

PROJECT: BALD EAGLE PRODUCTIVITY FOR WRANGELL-ST ELIAS NATIONAL PARK AND PRESERVE 1993-1996

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INTRODUCTION

Bald eagles (*Haliaeetus leucocephalus*) are common breeders in Wrangell-St Elias National Park and Preserve (WRST), where most nests are concentrated along the Copper River and its major tributaries, and along the Malaspina Forelands. Potential threats to nesting eagles include habitat loss, human disturbance, and exposure to environmental contaminants that may affect reproduction or survival. Specific threats include highway construction from Chitina to Cordova, development and timber harvest on private lands along rivers, lakes, and coastal areas, potential increases in fishing pressure along the Copper River and its tributaries, camping or other recreational or subsistence access/use activities (including use of ATVs and jet boats) in sensitive breeding areas, and environmental contamination from local and global sources. Pollution is of special concern in the wake of the oil spill that occurred near Valdez in March of 1989. Eagles from WRST may be affected directly if they winter in areas damaged by the spill or indirectly by eating contaminated prey migrating in from affected areas. The close proximity of the oil pipeline to the Copper River and its tributaries and the presence of trucks that transport oil along the Richardson Highway adjacent to the Copper River are also cause for concern because of the increased potential for accidental spills. Offshore oil drilling may occur along coastal areas of WRST. These are all important reasons to document long-term trends on population density and reproductive rates for bald eagles.

In late June/early July of 1987 and 1988, the US Fish & Wildlife Service (USFWS) surveyed the Copper River from its headwaters at Copper and Tanada Lakes to the Copper River Delta to document nesting raptors (Amaral 1988). While overall productivity cannot be accurately assessed from single surveys (since the number of pairs which attempted to nest but failed is unknown), these surveys provided invaluable information on bald eagle nest locations, productivity of some individual nesting pairs, habitat measurements, and some general information on food habits. WRST initiated annual bald eagle productivity surveys along the Copper River from Copper and Tanada Lakes to Chitina in 1989 and to the Bremner River in 1990 (Faber 1989, Route 1990). The USFWS also surveyed the Copper River from Batzulnetas to Miles Lake in 1989 (USFWS 1989) and from Chitina to the Copper River Delta in 1990 (USFWS, unpubl data). WRST and USFWS data were combined for 1989-1990. In 1991, the survey area was extended south along the Copper River to the Wernicke River and east along the Bremner

River to Happel Slough. In 1992, the survey area was extended further south to the north end of Miles Lake (Abercrombie Creek), east along the Bremner River to its confluence with the Little Bremner River and west along the Tasnuna River to the Woodworth Glacier. WRST surveyed the Malaspina Forelands, along the coastal region of the Park during 1992-1995.

STUDY AREA:

There are 2 study areas, one interior and one coastal. The interior study area extends from Copper and Tanada Lakes south along the Copper River to Miles Lake, east along the Bremner River to its confluence with the Little Bremner River and west along the Tasnuna River to the Woodworth Glacier (Fig. 1). The interior study area is further divided into 3 regions, the Upper Copper River (UCR), the Middle Copper River (MCR), and the Lower Copper River (LCR), based on changes in habitat.

The UCR extends from Copper and Tanada Lakes (including Tanada Creek) south along the Copper River to the confluence of the Chistochina River. This includes 160 km along the Copper River (80 km on either side) and 58 km along Copper and Tanada Lakes and Tanada Creek. The UCR is dominated primarily by white spruce (Picea glauca) and the river is relatively narrow.

The MCR extends from the Chistochina River south to the confluence of the Chitina River and includes 358 km along the Copper River and 13 km along the Lower Tonsina River (179 km and 6.5 km on either side of each river, respectively). The MCR contains a mixture of both white spruce and cottonwood (Populus balsamifera), with cottonwood being slightly more common. The Copper River becomes wider and more braided along the MCR.

The LCR extends from the Chitina River south to Miles Lake and includes the Tasnuna and Bremner Rivers. This includes 403 km along the Copper River, 68 km along the Bremner River, and 45 km along the Tasnuna River (188 km, 45 km, and 22.5 km along either side of each river, respectively and an additional 27 km along the Copper River and 23 km along the Bremner River). The LCR is dominated by cottonwood along the river. The vegetation also begins to exhibit coastal influences, adding several coastal species including black cottonwood (Populus trichocarpa), Sitka spruce (Picea sitchensis), and mountain hemlock (Tsuga mertensiana). The Copper River becomes wider and more braided with steep canyons on either side. Nesting begins consistently later along the LCR and is probably influenced by the numerous glaciers in the area which delay snow melt and maintain the area in a winter like state several weeks after green up has begun to occur to the north. A total of 1105 kilometers are surveyed annually in the interior study area.

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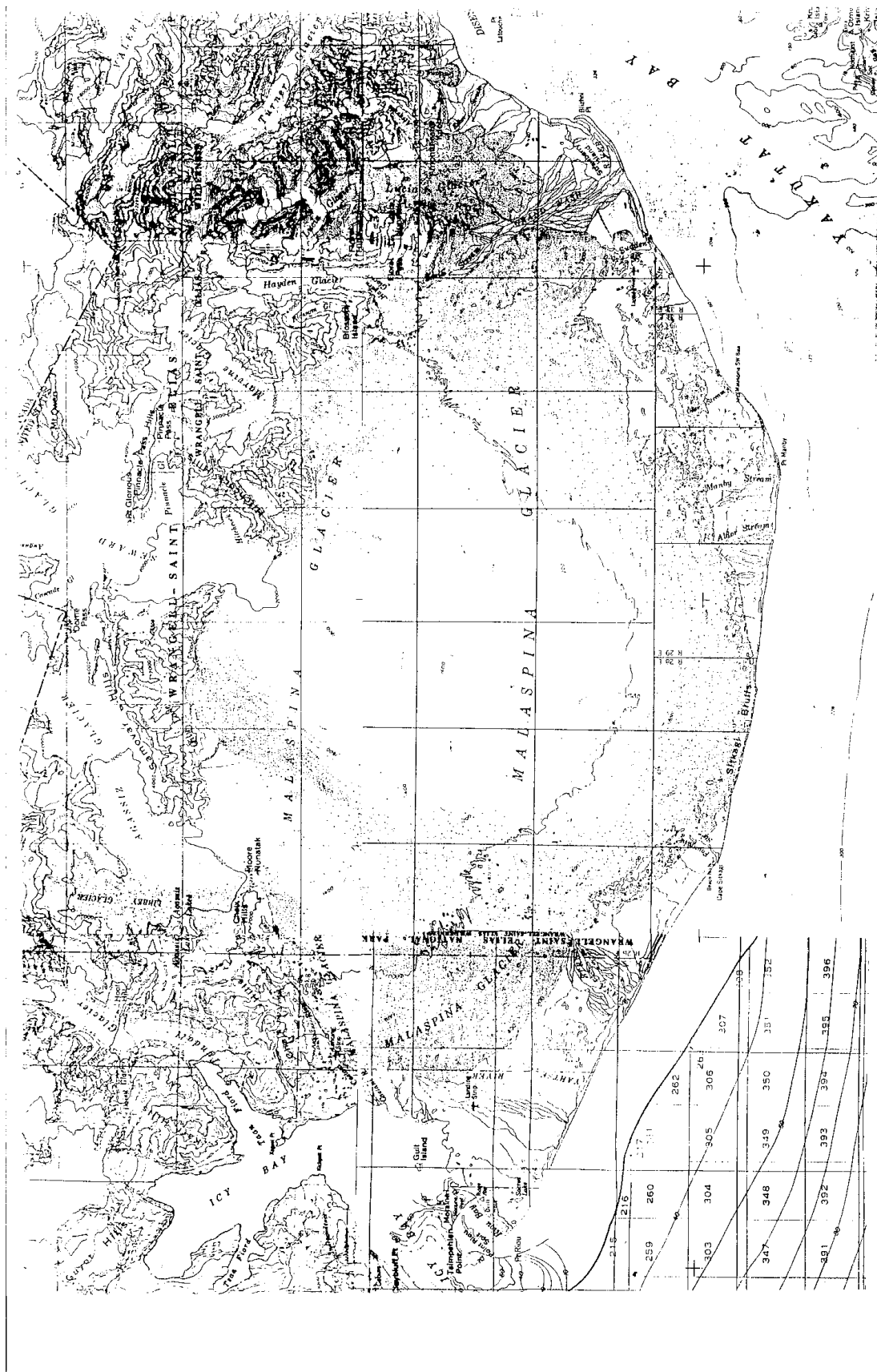


Figure 2. Coastal study area for bald eagle inventory and monitoring, Wrangell-St. Elias National Park and Preserve.

The coastal study area includes the shoreline of the Malaspina Forelands from Disenchantment Bay to Icy Bay and includes about 121 km (Fig 2). The dominant tree species are black cottonwood and Sitka spruce.

METHODS

The bald eagle survey consists of 2 flights, the first to locate occupied nests (occupancy survey) and the second to document reproductive success (productivity survey). Occupancy surveys are flown in mid-May and productivity surveys in late July. Survey information for 1989-1996 is outlined in Table 1.

Table 1. Survey information for bald eagle surveys, 1989-1996.

Occupancy Survey	Productivity Survey	Plane	Pilot	Observers
Interior				
5/23-27/89	7/1-7/89 & 8/2/89	Tern/Supercub Cessna 185	Hannah, Lee Rainy	Faber, Bird Bernatowicz
5/12-15/90	8/15-18/90	Tern/Supercub Cessna 185	Hannah, Lee Rainy	Bird, Route Bernatowicz
5/15-17/91	7/19-20/91	Tern/Supercub	Hannah, Lee	Kozie
5/12-14/92	7/30-31/92	Supercub	Lee	Kozie
5/7-9/93	8/2/93	Supercub	Lee	Steidl
5/11-12/94	7/29/94	Supercub	Lee	Kozie
5/11-12/95	7/27&31/95	Supercub	Lee	Kozie, Barten
5/10&13/96	7/28&31/96	Supercub	Lee	Barten
Coastal				
5/16/92	7/22/92	Supercub	Rainy	Kozie
5/14/93	8/3/93	Supercub	Sharp	Mossman
5/10/94	7/30/94	Supercub	Sharp	Mossman
5/12/95	8/2/95	Cessna 185	Sharp	Mossman

Specific methodology for bald eagle productivity surveys is described in detail in Kozie (1993). Briefly, the occupancy survey documents the breeding status of adults in each territory. The observer systematically checks all nests documented on topographic maps of the study areas. The following data is recorded directly on the maps during the occupancy survey: 1) the number of adults (**1** or **2 A**), and eggs (**1-3 eggs** but eggs are rarely observed) at the nest, 2) presence of an incubating adult (**I**), 3) an empty nest (**E**), 4) whether the nest is repaired (**egg cup visible, fresh greens, etc...**), 5) what condition the nest is in (**good, poor, remnant**), 6) whether the nest is not found (**NF**), gone (**NG**), or not checked (**NC**), and 7) new nest locations (include latitude/longitude and tree species). All nests which show evidence of breeding (e.g. 2 adults, an incubating adult, a

repaired nest, or a new nest) are considered occupied and are re-checked during the productivity survey. Any territory with at least one adult present is also re-checked since some pairs begin nesting after the occupancy survey. However, nests with only one adult and no other indication of breeding are not considered occupied unless there is evidence of breeding during the productivity survey.

The productivity survey consists of documenting nest success and the number of young produced. Data recorded on maps during the productivity survey includes: 1) the number of adults (**1 or 2 A**), 2) the number of young (**Y1, 2, or 3**), 3) empty nest (**E**), and 4) whether the nest is not found (**NF**), gone (**NG**), or not checked (**NC**). Only nests which were included in both surveys are used in productivity calculations.

Bald eagle productivity is measured by percent nest success (total number of successful nests/total number of occupied nests), the average number of young/occupied nest (total number of young/total number of occupied nests), and the average number of young/successful nests.

RESULTS AND DISCUSSION

Objective 1: To establish baseline data on bald eagle population size and trends in WRST.

The Copper River, its tributaries, and several other interior areas within WRST support 278 bald eagle breeding territories, 163 of which are surveyed annually by the National Park Service and 89 by the Bureau of Land Management (Table 2). The Malaspina Forelands along the coastal portion of WRST supports 23 breeding territories, all of which are generally surveyed annually. They were not surveyed in 1996, however, due to lack of available personnel in Yakutat.

Table 2. The number of bald eagle breeding territories along the Copper River, its tributaries, several interior areas within WRST and along the coastal region of the Park, 1996.

REGION	NUMBER OF TERRITORIES	REGION	NUMBER OF TERRITORIES
INTERIOR		COASTAL	
COPPER RIVER		YAKUTAT	23
UCR	23		
MCR	55		
LCR	51		
GULKANA RIVER BASIN	83		
DELTA RIVER 5			
TAZLINA RIVER	2		
KLUTINA RIVER	4		
TONSINA RIVER	3		
CHITINA RIVER	13		
NIZINA RIVER	2		
TASNUNA RIVER	12		
BREMNER RIVER	20		
TANA RIVER	3		
CHISANA RIVER	1		
PTARMIGAN LAKE	1		
TOTAL	278		23

Occupancy rates along the Copper River averaged 64% and have remained relatively stable during 1989-1996 (Table 3). The increase in occupied territories from 1989-1992 represents an increase in search effort as well as an expansion of the study area rather than an increase in the number of territories. This population is probably at carrying capacity and is not expected to increase. The number of occupied territories in Table 3 differs from occupied territories presented in productivity figures in Table 4. Table 3 contains all occupied nests (e.g. those which were occupied during the occupancy survey but not found or not re-checked during the productivity survey and those nests with young that were observed during the productivity survey only. These nests are not included in productivity figures).

Table 3. Territory occupancy rates for bald eagles nesting in the interior and coastal study areas of WRST, 1989-1996.

YEAR	TERRITORIES SURVEYED	OCCUPIED TERRITORIES	OCCUPANCY RATE
INTERIOR			
1989	104	67	64%
1990	115	76	66%
1991	127	88	69%
1992	149	98	66%
1993	153	97	63%
1994	157	98	62%
1995	162	102	63%
1996	164	100	61%
COASTAL			
1992	21	15	71%
1993	22	12	55%
1994	23	12	52%
1995	23	12	52%

Occupancy rates in the Gulkana River basin averaged 76% from 1989-1993 (Steidl and Anthony 1995). Territory occupancy in the upper Tanana Valley averaged 64% from 1986-1993, excluding 1988 (Timm et al 1993). Actual occupancy rates in the Upper Tanana are probably slightly higher since occupancy surveys were flown in late May after some nests may have already failed (Bernatowicz et al 1992).

Objective 2: Monitor reproductive success of bald eagles nesting in WRST.

Productivity (Interior)

Productivity of eagles nesting along the Copper River is slightly below that needed to maintain a stable population (Table 4). Eagles along the Copper River averaged 47% nest success and 0.7 young/occupied nest from 1989-1996. At least 50% of nesting pairs must be successful and produce a minimum of 0.7 young/occupied nest to maintain a stable population (Sprunt et al. 1973). However, 1.0 young/occupied nest is more indicative of a healthy population (Wiemeyer et al. 1984). Replacement of breeding adults along the Copper River probably occurs through emigration of eagles from the nearby Gulkana River basin and adjacent areas which have higher productivity. Eagles may also immigrate in from coastal areas.

The poorest nest success occurred along the MCR which averaged

34% nest success and 0.46 young/occupied nest during 1989-1996 (Table 5). The cause of poor productivity along this section of the Copper River is unknown but may be related to food availability. The lower productivity of eagles nesting along the Copper River in general may be a result of difficulty in capturing fish in highly silted glacial waters where eagles are unable to see their prey. The hypothesis of limited food availability is further supported by a lack of nests with 3 young. While more rare than nests with 1 or 2 young, only 1 nest containing 3 young has ever been observed in 8 years of surveys along the Copper River. Fifty-four percent of nests contained 1 young (N=168), forty-six percent contained 2 young (N=142), and < one percent contained 3 young (N=1).

Productivity within the Gulkana River drainage, adjacent to the Copper River, averaged 59% nest success, 0.89 young/occupied nest and 1.48 young/successful nest from 1989-1993 (Steidl 1994). Productivity in the Upper Tanana Valley averaged 60% nest success and 0.69 young/occupied nest from 1991-1993 (Timm et al 1993). These are both clear water rivers.

The timing of surveys is important. Eagles nesting along the LCR consistently have several nests with young that were not incubating during the occupancy survey (usually flown before May 15). This area tends to be later due to glacial influences which delay spring break up. Survey flights along the lower Copper River should be flown last, as close as possible to May 15. Even then, some occupied nests will be missed. Aging young by USFWS personnel in 1990 resulted in the estimation of the start of incubation at 2 nests along the LCR on May 27. Territories with 1 or 2 adults, or with a repaired nest during the occupancy survey should be re-checked during the productivity survey. The coastal study area also experiences glacial influences and should be surveyed on about May 15.

Table 4. Productivity of bald eagles nesting along the Copper River, 1989-1996.

<u>YEAR</u>	<u>OCC NESTS</u>	<u>SUCC NESTS</u>	<u>% NEST SUCCESS</u>	<u>NO OF YOUNG</u>	<u>YOUNG/ OCC NEST</u>	<u>YOUNG/ SUCC NEST</u>
1989	33	18	55%	27 ^a	0.82	1.50
1990	70	32	46%	52 ^b	0.74	1.63
1991	81	33	41%	44	0.54	1.33
1992	94	47	50%	71	0.76	1.51
1993	93	49	53%	75	0.81	1.53
1994	96	43	45%	60	0.63	1.40
1995	100	49	49%	67	0.67	1.37
1996	100	40	40%	59	0.59	1.48
AVERAGE			47%		0.70	1.47

^a This represents a minimum number of young in 1989. Adults were still brooding young at 2 nests during the second survey, making observations difficult. Calculations were based on estimates of 1 young in both of these nests.

^b The second survey was flown late (August 18) in 1990. This should be considered a minimum estimate of the number of young since some nestlings may have already fledged by this date.

Table 5. Productivity of bald eagles nesting along the Upper, Middle, and Lower regions of the Copper River, 1989-1996.

Upper Copper River

<u>YEAR</u>	<u>OCC NESTS</u>	<u>SUCC NESTS</u>	<u>% NEST SUCCESS</u>	<u>NO OF YOUNG</u>	<u>YOUNG/ OCC NEST</u>	<u>YOUNG/ SUCC NEST</u>
1989	3	2	67%	3	1.00	1.50
1990	9	2	22%	2	0.22	1.00
1991	13	7	54%	9	0.69	1.29
1992	10	9	90%	14	1.40	1.56
1993	15	9	60%	17	1.13	1.89
1994	14	9	64%	13	0.93	1.44
1995	11	10	91%	15	1.36	1.50
1996	13	8	62%	16	1.20	2.00
TOTAL			64%		0.99	1.52

Middle Copper River

<u>YEAR</u>	<u>OCC NESTS</u>	<u>SUCC NESTS</u>	<u>% NEST SUCCESS</u>	<u>NO OF YOUNG</u>	<u>YOUNG/ OCC NEST</u>	<u>YOUNG/ SUCC NEST</u>
1989	11	6	55%	7	0.64	1.17
1990	30	4	13%	6	0.20	1.50
1991	35	8	23%	11	0.31	1.38
1992	32	13	41%	18	0.56	1.38
1993	29	14	48%	21	0.72	1.50
1994	30	8	27%	11	0.37	1.38
1995	30	11	37%	13	0.43	1.18
1996	34	9	26%	14	0.41	1.56
TOTAL			34%		0.46	1.38

Lower Copper River

<u>YEAR</u>	<u>OCC NESTS</u>	<u>SUCC NESTS</u>	<u>% NEST SUCCESS</u>	<u>NO OF YOUNG</u>	<u>YOUNG/ OCC NEST</u>	<u>YOUNG/ SUCC NEST</u>
1989	19	10	53%	17	0.89	1.70
1990	31	26	84%	44	1.42	1.69
1991	33	18	55%	24	0.73	1.33
1992	52	25	48%	39	0.75	1.56
1993	49	26	53%	37	0.76	1.42
1994	52	26	50%	36	0.69	1.38
1995	59	28	47%	39	0.66	1.39
1996	53	23	43%	29	0.55	1.26
TOTAL			54%		0.80	1.46

Productivity (Coastal)

Productivity along the coastal portion of WRST was extremely poor (Table 6). Average productivity from 1992-1995 was 27% nest success, 0.32 young/occupied nest and 0.95 young/successful nest. There was complete nest failure in 1993. Although caution should be used in interpreting data from a small sample size, this poor productivity warrants further investigation. Productivity in other coastal areas is much higher. Average productivity in the Juneau vicinity and Seymour Canal from 1992-1994 was 67% nest success, 0.97 young/occupied territory, and 1.44 young/successful nest (M Jacobson, US Fish & Wildlife Service, unpub data). Productivity in Kodiak National Wildlife Refuge in 1992 averaged 65% nest success, 1.97 young/occupied nest, and 1.62 young/successful nest (Zwiefelhofer 1992, Bernatowicz et al 1992). Nest success in Prince William Sound in 1989-1990 averaged 44% nest success, 0.76 young/occupied nest (Bernatowicz et al 1992). Poor productivity in Prince William Sound during 1989-1990 was probably related to the Valdez oil spill and associated human disturbance.

Table 6. Productivity of coastal eagles nesting along the Malaspina Forelands, 1992-1995.

<u>YEAR</u>	<u>OCC NESTS</u>	<u>SUCC NESTS</u>	<u>% NEST SUCCESS</u>	<u>NO OF YOUNG</u>	<u>YOUNG/OCC NEST</u>	<u>YOUNG/SUCC NEST</u>
1992	15	7	47%	9 ^a	0.60	1.28
1993	12	0	0%	0	0.00	0.00
1994	12	2	17%	3	0.25	1.50
1995 ^b	12	5	42%	5	0.42	1.00
1996	NOT SURVEYED					
AVERAGE			27%		0.32	0.95

a This represents a minimum number of young. It was difficult to accurately assess the number of young at 2 nests due to dense canopy cover and small size of nestlings. Calculations were based on estimates of 1 young in both of these nests.

^b There were 5 additional occupied nests in 1995 for which the productivity could not be determined (the observer could see into the nest due to dense canopy cover). There were adults present at 4 of the 5 nests which may indicate the presence of young. Therefore, productivity may have been higher in 1995.

Objective 3: Document diet, identify foraging areas and measure habitat characteristics.

No quantitative data has been gathered on food habits. Anecdotal information on diet was collected during visits to measure habitat characteristics at nest trees in 1987-88. Several

additional nests were visited during 1991 and 1993, but limited food remains were found since many of the nests visited were not occupied (Table 7).

Table 7. Prey remains (includes 1 observation) found under bald eagle nest trees along the Copper River, 1987-1988, 1991, and 1993.

Mammals

Snowshoe hare (Lepus americanus)
Dall sheep lamb (Ovis dalli)

Birds

Trumpeter swan (Cygnus cygnus)
Canada goose (Branta canadensis)
Common snipe (Gallinago gallinago)
Mew gull
Sharp-shinned hawk (Accipiter striatus)

Fish

Sockeye salmon (Oncorhynchus nerka)
Chinook salmon (Oncorhynchus tshawytscha)

Other probable summer foods of bald eagles include Coho salmon (Oncorhynchus kisutch) which run up the Copper River in August and September. Arctic grayling (Thymallus arcticus) occur in clear feeder streams. Herring and mew gulls (Larus argentatus and L. canus) nest in colonies on sand bars and forage along the Copper River.

Prey availability in early spring may be critical to nesting eagles since salmon are not available in the Copper River or its tributaries until about mid-June. Steidl (1994) suggests that since most nest failures occur before hatching, prey levels before and during incubation are most critical. Spring food sources should be identified, monitored, and protected.

J Bernatowicz (US Fish & Wildlife Service, Cordova, AK) counted 1300 bald eagles, and estimated as many as 2000, feeding on hooligan (Thaleichthys pacificus) runs in the sloughs along the Copper River Delta on February 7, 1991. No radioed bald eagles from Prince William Sound were located along the Copper River Delta during the February 7 flight. It is possible these were interior eagles. Another hooligan run occurs in March. The hooligan runs along the Copper River Delta may be very important in late winter and early spring to bald eagles breeding along the Copper River and other interior areas (J Bernatowicz, pers comm). Dates that the sloughs are open, making hooligan available, vary in different years and may influence the productivity of bald eagles on the Copper River by affecting the

physical condition the eagles are in when they return to their breeding territories.

Alternate prey sources, including snowshoe hare, migrating birds, and winter killed ungulates are probably also critical in spring prior to ice out. Snowshoe hare were found among prey remains at several nests along the Copper River in 1987-88 and 1991 and were common among nests along the Gulkana River from 1989-1992 (RJ Steidl, pers commun). The snowshoe hare population crashed in 1992 and reached a low during the winter of 1993-94 in the Copper River basin (Route, unpub data). Migrating birds, including waterfowl, raptors, and some passerines are probably eaten by eagles in spring and later. This hypothesis is supported by limited prey collections and observations. The frequency of winter killed ungulates along the Copper River is unknown but probably low. Eagles likely use them opportunistically as they are available but ungulates are probably not a consistent spring food source. Twenty-seven bald eagles were observed near the Gakona bridge on April 8, 1994, presumably attracted by a dead ungulate or other large mammal although none was observed.

Plans to collect food remains and habitat data at nests along the Malaspina Forelands turned out to be too difficult logistically. No collections were made.

Objective 4: Identify occupied and potential bald eagle breeding habitat within WRST.

The primary habitat for bald eagles within WRST, the Copper River and the Malaspina Forelands, has been identified and is surveyed annually. The Chitina River was surveyed in 1991 and while it does contain at least 13 breeding territories, it represents somewhat marginal habitat for bald eagles due to the limited size of the trees. Resource staff will continue to document additional nests on an opportunistic basis. Potential impact areas will be surveyed as needed where nest information is not currently available.

The dominant tree species used for nesting varies by area (e.g. UCR, MCR, LCR; interior or coastal) and drainage (Table 8). Nest tree and nest measurements were recorded for 49 cottonwood and 22 spruce trees along the Copper River in 1987-1988, 1991, and 1993. Summary data are presented in Table 9.

Table 8. Nest tree species in interior and coastal study areas.

REGION	SPRUCE		COTTONWOOD		ASPEN	UNKNOWN	
	(N)	(%)	(N)	(%)		(N)	(%)
INTERIOR							
COPPER R							
UCR	35	71%	14	29%			
MCR	60	37%	98	61%		3	2%
LCR	1	1%	98	99%			
KLUTINA R	1		2				
TONSINA R			3			2	
CHITINA R	14		13		2	4	
NIZINA R	1					1	
TASNUNA R			15				
BREMNER R	4		28				
TANA R	2		1				
CHISANA R						1	
PTARMIGAN L	2						
TOTAL	120		272		2	11	
COASTAL							
YAKUTAT	15		29				

Table 9. Nest tree and nest measurements for nests along the Copper River, 1987-88, 1991, 1992, and 1993.

TREE SPECIES	TREE HEIGHT (M)			TREE DBH (CM)			NEST HEIGHT (M)			NEST DIAMETER (CM)			NEST DEPTH (CM)		
	N	x	SD	N	x	SD	N	x	SD	N	x	SD	N	x	SD
Cottonwood	49	18.4	4.2	48	47.7	11.7	50	14.0	3.9	25	117.9	62.1	26	77	38.3
Spruce	22	18.8	5.3	19	55.2	9.2	22	17.2	5.2	6	84.1	44.3	6	51	10.4

Objective 5: Monitor contaminant levels in bald eagles to gain secondary information on water quality.

Bob Steidl (Oregon State University) collected an addled bald eagle egg in 1990 from a nest along the Copper River (near the confluence of the Copper and Gulkana Rivers). It was submitted to USFWS (Fairbanks) for contaminant analysis in fall 1991. Unfortunately, this egg was lost and contaminant results will not be available.

Six egg shell fragments were collected from a nest along the MCR (161-23) in 1993. Three fragments measured 0.46 mm and 3 measured 0.47 mm. All of the fragments were missing shell membranes; 0.13 mm was added to each measurement to adjust for

missing membranes. Final measurements were 0.59 mm and 0.60 mm. This represents a 1% egg shell thinning from pre-DDT norms for eagles from Alaska (D Anderson, unpublished data). This suggests that the eagle that laid this egg had minimal amounts of DDE, the breakdown product of the organochlorine pesticide DDT which is responsible for egg shell thinning in birds. These data are approximations since the position of fragments on the egg was unknown and there is a potential for decrease in eggshell thickness during the latter part of embryonic development (Kreitzer 1972). Thinning >15-20% is associated with a declining population (Anderson and Hickey 1972, Newton 1979).

Goran Ewald from Lund University in Sweden sampled lipids and brains of sockeye salmon and arctic grayling as they migrated up the Copper and Gulkana Rivers for DDT, DDE, and DDD (reported as total DDT) and PCB contaminants in 1994 (Ewald 1996). Unfortunately, this data is difficult to interpret since DDT and PCB contaminants tend to concentrate in these tissues and do not accurately represent whole fish contaminant levels.

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