem, M. K. 1977. Interspecific relationship of fishers and martens in Ontario during winter. Pages 165-183 *in* R. L. Phillips, and C. Jonkel, editors. Proceedings of the 1975 Predator Symposium. Montana Forest Conservation Experimental Station, University of Montana, Missoula, Montana, USA.
- Colwell, R. K., and D. J. Futuyma. 1971. On the measurement of niche breadth and overlap. *Ecology* 52: 567-576.
- Cypher, B. L. 2003. Foxes (*Vulpes* species, *Urocyon* species and *Alopex lagopus*). Pages 511-546 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. Second edition. John Hopkins University Press, Baltimore, Maryland, USA.

- Day, M. G. 1966. Identification of hair and feather remains in the gut and feces of stoats and weasels. *Journal of Zoology* 148: 201-217.
- Dark, S. 1997. A landscape-scale analysis of mammalian carnivore distribution and habitat use by fisher. Thesis, Humboldt State University, Arcata, California, USA.
- deVos, A. 1952. Ecology and management of fisher and marten in Ontario. Technical Bulletin, Ontario Department of Lands and Forestry, Ontario, Canada.
- Giuliano, W. M., J. A. Litvaitis, and C. L. Stevens. 1989. Prey selection in relation to sexual dimorphism of fishers (*Martes pennanti*) in New Hampshire. *Journal of Mammalogy* 70: 639-641.
- Goin, C. J., O. B. Goin, and G. R. Zug. 1978. Introduction to herpetology. Third edition. W. H. Freeman and Company, San Francisco, California, USA.
- Golightly, R. T., Jr., M. R. Faulhaber, K. L. Sallee, and J. C. Lewis. 1994. Food habits and management of introduced red fox in Southern California. Pages 15-20 *in* W. S. Halverson and A. C. Crabb, editors. Proceedings of the Sixteenth Vertebrate Pest Conference. University of California, Davis, California, USA.
- Grenfell, W. E. and M. Fasenfest. 1979. Winter food habits of fishers, *Martes pennanti*, in northwestern California. *California Fish and Game* 65: 186-189
- Grinnell, J., J. S. Dixon, and J. M. Linsdale. 1937. Furbearing mammals of California. University of California Press, Berkeley, California, USA.
- Hall, E. R. 1981. The mammals of North America. Second edition. John Wiley, New York, New York, USA.
- Hall, E. R. and K. R. Kelson. 1959. The mammals of North America. Ronald Press, New York, New York, USA.

- Hamm, K. A. 1995. Abundance of dusky-footed woodrat in managed forests of north coastal California. Thesis, Humboldt State University, Arcata, California, USA.
- Hanson, W. R. and F. Graybill. 1956. Sample size in food-habits analyses. *Journal of Wildlife Management* 20: 64-68.
- Higley, J. M., D. V. Masters, and J. L. Sajecki. 2005. Black bear management plan, Hoopa Valley Tribe. Hoopa Tribal Forestry, Hoopa, California, USA.
- Ingles, L. G. 1965. *Mammals of the Pacific States: California, Oregon, and Washington*. Stanford University Press, Stanford, California, USA.
- Hickman, J. C., editor. 1993. *The Jepson manual: higher plants of California*. University of California Press, Berkeley, California, USA.
- Johnson, M. K. and R. M. Hansen. 1977. Comparison of point frame and hand separation of coyote scats. *Journal of Wildlife Management* 41: 319-320.
- Klug, R. R. 1997. Occurrence of Pacific Fisher (*Martes pennanti pacifica*) in the redwood zone of northern California and the habitat attributes associated with their detections. Thesis, Humboldt State University, Arcata, California, USA.
- Křivan, V. and A. Sikder. 1999. Optimal foraging and predator-prey dynamics, II. *Theoretical Population Biology* 55: 111-126.
- Kuehn, D. W. 1989. Winter foods of fishers during a snowshoe hare decline. *Journal of Wildlife Management* 53: 688-692.
- Leopold, A. S., R. J. Gutierrez, M. T. Bronson. 1981. *North American game birds and mammals*. Charles Scribner's Sons, New York, New York, USA.

- Lewis, J. C. and G. E. Hayes. 2004. Feasibility assessment for reintroducing fishers to Washington. Washington Department of Fish and Wildlife, Olympia, Washington, USA.
- Litvaitis, J. A. and W. M. Mautz. 1980. Food and energy use by captive coyotes. *Journal of Wildlife Management* 44: 56-61.
- Lockie, J. D. 1959. The food of the pine marten *Martes martes* in west Ross-Shire, Scotland. *Nature Conservancy* 12: 187-195.
- Loeb, S. C. 1999. Responses of small mammals to coarse woody debris in a southeastern pine forest. *Journal of Mammalogy* 80: 460-471.
- Martin, S. K. 1994. Feeding ecology of American martens and fishers. Pages 297-315 *in* S. W. Buskirk, A. S. Harestad, M. G. Raphael, R. A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Mayer, K. E. and W. F. Laudenslayer Jr. 1988. A guide to wildlife habitats of California. California Department of Forestry and Fire Protection, Sacramento, California, USA.
- Mayer, W. V. 1952. The hair of California mammals with keys to the dorsal guard hairs of California mammals. *The American Midland Naturalist* 48: 480-512.
- Menzel, M. A., W. M. Ford, J. Laerm, and D. Krishon. 1999. Forest to wildlife opening: habitat gradient analysis among small mammals in the southern Appalachians. *Forest Ecology and Management* 114: 227-232.
- Miller, K. V., L. I. Muller, and S. Demarais. 2003. White-tailed deer (*Odocoileus virginianus*). Pages 906-930 *in* G. A. Feldhamer, B. C. Thompson, and J. A.

- Chapman, editors. Wild mammals of North America: biology, management, and conservation. Second edition. John Hopkins University Press, Baltimore, Maryland, USA.
- Milne, L. and M. Milne. 1980. The Audubon society guide to North American insects and spiders. Alfred A. Knopf, New York, New York, USA.
- Moore, T. D., L. E. Spence, and C. E. Dugnolle. 1974. Identification of the dorsal guard hairs of some mammals of Wyoming. Wyoming Game and Fish Department Bulletin 14, Cheyenne, Wyoming, USA.
- Mullis, C. 1985. Habitat utilization by fisher (*Martes pennanti*) near Hayfork Bally, California. Thesis, Humboldt State University, Arcata, California, USA.
- Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. *Tree* 10: 58-62.
- Murray, D. L. 2003. Snowshoe hares and other hares (*Lepus americanus* and allies). Pages 147-178 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. Second edition. John Hopkins University Press, Baltimore, Maryland, USA.
- Nagy, K. A., V. H. Shoemaker, and W. R. Costa. 1976. Water, electrolyte and nitrogen budgets of jackrabbits (*Lepus californicus*) in the Mojave Desert. *Physiological Zoology* 49: 351-363.
- Petrusewicz, K., and A. MacFadyen. 1970. Productivity of terrestrial animals, principles and methods. International Biological Programme Handbook 13. F. A. Davis, Philadelphia, Pennsylvania, USA.

- Powell, R. A. 1979. Ecological energetics and foraging strategies of the fisher (*Martes pennanti*). *Journal of Animal Ecology* 48: 195-212.
- Powell, R. A. 1981. Hunting behavior and food requirements of the fisher (*Martes pennanti*). Pages 883-917 in J. A. Chapman and D. Pursley, editors. *Worldwide Furbearer Conference Proceedings*. Worldwide Furbearer Conference, Inc., 3-11 August 1980, Frostburg, Maryland, USA.
- Powell, R. A. 1993. *The Fisher: life history, ecology, and behavior*. Second Edition. University of Minnesota Press, Minneapolis, Minnesota, USA.
- Powell, R. A., and W. J. Zielinski. Fisher. 1994. Pages 38-73 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, W. J. Zielinski, editors. *The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the Western United States*. U. S. Forest Service General Technical Report RM 254.
- Powell, S. M., E. C. York, and T. K. Fuller. 1997. Seasonal food habits of fishers in central New England. Pages 279-305 in G. Proulx, H.N. Bryant and P.M. Woodard, editors. *Martes: taxonomy, ecology, techniques and management*. Provincial Museums of Alberta, Edmonton, Alberta, Canada.
- Proctor, N. S., and P. J. Lynch. 1993. *Manual ornithology, avian structure and function*. Yale University Press, New Haven, Connecticut, USA.
- Raine, R. M. 1987. Winter food habits and foraging behavior of fishers (*Martes pennanti*) and martens (*Martes americana*) in southeastern Manitoba. *Canadian Journal of Zoology* 65: 745-747.
- Rosenberg, K. V. and M. G. Raphael. 1984. Effects of forest fragmentation on vertebrates in Douglas-fir forests. Pages 263-272 in J. Verner, M. L. Morrison, and C. J.

- Ralph, editors. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. University of Wisconsin Press, Madison, Wisconsin, USA.
- Rego, P. W. 1984. Factors influencing harvest levels of fisher in south central and south eastern Maine. Thesis, University of Maine, Orono, Maine, USA.
- Roe, J. H., W. A. Hopkins, and L. G. Talent. 2005. Effects of body mass, feeding, and circadian cycles on metabolism in the lizard *Sceloporus occidentalis*. Journal of Herpetology 39: 595-603.
- Rosatte, R., and S. Larivière. 2003. Skunks (Genera *Mephitis*, *Spilogale*, and *Conepatus*). Pages 692-707 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. Second edition. John Hopkins University Press, Baltimore, Maryland, USA.
- Schopmeyer, C. S. 1974. Seeds of woody plants in the United States. Agriculture Handbook 450. USDA Forest Service, Washington, D.C., USA.
- Schoonmaker, W. J. 1938. The fisher as a foe of the porcupine in New York State. Journal of Mammalogy 19: 373-374.
- Seglund, A. E. 1995. The use of resting sites by the Pacific fisher. Thesis, Humboldt State University, Arcata, California, USA.
- Serafini, P., and S. Lovari. 1993. Food habits and trophic niche overlap of the red fox and the stone marten in a Mediterranean rural area. Acta Theriologica 38: 233-244.
- Southern, H. N. and J. S. Watson. 1941. Summer food of the red fox (*Vulpes vulpes*) in Great Britain: a preliminary report. Journal of Animal Ecology 10: 1-11.
- Stebbins, R. C. 1966. A field guide to western reptiles and amphibians. Houghton Mifflin Company, Boston, Massachusetts, USA.

- Truex, R. L., W. J. Zielinski, R. T. Golightly, R. H. Barrett, and S. M. Wisely. 1998. A meta-analysis of regional variation in fisher morphology, demography, and habitat ecology in California. Draft report, California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section, Sacramento, California, USA.
- Ucitel, D., D. P. Christian, and J. M. Graham. 2003. Vole use of coarse woody debris and implications for habitat and fuel management. *Journal of Wildlife Management* 67: 65-72.
- Unsworth, J. W., D. F. Pac, G. C. White, and R. M. Bartmann. 1999. Mule deer survival in Colorado, Idaho and Montana. *Journal of Wildlife Management* 63: 315-326.
- U. S. Fish and Wildlife Service. 1979. Mammalian predator damage management for livestock protection in the western United States. Final Environmental Impact Statement. Department of the Interior, Washington D.C., USA
- Waters, J. R., and C. J. Zabel. 1998. Abundances of small mammals in fir forests in northeastern California. *Journal of Mammalogy* 79: 1244-1253.
- Whitaker, D. A. 2003. Relation of thin and release timber management practices to abundance of woodrats, chipmunks, mice, and ticks within the Hoopa Valley Indian Reservation. Thesis, Humboldt State University, Arcata, California, USA.
- Yaeger, J. S. 2005. Habitat at fisher resting sites in the Klamath Province of Northern California. Thesis, Humboldt State University, Arcata, California, USA.
- Zielinski, W. J., T. E. Kucera, and R. H. Barret. 1995. Current distribution of the fisher, *Martes pennanti*, in California. *California Fish and Game* 81: 104-112.

Zielinski, W. J., R. L. Truex, G. A. Schmidt, F. V. Schlexer, K. N. Schmidt, and R. H.

Barrett. 2004. Resting habitat selection by fishers in California. *Journal of Wildlife Management* 68: 475-492.

Zielinski, W. J., N. P. Duncan, E. C. Farmer, R. L. Truex, A. P. Clevenger, and R. H.

Barrett. 1999. Diet of fishers (*Martes pennanti*) at the southernmost extent of their range. *Journal of Mammalogy* 80: 961-971.

Zielinski, W. J., and N. P. Duncan. 2004. Diets of sympatric populations of American martens (*Martes americana*) and fishers (*Martes pennanti*) in California. *Journal of Mammalogy* 85: 470-477.

Appendix A. Taxonomic groups in the fisher diet at 4 sites in the Klamath Bioregion of northern California were ranked. Rank was determined as the most frequent (1) to least frequent diet item within each site. Vegetation and insects were excluded from ranking.

Family	Rank			
	Shasta-Trinity	Six Rivers	Hoopa	Green Diamond
Amphibia	8	9	5	6
Canidae	7	8	7	0
Cervidae	4	1	3	0
Geomyidae	8	7	0	0
Leporidae	7	6	7	5
Muridae	6	3	1	1
Mustelidae	5	8	0	0
Passeriformes	0	0	7	0
Piciformes	8	9	7	0
Procyonidae	0	7	0	0
Sauria	3	5	5	5
Sciuridae	1	2	2	2
Serpentes	7	7	7	4
Soricidae	7	0	6	0
Talpidae	2	4	4	3
Vespertilionidae	8	0	0	0