**Mark V. Stalmaster**[1] and **James L. Kaiser,**[2] Stalmaster and Associates, 1570 East Burgundy Road, Shelton, Washington 98584

# Winter Ecology of Bald Eagles in the Nisqually River Drainage, Washington

## Abstract

We studied the winter ecology of a population of bald eagles (*Haliaeetus leucocephalus*) on the Nisqually River and a tributary, Muck Creek, in Washington, for 3 years. Peak eagle numbers on the river and creek combined occurred in early February and were 168 in 1991-92, 128 in 1992-93, and 156 in 1993-94. For the 3 years, 79% of eagles used the Nisqually River and 21% used Muck Creek. Eagle use of the river was high between 8 and 18 km (5 and 11 miles) upstream of Puget Sound and at the mouth of Yelm Creek; use on Muck Creek was concentrated on the lower 4 km (2.5 miles). The subadult proportion in the study area was 46% in 1991-92, 41% in 1992-93, and 43% in 1993-94; it increased throughout each winter; and it was higher where most eagles congregated. Chum salmon (*Oncorhynchus keta*) was the primary food source, and this eagle population was predicted to consume 1,100 salmon carcasses each winter based on the yearly average of 6,952 eagle use days on the river and creek. Black cottonwood (*Populus balsamifera*) was the most widely used tree species by both perching (53% of 1,423 eagle sightings) and roosting (53% of 94 roost trees) eagles, and 8 of 9 communal roosts were located in old-growth forests. Management to enhance chum salmon runs, maintain forest habitat, and regulate human disturbance is needed to protect this eagle population.

## Introduction

Washington has the largest number of wintering bald eagles in the contiguous United States (Stalmaster 1987:31), and most of these eagles use rivers in the western portion of the state. Large winter populations of eagles in Washington exist on the Skagit River (Servheen 1975, Ralph 1980, Stalmaster 1989, Hunt et al. 1992), Sauk and Suiattle rivers (Russell 1980, Stalmaster 1989), Nooksack River (Stalmaster et al. 1979, Knight and Knight 1983), Skykomish River (Hansen and Bartelme 1980), Lewis River (Anderson and Ichisaka 1986), and Columbia River (Fitzner and Hanson 1979, Knight et al. 1979, Fitzner et al. 1980, Wood 1980, Fielder and Starkey 1980, 1987). A wintering eagle population on the Nisqually River and its tributaries has been locally known for years (Harrington-Tweit and Kerwin 1979, 1980; U.S. Army unpubl. data), but never studied in detail. The purpose of this study was to determine the numbers and distribution of bald eagles on the Nisqually River and Muck Creek, locate communal night roosts, document diurnal and nocturnal habitat use, and assess dietary habits.

## Study Area

The study area is located south of Puget Sound and east of Olympia, Washington, mostly on the Fort Lewis Reservation (FLR), a U.S. Army Installation, and the Nisqually Indian Reservation (NIR) (Figure 1). The Nisqually River, which originates on Mount Rainier, traverses both reservations northward and empties into Puget Sound. Muck Creek traverses the FLR westward and empties into the Nisqually River 18 km (mile 11) upstream from Puget Sound. Yelm Creek passes through private land in the study area and enters the Nisqually River 21 km (mile 13) upstream from Puget Sound. Most shorelines of the river and creeks in the study area are undeveloped; the studied portion of Muck Creek flows through military firing ranges on the FLR.

The study area is in the *Tsuga heterophylla* (western hemlock) Vegetation Zone (Franklin and Dyrness 1973). Most forests on the FLR are composed of Douglas-fir (*Pseudotsuga menziesii*) and are managed for development of late successional stages. Forests on the FLR along the Nisqually River and Muck Creek are protected from harvest and some are old-growth. Riparian forests along the river and creek consist mostly of red alder (*Alnus rubra*), black cottonwood, Douglas-fir, big-leaf maple (*Acer macrophyllum*), western red cedar (*Thuja plicata*), and Sitka spruce (*Picea sitchensis*). Oregon white oak (*Quercus garryana*),

[1]Current address: Stalmaster and Associates, 11 Elm Street, Port Townsend, WA 98368

[2]Current address: 1333 Central Street N.E., Olympia, WA 98506

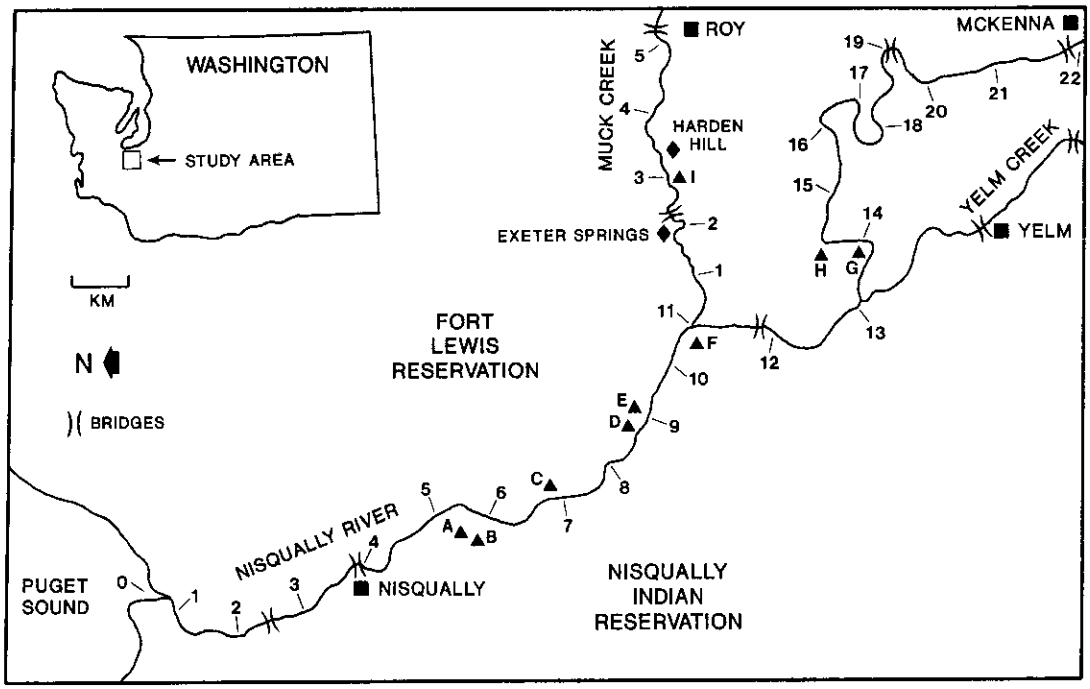


Figure 1. Map of the study area showing locations of the Nisqually River, Muck Creek, and Yelm Creek; numbers indicate river or creek mile designations. Locations of the 9 communal roosts (triangles) are also displayed (A = Tree Farm, B = Side-Channel, C = Carter Woods, D = Riverbend, E = Cabin Creek, F = Collard Woods, G = Yelm, H = Bluff, and I = Muck Creek).

grand fir (*Abies grandis*), shore pine (*Pinus contorta*), western hemlock, and snags of various species also exist.

Chum salmon spawn and die in the Nisqually River and Muck Creek. This chum salmon run is one of the latest in North America, with peak die-offs occurring in January and February, and as much as one-third of the run spawning in Muck Creek (Holler 1990). In droughty years, however, low instream flows can prevent salmon from entering the creek. Coho salmon (*Oncorhynchus kisutch*), steelhead trout (*O. mykiss*), and other salmonids also spawn in the drainage.

## Methods

We made weekly counts of bald eagles on the Nisqually River by drifting in a raft from McKenna (river mile 22) to Nisqually (mile 4) (Figure 1). We conducted 20 censuses from November to April in 1991-92, and 16 from December to April in both 1992-93 and 1993-94. We conducted all censuses from 0900 to 1400 hours on weekdays. Of the 31% of eagles that were flushed by our raft and flew downstream, ca. 75% remained within view and thus were not counted again. Of the remaining ca. 25% of eagles that flew downstream and out of view, we recorded each as one-half of a sighting to minimize duplicate counts. We believe our counts were accurate within a 5% range of error for eagles perched <50 m from the river. We recorded eagle age and behavior, river mile location, and use of perch tree species for all sightings. Eagles with mostly white heads were recorded as adults, and brown and mottled eagles were recorded as subadults. We assessed diets of eagles on the river by identifying food carcasses seen eaten by eagles during censuses.

The percentage of the population composed of subadults was analyzed for weekly trends during all 3 years and in relation to eagle density along the river. We plotted subadult proportions by week over the winter season using linear regression weighted by weekly subadult percentages. Subadult proportions also were compared with the seasonal total number of eagles recorded per river mile using linear regression.

We counted eagles on Muck Creek from the confluence with the Nisqually River to 8.4 km (5.2 miles) upstream, using UH-1 Huey or OH-58 Bell helicopters, the best method for censusing this inaccessible area (Figure 1). We conducted 14 censuses from December to March in 1991-92, 11 in 1992-93, and 9 in 1993-94. We conducted all censuses in late morning on weekdays for <1 hour in duration. Flight speeds generally were 35 to 55 km/hour and altitudes were 60 to 120 m above ground. To prevent duplicate counts, all eagles that flushed and flew ahead of the helicopter were kept in continuous view. We believe, however, that our counts by helicopter underestimated actual eagle numbers (Stalmaster 1994). Eagle sightings were subdivided into upper, middle, and lower reaches of the creek using the Nisqually River (creek km and mile 0.0), the bridge near Exeter Springs (km 3.9, mile 2.4), Harden Hill (km 5.6, mile 3.5), and the bridge near Roy (km 8.4, mile 5.2) as dividing landmarks (Figure 1).

We found night roosts by visually following eagles in late afternoon using vantage points along the Nisqually River and Muck Creek. After roost locations were determined, we made weekly counts of eagles arriving at each roost from 1500 hours until dark. Guano on the ground indicated specific roost trees used by eagles.

We used eagle use days (EUDs) to assess eagle use on the study area (McClelland et al. 1982). EUDs, the area under a population curve, represent a combination of eagle numbers and the length of time that eagles are present and are calculated as follows:

$$EUDs = \Sigma\, Di(C_i + C_{i+1})/2$$

where D = number of days between counts i and i + 1, i = count number, and C = number of eagles per count. Similarly calculated, eagle use nights (EUNs) were used to document eagle use of night roosts.

Perch tree use on the Nisqually River was compared to tree availability to determine if eagles preferred or avoided specific tree species (Stalmaster and Newman 1979). We determined tree species availability by establishing 72 plots and sampling 288 trees >25 cm diameter within 50 m of both shorelines of the river from river km 6.5 to 34.6 (mile 4.0 to 21.5), using the point-centered quarter method (Lindsey et al. 1958). We used $X^2$ 2 x 2 contingency tables to determine statistical significance of tree species preference or avoidance. We recorded species and health of trees at communal roosts, and measured representative trees for height (clinometer) and diameter at breast height (measuring tape).

## Results and Discussion

### Population Dynamics

Bald eagles wintered on the Nisqually River (Figure 2) and Muck Creek (Figure 3) primarily from late December to late March; weekly high counts on the river and creek combined were 168 in 1991-92, 128 in 1992-93, and 156 in 1993-94. Eagle numbers on the Nisqually River were high in 1993-94 compared to other years and numbers peaked between late January and late February, depending on the year. High counts on the river were 105 in 1991-92, 83 in 1992-93, and 155 in 1993-94. In contrast, eagle numbers on Muck Creek were exceptionally low in 1993-94 compared to other years, but peak counts were all recorded in early February. High counts on the creek were 77 in 1991-92, 60 in 1992-93, and 10 in 1993-94.

We recorded a 3-year average of 6,952 EUDs on the study area; 7,036 in 1991-92, 6,452 in 1992-93, and 7,367 in 1993-94 (Table 1). For the 3 years combined, 79% of EUDs were on the Nisqually River and 21% on Muck Creek. During 1991-92 and 1992-93, however, 70-71% of EUDs were on the river and 29-30% on the creek, compared to 1993-94 when 95% of EUDs were on the river and only 5% on the creek. Low eagle use on Muck Creek and higher use on the Nisqually River in 1993-94 were attributable to the low instream flows in Muck Creek which prevented salmon from entering the creek. These low flows were caused by unusually droughty weather and flows did not increase until mid-March, after the salmon spawning season.

The eagle population on the Nisqually River and Muck Creek (peak of 168 eagles) apparently is the fourth largest riverine concentration in Washington. Larger populations exist only on the Skagit River and its tributaries the Sauk, Suiattle, and Cascade rivers (peak count of 501 eagles, Stalmaster 1989), Nooksack River (peak of >200 eagles, Knight and Knight 1983), and Columbia River (Fielder and Starkey 1980, 1987).

Seventeen eagle counts by helicopter on the Nisqually River (river km 0-18, miles 0-11) and

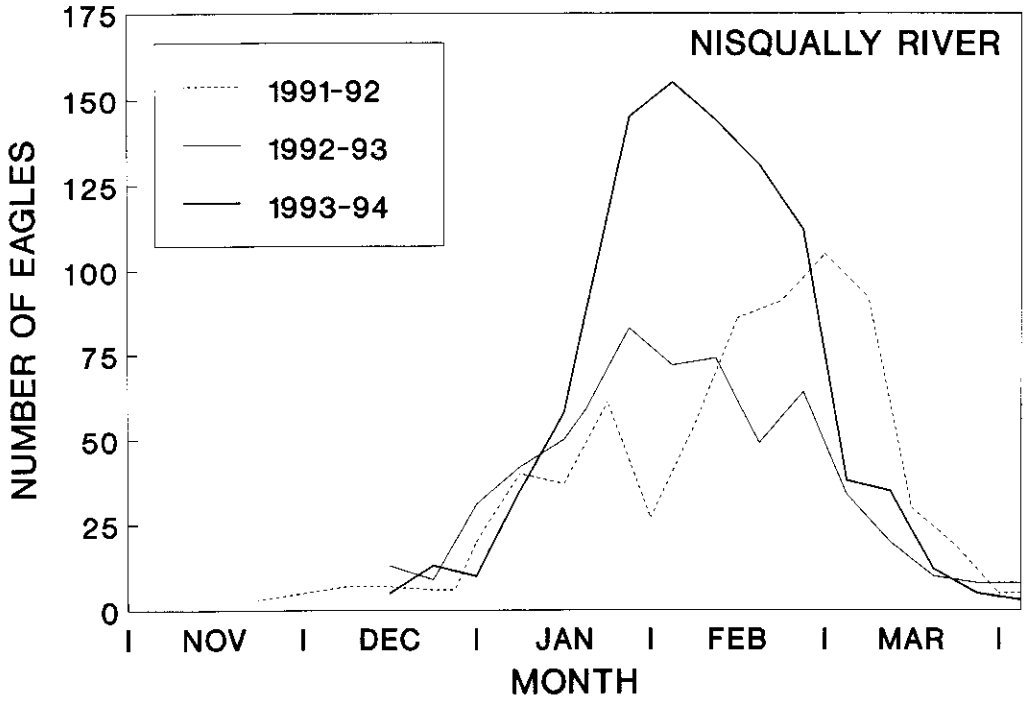


Figure 2. Numbers of bald eagles counted on 29 km (18 miles) of the Nisqually River by boat between McKenna and Nisqually during the winters of 1991-92, 1992-93, and 1993-94.

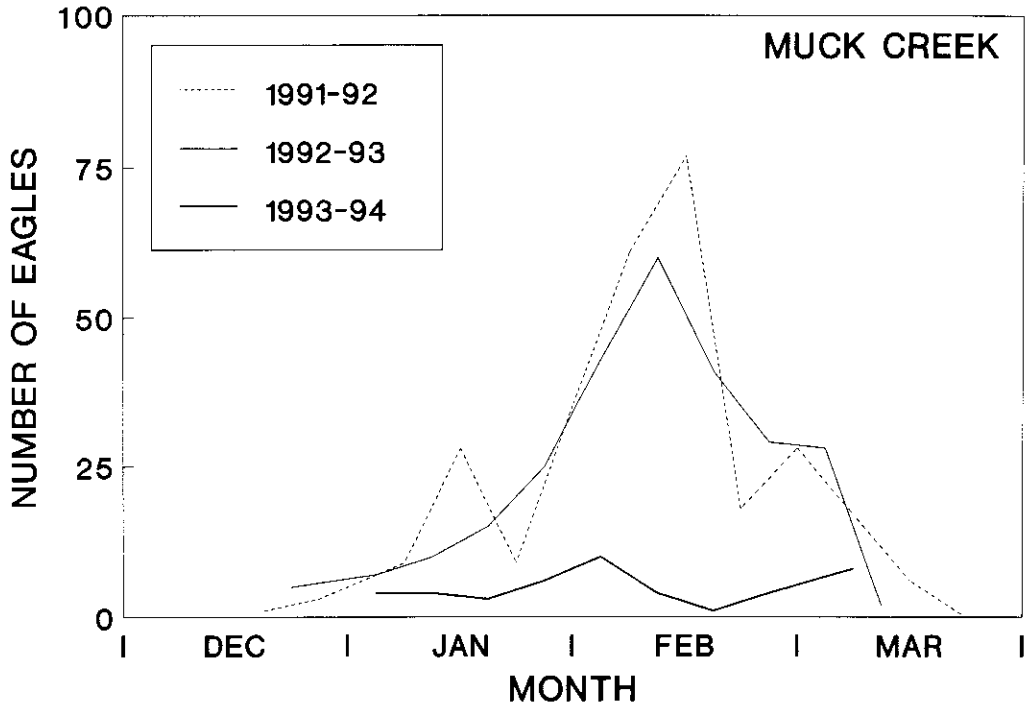


Figure 3. Numbers of bald eagles counted on the lower 8 km (5 miles) of Muck Creek by helicopter during the winters of 1991-92, 1992-93, and 1993-94.

TABLE 1. Mean number of eagle use days (EUDs) on the Nisqually River and Muck Creek during the winters of 1991-92, 1992-93, and 1993-94.

| Location | 1991-92 | | 1992-93 | | 1993-94 | | Means | |
|---|---|---|---|---|---|---|---|---|
| | EUDs | % | EUDs | % | EUDs | % | EUDs | % |
| Nisqually River | 4,943 | 70.3 | 4,568 | 70.8 | 7,001 | 95.0 | 5,504 | 79.2 |
| Muck Creek | 2,093 | 29.7 | 1,884 | 29.2 | 366 | 5.0 | 1,448 | 20.8 |
| Totals | 7,036 | 100.0 | 6,452 | 100.0 | 7,367 | 100.0 | 6,952 | 100.0 |

Muck Creek (creek km 0-8, miles 0-5) in January or February from 1981 to 1991 averaged 24 eagles and ranged from 2 to 56 eagles (U.S. Army unpubl. data). We believe 4 factors explain why our high count (168) was 3-fold higher than the highest historic count (56): (1) instead of using a helicopter, our river censuses were conducted by boat which is a more thorough and accurate means of counting eagles (Stalmaster 1994), (2) our counts included a longer time span and always included February when peak numbers typically occurred, (3) we censused 29 km (18 miles) of river compared to 18 km (11 miles) by the U.S. Army, and (4) we speculate that there has been an increase in the eagle population.

## Subadult Proportion

The subadult proportions on the Nisqually River and Muck Creek combined increased at similar rates during all 3 winters (Figure 4). This seasonal increase in the subadult proportion is explained by the early departure of adults to breeding areas in conjunction with the lateness of the salmon run and, therefore, the lateness of the eagle population.

The 46% subadult proportion on the Nisqually River and Muck Creek combined in 1991-92 was higher ($X^2$ 2 x 2 table, $P < 0.05$) than the 41% recorded in 1992-93 and 43% in 1993-94. For the Nisqually River, the 52% proportion in 1991-92 was higher ($X^2$ 2 x 2 table, $P < 0.05$) than the 41% in 1992-93 and 43% in 1993-94. For Muck Creek, the 16% proportion in 1993-94 was lower ($X^2$ 2 x 2 table, $P < 0.05$) than the 31% recorded in 1991-92 and 39% in 1992-93.

The high proportion of subadults on the river in 1991-92 (52%) occurred in conjunction with a shift in the population curve to late winter (Figure 2). Because subadults were proportionally more common in late winter (Figure 4), the subadult proportion was therefore higher in 1991-92. The low proportion of subadults on Muck Creek in 1993-94 (16%) was likely due to a lack of salmon in the creek. Subadults tend to be proportionally less common than adults at low-yielding feeding sites (Stalmaster 1987:83).

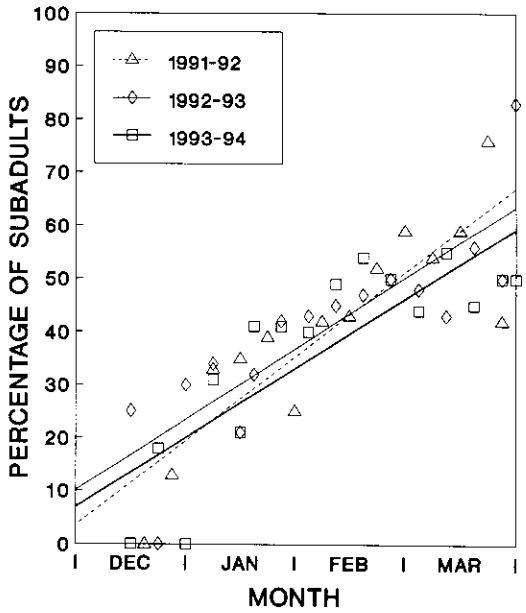


Figure 4. Relationship between the subadult proportion (Y) and week of season (X) during 3 winters on the Nisqually River and Muck Creek combined. Linear regressions were significant at $P < 0.001$ for 1991-92 ($n = 14$ weeks, $Y = 9.1 + 3.80X$, $r = 0.856$), 1992-93 ($n = 16$ weeks, $Y = 13.3 + 3.21X$, $r = 0.850$), and 1993-94 ($n = 16$ weeks, $Y = 10.2 + 3.13X$, $r = 0.833$).

Subadults were proportionately more common on Nisqually River reaches where eagles were most concentrated (Figure 5), on the lower reach of Muck Creek (36% subadults) where both food and eagles were most abundant compared to the

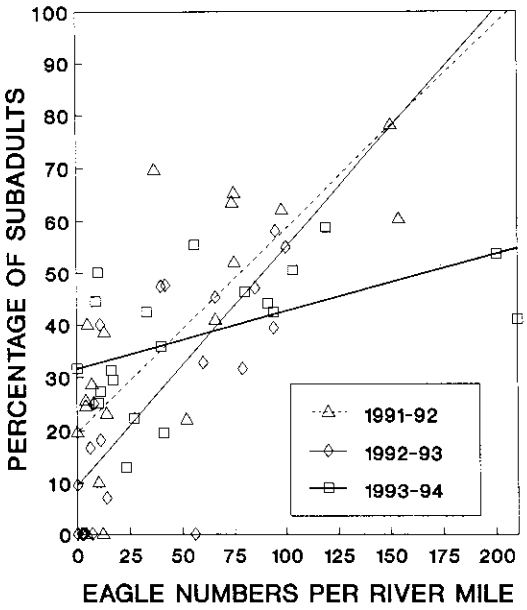


Figure 5. Relationship between the subadult proportion (Y) and total number of eagles counted during all censuses on 29 km (18 miles) of the Nisqually River ($X$) during each winter. Linear regressions were significant at $P < 0.001$ for 1991-92 ($n = 18$ censuses, $Y = 19.6 + 0.39X$, $r = 0.703$) and 1992-93 ($n = 17$ censuses, $Y = 10.8 + 0.44X$, $r = 0.774$), but not significant ($P = 0.061$) for 1993-94 ($n = 18$ censuses, $Y = 31.6 + 0.11X$, $r = 0.451$).

middle (32%) and upper (23%) reaches, and on the river (43%) instead of the creek (16%) in 1993-94 when low creek flows precluded spawning by salmon. Subadults are less adept at finding food than adults and more dependent on other eagles to find food (Knight and Knight 1983), and are therefore relatively more common in areas where the overall eagle population is high (Stalmaster 1987:83).

## Distribution

Eagles congregated on the Nisqually River between river km 6 and 23 (miles 4 and 14); there were relatively few birds upstream of river km 23 (Figure 6) and few downstream of river km 6 (Stalmaster 1994). There was an average of 56% of eagle use between river km 8 and 18 (miles 5 and 11) during the 3 study years. Eagles were also common on km 21-23 (mile 13-14) (15% of total for 3 years) where Yelm Creek enters the river, and use on this stretch increased from 7% in 1991-92, to 15% in 1992-93, to 21% in 1993-94.

We believe that eagle distribution on the Nisqually River was primarily influenced by the availability of chum salmon carcasses, but riverine features, riparian habitat, and human activity also affected distribution. Where eagles were common, the river was wide, braided, and shallow

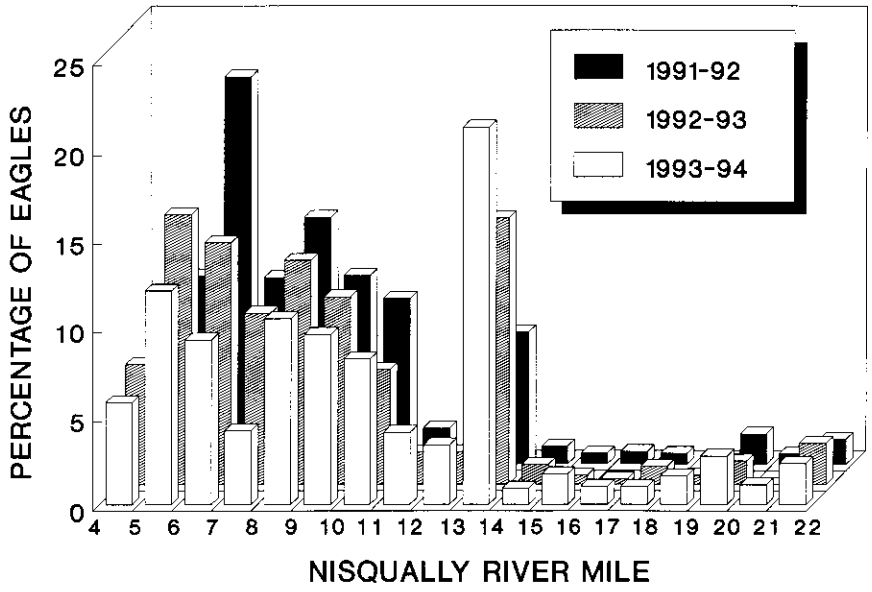


Figure 6. Distribution of bald eagles on 29 km (18 miles) of the Nisqually River during the winters of 1991-92, 1992-93, and 1993-94 (see Figure 1 for river mile locations).

which provided optimal salmon spawning habitat and caused stranding of carcasses. Tall, old-growth cottonwood trees often lined the banks where most eagles resided. Human presence also was generally low in areas of high eagle use. We speculate that the presence of numerous bank anglers on km 18-21 (miles 11-13) precluded normal eagle use of this river stretch (Stalmaster 1994). Also, eagles were common on the lower 1 km of Yelm Creek and along the adjacent river because they fed on a late winter salmon run in the creek.

On Muck Creek, 72% of eagle use was on the lower reach, compared to 15% on the middle reach and 13% on the upper reach. Feeding eagles were common near Exeter Springs (km 3.2, mile 2) in 1991-92 and 1992-93, where stream rehabilitation has enhanced chum salmon spawning habitat (Holler 1990).

## Food Source

Of 118 eagles observed feeding on the Nisqually River, 75 prey items were identified: 72 (96%) chum salmon, and 1 (1%) coho salmon, black-tailed deer (*Odocoileus hemionus*), and hooded merganser (*Lophodytes cucullatus*). Although not quantified, chum salmon also was the primary food source on Muck and Yelm Creeks. Given an average of 6,952 EUDs for the study area (Table 1), a consumption rate of 0.49 kg salmon/bird/day (Stalmaster and Gessaman 1984), a 96% diet of chum salmon, a mean mass of 3.76 kg and a mean edible mass of 2.97 kg for each carcass (Stalmaster and Gessaman 1984, Stalmaster 1994), an estimated 1,100 chum salmon would be consumed by this eagle population each winter. Chum salmon is perhaps the single most important winter food of wintering bald eagles on rivers in the Pacific Northwest (Stalmaster 1987:94), and eagles on the Nisqually River, Muck Creek, and Yelm Creek are virtually dependent on this food source.

## Roosts

We documented 6 traditionally-used, communal night roosts on the FLR and 3 on the NIR (Figure 1, Table 2). Using EUNs, Muck Creek was the largest roost (24% of use), followed by Carter Woods (22%), Cabin Creek (19%), and Yelm (18%). The highest nocturnal eagle counts were made at the Muck Creek roost in 1991-92 (68 eagles) and at the Yelm roost in 1993-94 (65 eagles).

TABLE 2. Peak bald eagle counts at 9 communal roosts on the study area during the winters of 1991-92, 1992-93, and 1993-94. Also presented are the mean number of eagle use nights (EUNs) during 1992-93 and 1993-94 combined.

| Roost | Winter | | | EUNs | |
|---|---|---|---|---|---|
| | 1991-92 | 1992-93 | 1993-94 | Mean | % |
| Muck Creek[a] | 68 | 36 | 22 | 1,107 | 24.2 |
| Carter Woods[a] | 27 | 26 | 16 | 984 | 21.5 |
| Cabin Creek[a] | 25 | 17 | 28 | 881 | 19.2 |
| Yelm[a] | - | 11 | 65 | 841 | 18.4 |
| Side-Channel[a] | - | 6 | 8 | 199 | 4.4 |
| Bluff[a] | - | 11 | 10 | 196 | 4.3 |
| Tree Farm[b] | 6 | 5 | 11 | 187 | 4.1 |
| Collard Woods[b] | - | 7 | 6 | 108 | 2.3 |
| Riverbend[a] | - | - | 8 | 74 | 1.6 |
| Totals | | | | 4,577 | 100.0 |

[a]On Fort Lewis Reservation.
[b]On Nisqually Indian Reservation.

In 1993-94, Muck Creek roost counts were low because of a lack of salmon in the creek, and Yelm roost counts were high when a large run of salmon spawned in nearby Yelm Creek. Eagle use of the Carter Woods and Cabin Creek roosts was relatively consistent, and use at the other 5 communal roosts was low (each with <12 birds per night and <5% of total use). We found 10 other roosts that were used inconsistently by few birds (Stalmaster 1994).

## Habitat Use

Black cottonwood was the most frequently used perch tree species (53%) on the Nisqually River, but red alder (18%) and Douglas-fir (11%) also were widely used (Table 3). Comparing perch use to availability, snags were strongly preferred, but black cottonwoods and big-leaf maples also were preferentially selected. In contrast, red alder and Douglas-fir were avoided by eagles, relative to their availability.

Eagles preferred diurnal perches that were (1) close to the shoreline and salmon carcasses, (2) tall with stout, horizontal branches that provided panoramic views, and (3) had open, unrestricted flight paths. Cottonwoods provided these characteristics thereby explaining why they were both frequently used and preferred by eagles. Preferred use of snags, cottonwoods, and maples in west-

TABLE 3. Perch type preferences of wintering bald eagles along the Nisqually River during the winters of 1991-92, 1992-93, and 1993-94.

| Perch type[a] | Availability | | Utilization | | Ratio[b] | $X^2$ |
|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | | |
| Snag[c] | 2 | 0.7 | 77 | 5.4 | 7.7 | 451.2* |
| Black cottonwood | 78 | 27.1 | 760 | 53.4 | 2.0 | 363.5* |
| Big-leaf maple | 12 | 4.2 | 112 | 7.9 | 1.9 | 45.6* |
| Sitka spruce | 2 | 0.7 | 14 | 1.0 | 1.4 | 1.6 |
| Western red cedar | 12 | 4.2 | 51 | 3.6 | 0.9 | 1.3 |
| Oregon white oak | 1 | 0.3 | 3 | 0.2 | 0.7 | 0.4 |
| Douglas-fir | 49 | 17.0 | 153 | 10.8 | 0.6 | 32.7* |
| Red alder | 132 | 45.8 | 251 | 17.6 | 0.4 | 246.4* |
| Western hemlock | 0 | - | 2 | 0.1 | - | - |
| Totals | 288 | 100.0 | 1,423 | 100.0 | | |

[a]Excludes gravel bars, driftwood, fence-posts, and trees >50 m from the river.

[b]Ratio of utilization to availability; ratios larger than 1 with significant $X^2$ values indicate a preference for a perch type and ratios smaller than 1 with significant $X^2$ values indicate an avoidance of a perch type.

[c]Various species.

*$P < 0.001$.

ern Washington has also been documented on the Nooksack River (Stalmaster and Newman 1979) and Skykomish River (Hansen and Bartelme 1980).

Of 94 measured trees at 9 roosts, black cottonwood was most commonly used (53%) by eagles, followed by Douglas-fir (40%) and western red cedar (6%). Eagles roosting along the Nisqually River or its side-channels used cottonwoods almost exclusively, and eagles roosting off the river used firs and cedars. The 94 roost trees were a mean of 49 m in height (29-76 m range) and 101 cm in diameter (43-180 cm range). Thirteen of 94 roost trees (14%) were dead, having died from either inundation or girdling by beavers (*Castor canadensis*).

Cottonwood, fir, and cedar are the most common roost tree species used by eagles on the Skagit, Nooksack, and Skykomish rivers (Hansen et al. 1980, Anthony et al. 1982), similar to our findings. Heights and diameters of roost trees in our study area generally were larger than trees in 13 communal roosts measured throughout the Pacific Northwest (Anthony et al. 1982). Mean diameters of trees in 8 of the 9 communal roosts surpassed the 81-cm diameter minimum specification for old-growth (Anthony et al. 1982). Only fir trees in the Bluff roost were not old-growth; they were being managed for harvest prior to roost discovery. Fir trees in the Muck Creek roost were exceptionally tall, up to 76 m in height, and dead cedar trees in the Cabin Creek roost were exceptionally wide, up to 180 cm in diameter.

## Protective Management

Wintering populations of bald eagles need an abundant, accessible, and uncontaminated food source; old or mature forests for perching and roosting; and seclusion from disturbing human activities (Steenhof and Brown 1978). These elements exist in the study area despite the close proximity of the FLR and the NIR to large metropolitan centers and associated human influences. However, management is needed to enhance conditions to provide for both the existing and an expanding eagle population. We recommend enhancing existing chum salmon spawning habitat and restoring degraded sites, especially in areas secluded from human activity, as well as allowing higher spawning escapements for the drainage (reducing commercial and sport harvest). Old-growth and mature forests along the Nisqually River and Muck Creek need to be continually protected from harvest, as is the present FLR policy. Riparian forest management on the NIR also should consider habitat needs of bald eagles. Disturbing human activity should be selectively restricted

during the winter season. This includes regulating (or monitoring) boating and helicopter traffic along the Nisqually River, and eliminating explosive ordnance disposals and other disturbing military firing activity near Muck Creek (Stalmaster 1994).

## Acknowledgements

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