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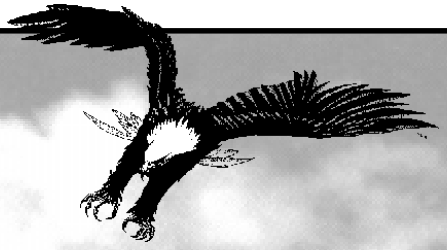
Skagit River Bald Eagles:
Movements, Origins, and Breeding Population Status



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Abstract: In winter 1997−98, we completed the second season of an investigation into the origins and breeding population status of bald eagles (*Haliaeetus leucocephalus*) on the Skagit River, Washington. We captured 14 adult eagles and 5 subadult eagles, for a total of 23 adults and 37 eagles captured during the study. As of July, 1998, 17 of the 23 satellite transmitters (PTTs) deployed on adult eagles were transmitting, and 4,760 satellite locations had been received. Satellite monitoring of adult eagles during spring migration (16 February to 5 April, n = 25 movements), and fall migration (8 August and 14 December, n = 5 movements) found eagles migrated along the coastal corridor from Washington to southeast Alaska, and through interior British Columbia along the Fraser River. Of 20 telemetered eagles, 40% originated from British Columbia, 35% from Alaska, 20% from the Northwest Territories, and 5% from the Yukon Territory. Breeding adults comprised 50% of the 16 adults for which nesting status was determined. Four of 5 eagles captured in winter 1996−97 returned to the Skagit River for nearly 3 weeks ($\bar{x}$ = 20 ± 23 days) of the 8 weeks ($\bar{x}$ = 55 ± 28 days) they spent in Washington and southwestern British Columbia in winter 1997−98. With the exception of 1 eagle that moved to the Feather River in northern California, winter movements of the 23 eagles in Washington were confined to the area east from the San Juan Islands to the Columbia River. We monitoried daily activities of 11 telemetered eagles over 42 days to examine movement and activity patterns. Eagle abundance and behavior were potentially influenced by prey; 93% fewer salmon carcasses were available to eagles on the Skagit River in winter 1997−98, compared to 1996−97. Two confirmed mortalities, and 1 suspected mortality occurred in the study population during the first 2 years. In winter 1998−99, we plan to complete deployment of PTTs, and conduct further behavioral observations of telemetered eagles to assess daily movements and activity patterns. Satellite monitoring will continue 2 years beyond the last date of PTT deployment.

The Skagit River is one of the key wintering areas for bald eagles (*Haliaeetus leucocephalus*) in the Pacific northwest and Washington state. As many as 500 eagles are found on the upper reaches within the Skagit Wild and Scenic River System (SW&SRS) (Stalmaster 1989). Eagles are attracted to the river because of the spawned carcasses of chum salmon (*Oncorhynchus keta*) and coho salmon (*Oncorhynchus kisutch*) deposited in the backwaters and on the riverbanks. Wintering eagles are found on the river from late October through March.

The river also attracts recreationists, principally sport fishers, rafters, and bird watchers. Steelhead (*Salmo gairdnerii*) fishing, which lasts from November through spring, is particularly popular to bank and boat anglers. Up to 115 recreational events/day have been documented in the SW&SRS (Stalmaster and Kaiser 1998). Research in the late 1980's correlated recreational activity with reduced eagle presence and feeding in the SW&SRS (Stalmaster and Kaiser 1998).

In 1993, the U. S. Forest Service (USFS), which is in charge of managing the SW&SRS, submitted a Biological Evaluation to the U. S. Fish and Wildlife Service concluding that the existing recreational use and/or proposed permitting of existing commercial users of the SW&SRS was "likely to adversely affect" the bald eagle. A subsequent Environmental

Assessment issued by the USFS proposed closing portions of the SW&SRS to surface water use during the morning hours as mitigation. The decision was very controversial and aggressively opposed by some recreationists. In 1996, voluntary river closures were enacted on the upper river between Rockport and Marblemount to ensure adequate feeding opportunities for bald eagles (Appendix, Fig. 1). The USFS is analyzing the effects of that effort.

To better understand the ultimate effects of recreational activity on eagle survival and reproduction of the wintering population of bald eagles on the Skagit River, it is necessary to establish the relationship between human interference and population dynamics of these eagles (Stalmaster and Kaiser 1998). This includes identifying the origins and population status of eagles wintering on the Skagit River, assessing their survival, and determining movement and activity patterns of individuals in relation to prey and human activity. Telemetry studies of eagles from the Skagit River and southeast Alaska (Servheen and English 1979, Hunt et al. 1980, Hunt and Johnson 1981, Hodges et al. 1987) suggested wintering eagles in Washington and the Skagit River originated from northern latitudes, but were not conclusive. In the winter of 1996–97, we initiated a study to investigate population characteristics of Skagit River bald eagles. We report here on the first 2 years of that investigation, with specific objectives to: 1) determine population origins of the SW&SRS bald eagles; 2) determine the breeding status of the monitored eagles and summarize what is known about the history of their nesting populations; 3) assess survival of marked eagles; 4) monitor local winter movements and activity of telemetered eagles, relate these to distribution of prey and human activity, and assess eagle fidelity to the SW&SRS.

STUDY AREA AND METHODS

We defined the limits of the study area as the Skagit River from Concrete to Newhalem, and the lower Sauk River (Appendix, Fig. 1). These reaches of the SW&SRS included both relatively high and low levels of human activity (Stalmaster 1989). In winter 1996–97, we captured eagles at 6 of 12 trap stations throughout the study area (Appendix, Fig. 1), and used variety of trap methods including padded leg-hold traps (Hunt et al. 1980), noose carpets (Watson 1985), noosed-salmon carcasses, floating-noosed fish (Cain and Hodges 1989), and remote noose snares (Jackman et al. 1994). In winter 1997–98, we set traps on gravel bars where eagles were successfully trapped the previous winter, and avoided islands that required boat access and increased the time necessary to secure ensnared eagles. In early December, when adult eagles began to arrive in increasing numbers, we initiated trapping efforts using remote-controlled noose snares placed around chum salmon and steelhead carcasses, which was the most effective trapping method used to capture adult eagles in winter 1996–97. On a few trap days we used noosed-salmon carcasses to capture eagles.

Traps were placed prior to dawn before eagles flew from the roosts to the river. Captured eagles were sexed by using hallux length and beak depth (Bortolotti 1984). Vinyl, teal-blue band markers (McCollough 1990) were attached to USFWS leg bands. Markers were coded with three alpha-numeric digits identifying the general location of origin (S), trapping year (6, 7 or 8), and sequential order of capture (a-z). Adult eagles were outfitted Platform Terrestrial Transmitter

Terminals (PTTs) from *Microwave Telemetry, Inc.* PTTs allowed for long-range satellite monitoring. VHF transmitters from *Advanced Telemetry Systems, Inc.* were piggy-backed to PTTs for local monitoring. Both transmitters were pre-programmed to transmit at varying diurnal and annual cycles in order to maximize battery life to last 3 winters. PTTs transmitted every 4th to 5th day during migration and winter, and once every 10 days during the nesting season; VHF transmitters transmitted only during the 12-hour period between dawn and dusk. Transmitters were attached with "X-attachment" backpacks (Buehler et al. 1995) using 0.66-inch teflon ribbon. Most eagles were released at capture locations within 1 hour following capture.

Because the 2 NOAA satellites that retrieve data orbited the earth approximately every 2 hours at the latitude of the study area, a potential of 8, but most often 3 or 4 locations were obtained during a given transmission period. Each location was coded during during down-loading into one these of 7 classes (Service Argos, Inc. 1994) based on the quality of the data received: class 3, accurate to <150m; class 2, accurate to <350m; class 1, accurate to <1000m; class 0, accurate to >1000m (i.e., no more accurate than 1000 m); class A, no accuracy assigned; class B, no accuracy assigned; class Z, invalidated location. Field testing of class 0 locations in northwestern Washington estimated error bias of 1.7 ± 2.2 km for latitude coordinants, and 4.4 ± 4.8 km for longitude coordinants (Watson and Pierce 1998). Thus, locations for classes 0-3 were considered useful for interpretation of movements, and probably described a geographic location <10 km of the actual location. We compared time eagles spent on the Skagit River and entire wintering area between 1997 and 1998 with Student's *t*-tests, and days spent in fall and spring migration with a paired *t*-test. Standard deviations were reported with means for movement summaries.

Using VHF telemetry, we opportunistically located telemetered eagles on the Skagit River during winter 1997−98. Our plan was to record daily and seasonal movements and activities of eagles, and compare them during and after the voluntary river closure to be enacted on mornings from late December through mid-January. However, because of an emergency closure of the steelhead fishing season in winter 1997−98, the voluntary river closure was not enacted and very few anglers were on the river. Consequently, too little human activity information was available for this analysis. Regardless, we recorded roost to roost movements of eagles to determine daily movement patterns. Eagle locations were recorded on laminated air photos for later digitization and plotting. Eagles were located in the morning and observed from upland viewpoints to record duration of perching, feeding, and flight activities. Human activity types and disturbance responses were noted. When eagles left the River, we attempted to complete the observations for that day, but otherwise did not follow eagles outside the study area.

To provide a baseline for comparing prey availability and eagle movements and distribution, counts of salmon carcasses were recorded throughout the study area as they were in 1996−97. Carcasses on river bars and in backwater areas <0.5 m feet deep were counted weekly by volunteers in boats from Concrete to Marblemount (Appendix, Fig. 1). Carcasses were tallied by species for each river mile on laminated air photos.

In April, when satellite locations indicated eagle movements had stabilized following spring migration, regional biologists in Alaska, and the Canadian provinces were contacted to assist in locating telemetered birds at nest sites. If birds were not located on breeding areas, we determined their nesting status by interpreting their movements. Eagles were classified as breeders if their satellite locations were within a confined area (e.g., < 20-km radius, and typically much less) for a 4-6 month period beginning in early spring. This was consistent with movements of satellite-telemetered eagles breeding in Washington (Watson and Pierce 1998). Requests for resighting information of marked birds were distributed to regional biologists and via the eagle communication network on the internet (eaglenet@unixg.ubc.ca). Additionally, a web page was created to educate the general public about the project (www.wa.gov/wdfw/wlm/research/eagle), and the project was featured as a K-12 educational study of animal migration throughout the winter of 1997−98 (www.learner.org/jnorth).

RESULTS

Trapping Summary and PTT Status

We captured 14 adult eagles and 5 subadult eagles in winter 1997−98, resulting in a total of 23 adults and 37 eagles captured during combined winters (Appendix, Table 1). We also captured and banded an immature golden eagle (*Aquila chrysaetos*) and red-tailed hawk *(Buteo jamaicensis*) in winter 1997−98. The golden eagle was found dead 47 days later on the lower Skagit River in Mount Vernon. His death was attributed to starvation. Eagles were captured at 3 of 12 trap stations used in 1996−97 (Appendix, Fig. 1). Remote-controlled nooses were used to capture all adults and all but 2 juveniles, which were captured on noosed salmon carcasses (Appendix, Table 2). Only 2 adult eagles escaped from traps after being ensnared in winter 1997-98, because we avoided use of trap stations on islands that required boat access, and reduced the time needed to secure eagles.

As of July, 1998, 17 of the 23 PTTs deployed both winters were transmitting (Table 1) and 4,760 satellite locations had been received. Six of 9 eagles captured in winter 1996−97 continued to be monitored. Inexplicably, signals from 1 of these adults (28006) provided location information only on the breeding area. Of the eagles captured in winter 1997−98, 1 PTT (28021) failed immediately after deployment, the signal from another PTT (28015) was lost within 6 weeks after deployment, and another telemetered adult (28018) was electrocuted near Chilliwack, B.C., 2 weeks after capture. The PTT was recovered, still functioning, and shipped to the manufacturer for lab testing. Electrocution was unrelated to presence of the PTT. This was the second confirmed mortality of eagles from the study, the first being a subadult eagle that was found at Pelican Lake, south of Prince George, B.C., in October, 1997. This was a suspected human-caused mortality. A third eagle (28008) was suspected to have died in spring, 1997, based on a lack of movement indicated by the activity sensor on the PTT.

Local Winter Movements

After being captured, the 23 adult eagles spent from 1 to 52 days ($\bar{x}$ = 16 ± 14 days) on the Skagit River, and on local tributaries of the Skagit River (Table 2). These eagles spent from 2 to 111

Table 1. Status of 23 PTTs deployed on adult bald eagles captured on the Skagit River as of July, 1998. PTTs 24015 through 28010 were deployed in winter 1996–97, and other PTTs were deployed in winter 1997-98.

PTT ID	Date Deployed	Life (mo.)	Status
24015	12/9/96	19	Functioning.
24016	1/2/97	18	Functioning.
28004	1/10/96	18	Functioning.
28005	1/29/97	18	Functioning.
28006	1/7/97	18	Functioning on breeding area; no winter movement info.
28007	2/6/97	11	Expired abruptly, 1/10/98.
28008	2/6/97	2	Expired 4/22/97; suspected mortality.
28009	2/12/97	18	Functioning.
28010	2/18/97	6	Expired abruptly, 8/4/97.
28011	12/5/97	7	Functioning.
28012	12/5/97	7	Functioning.
28013	12/13/97	7	Functioning.
28014	12/18/97	7	Functioning.
28015	1/7/98	1	Expired abruptly, 2/18/98.
28016	1/14/98	6	Functioning.
28017	1/20/98	6	Functioning.
28018	1/22/98	1	Eagle electrocuted 2/4/98.
28019	1/29/98	6	Functioning.
28020	2/3/98	5	Functioning.
28021	2/4/98	0	Failed after deployment.
28022	2/5/98	5	Functioning.
28023	2/5/98	5	Functioning.
22169	2/23/98	5	Functioning.

total days ($\bar{x}$ = 34 ± 24 days) on wintering areas in Washington and southwestern British Columbia after being captured and prior to spring migration. This excluded 1 adult that remained in southwestern British Columbia through late July (28012). There was no difference between post-capture time eagles spent on the Skagit River for eagles captured in 1997 and 1998 (P = 0.332). Post-capture time that eagles spent in Washington and southwestern British Columbia tended to be greater (t = 1.85, 20df, P = 0.079) in winter 1997 ($\bar{x}$ = 44 ± 29 days) than in winter 1998 ($\bar{x}$ = 27 ± 18 days). However, the median date of capture was also 14 days earlier in 1997 (1/7/97) than in 1998 (1/21/98) (see date of PTT deployment, Table 1).

Four of 5 eagles that were telemetered in 1997 returned to the Skagit River in winter 1998 (Table 2). For these eagles, time spent on the Skagit River throughout the entire winter ($\bar{x}$ = 20 ± 23

Table 2. Summary of winter movements and spring migration of adult bald eagles captured on the Skagit River in winters 1996–97, and 1997–98 .

Eagle ID	Year	Days on[a] Winter Area		Local Movement Pattern Among Rivers in Washington and southwest British Columbia	Spring Migration	Date Arrived on Breeding Pathway	Terminal Location Area	Breeding Status[b]
		Skagit	Total					
24015	1997	11	88	Skagit, Samish, Nooksack, Vanc. Is., Skagit	coast	4/15/97	Gulkana R., AK	NB
24015	1998	24	77	Fraser, Nook., Skag., Whatcom L., Nook., Samish, Nook., Skag..	coast	4/21/98	Gulkana R., AK	NB
24016	1997	10	68	Gold, Chilliwack, Nooksack, Campbell, Sumas, Skagit, Fraser	interior	4/28/97	Mackenzie R., NWT	NB
24016	1998	0	43	Fraser, Whatcom L., Pilchuck, Chilliwack	interior	4/3/98	Mackenzie R., NWT	NB
28004	1997	1	57	Skagit, Nisqually, Yakima	interior	4/2/97	Columbia R., BC	B
28004	1998	14	70	Skagit, Nooksack, Skagit, Chelan L., Columbia, Klickitat, Yakima	interior	4/15/98	Columbia R., BC	B
28005	1997	52	52	Skagit	coast	4/30/97	Smith R., BC	B
28005	1998	57	111	Squamish, Pitt, Fraser, Cascade, Skagit, Sauk, Skagit	coast	4/14/98	Smith R., BC	B
28006	1997	41	70	Skagit, Suiattle, Snohomish, Skykomish, Skagit	coast	4/26/97	Porcupine R., YT	B
28007	1997	6	13	Skagit	interior	4/12/97	Copper R., AK	NB
28008	1997	14	14	Skagit	interior	3/28/97	Williston L., BC	U
28009	1997	10	10	Skagit	coast	3/13/97	Ballenas Is., AK	B
28009	1998	5	72	Squamish, Fraser, Skagit, Fraser, Campbell, Nooksack	coast	3/10/98	Ballenas Is., AK	B
28010	1997	30	30	Skagit	coast	4/15/97	Beaver Creek, AK	NB
28011	1998	39	63	Skagit, Fraser, Pitt, Sumas	interior	2/26/98	Upper Fraser R., BC	U
28012	1998	2	[c]	Skagit, Boulder, Stillaguamish, San Juan Is., Campbell, Fraser	interior	4/25/98[c]	Upper Fraser R., BC	NB
28013	1998	18	111	Skagit, Suiattle, Columbia, Potholes Res., Chelan L.	interior	4/23/98	Mackenzie R., NWT	NB
28014	1998	5	18	Skagit, Pilchuck, Tolt, Naches, Klickitat	interior	5/8/98	Great Slave L., NWT	NB
28015	1998	5	42	Skagit, Sauk, Stillaguamish, Columbia, Yakima, Klickitat	n/a[d]	n/a[d]	n/a[d]	U
28016	1998	16	16	Skagit	interior	3/26/98	Trembleur L., BC	U
28017	1998	10	26	Skagit, Sauk, Nooksack, Fraser, Sumas	coast	3/8/98	Wrangell Is., AK	B
28018	1998	5	13	Skagit, Fraser	n/a[d]	n/a[d]	n/a[d]	U
28019	1998	25	44	Skagit, Sauk, Orcas Is.	coast	4/17/98	Great Bear L., NWT	B
28020	1998	30	36	Skagit, Cascade, Stillaguamish, Fraser	coast	3/26/98	Morice L., BC	B
28021	1998	11	11	Skagit[d]	n/a[d]	n/a[d]	n/a[d]	U
28022	1998	11	19	Skagit, Fraser	coast	3/10/98	Mitkof Is., AK	NB
28023	1998	11	43	Skagit, Shannon L., Fraser, Skagit, Sumas	coast	5/16/98	Susitna R., AK	U
22169	1998	2	2	Skagit	interior	2/26/98	Fraser L., BC	B

[a]Times were tallied post-capture for eagles during the first year; times were tallied for complete winters for eagles captured in 1997 and monitored in 1998. Time spent on the Skagit River included the lower Sauk River, Cascade River, and small tributaries of the upper and lower Skagit River. Total time included time spent in southwest British Columbia and western and eastern Washington.

[b]NB = nonbreeder; B = breeder; U = unknown breeding status.

[c]Remained on in southwest British Columbia until late July, then moved to upper Fraser River.

[d]PTT failed or eagle died before migration.

days) averaged 5 weeks less than the total time spent in Washington and southwestern British Columbia ($\bar{x}$ = 55 ± 28 days).

Winter movements of telemetered eagles in Washington were within the area bounded by the San Juan Islands to the northwest, Nisqually River to the southwest, Klickitat River to the southeast, and Columbia River to the northeast. Virtually all major river systems and lakes in this area were used by telemetered eagles, including the Hanford Reach of the Columbia River, the Yakima River, and Klickitat River in eastern Washington (Table 2). No eagles moved to the coast. Only 1 eagle (28014) captured on the Skagit River wintered south of Washington. The destination for this eagle was the Feather River in northern California, via the Harney Basin, Pit River, and Sacramento River. After spending 36 days on the Feather River, he migrated northward in spring to the Great Slave Lake in Northwest Territories through western Alberta.

During winter 1997–98, we observed 11 different telemetered eagles during 42 observation periods to record daily movement and activity patterns. Continous monitoring proved difficult because of the challenge of finding viewpoints without disturbing birds, and eagles typically moved between channels that were inaccessible except by boat or in areas where signal bounce was substantial. Because of the closure of the steelhead season, few human encounters with telemetered eagles were observed, reducing the opportunity to evaluate potential influences of disturbance on eagle behavior. Daily movement data are in the process of being digitized for analysis.

Spring Migration

Adult eagles migrated northward during the spring between 16 February and 5 April (n = 25 migration periods for combined winters). Migration from the Skagit River was along 2 general corridors (Table 2). Ten eagles moved along coastal British Columbia to southeast Alaska before moving to breeding areas. Ten eagles eagles moved through interior British Columbia up the Skagit River, Fraser River, and Columbia Rivers. Five eagles that we monitored both winters used the same spring flight corridors both years. Eagles arrived at terminal destinations (location where movements stabilized) between 26 February and 16 May (Table 2). Eagles reached breeding areas an average of 25 days (SD = 13; n = 25 movements) after leaving the wintering area. Average movement rate was 53 km/day during spring migration.

Origins and Breeding Status

Breeding areas of all monitored eagles wintering on the Skagit River were north of 49 degrees latitude, and were widely dispersed from southern British Columbia to north Yukon Territory, west to the Susitna River in interior Alaska, and east to Great Slave Lake in the Northwest Territories (Fig. 1). Forty percent of the 20 eagles originated from British Columbia (30% from central region, 5% from southern region, 5% from northern region), 35% from Alaska (20% from interior region, 15% from southeast region), 20% from the Northwest Territories, and 5% from the Yukon Territory. While no telemetered birds from the Skagit River nested in the contiguous United States, eagle 28012, which was a nonbreeder, remained on the Campbell River just north

Fig. 1. Breeding area locations of bald eagles captured on the Skagit River in winters 1996-97, and 1997-98.

of the Canadian border through late July, and made 2 visits during spring to the San Juan Islands in northwest Washington, before moving northward to the upper Fraser River.

Direct distance from eagle origins to the Skagit River averaged 1350 km (SD = 722), and ranged from 57 to 2426 km. The greatest distance between origins and the wintering area was 2570 km for eagle 28014, which wintered in northern California and returned to the Northwest Territories.

Based on air and ground searches and interpretation of locations, 8 adults were determined to be breeders, 8 nonbreeders, and 4 were unknown (Table 2). Nesting status of 3 adults was confirmed in 1997. Eagle 28009 occupied a territory on Ballenas Island in southeast Alaska, but did not nest. Nonbreeding adult 28010 was observed feeding on the Yukon River, and adult male 28004 successfully bred and raised 2 young on the upper Columbia River in southern British Columbia. As of July, 1998, nest status of 4 adults that were believed to be breeding had not been confirmed from ground or air searches. Opportunities for cooperating biologists to visit even the less-remote nests in 1998 were limited by the reduced emphasis on agencies to conduct bald eagle nesting surveys.

Fall Migration and Fidelity to Skagit River

Fall migration from breeding areas to southernmost destinations for 6 eagles captured in 1997 was initiated between 8 August and 14 December. Eagles migrated southward along similar flight corridors used in spring migration. Three eagles from coastal and interior Alaska used the coastal corridor to the wintering area. Signals for 1 of these eagles (28007) was lost before he arrived in Washington so it was unknown whether this eagle returned to the Skagit River. Eagles from the Mackenzie (24016) and Smith Rivers (28005) flew through interior British Columbia to southeast Alaska, before progressing down the coast to Washington. Eagle 28004, which nested on the upper Columbia River, migrated through interior British Columbia to arrive on the Skagit River. Of the 4 previously radioed eagles that returned to the Skagit River, he was the only eagle that immediately returned to the Skagit River upon arriving on the wintering area. Of 3 other eagles that eventually returned to the Skagit River, 2 initially returned to the Squamish River, and the other to the lower Fraser River.

Eagles left breeding areas between 8 August and 27 November, and first arrived on the wintering area between 27 November and 10 January. The 5 eagles took an average of 69 days (SD = 55) to reach the wintering area after leaving the breeding area, and moved an average of 19 km/day. This was half the rate the same eagles moved during spring migration (i.e., 38 km/day), but differences were not significant (paired-t = 1.61, 4df, P = 0.183).

Salmon Carcass Counts

In 1997−98, 8 salmon carcass surveys were conducted between Concrete and Marblemount from 5 December through 8 January. Only 390 carcasses were counted the entire period, with the highest count of 127 carcasses on 11 December. This compared to 6,000 carcasses tallied the winter of 1996−97 (Fig. 2). River miles 66 and 78 held the greatest number of carcasses both

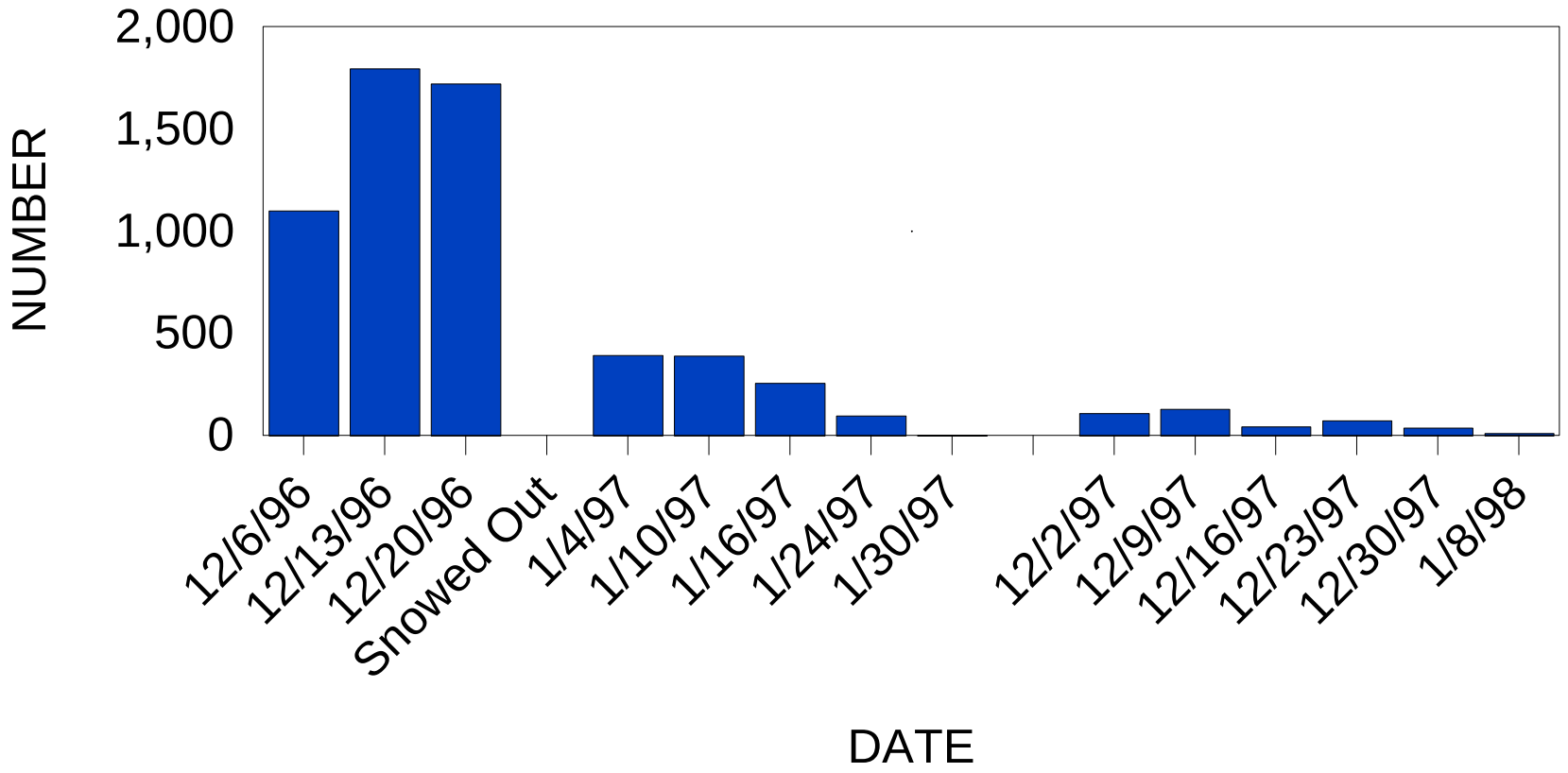

Fig. 2. Counts of salmon carcasses on river bars from boat surveys between Concrete and Marblemount on the Skagit River.

winters (Appendix, Fig. 2), and the confluence of the Sauk River (RM 66 and 67) and Cascade River (RM 77 and 78) had the most consistent abundance of fish throughout both winters.

DISCUSSION

Origins of Skagit River Bald Eagles

We believe the origin of adult eagles (i.e., natal region) can be surmised from where they spent most of their time during the breeding season. Results from 2 years of monitoring indicated that all 20 adult eagles we telemetered on the Skagit River originated north of the 49th parallel from broadly distributed breeding populations in British Columbia, Alaska, the Northwest Territories, and Yukon Territory. No telemetered individuals were from breeding populations in the contiguous United States, although 1 nonbreeding adult spent the spring in southwestern British Columbia, and moved twice to the San Juan Islands before moving northward. Similar movements were noted for 2 nonbreeding adult eagles from the Skagit River that wandered throughout north Puget Sound as late as early June (Hunt and Johnson 1981). Like the breeding adults, spring destinations for most nonbreeding adults were region-specific, although nonbreeders tended to wander locally after arriving at these areas because they were not nesting. Fidelity of 2 nonbreeders to their previous destinations the second spring provided evidence of a return to natal regions. In western Washington, nonbreeding adult bald eagles exhibited the same fidelity as adults to breeding areas and remained <35 km of previous destinations during the breeding period (Watson and Pierce 1998).

Wintering adult eagles on the Skagit River, and presumably throughout western Washington, composed a distinct population from breeding eagles in western Washington. Eagles breeding in western Washington migrated northward for several weeks in the summer and fall, and returned to southern breeding areas by early November, when winter migrants begin to arrive on the Skagit River (Watson and Pierce 1998). With 1 exception, these breeding eagles remained on their territories post-migration, and did not move to northwest rivers. We did not expect adult eagles to originate from breeding areas in California because earlier research indicated adults from northern California are resident throughout the year (Hunt et al. 1992*b*).

Ninety-five percent (19 of 20) adults that used the Skagit River remained within the region of southwestern British Columbia and Washington during the winter. The 1 transient adult that migrated through the region to winter in northern California returned to the eastern-most breeding range we identified (i.e., Great Slave Lake). Curiously, 3 wintering adults and a subadult recently captured in northern California and monitored via satellite-telemetry also returned to the Great Slave Lake or northwestern Saskatchewan/northeastern Alberta (J. Linthicum, Santa Cruz Predatory Bird Research Group, person comm.). Similarly, a satellite-telemetered 3-year old bald eagle that wintered in central Arizona returned to her summer range on Great Slave Lake (Grubb et al. 1994). These data indicate breeding bald eagle populations in the central Northwest Territories segregate on wintering areas, some individuals migrating along the Mackenzie-Intermountain Flyway of the Rocky Mountain front to California (McClelland et al. 1994), and others along the Pacific Flyway to Washington. Within the Pacific Flyway, we found eagles used

2 general migration corridors for both spring and fall migration (i.e., coast and interior) that were presumed to be the pathways used by migrants in earlier research (Servheen and English 1979). These 2 corridors were also used by eagles migrating from breeding areas in Washington in the summer and fall (Watson and Pierce 1998).

We suspect that wintering subadult eagles on the Skagit River also originated from populations north of the 49th parallel, but the only evidence from our study was 1 band return from central British Columbia. The subadult cohort likely included birds from a wider geographic area than adults, because juvenile bald eagles tend to be more nomadic in movements and timing of migration (Stalmaster 1987), and may even migrate longitudinally across flyways (McClelland et al. 1994). Juvenile eagles fledged in Washington were not believed to compose part of this wintering population, since their movements mirrored that of breeding adults and they returned to natal areas in the breeding season (Watson and Pierce 1998). Previous telemetry studies found subadult eagles that wintered in western Washington originated from breeding populations to the north, as well as south, and east. Migrant subadults from northern populations included a fledged juvenile from Whitehorse, Yukon that wintered as far south as the Olympic Peninsula (Hodges et al. 1987), a subadult from the Chilkat River, Alaska, that was detected on Hood Canal in late spring (Hunt and Johnson 1981), and 3 juveniles that wintered on the Skagit River and migrated northward as far as the central coast of British Columbia and southeast Alaska (Hunt and Johnson 1981). Two nestlings banded in interior Alaska on the Kandik and Tanana Rivers were recovered in south-central British Columbia and north-central Washington (Ritchie and Ambrose 1996). Subadult bald eagles that migrated in fall or winter from breeding populations south of Washington, included 4 juvenile eagles from California that moved up the Washington coast and western front of the Cascade Mountains (Hunt et al. 1992*a*), 4 juveniles hacked at nest sites in northern California that migrated northward to or beyond Washington (Sorenson 1995), and a juvenile fledged at Lake Shasta, California, that migrated through Washington to Dean River, British Columbia (J. Linthicum, Santa Cruz Predatory Bird Research Group, pers. comm.). Migrant juvenile eagles from breeding populations to the east of Washington in Glacier National Park, and the Greater Yellowstone Ecosystem, Montana, have wintered on the Skagit and Stillaguamish Rivers, south-central Washington, and coastal British Columbia (Swenson et al. 1986, McClelland et al. 1996, J. Watson, pers. obs.).

Breeding Population Status of Skagit River Bald Eagles

Bald eagles from the same breeding population may winter in areas separated by several hundred kilometers. This pattern is well established for subadult eagles (Gerrard et al. 1974, Swenson et al. 1986, Hunt et al. 1992, Mabie et al. 1994, Wood and Collopy 1995), and although less-studied, appears to be true for adults (Watson and Pierce 1998). Evidence from our study, combined with other investigations (Grubb et al. 1994, J. Linthicum, Santa Cruz Predatory Bird Research Group, person comm.) also suggests that not all adult eagles from a breeding area (e.g., Great Slave Lake) winter in the same location (e.g., Skagit River, northern California, Arizona). Assuming eagles from other source populations that winter on Skagit River behave similarly, any impacts to the wintering eagle population on the Skagit River from human activity, habitat loss, or prey declines are absorbed among many breeding populations. None of these populations are

known to be threatened, although based on earlier studies, some juveniles originate from threatened populations in California and Montana. Nest success and productivity of some of these northern breeding populations have been studied (Table 3). Productivity (i.e., young/occupied territory) of these populations is variable, particularly in Alaska, but is above that described for stable populations in which ≥50% of the pairs occupying territories breed, and produce an average of 0.7 young/pair (Sprunt et al. 1973). Status and population sizes of northern breeding populations are summarized below.

British Columbia.--Breeding bald eagle populations throughout Canada are considered stable (Fyfe 1976) to increasing in the interior (Swenson 1983). Increased populations may have resulted from a warming trend in the northern interior over the past century which has opened frozen lakes and rivers to foraging eagles (Swenson 1983). Populations in British Columbia are considered large, and either stable or increasing (Blood and Anweiler 1994). Except for large numbers of bald eagles killed by bounty hunters in southeast Alaska and British Columbia early this century (Alcorn 1975), coastal populations have probably changed little over prehistoric times (Beebe 1974). These coastal eagle populations were considered stable in comparison to other populations during the era when pesticides severly impacted productivity (Sprunt 1969). Forest clearing in the southern interior of British Columbia has probably resulted in a reduced population in that region over prehistoric times (Blood and Anweiler 1994).

An estimated 9,000 adult eagles resided in coastal British Columbia in 1980 (5,000 on north coast, 4,000 south coast), and 6,000 in the interior (Hodges et al. 1984). Blood and Anweiler (1994) revised the nesting population estimate, based on a hypothetical proportion of 56% nonbreeders (Hodges et al. 1984), to 1,980 territories on the coast, and 2,400 territories in the interior. In 1980, coast populations north of Vancouver Island were estimated to be 9 nests/100 km in 1980, and densities on the south coast at 8 nests/100 km (Hodges et al. 1984). In the areas from which Skagit River eagles originated, breeding territories are considered to be of low abundance (e.g., province interior to the north including the Smith River), of moderate abundance (e.g., central lakes region of the interior including Williston Lake, Morice Lake, Fraser Lake, and Upper Fraser River), and of low to moderate abundance (e.g., south interior, including Columbia and Fraser River) (Blood and Anweiler 1994). Nesting densities have been estimated in 2 interior areas occupied by Skagit River bald eagles, including 12 nests/100 km on the lower Fraser/Harrison River (Farr 1988), and 9 nests/100 km on the upper Columbia River (Blood and Anweiler 1994).

Alaska.--As in Canada, bald eagle populations in Alaska were most heavily influenced by bounty hunting early in this century, rather than pesticides or habitat loss (King et al. 1972, Hansen and Hodges 1985, Ritchie and Ambrose 1996). Populations in interior Alaska have increased substantially since the middle of this century, and continue to increase along the Tanana River (Ritchie and Ambrose 1996), but are at carrying capacity on the Copper River and may be producing below levels needed for population stability (Kozie 1996).

In 1996, an estimated 525 to 725 pairs of eagles nested in interior Alaska, with 85% of known

Table 3. Bald eagle nest success and productivity of populations that winter on the Skagit River, Washington. NI = no information provided.

Province/State	Location	Territories (*n*)	% Nest[a] success	Young/occupied territory	Young/successful territory	Years	Source
British Columbia							
	Fraser Valley	32	84	1.5	1.7	NI	Dunbar 1988[b]
	southeast interior	11	91	1.4	1.5	NI	Forbes and Kaiser 1984[b]
	Vancouver Island	53	62	0.9	1.5	NI	Blood 1989[b]
	Interior Lakes	NI	NI	NI	1.4	NI	Blood and Anweiler 1983[b]
Alaska							
	Gulkana River	274	59	0.9	1.5	1989–94	Steidl et al. 1997
	Copper River	471	48	0.7	1.5	1989–94	Steidl et al. 1997
	Interior coast	12	27	0.3	1.0	1992–95	Kozie 1996
	southeast	NI	67	1.0	1.4	1992–94	M. Jacobson unpubl. data
Yukon							
	entire province	163	39-63	NI	1.7	1977–88	Mossop 1997
	southwest	39	72	1.1	1.5	1980–82	Blood and Anweiler 1990
	Porcupine River	24	53	0.8	2.0	1977–84	Mossop 1997

[a]% of occupied nest sites producing young to fledging age.

[b]Reported in Blood and Anweiler (1994).

nests on the Susitna, upper Copper, and Tanana drainages (Ritchie and Ambrose 1996). In the areas from which Skagit River eagles originated, breeding territories are considered to be common (Tanana Region including the Tanana River, 75-100 estimated breeding pairs; Upper Copper Region including the Copper, Gulkana, and Gakona Rivers, estimated 125-175 breeding pairs; and Susitna Region including the Susitna River, estimated 150-200 breeding pairs) or uncommon and dispersed (e.g., Upper Yukon including Yukon and Porcupine Rivers, 75-100 estimated breeding pairs) (Ritchie and Ambrose 1996).

From 1967 to 1977 adult bald eagle populations in southeast Alaska were stable (Hodges et al. 1979). However, surveys in the decade of the 1970's found a surplus of nonbreeding adults, and variable productivity, indicative of population saturation from a lack of suitable nesting habitat and foraging resources (King et al. 1972, Hansen and Hodges 1981, Hansen 1987). Hodges et al. (1979) estimated 0.9 adults/km of shoreline in southeast Alaska, for a population total of 7,300 adults. Surveys every 5 years from 1977 to 1997 suggest the population of adults in southeast Alaska has stabilized between 12,000-13,000 individuals (P. Schempf, USFWS, unpubl. data).

Northwest Territories.--In the Northwest Territories, from the Mackenzie River to the Arctic Ocean and the Great Slave Lake area, there are a number of nesting eagles but no figure for population size (Davies 1985). In the Yellowknife area of the Great Slave Lake, 60% of 35 territories were occupied, and 43% successful, while on the east arm of the Lake 51% of 78 territories were occupied and 36% successful (Allen and Ealey 1979). Fifty-seven percent of 207 bald eagle nests on the Lake were situated in cliffs (Allen and Ealey 1979). Low nest success may be characteristics of eagles in this region because of extended freezeup of the Lake resulting in a shortened breeding season (Allen and Ealey 1979).

Yukon Territory.--Nesting bald eagles have been recorded in all drainage basins of the Yukon , and the species is considered a common breeder, with 163 nest sites known throughout the territory (Mossop 1997). Total population numbers are likely between 400 and 550 breeding pairs; 1,250-1,900 total eagles, including 800-1,100 adults, comprise the migrant “fall flight” population (Mossop 1997). The population appears stable, and normally productive (Mossop 1997). The Porcupine River, along which 1 Skagit River bald eagle nested, supports between 36 and 43 nesting pairs, separated by an average of 32 km of waterway (Mossop 1997).

Population Structure, Survival, and Fidelity to Wintering Areas

If the bald eagle population we sampled on the Skagit River was representative of the wintering population, about half of the adults on the Skagit River were territorial breeders, and the other adults were non-breeders. Age class ratios of bald eagles on wintering areas reflect the demographic structure of the source population (Stalmaster 1987). Presumably, this principle applies to the adult sector of the population, with the ratio of nonbreeders to breeders reflecting that of the source populations. Four of 8 (50%) telemetered nonbreeders returned to interior and southeast Alaska, but only 2 of 8 (25%) breeding adults originated from Alaska. Hansen and Hodges (1985) identified a disproportionate number of nonbreeding adult bald eagles in southeast Alaska in the 1970's (e.g., >50% for 3 of 4 years), and attributed it to naturally occurring

ephemeral food supplies and strong territoriality of breeding adults that excluded nonbreeders (Hansen 1987). As breeding bald eagle populations stabilize and habitat becomes saturated in northern populations, nonbreeding:breeding adult ratios might be expected to increase to >50% on wintering areas, such as the Skagit River. Because survival rates are the overriding factor determining population trends, they should be used together with age ratios to determine population trends (Grier 1980). For the 2 winters of monitoring, we identified 3 mortalities among 37 marked and telemetered eagles (8%), and 2 mortalities among 21 telemetered adults (10%). Analysis and interpretation of survival rates will be conducted following another year of monitoring.

Examination of historic records suggested differential migration of adult and juvenile bald eagles occurs in some source populations from which Skagit River eagles originate (i.e., California and Montana), and that the Skagit River, as well as other Washington rivers, may serve as a winter "magnet" for young eagles from breeding populations east and south of Washington. This has implications for how human activities or prey availability on the Skagit River may affect the source populations. Subadult eagle survival on the Skagit River may be more affected by human activities than adult eagles because subadults are less tolerant of boating activity, have higher flush responses, lower foraging effectiveness, and presumably higher energy expenditures (Stalmaster and Kaiser 1998). Similarly, higher energetic demands and poorer foraging efficiency of wintering juvenile eagles, coupled with the potential increased human disturbance, were identified as potential negative impacts on winter survivorship of eagles on the Connecticut River in eastern North America (Craig et al. 1988).

Prey availability may also influence age ratios of bald eagle populations (Stalmaster 1976, Knight 1981) and potentially affect winter movements and fidelity to winter grounds. Reduced prey abundance on wintering areas, such as experienced in 1997–98 on the Skagit River, might increase ratios of subadult and adult eagles (Stalmaster 1976, Knight 1981), with unknown affects on the ratio of nonbreeding to breeding adults. One of 2 nonbreeding eagles demonstrated fidelity to the Skagit River the second winter when salmon carcasses were in very low abundance, compared to 3 of 3 breeding eagles.

Migrant adult bald eagles from Saskatchewan and Manitoba were more faithful to wintering areas in south-central Colorado than subadults, and returned for up to 10 years (Harmata and Stahlecker 1993). Similarly, adults that migrated from northern breeding grounds to Montana exhibited greater fidelity to wintering grounds than immatures (McClelland et al. 1994). The fact that 80% (4 of 5) adult eagles exhibited fidelity to the Skagit River, and spent 38% of their time in winter (average 3 weeks) on the Skagit River even in a year of comparatively low prey abundance, shows that the river is an important, traditional, feeding location for migrating adult eagles. Post-capture time eagles spent on the river the 2 winters was the same (average 14-19 days), and similar to post-capture time (average 18 days) that 15 adult and subadult eagles spent on the Skagit River in the early 1980's (Hunt and Johnson 1981).

The continued availability of chum salmon carcasses on the river, associated with healthy salmon

stocks, may be the most important condition for continued use of the Skagit River by wintering eagles. Numbers of bald eagles wintering on the Skagit was correlated with salmon biomass on the river in winter 1980−81, and eagles movements off the river corresponded with reduced salmon carrion abundance (Hunt et al. 1992*c*). After the demise of the salmon population on Flathead Lake, Montana, over a 10-year period, only a few of the 639 eagles that formerly wintered on the Lake returned, although many continued to migrate past the lake to other winter areas (McClelland et al. 1994). For eagles using the Skagit River in winter, their destination from northern breeding areas is not the river specifically, but is the region, based on the local movements of 95% (19 of 20) birds that remained in southwestern British Columbia and Washington state during the entire wintering period. Only 1 of 5 eagles monitored the second winter flew immediately to the Skagit River to winter. The more typical pattern was southward migration (averaging 1350 km over 69 days for all birds) to the northernmost rivers in this region (i.e., lower Fraser and Squamish), and then local movements (averaging <180 km over 55 days for all birds) throughout the wintering area, including some return visits to the Skagit River. Presumably, these local movements were in response to variable food supplies, and other factors, such as human activity levels. Regional fidelity of these eagles during the entire winter emphasizes the need for protection of salmon stocks on the northwest rivers listed in Table 2, which is fundamental to eagle survival and health of their breeding populations.

Winter 1998−99

In winter, 1998−99, we hope to further examine winter fidelity in light of potential changes in annual salmon carcass availability, and enacted river closures that regulate human activity. Future analysis of local movement data will involve digitization of locations and analysis of movements and activity patterns in light of salmon carcass distribution. Telemetered eagles will continue to be monitored into fall migration, 1998. During winter, 1998−99, at least 1 additional satellite transmitter will be deployed. Because questions remain concerning origins of subadult eagles, any further monitoring may focus on the population of subadult eagles. Carcass counts will be conducted again next winter.

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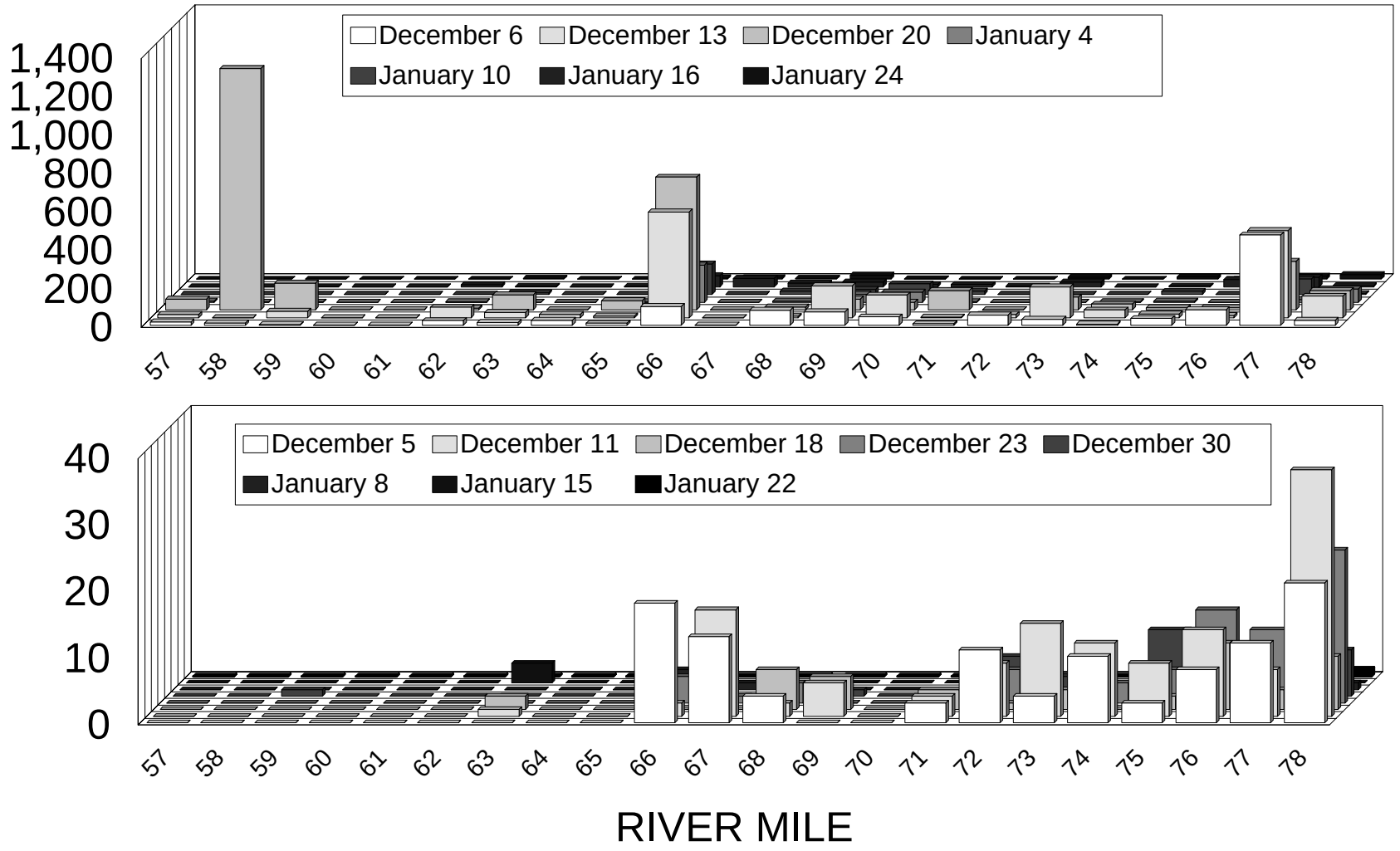
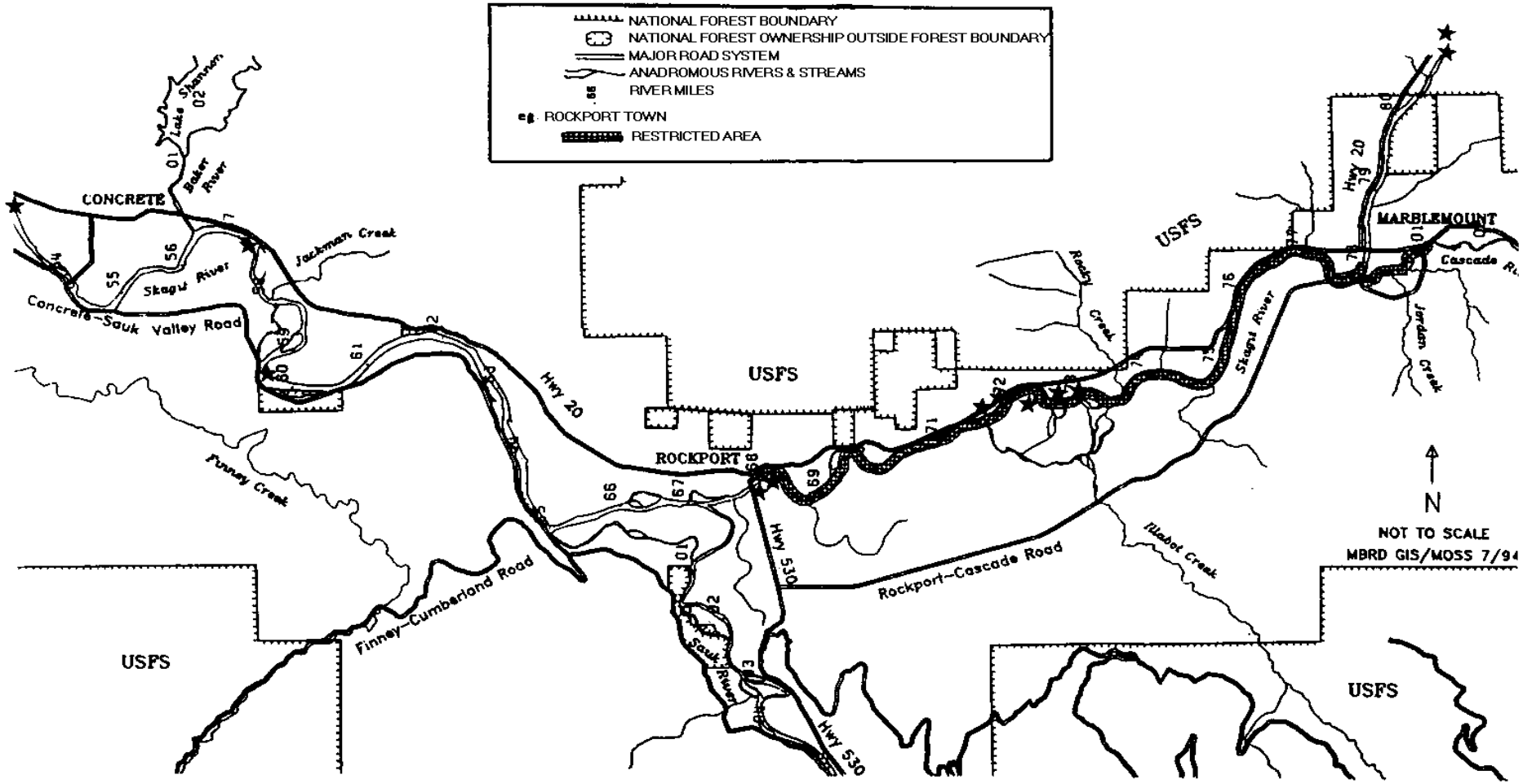


APPENDIX. Fig. 2. Counts of salmon carcasses per river mile from boat surveys between Concrete and Marblemount on the Skagit River for 2 winters. For reference, River Mile 58 includes Jackman Creek, River Miles 66-67 are at the confluence of the Sauk River, and River Mile 78 is at the confluence of the Cascade River.



Appendix Figure 1. Bald eagle study area on the upper Skagit River showing the voluntary restriction zone between Rockport and Marblemount. River miles are identified adjacent to the main channel. Stars identify locations of eagle trapping stations.

APPENDIX

Table 1. Information on bald eagles captured on the Skagit River in winters, 1996–97 and 1997–98.

Date	Age (yr)	Hallux Length (mm)	Beak Depth (mm)	Sex[a]	Marker Code	Band Number	Satellite ID	VHF Frequency	Location
12/5/96	1.5	42.0	35.3	male	S6A	629-08976	n/a	n/a	Buehler Farm
12/9/96	4.5+	39.6	35.0	male	S6B	629-08977	24015	164.245	Rockport Bar
12/31/96	1.5	38.0	33.5	male	S6C	629-08979	n/a	n/a	Rockport Bridge
1/2/97	1.5	40.5	34.0	male	S7A	629-08980	n/a	n/a	Buehler Bar
1/2/97	3.5	39.4	32.0	male	S7B	629-08981	24016	164.203	Buehler Bar
1/3/97	1.5	40.0	31.5	male	S7C	629-08982	n/a	n/a	Buehler Farm
1/7/97	4.5+	40.5	33.6	male	S6D	629-08983	28006	164.293	Buehler Bar
1/10/96	4.5+	40.2	32.0	male	S7D	629-08984	28004	164.223	Buehler Bar
1/13/97	1.5	37.0	34.5	male	S7E	629-08985	n/a	n/a	Buehler Bar
1/14/97	1.5	40.7	33.6	male	S7F	629-08986	n/a	n/a	Buehler Bar
1/29/97	4.5+	43.0	34.5	female	S7G	629-08987	28005	164.215	Bacon Creek
1/31/97	1.5	45.5	40.5	female	S7H	629-08988	n/a	n/a	Buehler Bar
2/6/97	4.5+	40.3	32.5	male	S7I	629-08989	28007	164.354	Bacon Creek
2/6/97	4.5+	40.7	33.0	male	S7J	629-08990	28008	164.305	Rockport Bar
2/7/97	1.5	42.0	38.0	female	S7L	629-08991	n/a	n/a	Rockport Bar
2/12/97	4.5+	46.6	36.3	female	S7K	629-08992	28009	164.253	Rockport Bar
2/18/97	4.5+	44.4	36.0	female	S7M	629-08993	28010	164.263	Bacon Creek
2/21/97	1.5	46.0	36.0	female	S7N	629-08994	n/a	n/a	Bacon Creek
12/5/97	4.5+	37.6	33.3	male	S7O	629-08956	28011	164.324	Rockport Bar
12/5/97	4.5+	39.1	33.0	female	S7P	629-08957	28012	164.283	Rockport Bar
12/11/97	2.5	45.0	35.2	female	S7R	629-08958	n/a	n/a	Rockport Bar
12/13/97	4.5+	38.5	31.9	male	S7Q	629-08959	28013	164.344	Rockport Bar
12/18/97	3.5	38.0	35.1	male	S7S	629-08960	28014	164.336	Buehler Bar
1/7/98	4.5+	42.0	32.7	female	S7T	629-08997	28015	164.366	Swift Creek Bar

APPENDIX. Table 1. Cont'd.

Date	Age (yr)	Hallux Length (mm)	Beak Depth (mm)	Sex[a]	Marker Code	Band Number	Satellite ID	VHF Frequency	Location
1/14/98	4.5+	41.0	35.5	female	S8A	629-08998	28016	164.313	Swift Creek Bar
1/15/98	0.5	39.3	33.8	male	S8B	629-08999	n/a	n/a	Buehler Bar
1/16/98	1.5	39.0	32.2	male	n/a[b]	629-09000	n/a	n/a	Buehler Bar
1/20/98	4.5+	42.5	33.6	female	S8D	629-09102	28017	164.414	Swift Creek Bar
1/22/98	4.5+	40.5	33.4	male	S8E	629-09103	28018	164.462	Rockport Bar
1/26/98	0.5	38.3	33.7	male	S8F	629-09104	n/a	n/a	Rockport Bar
1/27/98	0.5	46.4	37.1	female	S8G	629-09105	n/a	n/a	Buehler Bar
1/29/98	4.5+	42.0	37.0	female	S8H	629-09106	28019	164.404	Rockport Bar
2/3/98	4.5+	39.6	33.2	male	S8I	629-09107	28020	164.455	Swift Creek Bar
2/4/98	4.5+	45.4	41.1	female	S8J	629-09108	28021	164.424	Bacon Creek
2/5/98	3.5	46.5	38.8	female	S8K	629-09109	28022	164.443	Swift Creek Bar
2/5/98	4.5+	39.8	32.4	male	S8L	629-09110	28023	164.433	Bacon Creek
2/23/98	4.5+	44.5	35.0	female	S8M	629-09111	22169	164.541	Bacon Creek

[a]Sex based on Bortolotti index (Bortolotti 1984) from hallux and beak measurements. Index determined from adult eagles; appropriateness of application to subadults is unknown.

[b]Right leg missing, no band marker.

APPENDIX

Table 2. Trap effectiveness and success in capturing bald eagles on the Skagit River in winters, 1996–97 and 1997–98.

Trap type	Captures		Escapes[a]		Total
	Adults	Subadults	Adults	Subadults	
Leg-hold in water	0	0	0	0	0
Leg-hold on land	0	1	1	1	3
Floating Noosed Fish	0	0	0	0	0
Noosed Carcass (salmon)	1	6	4	7	16
Noose Carpet (deer)	0	0	0	0	0
Remote Snare	22	7	7	0	16
Total	23	14	12	8	35

[a]Eagles slipped out of traps or broke away from nooses after being captured.