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PREY OF NESTING BALD EAGLES IN NORTHERN CALIFORNIA

RONALD E. JACKMAN
Garcia and Associates, P.O. Box 776, Fall River Mills, CA 96028 U.S.A.

W. GRAINGER HUNT
Predatory Bird Research Group, Long Marine Laboratory, University of California, Santa Cruz, CA 95064 U.S.A.

J. MARK JENKINS
Pacific Gas and Electric Co., Technical and Ecological Services, 3400 Crow Canyon Rd., San Ramon, CA 94583 U.S.A.

PHILLIP J. DETRICH
U.S. Fish and Wildlife Service, 1215 S. Main St., Yreka, CA 96097 U.S.A.

ABSTRACT.—Inland nesting Bald Eagles (*Haliaeetus leucocephalus*) in northern California preyed on both native and introduced freshwater fish species, primarily brown bullhead (*Ameiurus nebulosus*), Sacramento sucker (*Catostomus occidentalis*), common carp (*Cyprinus carpio*) and tui chub (*Gila bicolor*). At most locations, eagles ate mainly fish; however, birds, principally American Coots (*Fulica americana*) and Mallards (*Anas platyrhynchos*), were more important than fish at sites isolated from large rivers. Fish species taken by eagles varied between major drainages: Sacramento sucker were most common in eagle diets at impoundments along the Pit River and the American River, catfish predominated on the Feather River and Trinity River drainages, and tui chub were the principal prey of eagles nesting in the Lahontan System. Mean standard lengths of common prey fishes ranged from 240 mm for brown bullhead to 510 mm for carp; Sacramento sucker prey averaged 393 mm standard length. Productivity of eagle pairs using mostly native fishes on the Pit River was nearly identical to that of pairs taking mostly introduced fishes on the Feather River. We recommended that resource managers consider prey species composition and fish prey sizes in management decisions affecting Bald Eagle breeding habitat. Important management factors affecting fish populations included dam construction and operation and nongame fish control.

KEY WORDS: *Bald Eagle;* Haliaeetus leucocephalus; *California; food habits; prey remains.*

Presas de *Haliaeetus leucocephalus* anidando en el norte de California

RESUMEN.—Las águilas calvas anidantes de tierras adentro en el norte de California depredaron a especies nativas e introducidas de peces de agua dulce. Principalmente *Ameiurus nebulosus, Catostomus occidentalis, Cyprinus carpio* y *Gila bicolor.* En casi todas las localidades las águilas se alimentan de peces; sinembargo las aves principalmente *Fulica americana* y *Anas platyrhynchos* fueron mas importantes que los peces en los sitios aislados de los grandes ríos. Las especies de peces consumidas por las águilas varió entre los mayores drenajes: *Castomus occidentalis* fue el mas común en la dieta de las águilas a lo largo del Rio Pit y Río American, los bagres predominaron en los drenajes de los ríos Feather y Trinity. *Gila bicolor* fue la presa principal de las águilas anidando en el sistema Lahontan. La media estandar longitudinal de las presas comunes osciló entre 240 mm para *Ameiurus nebulosus* hasta 510 mm para *Cyprinus carpio*; *Catostomus occidentalis* promedio 393 mm de longitud. La productividad de las parejas de águilas que utilizaron peces nativos en el Río Pit fue casi idéntica a otras parejas que consumieron peces introducidos en el Río Feather. Recomendamos a los manejadores de recursos considerar la composición de especies presa y los tamaños de peces presa en las decisiones de manejo que afectan los habitats de anidación de las águilas calvas. Algunos factores importantes de manejo que pueden afectar las poblaciones de peces incluyen la construcción y operación de represas así como también el control de especies que no son de pesca comercial.

[Traducción de César Márquez]

Numerous introductions of nonnative game fish have greatly altered species composition within California waterways (Moyle 1976a). Likewise, extensive habitat alterations, especially dam construction, river flow regulation and channelization, have tended to favor introduced species (Moyle 1976b). Nongame fish eradication programs and flow changes specifically benefit recreational fisheries. Decisions regarding such habitat alterations and management programs have rarely considered the prey of Bald Eagles (*Haliaeetus leucocephalus*) and other piscivorous birds (Dombeck et al. 1984). Even so, nesting populations of Bald Eagles in California have increased in the post-DDT era (Detrich 1986), and the number of occupied nesting territories now exceeds 140 (R.M. Jurek unpubl. data). Most pairs nest in highly modified habitats and feed on both native and introduced fishes (Detrich 1989, Hunt et al. 1992c).

In this paper, we examine the relationship of eagle diets to habitat and prey regimes now characterizing northern California rivers. By analyzing prey remains obtained during this and several other studies (Hunt et al. 1992b, Jenkins 1992, Jenkins et al. 1994), we were able to compare differences in prey utilization between various river drainages, assess the dietary importance of various native and introduced fish species and provide information relative to conservation and enhancement of prey populations in important eagle management areas.

STUDY AREA

We collected prey remains from Bald Eagle nests located within three major drainage basins in northern California, each containing a different composition of native fishes: the Sacramento-San Joaquin drainage, the Lahontan system, and the Klamath River drainage (Moyle 1976a). In our study, the principal rivers of the Sacramento-San Joaquin drainage system with nesting Bald Eagles were the Pit River (including the Fall River and its tributary, the Tule River), the McCloud River, the Sacramento River, the Feather River (including the North, Middle, and South forks), the American River, and the Eel River (Fig. 1). Study sites in the Lahontan system, which flows into the Great Basin, were along the Little Truckee River, the Susan River and Eagle Lake. Within the Klamath system, eagle territories were near the Lost River and along the Trinity River. More than 80% of the nesting territories in this study were near reservoirs; the remainder were on natural lakes. Adjacent riverine habitats were often accessible to the eagles. Most nest sites occurred in ponderosa pine (*Pinus ponderosa*) or mixed conifer forests at elevations ranging from 450–1800 m.

For comparative purposes, we divided Bald Eagle territories into subgroups based on their proximity to one another along a shared drainage or impoundment. We also grouped pairs according to similarities of available fish fauna or aquatic habitat characteristics. For example, reservoirs designated as "Trout-managed" were stocked annually with hatchery salmonids (trout and salmon) and contained no significant populations of other prey fishes, although native catostomids (suckers) and cyprinids (minnows) were potentially available in nearby riverine habitats. We classified relatively small and isolated impoundments as "Basin Reservoirs," where there was no discernable watershed, or if they lay within an intermittent portion of a watershed.

METHODS

During 1983–92, we collected prey remains in and below nests, usually following dispersal of young and sometimes during the late nestling stage. Some sites were visited in multiple years and others only once during the study. From nest sites, we obtained bones, fur, feathers and fine nest lining, the latter containing fish scales and fine bones. We assembled a reference collection of common fish species in various size categories. We used reference bones and keys (Casteel 1976) and reference scales and scale keys (Lagler 1940, Casteel 1972) to identify the species and size of fish represented by each prey item found in the prey collections (Hunt et al. 1992c). For each fish species in our reference collection, we developed bone-length to standard-body-length regression equations for opercula, cleithra, crania, dentary and other species-diagnostic bones (McConnell 1952, Hansel et al. 1988). Using these equations, we calculated standard fish lengths (i.e., head to end of caudal peduncle) for each prey item and eliminated duplicate prey items by matching parts representing like-sized individuals falling within 95% confidence intervals. We determined the ages of fish scales by standard methods (i.e., counting annuli; Bagenal and Tesch 1978); we used length/annulus tables (Carlander 1969, 1977) to estimate size of fish represented only by scales. Since scales can only be aged and not assigned to individual fish numbers, we did not quantify fish prey from scales unless scales were the only remains for a particular species. In those cases, one fish was counted for each age represented. We calculated total weights for the selected (nonduplicate) prey items using length-to-weight equations from our reference fish and from Carlander (1969, 1977). From these total weights, we subtracted the weights of bones and scales plus 5% of the total weight (estimated unavailable or discarded biomass) to arrive at the edible biomass for each prey fish (Hunt et al. 1992c). For comparisons, we referred to "primary" prey fish species as those represented by ≥30% of total prey numbers or biomass, and "important" prey fish species as those with 15–29% of numbers or biomass.

We identified nonfish remains by comparison with museum collections. Identifying mammal hair required keys (Adorjan and Kolenosky 1969, Moore et al. 1974) and microscopic examination. We calculated biomass for nonfish prey from standard mean weights (Burt and Grossenheider 1964, Steenhof 1983, Dunning 1984) minus 10% to account for bones and unavailable biomass. Large species (i.e., weighing >5 kg) were assigned an arbitrary estimate of 2.5 kg biomass contribution, assuming that eagles obtained only a portion of each carcass.

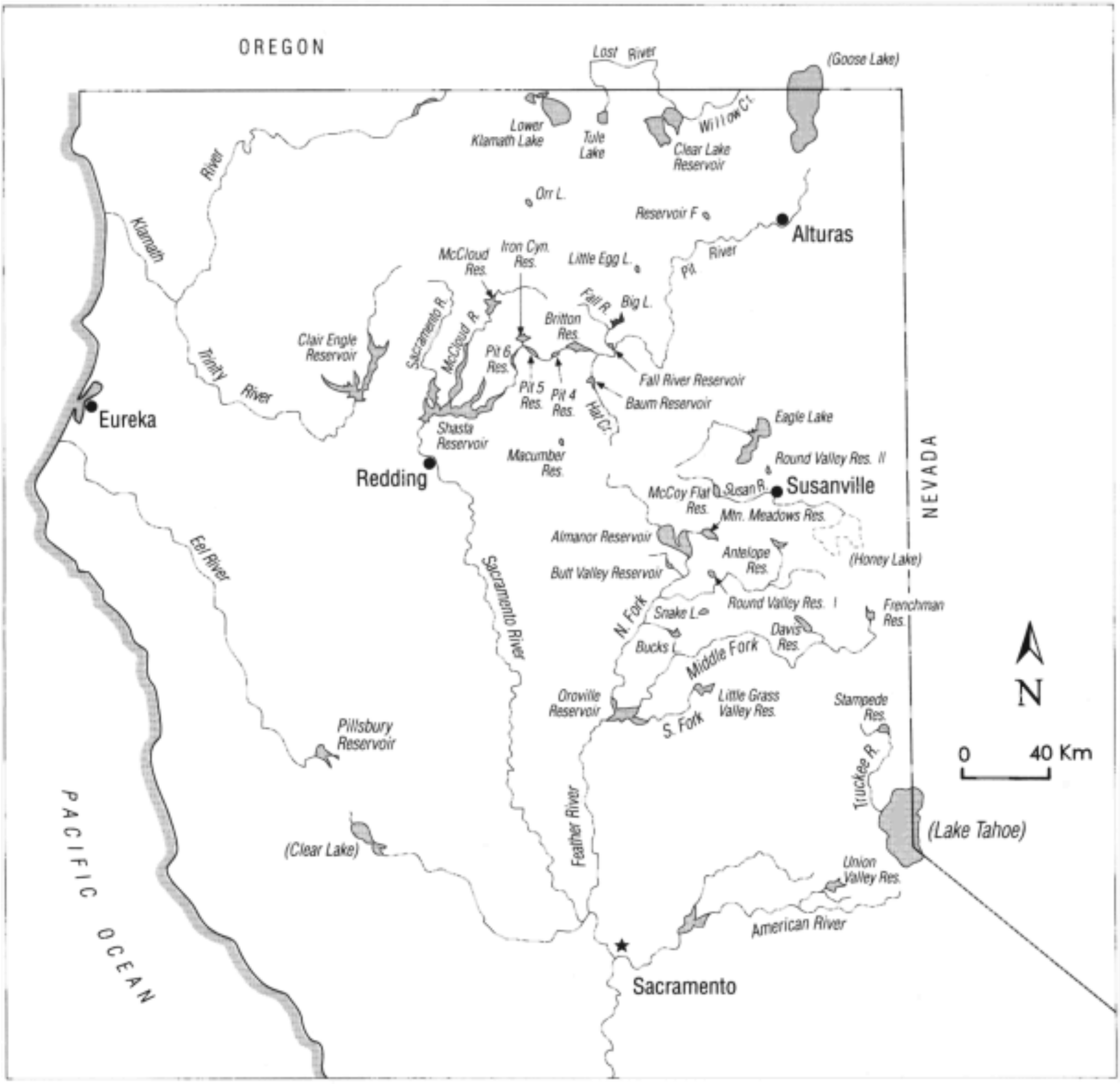

Figure 1. Location of the study area in northern California. Lakes indicated in parentheses were not included in the study.

Our analysis of prey use was biased in that it was based exclusively on prey remains. Previous studies comparing the analysis of Bald Eagle prey remains with observations of prey deliveries to the nest (Todd et al. 1982, Dugoni et al. 1986, Knight et al. 1990, Hunt et al. 1992a, 1992c, Grubb 1995) indicated that while prey remains tend to show all taxa used by eagles, in most cases small, soft-boned fish (e.g., trout) were underrepresented, and large, bony fish (e.g., carp and catfish) and birds were generally overrepresented in remains. The fish scale collections from nest linings helped mitigate this potential bias. With a few exceptions and catfish which have no scales, the relative number of scales found in nests reflected our fish bone analysis (i.e., large numbers of scales accompanied large numbers of conspecific bones).

RESULTS

Diet. We identified 2351 individual prey items representing 1637 kg of biomass from 56 nesting territories in our study area (Table 1). Nesting Bald Eagles utilized 20 species of fish, 41 bird, 15 mam-

Table 1. Number of individuals and estimated biomass (kg) of prey identified from remains collected in and below 56 Bald Eagle nests in northern California from 1983–92.

SPECIES	NUMBER	(%)	BIOMASS	(%)
FISH (Osteichthyes)				
Brown bullhead (*Ameiurus nebulosus*)[a]	817	(34.8)	214.2	(13.1)
Sacramento sucker (*Catostomus occidentalis*)	285	(12.1)	290.3	(17.7)
Common carp (*Cyprinus carpio*)[a]	122	(5.2)	368.9	(22.5)
Tui chub (*Gila bicolor*)[b]	110	(4.7)	57.5	(3.5)
Hardhead (*Mylopharodon conocephalus*)	80	(3.4)	48.1	(2.9)
Trout (Salmonidae)	32	(1.4)	15.5	(0.9)
Sacramento squawfish (*Ptychocheilus grandis*)[c]	30	(1.3)	25.9	(1.6)
Channel catfish (*Ictalurus punctatus*)[a]	21	(0.9)	17.8	(1.1)
Crappie (*Pomoxis* spp.)[a]	19	(0.8)	3.6	(0.2)
Tule perch (*Hysterocarpus traski*)	15	(0.6)	0.6	(trace)
Sacramento blackfish (*Orthodon microlepidotus*)	14	(0.6)	26.5	(1.6)
Rainbow trout (*Oncorhynchus mykiss*)	14	(0.6)	8.1	(0.5)
Largemouth bass (*Micropterus salmoides*)[a]	6	(0.3)	4.1	(0.2)
Sacramento perch (*Archoplites interruptus*)[d]	5	(0.2)	6.6	(0.4)
Tahoe sucker (*Catostomus tahoensis*)	5	(0.2)	6.5	(0.4)
Other sunfish (Centrarchidae)[a,e]	61	(2.6)	38.7	(2.4)
Other catfish (Ictaluridae)[a,f]	46	(2.0)	13.1	(0.8)
Unidentified minnows (Cyprinidae)	30	(1.3)	9.9	(0.6)
Unidentified trout/salmon (Salmonidae)	18	(0.8)	4.1	(0.2)
Unident. suckers (Catostomidae)	5	(0.2)	4.0	(0.2)
Other fish[g]	3	(0.1)	1.5	(0.1)
Subtotal fish	1738	(73.9)	1165.5	(71.2)
BIRDS (Aves)				
American Coot (*Fulica americana*)	120	(5.1)	69.3	(4.2)
Mallard (*Anas platyrhynchos*)	53	(2.3)	51.6	(3.2)
Western Grebe (*Aechmophorus occidentalis*)	25	(1.1)	33.2	(2.0)
Mountain Quail (*Oreortyx pictus*)	21	(0.9)	4.4	(0.3)
American Wigeon (*Anas americana*)	15	(0.6)	10.2	(0.6)
Northern Pintail (*Anas acuta*)	14	(0.6)	12.7	(0.8)
Gull (*Larus* spp.)[h]	17	(0.7)	7.7	(0.5)
Northern Shoveler (*Anas clypeata*)	12	(0.5)	6.6	(0.4)
Western Meadowlark (*Sturnella neglecta*)	12	(0.5)	1.1	(0.1)
Pied-billed Grebe (*Podilymbus podiceps*)	11	(0.5)	4.4	(0.3)
Cinnamon Teal (*Anas cyanoptera*)	11	(0.5)	3.8	(0.2)
Eared Grebe (*Podiceps nigricollis*)	10	(0.4)	2.7	(0.2)
Ruddy Duck (*Oxyura jamaicensis*)	9	(0.4)	4.4	(0.3)
Gadwall (*Anas strepera*)	8	(0.3)	6.6	(0.4)

Table 1. Continued.

SPECIES	NUMBER	(%)	BIOMASS	(%)
Band-tailed Pigeon (*Columba fasciata*)	8	(0.3)	2.8	(0.2)
Canada Goose (*Branta canadensis*)	7	(0.3)	21.2	(1.3)
Common Merganser (*Mergus merganser*)	7	(0.3)	9.3	(0.6)
Other puddle ducks (Anatinae)[i]	52	(2.2)	32.6	(2.0)
Unident. grebes (Podicipedidae)	26	(1.1)	17.3	(1.1)
Other diving ducks (Aythyinae)[j]	21	(0.9)	15.2	(0.9)
Other perching birds (Passeriformes)[k]	15	(0.6)	2.5	(0.2)
Other Anatidae[l]	10	(0.4)	18.7	(1.1)
Other birds[m]	39	(1.7)	34.5	(2.1)
Subtotal Birds	523	(22.3)	372.8	(22.8)
MAMMALS (Mammalia)				
Muskrat (*Ondatra zibethicus*)	13	(0.6)	13.7	(0.8)
Mule deer (*Odocoileus hemionus*)	10	(0.4)	25.0	(1.5)
Ground squirrels (*Spermophilus* spp.)[n]	10	(0.4)	2.7	(0.2)
Rabbits (Leporidae)[o]	8	(0.3)	9.4	(0.6)
Western gray squirrel (*Sciurus griseus*)	7	(0.3)	5.4	(0.3)
Other Sciuridae[p]	15	(0.6)	11.9	(0.7)
Other mammals[q]	25	(1.1)	30.6	(1.9)
Subtotal Mammals	88	(3.7)	98.7	(6.0)
REPTILES (Reptilia)				
Western pond turtle (*Clemmys marmorata*)	1	(trace)	0.2	(trace)
INVERTEBRATES				
Crayfish (Crustacea)	1	(trace)	0.1	(trace)
GRAND TOTAL	2351	(100.0)	1637.3	(100.0)

[a] Introduced fish species in California.
[b] Native to California, introduced into Almanor and Mtn. Meadows reservoirs.
[c] Native to California, introduced into Eel River/Pillsbury Reservoir.
[d] Native to California, introduced into Almanor Reservoir.
[e] 45 unidentified, 10 bass (*Micropterus* spp.)[a], 4 sunfish (*Lepomis* spp.)[a], 1 smallmouth bass (*Micropterus dolomieui*)[a] and 1 bluegill (*Lepomis macrochirus*)[a].
[f] 20 bullheads (*Ameiurus* spp.)[a], 2 white catfish (*Ameiurus catus*)[a] and 24 unidentified.
[g] 1 American shad (*Alosa sapidissima*)[a], 1 golden shiner (*Notemigonus chrysoleucas*) and 1 unidentified fish.
[h] Includes at least 2 California Gull (*Larus californicus*) and 2 Ring-billed Gull (*Larus delawarensis*).
[i] 4 Green-winged Teal (*Anas crecca*), 2 Wood Duck (*Aix sponsa*) and 46 unidentified.
[j] 3 Common Goldeneye (*Bucephala clangula*), 3 Scaup (*Aythya* spp.), 2 Ring-necked Duck (*Aythya collaris*), 1 Redhead (*Aythya americana*), 1 Bufflehead (*Bucephala albeola*) and 11 unidentified.
[k] 3 Steller's Jay (*Cyanocitta stelleri*), 2 Black-billed Magpie (*Pica pica*), 1 Common Raven (*Corvus corax*), 1 American Crow (*Corvus brachyrhynchos*), 1 blackbird (Emberizidae) and 7 unidentified.
[l] 2 Snow Goose (*Chen caerulescens*), 1 Tundra Swan (*Cygnus columbianus*), 1 Greater White-fronted Goose (*Anser albifrons*), 1 goose (Anserinae) and 5 unidentified.
[m] 4 Double-crested Cormorant (*Phalacrocorax auritus*), 2 Ring-necked Pheasant (*Phasianus colchicus*), 2 Western Screech-Owl (*Otus kennicottii*), 2 Belted Kingfisher (*Ceryle alcyon*), 2 Northern Flicker (*Colaptes auratus*), 2 Acorn Woodpecker (*Melanerpes formicivorus*), 1 Great Blue Heron (*Ardea herodias*), 1 Rock Dove (*Columba livia*), 1 pigeon (Columbidae), and 22 unidentified.
[n] At least 2 California ground squirrel (*Spermophilus beecheyi*) and 1 Belding's ground squirrel (*Spermophilus beldingi*).
[o] 2 jackrabbits (*Lepus* spp.), 1 black-tailed jackrabbit (*Lepus californicus*) and 5 unidentified.
[p] 2 yellow-bellied marmot (*Marmota flaviventris*), 1 chipmunk (*Tamias* sp.) and 12 unidentified.
[q] 4 rodents (Rodentia), 3 voles (*Microtus* spp.), 2 raccoons (*Procyon lotor*), 2 ungulates (Artiodactyla), 1 domestic cow (*Bos taurus*), 1 striped skunk (*Mephitis mephitis*), 1 western spotted skunk (*Spilogale gracilis*), 1 broad-footed mole (*Scapanus latimanus*) and 10 unidentified.

Table 2. Mean standard length of fish species commonly selected as prey by nesting Bald Eagles in northern California as measured from prey remains collected at nests.

SPECIES	N	MEAN STANDARD LENGTH (mm)	RANGE (mm)	SE
Trout	18	321	185–498	24
Common carp	85	510	244–854	13
Hardhead	64	330	194–527	8
Sacramento squawfish	28	418	278–631	14
Tui chub	98	282	180–341	4
Sacramento sucker	228	392	131–587	4
Channel catfish	17	368	251–551	24
Brown bullhead	456	240	129–356	2

mal and one each of reptile and invertebrate species. Fish accounted for >70% of overall prey numbers and biomass, while birds contributed approximately 20% and mammals <10% to both number and biomass totals. Mean standard lengths of most commonly taken prey fishes were greater than 300 mm, except for tui chub and brown bullhead (Table 2). Common carp showed both the greatest mean length and the widest range of lengths.

Regional Differences in Prey Utilization. Bald Eagle food habits varied widely between drainage and habitat groups (Table 3). Both the numbers and biomass of fish (χ^2 = 383.3, df = 18, $P <$ 0.001; χ^2 = 415.8, df = 18, $P < 0.001$), birds (χ^2 = 306.2, df = 18, $P < 0.001$; χ^2 = 283.8, df = 18, $P < 0.001$), and mammals (χ^2 = 77.6, df = 18, P < 0.001; χ^2 = 105.3, df = 18, $P < 0.001$) differed between 19 study locations as grouped in Table 3. Overall, fish dominated the diet (>50% of biomass and prey numbers) at most locations. Exceptions included Basin Reservoirs, Trout-managed reservoirs and Lost River, where birds and, to a lesser extent mammals, exceeded fish as prey.

Anatids were most prevalent in bird remains at the majority of sites; however, American Coots were more abundant in remains collected at the Lost River sites, Almanor, Butt Valley, and Pillsbury reservoirs. Gulls (Laridae) and grebes (Podicipedidae) were the predominant avian prey at Union Valley Reservoir and Lahontan sites, respectively.

All Bald Eagles nesting along the Pit River relied primarily on native Sacramento suckers (31–55% of prey biomass and 18–42% of prey numbers at all sites). Introduced ictalurids (catfish) were important only at Fall River Valley and Britton Reservoir nests (25% and 17% prey numbers, 14% and 8% biomass, respectively). Native cyprinids were important at all Pit River sites (17–22% prey numbers, 12–19% biomass) except Baum Reservoir (5% prey numbers, 4% biomass). Tui chub were the predominant native minnow taken in the Fall River Valley, and we found mostly hardhead in remains of cyprinids from nests along the rest of the Pit River drainage.

Native Sacramento blackfish and introduced common carp (38% and 34% biomass, 26% and 21% prey numbers, respectively) were the primary prey fish species of eagles at Shasta Reservoir. At the inflow of the North Fork Feather River to Oroville Reservoir, one eagle pair captured relatively large numbers of another native cyprinid, Sacramento squawfish (18% biomass, 15% prey numbers), although catfish were their primary prey (34% biomass, 37% prey numbers). A diversity of mostly introduced fish species populate both Shasta and Oroville Reservoirs.

Eagles nesting at reservoirs along all portions of the Feather River relied heavily on catfish (36–87% of prey individuals, 5–73% biomass for all sites). Common carp were the primary prey at Butt Valley Reservoir (86% biomass, 38% prey numbers), where catfish numbers were high (36% prey numbers), but their biomass (5%) was unimportant by comparison. With the exception of the Oroville Reservoir pair mentioned above, Feather River eagles captured very few native fishes. Although present throughout the Feather River system, Sacramento suckers were taken rarely, except at Oroville Reservoir (15% biomass and 14% prey numbers).

Table 3. Percent biomass of major prey groups and total number of prey items utilized by California breeding Bald Eagles as calculated from analysis of prey remains for 19 waterway territory groups.

								TOTAL			
WATERWAYS (N TERRITORIES)	TROUT	CARP	MIN-NOWS	SUCKERS	CAT-FISH	SUNFISH	OTHER FISH	FISH	BIRDS	MAM-MALS	N
Pit R.: Fall River Valley (3)[a]	1.5	3.3	12.4	30.5	13.9	4.4	0.0	66.0	25.1	8.9	178
Pit R.: Baum Res./Hat Cr. (1)	9.0	0.0	3.5	54.5	3.4	0.0	0.0	70.4	20.6	9.0	36
Pit R.: Britton Reservoir (6)	0.9	5.0	18.8	49.4	8.2	1.6	0.4	84.3	11.2	4.5	414
Pit R.: Pit 4, 5, 6 res. (4)	2.2	7.5	15.0	46.0	0.0	0.3	0.1	71.3	22.0	6.7	121
Shasta Reservoir (6)[b]	0.0	34.2	37.7	0.7	7.9	2.6	0.0	83.0	13.5	3.5	58
NFFR[c]: Oroville Reservoir (1)	1.3	9.1	18.3	14.9	34.4	5.1	0.0	83.1	16.9	0.0	52
NFFR: Mtn. Meadows Res. (2)	0.1	0.0	0.9	0.1	73.0	2.1	0.0	76.3	22.1	1.6	316
NFFR: Almanor Reservoir (4)	1.3	10.3	13.0	7.7	34.6	10.8	0.0	77.8	18.8	3.4	182
NFFR: Butt Valley Res. (2)	1.0	85.5	0.1	1.8	5.0	0.8	0.0	94.2	5.2	0.6	155
NFFR: East Fork (3)[d]	0.0	20.4	0.0	9.7	34.5	6.5	0.2	71.3	28.7	0.0	97
Middle Fork Feather R. (3)[e]	1.1	19.3	0.0	0.0	18.7	6.5	0.0	45.6	41.8	12.6	267
South Fork Feather R. (1)[f]	0.0	41.2	9.1	0.0	15.9	0.0	0.0	66.1	33.9	0.0	22
American River (1)[g]	0.6	0.0	0.0	47.8	0.0	17.6	0.0	66.0	27.0	7.0	28
Eel River/Pillsbury Res. (1)	1.9	3.6	31.6	27.9	0.0	18.2	0.0	83.1	7.4	9.5	37
Lahontan System (5)[h]	4.1	0.0	35.7	9.8	3.4	1.4	0.0	54.4	42.4	3.2	97
Trinity R./Clair Engle Res. (2)	1.8	0.0	0.0	9.1	57.6	10.4	0.0	78.9	18.8	2.3	72
Lost River (2)[i]	0.0	0.0	0.7	3.7	0.3	0.0	0.0	4.7	70.6	24.7	42
Basin Reservoirs (5)[j]	1.4	0.0	0.0	0.0	16.9	1.9	0.0	20.2	62.0	17.8	72
Trout-managed res. (4)[k]	9.8	0.0	0.3	4.4	0.0	0.2	0.9	15.6	63.0	21.4	103
All Sites (57)	1.7	22.5	10.3	18.4	15.0	3.2	0.1	71.2	22.8	6.0	2349

[a] Fall R., Tule R., Big Lk., Fall R. Res.; [b] Sacramento R., McCloud R., Pit R.; [c] North Fork Feather R.; [d] Snake Lk., Round Valley Res I, Antelope Res.; [e] Davis Res., Frenchman Res.; [f] Little Grass Valley Res.; [g] Union Valley Res.; [h] Eagle Lk., Stampede Res.; [i] Clear Lk Res., Willow Cr., Lower Klamath Lk., Tule Lk.; [j] Orr Lk., Res. F, Little Egg Lk., Round Valley Res. II, McCoy Flat Res.; [k] McCloud Res., Iron Canyon Res., Macumber Res., Bucks Lk.

The most common cyprinid taken by eagles at Almanor Reservoir was the tui chub (13% biomass, 12% prey numbers), a species native to most areas and introduced into the reservoir.

Sacramento sucker was a primary prey of Bald Eagles nesting on two reservoirs along the American and Eel rivers: Union Valley and Pillsbury Reservoirs (48% and 28% biomass, 36% and 30% prey numbers, respectively). Sacramento squawfish, introduced into the Eel River, was also a primary prey fish at Pillsbury Reservoir (32% biomass, 35% prey numbers). Our examination of scales in nest linings suggested that both eagle pairs took more salmonids than indicated by the bone samples. Eagles at both reservoirs captured more centrarchids (sunfish) than other California eagles (both 18% biomass and 14% numbers). All centrarchids identified in this study were introduced; the only sunfish native to California and taken by eagles, the Sacramento perch, was planted in Almanor Reservoir.

Within the Lahontan system, our studies focused principally on Eagle Lake (Table 3). The native tui chub was the primary prey of Lahontan eagles (36% biomass, 44% of prey individuals), and we found some use of native Tahoe suckers (10% biomass, 5% prey numbers). Birds, especially grebes, were also important (42% biomass, 41% numbers).

At Clair Engle Reservoir on the Trinity River, we identified catfish as the primary prey of nesting Bald Eagles (58% biomass, 72% prey numbers). Salmonids and centrarchids were probably underestimated in our analysis as evidenced by the relatively high numbers of their scales found in nest linings. Prey remains and scale samples indicated no use of native suckers.

In the Klamath Basin, Lost River Bald Eagles relied mostly on birds (i.e., American Coots; 71%

biomass, 76% of prey numbers) and mammals (25% biomass, 12% prey numbers). Fish, including native suckers and tui chub, were used infrequently (5% biomass, 12% numbers).

Like the eagles at Lost River, those nesting at Basin and Trout-managed reservoirs also captured many birds, mostly anatids (62% and 63% biomass, 53% and 57% prey numbers, respectively) and mammals. In addition, Basin and Trout-managed reservoir eagles exploited catfish (brown bullhead, 17% biomass and 33% numbers) and salmonids, respectively. Statewide, salmonids were important prey to Bald Eagles only at these Trout-managed reservoirs (18% prey numbers, 10% biomass) and at Baum Lake near a trout hatchery (14% numbers, 9% biomass). Also, salmonid use by eagles was likely even greater at these reservoirs, judging from the large number of scales collected. Bald Eagles captured hatchery-released trout, as evidenced by tag recoveries at Macumber Reservoir and Eagle Lake nests.

Prey Selection and Eagle Productivity. To evaluate the relative ecological benefit to eagles of exploiting mostly native versus mostly introduced prey fishes, we compared the productivity of all Bald Eagle pairs nesting on the Pit River with that of eagles nesting on the Feather River. Prey selection of fish groups differed significantly between drainages ($\chi^2 = 633.8$, df = 5, $P < 0.001$): Pit River eagles consumed mostly native suckers and native cyprinids while pairs on the Feather River took mostly introduced catfishes and carp. Mean productivity during 1983–92 on the Pit River ($\bar{x} = 0.93$ young/occupied year, $N = 121$ occupied years in 14 territories, SE = 0.08) was nearly identical to that on the Feather River ($\bar{x} = 0.95$ young/occupied year, $N = 112$ occupied years in 16 territories, SE = 0.08; $t = 0.11$, df = 231, $P = 0.46$). The annual success rates (successful years/occupied years, 1983–92) for the two areas were also similar: 55% ($N = 121$, SE = 5%) on the Pit River and 60% ($N = 112$, SE = 5%; $t = 0.68$, df = 231, $P = 0.25$) on the Feather River.

DISCUSSION

Fisheries. Like other populations of Bald Eagles (Swenson et al. 1986, Hunt et al. 1992a), those nesting in northern California exhibited a high degree of versatility in exploiting prey types that varied within and between drainage systems. Several studies have positively correlated the abundance of fish (measured by gill-netting) in open water habitats (i.e., estuary, reservoir and natural lake) with the diets of Bald Eagles (Gerrard and Bortolotti 1988, Mersmann 1989, Vondracek et al. 1989, Hunt et al. 1992c). We, however, did not sample fish populations for this study. Fish predominated in the diets of eagles at most locations, except in the Lost River area and at Basin and Trout-managed reservoirs. These reservoirs tended to be isolated from major river drainages and, hence, from large standing populations of fish. Many Basin Reservoirs periodically underwent drawdowns (e.g., from drought) with a resultant loss of fish. Past irrigation farming practices adversely affected native sucker populations in the Lost River system (Moyle 1976a). At Trout-managed reservoirs, salmonid populations were usually nonsustaining and were stocked annually. In these areas with depleted or unstable fish populations, eagles relied more on birds.

Overall, native fishes contributed substantially to the diets of California's Bald Eagles where exotics were absent (e.g., Eagle Lake), within regulated and unregulated riverine habitats (Hunt et al. 1992c), and where circumstances or adaptations allowed native fish to compete with introduced species within reservoirs. For example, pool fluctuations and low retention time due to hydroelectric operations of the relatively narrow Pit River reservoirs discourage spawning success and skew optimum temperatures for introduced centrarchids that prey on native fishes (Vondracek et al. 1989). By interviewing local fisheries biologists, we learned that native prey fish populations were relatively uncommon in reservoirs where eagles captured mostly exotics (R. Decoto, R. Flint, P. Chappel pers. comm.). Our research does not reveal how habitat modifications and reductions in native fish populations have affected Bald Eagles in a historical perspective.

Bald Eagles in California readily exploit the large populations of introduced fishes in reservoirs, and, indeed, most pairs (74%) are associated with reservoirs (Detrich 1989). Despite the destructive effects of carp on aquatic systems (Moyle et al. 1987), the species provided the greatest caloric contribution to breeding eagles overall, although they were not found as prey at many locations. Introduced species can fill human-created niches unsuitable for native fishes and thus provide prey for eagles in otherwise unsuitable habitat. For example, bullheads endure low temperatures and reduced oxygen conditions associated with low water levels (Moyle 1976a), an adaptation allowing them to persist in intermittent or widely fluctuating water bodies such as Mountain Meadows Reservoir. Annual stocking of salmonids at higher elevation, oligotrophic lakes (e.g., Bucks Lake) no doubt increases foraging opportunities for Bald Eagles.

Management Issues. Historically, Bald Eagle management activities focused on manipulating forest stands and restricting human activities at breeding sites (Dzus and Gerrard 1993). Bald Eagle prey species are now being considered more frequently when alterations to fish fauna or hydrological systems and wetlands are contemplated. For example, Hunt et al. (1992c) provided flow recommendations which benefitted both Bald Eagle foraging and trout fishing on the regulated Pit River.

There has been concern that efforts to convert to or restore salmonid fisheries by poisoning nongame fishes with rotenone may depress Bald Eagle productivity. Poisoning of Macumber Reservoir (1977) was followed by two years of no production for the single pair of nesting Bald Eagles, then succeeded by 14 years of reproduction averaging 1.3 young per occupied year. More recently at Reservoir F and Frenchman Reservoir, both eagle pairs were successful for the two years subsequent to rotenone treatment (R. Jurek, G. Studinski pers. comm.). Certain conditions were implemented to limit impacts of these treatments to nesting Bald Eagles, including timing eradication outside the breeding season and the immediate and continued generous stocking of salmonids following eradication. Waterbirds were also readily available to eagles to supplement their diet. If managed properly, salmonid restoration apparently has minimal impact on Bald Eagle productivity.

Both natural and human-related factors such as spawning stress, powerhouse tailrace kills, reservoir fluctuations stranding fish, hatchery trout releases and angling mortality contribute to carrion availability, which eagles habitually exploit (Hunt et al. 1992c, Stalmaster and Plettner 1992). We periodically observed substantial numbers of dead fish floating in reservoirs, including suckers at Britton Reservoir (Hunt et al. 1992c) and bullheads at Mountain Meadows Reservoir, where each species was prominent in the prey of eagles nesting at those respective sites. Prior to altering existing operations at water facilities, managers should consider potential impacts on carrion availability for Bald Eagles.

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