AN ABSTRACT OF THE THESIS OF

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Abstract approved: Signature redacted for privacy.

Edward E. Starkey

If two dams on the Elwha River are removed, the ecosystem will be open to the downstream flow of sediments and the upstream flow of marine nutrients in the form of anadromous fish. Nutrient enrichment may influence trophic dynamics of the entire ecosystem, extending beyond the aquatic boundary. I assessed the current relative densities of five river dependent bird species on the Elwha and three other rivers in Olympic National Park in Washington State to describe pre-treatment reference conditions as a basis for assessment of post-treatment ecosystem responses. I also compared the amount of time that non-breeding and failed-breeding (NB/FB) female Harlequin Ducks (*Histrionicus histrionicus*) spent foraging on different rivers and on adjacent coastal habitat to determine whether time spent foraging could be used as an indicator of habitat preference.

Surveys of key river-dependent bird species were conducted on two rivers in 1996 and on four rivers in 1997. The benthivorous foraging guild was represented by the American Dipper (*Cinclus mexicanus*), Harlequin Duck and Spotted Sandpiper *(Actitis macularia)*. Harlequin Ducks had higher relative densities on the Elwha than the Hoh and Soleduck Rivers, but densities were similar to those found on the Duckabush River. There were greater numbers of Harlequin Ducks per linear kilometer above the two dams than between or below them. Relative densities of American Dippers on the Elwha were lower than on the Duckabush but not statistically different from those on the Hoh and Soleduck Rivers. Spotted Sandpipers had similar densities on all rivers except the Soleduck River where their numbers were lower.

The piscivorous foraging guild was represented by the Common Merganser (*Mergus merganser*) and Belted Kingfisher (*Ceryle alcyon*). Common Mergansers were relatively more abundant on the Elwha River than on the other rivers due to their high numbers below the lowest dam where wild and hatchery anadromous fish are present. Belted Kingfisher relative densities showed no significant differences between rivers as they were found in low numbers on all rivers.

Using relative abundances of some river dependent bird species as indicators of ecosystem recovery after dam removal may be useful tool surveys are continued throughout the process. In spite of lack of anadromy, the Elwha River ecosystem supports a significant population of Harlequin Ducks when compared to other Olympic rivers. American Dippers are also well represented on the Elwha River, specifically above the dams. Because of their relative abundance, these benthivore populations may have a measurable, upriver response to any nutrient enrichment as a result of dam removal and both species should be monitored. The Duckabush River, with a similar Harlequin Duck relative abundance in the lower reaches, should be monitored concurrently to account for region-wide population shifts of that species over time. The Common Merganser may be the best indicator of below dam effects on the Elwha River and numbers could be compared with the lower Soleduck River, however alternative survey methods, specifically drift boat surveys, should be considered to improve count accuracy.

During June and July of 1997, time-activity budget data were gathered on NB/FB Harlequin Ducks on the Elwha, Duckabush and Dosewallips Rivers and at their mouths and at the mouth of Salt Creek. Time spent foraging by NB/FB Harlequin Ducks was similar among the three rivers examined. NB/FB Harlequin Ducks on the spent 33.1%, 33.2%, 36.4% of their time feeding, on the Elwha, Duckabush Dosewallips Rivers respectively. The Elwha River system was the only system where time activity budgets could be compared between river and adjacent coastal habitats. Time spent foraging at the mouth of the Elwha was significantly higher (52.5%) than on the Elwha River proper. Food availability on river habitat may be a factor in NB/FB females' decision to remain on river habitat during the breeding season or migrate to the ocean. Time-activity budgets provide information on Harlequin Duck life history but a better understanding of their foraging behavior and the role of food availability in habitat selection is needed before time-activity budgets alone can be used as a tool for assessing ecosystem response to dam removal. Time-activity budget data collected concurrently with food availability data from field studies, along with energetics and food preference data from field or laboratory studies may establish a clearer link between time spent feeding and habitat quality and preferences.

River-dependent Bird Species as Potential Indicators of Ecosystem Response to Removal of Dams on the Elwha River, Washington

by

Barbara A. Blackie

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River-dependent Bird Species as Potential Indicators of Ecosystem Response to Removal of Dams on the Elwha River, Washington

GENERAL INTRODUCTION

The proposed removal of two dams and the subsequent return of anadromous fish to the Elwha River will provide a unique opportunity to examine linkages between salmon and river dependent birds. If one or both dams are removed from the Elwha River and salmon return in large numbers, densities of river dependent birds could be monitored both prior to and during ecosystem restoration. This approach may provide insight into the influence of salmon on many trophic levels, and specifically on the piscivorous and benthivorous avian foraging guilds.

With the return of anadromy to the Elwha ecosystem, salmon populations will likely increase and river spawning will be restored to nearly 64 km of the mainstem of the Elwha (National Park Service Olympic National Park 1995). Increased spawning would increase the number of juvenile salmonids in the system, as well as increase the number of carcasses from spawned-out salmon. Piscivorous and benthivorous birds that breed along rivers may be affected by increased juvenile salmon and may respond to nutrient enrichment from salmon carcasses as reflected in increased aquatic invertebrate densities and composition. Populations of river dependent birds such as the piscivorous Common Merganser (*Mergus merganser*) and Belted Kingfisher (*Ceryle alcyon*) and the benthivorous

Harlequin Duck (*Histrionicus histrionicus*), American Dipper (*Cinclus mexicanus*) and Spotted Sandpiper (*Actitis macularia*) may serve as indicators of ecosystem recovery.

Historical Background: Two hydroelectric dams, erected on the Elwha River in 1914 and 1927 respectively, have blocked the return of 10 historically large anadromous fish runs for 88 years. Initially the dams provided some of the first electrical power to Port Angeles, however current power produced from the dams is used to partially supply (38%) the Daishowa America pulp and paper mill in Port Angeles. In 1968 and 1973 respectively, the owner of the dams at the time, Crown Zellerbach, applied to the Federal Energy Regulatory Commission to license the Elwha Dam (which had never been licensed) and to re-license the Glines Canyon Dam. The licensing process, along with the concurrent decline of wild salmon populations in the Pacific Northwest, kindled an examination of the effects of the dams on anadromous fish populations and of possible ways of mitigating those effects. In 1992, Congress passed the Elwha River Ecosystem and Fisheries Restoration Act, which mandated that the Elwha ecosystem be restored. Research on how to fully restore native anadromous fish to the river ensued. The Secretary of the Interior concluded that removing the dams was both feasible and necessary to fully restore the ecosystem. Studies by the US Department of Interior, along with local tribal, state, and other federal agency studies, culminated in an Environmental Impact Statement that recommended removing both dams in order to achieve full restoration of the Elwha and its anadromous fish runs. Researchers predicted that removing both dams simultaneously could produce approximately 390,000 salmon and steelhead in about 30 years (National Park Service Olympic National Park 1995). The Department of the Interior purchased the two dams from their current owner, the James River Corporation in February of 2000. Funding for the engineering and design phase of dam removal has been appropriated, however, funds for dam removal and river restoration have not yet been appropriated (American Rivers 2001). Removing the two dams will provide an historic opportunity to study ecosystem responses to anadromy.

The purpose of this study was to determine an index of population abundance and describe existing river use patterns of selected river and riparian area dependent bird species. This information will provide a pre-treatment reference as a basis for assessing watershed and river recovery following removal of the dams. In Chapter 2, I describe the current relative abundances and distribution of five river-dependent species on the Elwha River and three similar but un-dammed river systems in the region. I also describe the methodology used and suggest how it may best be repeated during and after dam removal to detect the effects of dam removal on river-dependent birds. Chapter 3 focuses specifically on Harlequin Duck foraging behavior. Time-activity budgets were used to indirectly examine the prey quality and availability of three different river systems and adjacent coastal foraging habitat. Although the primary objective of this study was to provide life history information on Harlequin Ducks, the use of time-activity budgets as a tool for assessing habitat quality in light of ecosystem recovery after dam removal is also discussed.

ASSESSING THE RELATIVE ABUNDANCE AND DISTRIBUTION OF RIVER DEPENDENT BIRD SPECIES ON THE ELWHA RIVER PRIOR TO DAM REMOVAL

Abstract

If two dams on the Elwha River are removed, the ecosystem will be open to the downstream flow of sediments and the upstream flow of marine nutrients in the form of anadromous fish. Nutrient enrichment may influence trophic dynamics of the entire ecosystem, extending beyond the aquatic boundary. I assessed the current relative densities of five river dependent bird species on the Elwha and three other rivers in Olympic National Park in Washington State to describe pre-treatment reference conditions as a basis for assessment of post-treatment ecosystem responses. Surveys of key river-dependent bird species were conducted on two rivers in 1996 and on four rivers in 1997. The benthivorous foraging guild was represented by the American Dipper (*Cinclus mexicanus*), Harlequin Duck and Spotted Sandpiper *(Actitis macularia)*. Harlequin Ducks had higher relative densities on the Elwha than the Hoh and Soleduck Rivers, but densities were similar to those found on the Duckabush River. There were greater numbers of Harlequin Ducks per linear kilometer above the two dams than between or below them. Relative densities of American Dippers on the Elwha were lower than on the Duckabush but not statistically different from those on the Hoh and Soleduck Rivers. Spotted Sandpipers had similar densities on all rivers except the Soleduck River where their numbers were lower.

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Using relative abundances of some river dependent bird species as indicators of ecosystem recovery after dam removal may be useful tool surveys are continued throughout the process. In spite of lack of anadromy, the Elwha River ecosystem supports a significant population of Harlequin Ducks when compared to other Olympic rivers. American Dippers are also well represented on the Elwha River, specifically above the dams. Because of their relative abundance, these benthivore populations may have a measurable, upriver response to any nutrient enrichment as a result of dam removal and both species should be monitored. The Duckabush River, with a similar Harlequin Duck relative abundance in the lower reaches, should be monitored concurrently to account for region-wide population shifts of that species over time. The Common Merganser may be the best indicator of below dam effects on the Elwha River and numbers could be compared with the lower Soleduck River, however alternative survey methods, specifically drift boat surveys, should be considered to improve count accuracy.

Introduction

Trophic Interactions and Anadromy

Anadromous fish are keystone food resources for vertebrate predators and scavengers in freshwater systems (Willson and Halupka 1995). Salmon carcasses, experimentally released on the Olympic Peninsula, Washington, were consumed by 14 species of mammals and 8 species of birds (Cederholm et al. 1989). Cederholm et al. (1989) also showed that the carcasses were retained in the system and not flushed out even during high waters, indicating that spawning salmon would provide a food resource for terrestrial vertebrates as far up a river system as the salmon spawn. Yet, enrichment of stream systems by anadromous fish may reach far beyond the vertebrate predator/scavenger foraging guilds.

Enrichment of stream systems by anadromous fish has been indirectly quantified using stable isotopes that identify marine derived nutrients. Bilby et al. (1996) showed that epilithic organic matter, all aquatic macroinvertebrates except shredders, and fish were significantly enriched with ^{15}N and ^{13}C in streams of western Washington where spawning Coho salmon were present. Shredding macroinvertebrates and riparian vegetation adjacent to salmon-bearing streams were enriched with ^{15}N but not ^{13}C (Bilby et al. 1996). A similar pattern was observed in S. Central Alaska, along with greater taxonomic diversity of macroinvertebrates in salmon streams when compared with non-salmon streams (Piorkowski 1995). Though a very small sample size, Piorkowski (1995) also detected greater percentages of ^{15}N and ^{13}C in American Dippers (*Cinclus* *mexicanus*) collected from an open stream system versus dippers collected in closed systems, indicating that nutrient enrichment by salmon can be detected in the avian trophic guild using stable isotope techniques. These studies suggest salmon have important roles in freshwater and adjacent terrestrial ecosystems and influence various trophic levels throughout aquatic-terrestrial food webs. However, as Willson and Halupka (1995) point out, there are few existing studies that attempt to quantify these interactions.

Since Willson and Halupka's paper, several studies have addressed the quantification issue. Wipfli et al. (1998) quantified total macroinvertebrate numbers and ash free dry mass (AFDM) of stream biofilm in a controlled field study in Alaska. They found that the number of macroinvertebrates in the carcass-enriched areas of the artificial streams increased eightfold when compared to the control streams. There was no detectable difference in biofilm mass between the treatment and control streams; however, the researchers speculated that the increased grazing of macroinvertebrate grazers may have masked any total increase in biofilm productivity (Wipfli et al. 1998). These researchers also measured the same parameters in two reaches of a nearby stream, one with significant salmon spawning, and one above all spawning. Total invertebrate densities were 25 times higher, and biofilm AFDM was 15 times higher in the carcass-enriched areas of the natural stream (Wipfli et al. 1998).

In a case study conducted in western Washington, large numbers of salmon carcasses were added to two streams and compared to paired, similar streams without salmon carcass enrichment in order to observe potential effects on juvenile resident salmonids (Bilby et al. 1998). Densities of age 0+ Coho and age 0+ and age 1+ steelhead increased in the treated streams following carcass addition, whereas no similar pattern was observed at the reference streams. Stomach contents of the juvenile salmon collected where salmon carcasses were added contained primarily carcass remains and salmon eggs, and stable isotope analysis showed as much as a 39% increase of marine derived N in their muscle tissue after the addition of carcasses (Bilby et al. 1998).

Studies such as the ones above suggest that the nutrient return from anadromous fish may have significant bottom-up effects for stream ecosystems. The nutrients returned to the river system in the form of salmon carcasses stimulate primary productivity in the form of algal biofilm in the river proper and riparian vegetation as well. Higher productivity can, in turn, support more herbivorous grazing and shredding invertebrates, which feed on carnivorous invertebrates. Macroinvertebrates support juvenile fish and benthivorous birds, whereas the fish themselves support piscivorous birds. With the exception of Piorkowski (1995), few studies have looked beyond the links in the immediate aquatic food chain for the ecological contributions of anadromous fish. Can effects be quantified at the aquatic-terrestrial interface? When avian predators are dependent on stream productivity for survival and reproduction, are their numbers and river-use patterns affected by enrichment from anadromous fish?

River-dependent Avian Species

Several bird species that live in the Elwha River system depend on the river for resources during their breeding season. Resources can include food, near-shore nesting sites, predator protected loafing sites, and brood rearing habitat. Bird species of interest to this study include Common Merganser *(Mergus merganser)*, Belted Kingfisher (*Ceryle alcyon),* Harlequin Duck *(Histrionicus histrionicus)*, American Dipper *(Cinclus mexicanus)*, and Spotted Sandpiper *(Actitis macularia).* Bald Eagle *(Haliaeetus leucocephalus)* and Osprey *(Pandion haliaetus)* are also present on the Elwha River and often use dead and living fish as food resources. All of these species could respond to the return of anadromous fish to the Elwha ecosystem by increasing their densities or by shifting their river-use patterns.

Piscivorous Avian Foraging Guild

The Elwha River historically supported five species of salmon including Coho salmon. Juvenile Coho reside in their natal stream for over a year. As Bilby et al (1998) point out; crucial rearing times for Coho and steelhead are at age 0+ and 1+ year. Their research indicates that enrichment from adult salmon carcasses may improve juvenile Coho survival during those critical times, thus enhancing Coho runs in general. The addition of increased numbers of resident salmon juveniles may, in turn, increase the survivorship of piscivorous birds such as mergansers and kingfishers.

Use of rivers by Common Mergansers may be correlated with abundance of juvenile salmon. The number of Common Merganser *(Mergus merganser)* broods produced on selected streams in British Columbia, Canada was highly correlated with the drainage size and juvenile salmon production of those streams (Wood 1986). In other studies, Wood (1985) showed that the number of juvenile salmon present influenced which foraging locations were used by mergansers. Broods that were raised on streams with higher salmonid densities stayed in freshwater habitats longer than broods on streams with lower salmonid densities (Wood 1987a). With the return of anadromy to the Elwha, the distribution of Common Mergansers may expand to river reaches that are currently inaccessible to salmon, and breeding success may increase.

Belted Kingfishers (*Ceryle alcyon)*, have specific habitat requirements, (high banks with a substrate suitable for excavating), indicating that they are nest-site limited (Davis 1982, Hamas 1994) but there is evidence that food availability may also affect population densities. When nest-sites are readily available, kingfisher population densities appear to depend on the number of suitable foraging sites (Brooks and Davis 1987). Distribution of food within territories of the monogamous Amazon Kingfisher (*Chloroceryle amazona)* was correlated with the number of fish that a male courtship-fed his mate. This, in turn, determined the success of the courtship attempt, influenced the egg-laying date, and predicted the frequency of provisioning of nestlings (Davis and Graham 1991). In a field experiment, Kelly and VanHorne (1997) artificially altered the food availability for breeding Belted Kingfishers on a Colorado stream. They found that there is a potential reproductive advantage to an inflated food supply in the form of earlier nesting dates, higher rates of nest attendance, heavier nestlings and a greater likelihood of re-nesting in the event of a nest failure. When the Nile perch was introduced to Lake Victoria, the prey species composition of the Pied Kingfisher (*Ceryle rudis)* was changed dramatically; the abundance of the preferred prey species was reduced while numbers of a smaller, less nutritious fish increased. This was correlated with an increase of the daily number of fish a kingfisher needed to catch to meet its energetic demands (Wanink and Goudswaard 1994). This species introduction is an example of how a significant change within one trophic level of a system may have repercussions at other trophic levels. These studies suggest that removal of the dams on the Elwha and the subsequent return of resident juvenile anadromous fish in significant numbers may increase the density of Belted Kingfishers found locally on the Elwha River when nest-sites are also available.

Large raptors that feed on adult salmon and scavenge on carcasses may increase their use of the river habitat with the return of anadromous fish to upper reaches of the river. Although enrichment was not the focus of his study, Knight, et al. (1991) was able to alter river use by Bald Eagles by experimentally placing salmon carcasses along the Toutle River in Washington State. It would be expected that Bald Eagles and Osprey would be likely to use the river for foraging more often during the salmon spawn.

Benthivorous Foraging Guild

Trophic interactions between avian benthivores and macroinvertebrates in river systems are less understood than between avian piscivores and fish. One avian benthivore of the British Isles, the European Dipper (*Cinclus cinclus)* had smaller broods and bred significantly later when nesting on acidic streams (where important prey species are scarce) than those breeding on circumneutral streams (Ormerod and Tyler 1993). In a field experiment on American Dippers in Utah, Harvey and Marti (1993) found that, when dippers were excluded from sections of the stream for 16 days, higher densities of limnephilid caddisfly larvae and heptageniid mayfly larvae were observed in the exclosures compared to the unmanipulated stream sections and the exclosure controls. These studies indicate that there may be strong interactions between prey availability and breeding success, fledging survival or densities of river-dependent benthivorous birds. Because avian benthivores consume macroinvertebrates, population responses to enrichment of the river by salmon would represent a more indirect effect involving one more trophic level than the case with piscivorous birds or the scavenging guild. Nutrient enrichment would be manifested in larger macroinvertebrate populations, which, in turn, would positively influence avian benthivore abundance. The first link of that chain is documented in the literature, e.g., (Li 1990, Wipfli 1998, Piorkowski 1995), the link to avian benthivores is less clearly documented.

A second predominantly benthivorous bird that breeds on the Elwha River is the Harlequin Duck. Bengston's studies in Iceland provide descriptive data on the relationship of macroinvertebrates to breeding frequency and other aspects of Harlequin Duck breeding ecology (Bengtson and Ulfstrand 1971, Bengtson 1972). Most other foraging studies for this species have been conducted on the ocean during the non-breeding season, (Vermeer 1983, Goudie and Ankney 1986, Gaines and Fitzner 1987, Fischer 1998) and document their diet of marine invertebrates. Dzinbal (1982) did look at foraging behavior of Harlequin Ducks during the breeding season, but conducted his studies in Prince William Sound, Alaska (a marine/intertidal area) and in the very lowest reaches of Sawmill Creek since breeders and non-breeders alike moved to the estuaries through June and July. Farrell (1997) analyzed the invertebrate densities from stream data collected by the Washington State Department of Ecology for differences between streams with known Harlequin Duck populations and those without and found the groups to be significantly different. Wright (1997) found temporal and spatial correlations between Harlequin Duck numbers and densities of the caddisfly, *Dicosmoecus gilvipes* on Quartzville Creek in Oregon. Hunt (1998) found a positive correlation between the quantity of benthic macroinvertebrate prey and the daily abundance of

Harlequin Ducks in Jasper National Park, Canada. These studies suggest that Harlequin Ducks may be positively affected by nutrient enrichment if macroinvertebrate populations are increased and sustained through the breeding season. Because Harlequin Duck populations are declining in the southern portions of their western range (Cassirer et al. 1993a, U.S. Fish and Wildlife Service 1994), and are already a species of special concern in their eastern ranges (Robertson and Goudie 1999), factors that influence the population dynamics of Harlequin Ducks are of concern.

Spotted Sandpipers are ubiquitous river dwellers during their breeding season. They are predominantly benthivores, although they do eat small fish and also forage from the riverbank environment. Little is known about the relationship of food availability and Spotted Sandpiper density on rivers but they may be influenced in ways similar to other benthivores.

In order to identify any influence of nutrient enrichment on piscivorous and benthivorous birds in the Elwha following the removal of the Elwha River dams, present relative populations must be defined and current relative distributions must be identified. Because removal will only occur on one river, and dam removal and recovery will occur over many years, it is also necessary to measure population indices of the selected bird species on other, similar river systems in the same geographic region. Existing abundance and distribution patterns can be examined for differences among dammed and un-dammed rivers. A primary objective of this study was to determine the pre-dam removal relative abundances and use patterns on the mainstem of the Elwha for the following river-dependent species: Harlequin Duck, American Dipper Spotted Sandpiper, Common Merganser, and Belted Kingfisher. Relative abundance and patterns of use on the Elwha River were compared with those concurrently found on the Hoh (1996 and 1997), Soleduck and Duckabush Rivers (1997 only). These rivers were selected for comparison because they are similar to the Elwha River but have no human-made barriers and are thus open to anadromy. All rivers originate in the pristine wilderness of Olympic National Park providing similarly high water quality for most of their length. The Hoh River originates at a glacier providing a cold water source throughout the summer season, which is similar to the hydrology on the Elwha River. The cool summer water temperatures provide summer spawning opportunities for salmon that do not exist on rivers originating on runoff and snow melt alone. The Elwha River, prior to the dam installations, had similar salmon runs to the Hoh River in species composition and run timing. The upper reaches of the Soleduck River are most similar to the upper reaches of Elwha River in elevation and forest vegetation. The Soleduck River is open to salmon spawning up to the Soleduck Falls, a natural barrier. The Duckabush River is a smaller system with similar hydrology and bank vegetation and it has anadromous fish runs in its lower reaches.

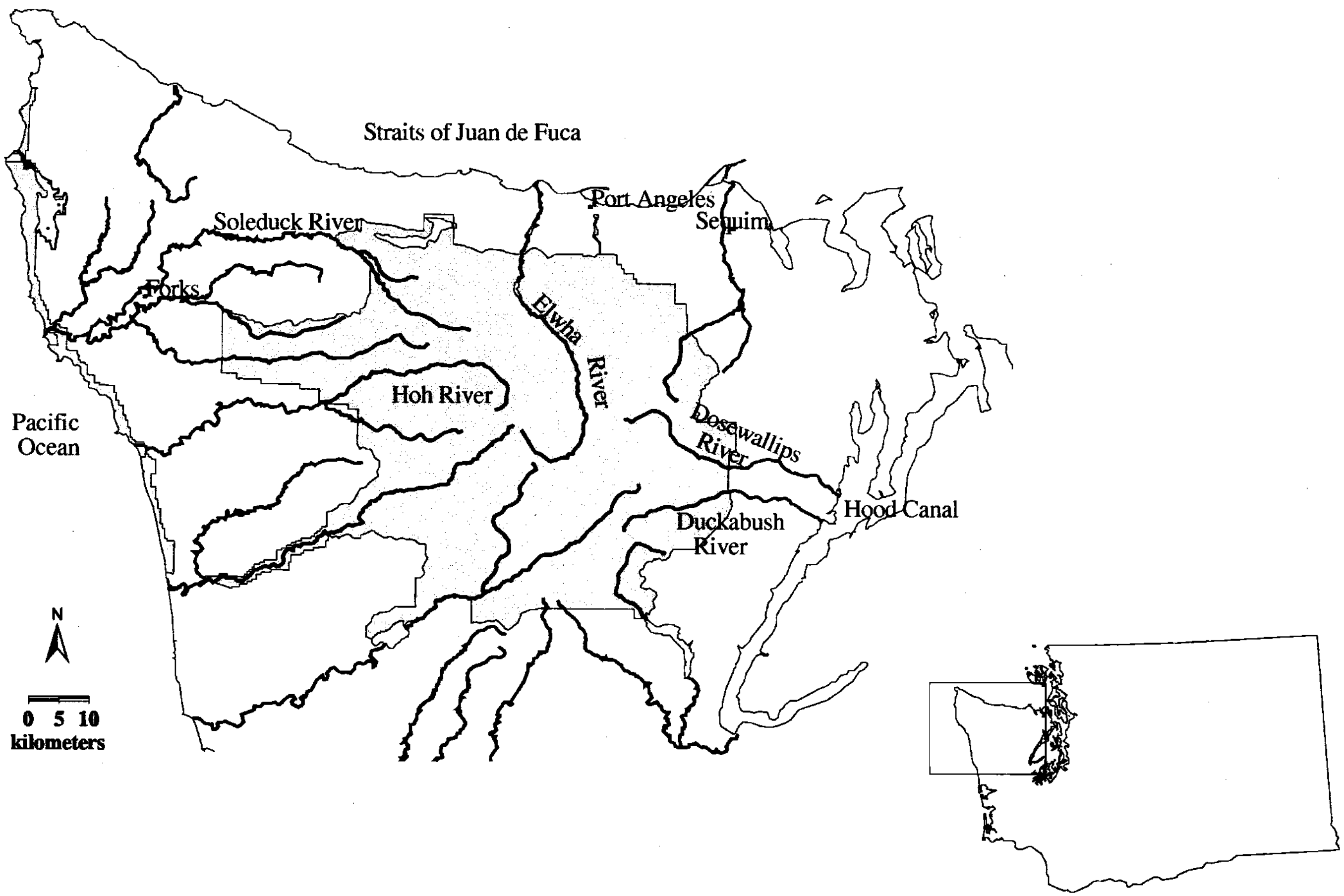
The purpose of this study was to assess the relative abundance and distribution of representative species of piscivorous and benthivorous avian species on the Elwha River and compare results to similar river systems on the Olympic Peninsula. Specifically I tested the hypotheses that 1) the distributions of selected piscivorous and benthivorous birds species do not differ within and among river systems, and 2) that the abundances of selected piscivorous and benthivorous species do not differ between river systems that are open to anadromy and those that are not.

In addition, survey protocol was defined in such a way that surveys can be repeated after dam-removal and throughout the ecosystem restoration period, providing a basis of comparison for ecosystem recovery. The inclusion of data from three other river systems can serve as control data for potential long-term, broad-scale ecological perturbations such as global climate change or region-wide population shifts of the selected species.

Study Area

The Olympic Peninsula is located in northwest Washington State and includes the northwest tip of the contiguous United States (Figure 2.1). Its aquatic boundaries include the Pacific Ocean to the west, the Strait of Juan de Fuca to the north, and Puget Sound to the east. At the heart of the Peninsula is Olympic National Park, a 3626 km^2 roadless wilderness area with the Olympic Mountain Range at its core (highest elevation, Mt. Olympus at 2428 m.). In the western

Figure 2.1 Olympic Peninsula study area map.



drainages, old-growth forests of Sitka Spruce (*Picea sitchensis*) and Western Hemlock (*Tsuga heterophylla*) dominate the lowland valleys. Douglas Fir (*Pseudotsuga menziesii*), western hemlock and Western Red Cedar (*Thuja plicata*) are the predominant canopy tree types to the north and east. Riparian vegetation is dominated by Red Alder (*Alnus rubra*), Vine Maple (*Acer circinatum*), willow (*Salix spp.*), and Big Leaf Maple (*Acer macrophyllum*). The Elwha River is the fourth largest river system on the Olympic Peninsula. It is 72.4 kilometers (45 miles) long and has 160 kilometers (100 miles) of associated tributaries. Eighty three percent of the drainage is within the Olympic National Park boundary and is therefore surrounded largely by unmanipulated landscapes. The Elwha River originates at the Elwha Snowfinger, a permanent snowfield in the Bailey Range, and flows north where it enters the Strait of Juan de Fuca, 7 km west of Port Angeles.

The 32 m high Elwha Dam is located 7.9 km (4.9 mi) from the mouth of the river and impounds the Lake Aldwell Reservoir. The 64 m high Glines Canyon, constructed in 1927, was installed 21.6 km upstream (at river mile 13.4) and it impounds the 3.2 km long Lake Mills reservoir. The Glines Canyon dam is located within the boundary of Olympic National Park.

Three other of the eleven major drainages of the Peninsula were included in this study. The Hoh River is an undammed river that originates at the Blue Glacier on Mt. Olympus and flows west for 94.8 km where it enters the Pacific Ocean near

Oil City. The Soleduck River originates with snowmelt from the High Divide, flows northwest, then west for 101.5 km where it joins the Bogachiel River at Three Forks (west of Forks, WA) to form the Quillayute River. The Quillayute River is 8.0 km long and flows into the Pacific Ocean at Rialto Beach. The Soleduck River is open to anadromy for 105 km where the Soleduck Falls arrests further upriver migration of salmonids. The Duckabush River originates with snowmelt between Mt. LaCrosse and Mt. Steel and flows east for 41.4 km where it flows into the Hood Canal of Puget Sound just south of the town of Brinnon. There are no human-made barriers on the river although anadromy is not reported to extend upstream beyond 19 km. All four rivers can be accessed via adjacent hiking trails for a majority of the length of their mainstems. Outside the park boundary, and along the lower reaches within the park boundary on the Elwha and the Hoh Rivers, rivers can be accessed via adjacent roads.

The Hoh River was chosen for comparison to the Elwha because it is of relatively comparable size and its similar seasonal geomorphology. Both rivers are fed by glacial melt and therefore the water temperature remains cooler and flow remains higher throughout the summer dry season. Both rivers historically supported four species of salmon (Chinook - *Oncorhynchus tshawytscha*, Coho - *Oncorhynchus kisutch,* Chum - *Oncorhynchus keta* and Pink - *Oncorhynchus gorbuscha*) while the Elwha River also supported Sockeye – *Oncorhynchus nerka*. The Duckabush was selected because its geomorphology is similar to that of the

Elwha River, in that they are both swift moving, constrained systems. Coho, Pink and Chum Chinook salmon use this River. The Soleduck River was selected because some of its upper reaches are similar to the Elwha in elevation, aspect (northward orientation) and terrain. Its lower sections are intermediary between the Hoh and the Elwha in terms of gradient and bank constraints. The Soleduck supports runs all five species of salmon.

Methods

The Elwha and the Hoh Rivers were surveyed in 1996 and 1997. The Duckabush and Soleduck Rivers were added in the 1997 field season. All rivers were divided into 6 sections (7 sections in 1996 only), one section that encompassed the mouth and estuary of the river, and five reaches of the mainstem of river (Table 2.1). The reaches were selected with the intent of representing the mainstem. The percent of the total river surveyed for each river was as follows: 18.5% of the Soleduck River, 34.3% of the Hoh River, 34.9% of the Elwha River and 37.5% of the Duckabush River (Figures 2.2a-d). The selection of reaches was constrained by accessibility (e.g., extremely hazardous canyons and some privately owned stretches of riverbank were necessarily avoided). The Elwha River was the template, where I originally chose reaches by trying to access as much of the river as possible from the adjacent road or trail. Analogous reaches were then chosen on the other rivers according to the following hierarchical criteria: (1) elevation, (2) representation of the mainstem of the river, (3) accessibility.

Table 2.1. River reaches surveyed on Elwha, Hoh, Duckabush and Soleduck Rivers.

River	Reach No.	Length (km)	Lower Boundary[a] (km)	Lower Elevation (m)	Gradient (Δelev(m)/length (km))
Elwha	0	0.50	0.00	0.00	0.00
Elwha	1	4.00	0.25	0.00	5.72
Elwha*	2	7.50	11.25	70.41	6.87
Elwha*	3	3.75	26.25	198.12	16.26
Elwha*	4	6.75	36.50	374.90	9.98
Elwha*	4.1	4.50	36.50	374.90	11.52
Elwha*	4.2	2.25	41.00	426.72	6.91
Elwha*	5	4.00	46.25	469.39	10.67
Elwha*	6	4.00	53.00	548.64	11.43
Total length		**26.0[b]**			
Hoh	0	1.25	0.00	00.00	0.00
Hoh	1	2.75	0.00	00.00	1.11
Hoh	2	9.75	14.50	30.48	2.50
Hoh*	3	8.75	49.88	129.54	4.70
Hoh*	4	5.50	58.00	175.26	4.16
Hoh*	4.5	4.50	62.75	198.12	6.77
Hoh*	5	6.00	67.00	228.60	9.65
Total length		**32.50[b]**			
Duckabush	0	0.75	0.00	0.00	0.00
Duckabush	1	3.75	0.00	0.00	4.47
Duckabush	2	3.75	6.25	71.63	9.75
Duckabush*	3	1.75	12.25	170.69	20.90
Duckabush*	4	2.00	17.00	330.71	11.43
Duckabush*	5	4.25	19.25	353.57	11.47
Total length		**15.5[b]**			
Soleduck	0	2.25	0.00	0.00	0.00
Soleduck	1	2.50	2.25	0.00	1.22
Soleduck	2	5.00	71.60	216.41	6.71
Soleduck*	3	6.75	83.20	298.71	12.42
Soleduck*	4	3.75	100.50	487.68	17.88
Soleduck*	5	2.25	104.59	586.74	23.71
Total length		**20.25[b]**			

* Within Olympic National Park boundary

[a] River distance from mouth to lower and upper boundaries

[b] River lengths only, does not include length of mouth. Consistent surveys included reaches 1 through 5

Figure 2.2a. The Elwha River watershed with numbered survey reaches.

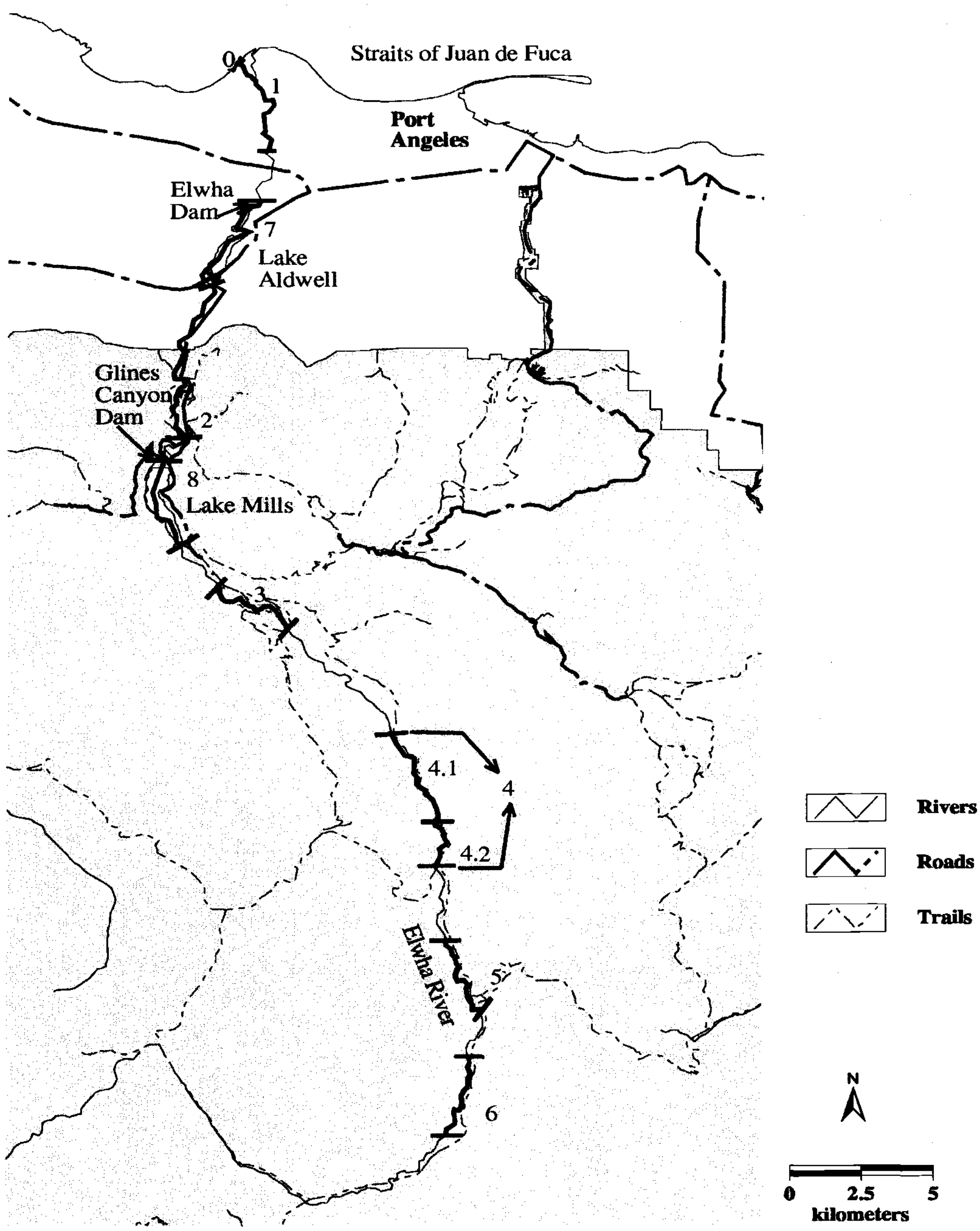


Figure 2.2b. The Hoh River watershed with numbered survey reaches.

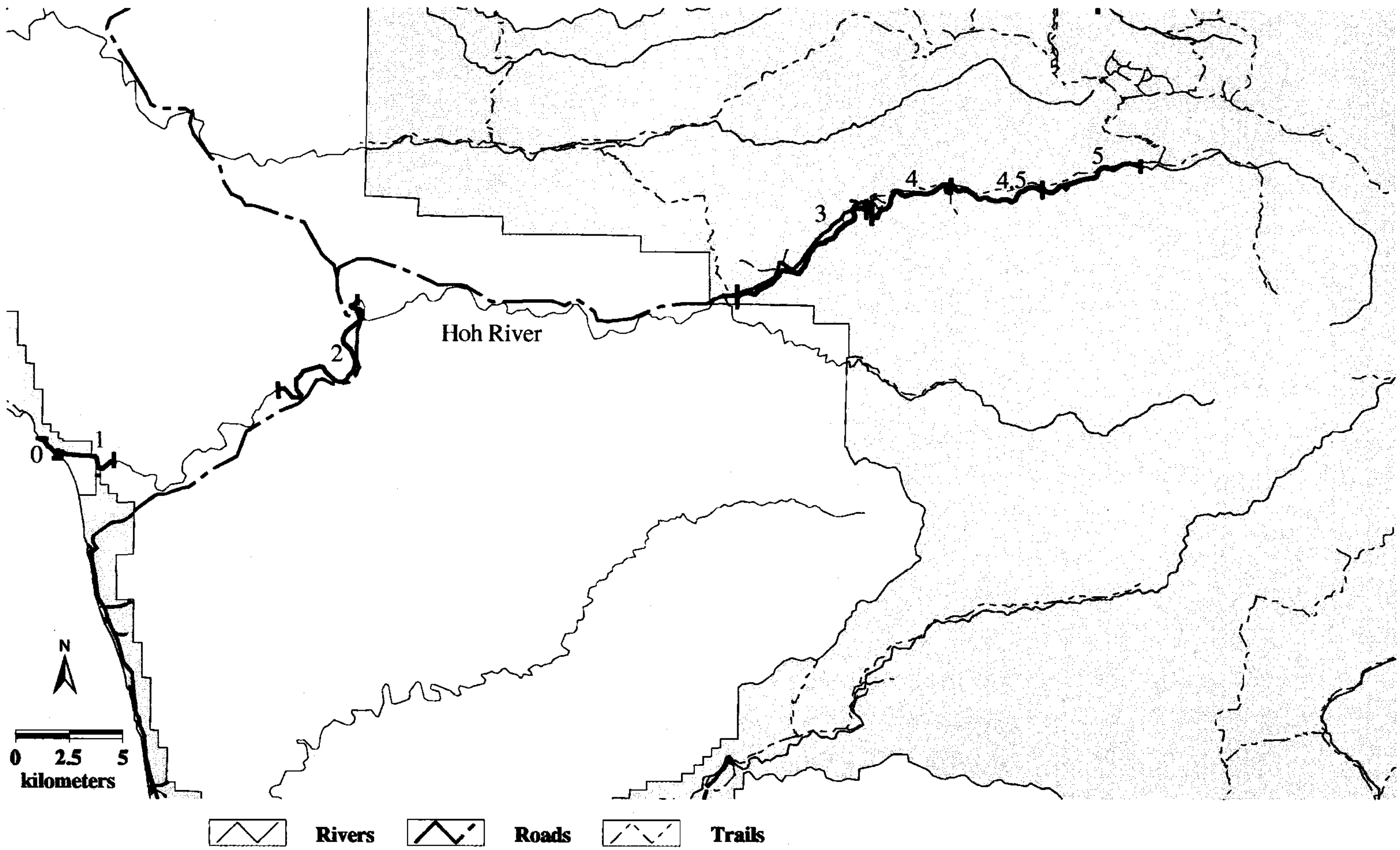


Figure 2.2c. The Duckabush River watershed with numbered survey reaches.

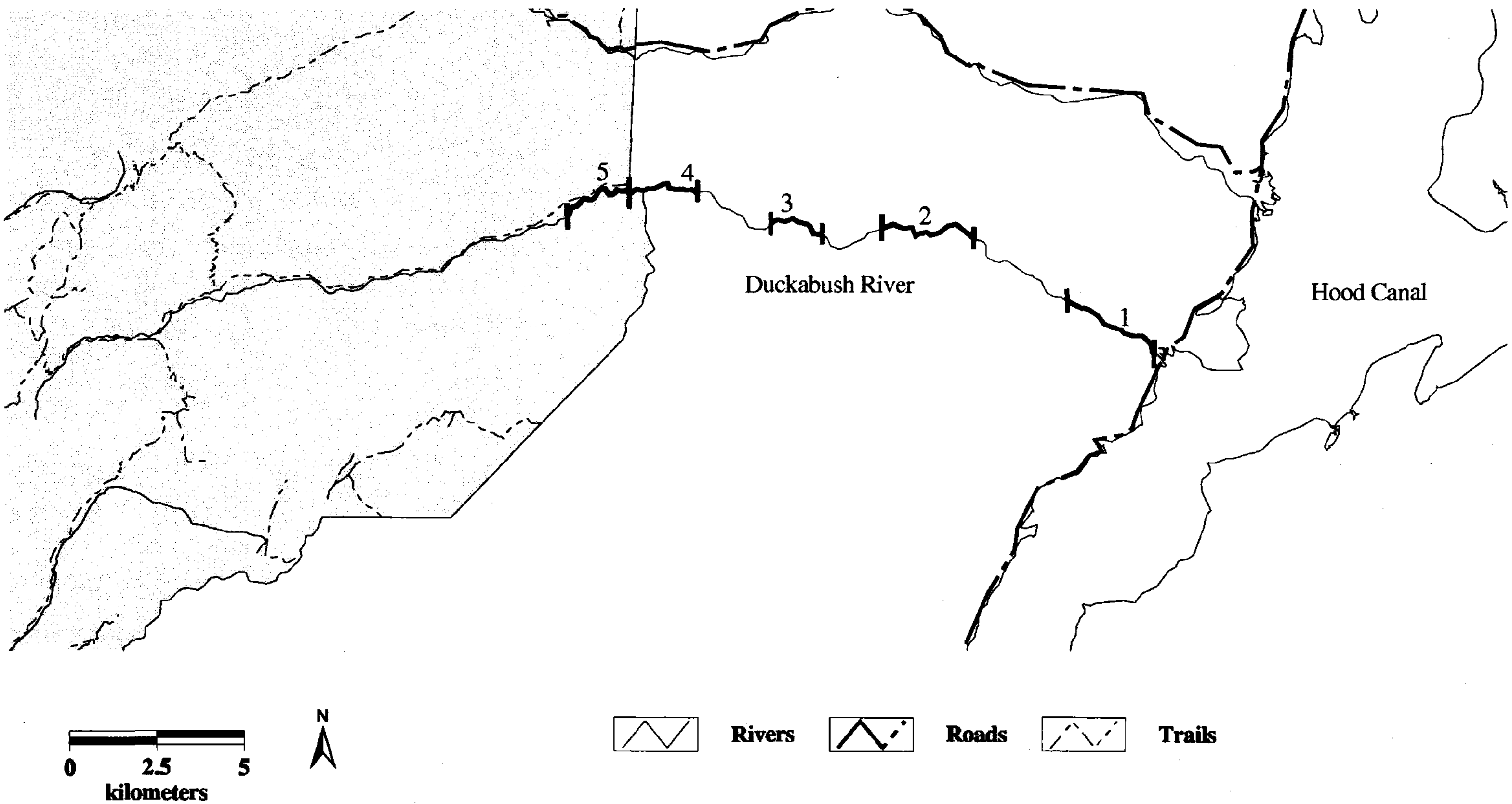
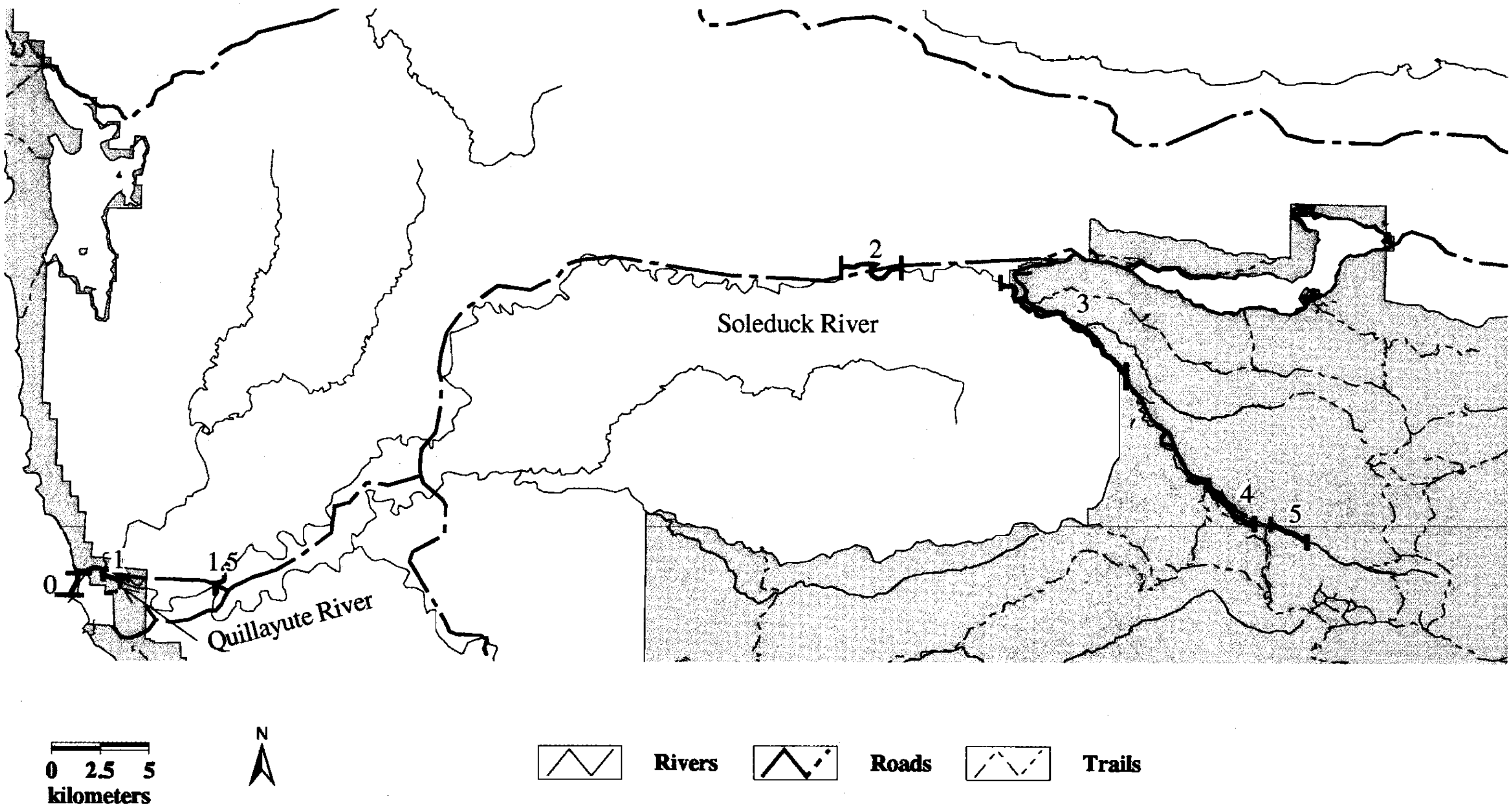


Figure 2.2d. The Soleduck River watershed with numbered survey reaches.



The length of the coastline delineated by the mouths of the rivers was measured across the mouth and limited by field of view. Lengths of mouth sections ranged from 0.5 km (Elwha) to 2.25 km (Quillayute). Reaches were measured along the length of the main river and ranged in length from 1.75 km to 9.5 km All lengths were measured using a map wheel on 7 ½ minute U.S.G.S. topographic maps. In 2001, GPS coordinates were used to ground-truth the original positions of the start and end point of all the reaches.

Each reach of river was surveyed according to the Harlequin Duck Survey Protocol (U.S. Forest Service and Willamette National Forest 1992). One observer walked upstream (preferred) or downstream (when necessary) and counted all birds seen or heard within an identified reach. Five main species were recorded; Harlequin Duck, Common Merganser, Belted Kingfisher, American Dipper, and Spotted Sandpiper. Two raptorial species, Bald Eagle, and Osprey were also counted. Locations of all sightings and nest locations were recorded on USGS topographic maps (7 ½ minute quads). To minimize disturbance to the birds, surveys were conducted by walking the riverbank rather than in the water whenever possible. High water precluded river crossings until late July in both seasons so most surveys were done from only one bank. To avoid counting the same individual twice, a bird was only counted when the observer passed it while he or she was moving up river. If a bird flew up river after being counted, the next bird of that species was not counted as a different individual unless there was reasonable evidence that it was a new bird. Observer bias was minimized by practicing survey methods and identification skills with pairs of observers early in the season as a way to standardize observation skills.

Where roads were adjacent to reaches (Reach 2 on the Elwha River and Reaches 2 and 3 on the Hoh River), vehicles were used to move between predetermined stops. The upper field of view of one stop would usually overlap with the lower field of view of the next, although there were some minimal blind spots where foot access was not available.

Lake Aldwell and Lake Mills, the two lakes behind the dams on the Elwha River, were surveyed opportunistically. Observers used kayaks to complete surveys on Lake Aldwell and a Park Service outboard motor boat was used to survey Lake Mills. With either type of vessel, two observers traveled the perimeter of each lake, one serving as the primary recorder, the other as the primary observer.

Sampling Design

In the 1996 breeding season (from 6 April 1996 to 13 Sept 1996), 7 reaches plus the two lakes of the Elwha River, and 7 reaches of the Hoh River were surveyed. Reaches were stratified into two categories: the mouths and the two river reaches lowest in the system (reach 1 and 2) were considered "lower" reaches while reaches 3, 4, 5 and 6 were considered "upper". The Elwha River was surveyed 9 times and the Hoh River was surveyed 8 times. In order to survey reaches of similar distance from the ocean during a similar time frame, each sampling period (approximately 14 days long) was divided into two portions. In the first portion (3-5 days long) all the lower reaches and the mouths of both rivers were surveyed followed by the second portion (5-12 days long), whereby all the upper reaches of both rivers were surveyed. The longer time dedicated to the upper reaches reflects the time investment needed to access the upper reaches by trail. Alternating the surveying of all lower reaches with all upper reaches was repeated for all survey periods (Figures 2.2a-d).

For all species, counts were taken of the number of males, females, pairs, juveniles, broods, unknown adults (known adult but gender not distinguishable), and unknown aged birds (known species but neither gender nor age class distinguishable). In addition, a subadult category was included for Bald Eagles.

In 1997, the Hoh and the Elwha Rivers were surveyed again while the Duckabush and Soleduck Rivers were added to the sampling design. Each river had six sections stratified into categories, "lower" (the mouth and reaches 1 and 2) and "upper" (reaches 3, 4, and 5). For the Hoh and Elwha Rivers, these were the same reaches used in 1996 except that, due to time constraints, reach 6 was not consistently surveyed in 1997. After a preliminary analysis of the 1996 data, the number of surveys per breeding season was reduced from nine to six (Table 2.2). Sampling periods 1 through 4 occurred in succession between 11 April and 11 June, each lasting an average of 15 days. The 5th sampling period, considered

Table 2.2. Sampling periods, 1996-97.

	1996		1997	
Sampling Period	Start Date	End Date	Start Date	End Date
1	4/6/1996	5/9/1996	4/11/1997	4/27/1997
2	5/10/1996	5/20/1996	4/28/1997	5/11/1997
3	5/22/1996	6/4/1996	5/13/1997	5/26/1997
4	6/5/1996	6/14/1996	5/29/1997	6/11/1997
5	6/18/1996	7/6/1996		
6	7/5/1996	7/19/1996	7/6/1997	7/25/1997
7	7/22/1996	7/31/1996		
8	8/6/1996	8/14/1996	8/6/1997	8/16/1997
9	8/19/1996	9/13/1996		

mid-season, was conducted in early July (6 July and 25 July), and the 6th, considered late-season, was conducted in early August (6 August through 16 August). To determine in which order the rivers would be sampled during each sampling period, rivers were selected randomly without replacement for lower and upper categories. As in 1996, each sampling period was divided into two portions; in the first portion, all lower reaches were surveyed within 3 to 5 days, then, with a new sampling order, all upper reaches were surveyed within 5 to 12 days. One sampling period, (surveys of all reaches for all rivers) was completed within 12 to16 days. The first sampling period (both years) was used to establish the reaches on the river. On the Hoh River in 1996 and on the Duckabush in 1997, for instance, the reach scheme needed to be modified for the second sampling period, therefore, the total river kilometers surveyed in some sampling periods vary and reflect the exact kilometers surveyed. Indices of relative abundance were selected to reflect the natural history of each species (Table 2.3).

Statistical Analyses

Seasonal river use patterns of the focal bird species were examined using relative densities calculated for every reach of every sampling period. The number of birds counted within any recognizable age or gender categories (individual, adult, female, male, immature, juvenile) was divided by the length of the reach to obtain individuals per kilometer.

Table 2.3. Abundance indices for river-dependent avian species.

Species	Primary index	Comments
American Dipper	Total number of dippers/km (includes juveniles and unknown age class dippers)	Male and female plumage is indistinguishable. Difficult to differentiate between adults and juveniles late in the season.
Harlequin duck	Total number of female Harlequin Ducks per km	Male and females are easy to differentiate, however, females best reflect the breeding population as males leave the river when incubation begins
Spotted Sandpiper	Total number of adult sandpipers per km	Adult plumage differs significantly from juvenile plumage. Male and female plumage is indistinguishable
Belted Kingfisher	Total number of kingfishers per km (includes juveniles and unknown age class kingfishers)	Although male and female plumage does differ, it is often difficult to discern on flying individuals, which are the most common kind of detection. Juvenile plumage is also difficult to tell at any distance.
Common Merganser	Total number of female mergansers per km	Male and females are easy to differentiate, however, females best reflect the breeding population as males leave the river when incubation begins

During the early stages of the first field season (1996) when exact survey effort/time was still undetermined, some reaches were surveyed more than once during a sampling period. It was necessary for the comparative analyses to have only one value per sampling period; therefore, when there was more than one count per reach per sampling period, the maximum count was used.

In 1996, reach 4 was originally considered two distinct but adjacent reaches, reach 4.1 and 4.2. This meant that the segments were occasionally surveyed on consecutive days, rather than on the same day, or a segment was surveyed more than once in a sampling period. To correct for this in analysis, counts where both segments were surveyed consecutively on the same day were considered equal to a continuous survey of Reach 4. When reach 4.1 or 4.2 was surveyed more than once within a sampling period, the averages of the values for each segment were added together and analyzed as one value. Because of the close proximity of the segments and the potential for movement of birds between the two, using the average rather than the maximum was deemed the more conservative, therefore appropriate choice. Some reaches of the Elwha (Reach 6) and the Hoh Rivers (Reach 4.5) were surveyed more than once but, because of time constraints and/or remoteness, they did not receive the same amount of effort and therefore were not included in the statistical analyses. They are, however, referred to in some of the descriptive text when useful (Table 2.1).

In1996 the Elwha and the Hoh Rivers were surveyed continuously throughout the breeding season. The continuity of the surveys provided information on the phenology of each species, including approximate arrival and departure times. Phenological information was used to determine which range of sampling periods best captured the extent of the breeding season for each species (Table 2.4). The subset of sampling periods was then used to calculate mean relative density values. Only data from the sampling periods that best captured the consistent breeding season of a given species were averaged, e.g., sampling periods where a significant number of birds had not yet arrived on the river or had already migrated from the river were excluded from the calculations for that species.

To compare the relative abundances of species among rivers, a relative density value was calculated for the total length of the river surveyed. For each sampling period, the sum of the number of birds on each reach was divided by the total number of kilometers surveyed (e.g., the sum of the lengths of the reaches) to get individuals/km. The river density values for each appropriate sampling period were treated as independent samples of the relative density of that species for each river, providing an error term that described sampling error. These data were screened for normality and equal variance and were analyzed using parametric techniques if assumptions of normality and equal variance were met; otherwise, they were analyzed using non-parametric statistical techniques. In 1996, the two rivers were compared using two-sample T-tests (or Mann-Whitney U Test when

Table 2.4. Subsets, and rationale for selection, of sampling periods that best included breeding seasons of species studied.

Species	Sampling Periods Included	Rationale
American Dipper (All Individual Birds)	1996 2 through 8 1997 2 through 8	Dippers are resident on streams and were present throughout the breeding season however, early and late surveys showed unusually high numbers in some locations, indicating that birds were moving around prior to and following breeding.
Harlequin duck (Females)	1996 2 through 7 1997 2 through 6	SP 1, Harlequin Ducks were still moving onto the breeding ground, or females were incubating and not visible. SP 8 and 9, early broods and females had begun to fledge and migrate to the ocean
Spotted Sandpiper (Adults)	1996 3 through 8 1997 3 through 8	Highly migratory, Spotted Sandpipers did not show up on the rivers in numbers until late June
Belted Kingfisher (All Individual Birds)	1996 1 through 9 1997 1 through 8	Kingfishers are resident on streams and were present throughout the breeding season.
Common Merganser (Females)	1996 2 through 7 1997 2 through 6	SP 1, mergansers were still moving onto the breeding ground, or females were incubating and not visible. SP 8 and 9, early broods and females had begun to fledge and migrate to the ocean
Bald Eagle and Osprey (All Individual Birds)	1996 1 through 9	Raptors were potentially present on the rivers during any sampling period

assumptions of normality were not met). In 1997 comparisons among the four rivers were analyzed using one-way ANOVA, (or the Kruskal-Wallis Test for non-normal data with equal variances). To answer the question, which rivers were different from the Elwha, multiple comparisons were made using contrasts comparing the Elwha means to each of the others using the Dunnett's Multiple Comparison Test. The significance level was set at $p < 0.05$ for all statistical tests. NCSS Statistical software (Hintz 1999) or SPSS Statistical software was used for the analyses.

For the two duck species, Harlequin Duck and Common Merganser, it was also possible to count the number of broods and the number of offspring on each reach. Relative densities of broods and young were calculated in the same manor as other count data. Relative densities of broods and young provided an indication of productivity of reaches and rivers.

Use of the lake habitats in the Elwha basin by the river dependent bird species was characterized using opportunistic counts in both 1996 and 1997. The entire lake shoreline was surveyed and total counts reported.

Results and Discussion

Distribution and Abundance of Benthivores

American Dippers

Dippers were present on the Elwha River during all sampling periods. However, unusually high numbers were seen both very early in the season and late in the season, indicating some movement prior to and following the main breeding season. Therefore sampling periods 2 through 8 were used in examination of the data. Dippers could be distinguished as adult and juvenile at close range, but at a distance, age differences could not be observed and such sightings were recorded as dippers of unknown age. Although adult dippers may be a more specific indicator of the breeding population, because of the difficulty in late season identification of adults from juveniles, the number of total dippers is used in all analyses.

The highest American Dipper density observed during any survey was 4.5 individuals/km on reach 4 of the Duckabush (1997 field season). The maximum density of American Dippers observed on the Elwha River was 3.1 individuals/km on reach 4.2 in 1996. The highest American Dipper density observed for cumulative river totals was 1.7 individuals/km (Duckabush River, sampling period 8, 1997 and Elwha River, sampling period 9, 1996).

Temporal Patterns

The number of American Dippers increased through the breeding season, with greatest numbers in the later sampling periods, 8 and 9. In 1997, a large number of adult dippers were also observed during the first sampling period (on the Elwha River only).

Year to year variation

Only the Elwha and the Hoh Rivers were surveyed in both years of the study. American Dippers exhibited similar spatial patterns among reaches and similar relative densities from year to year, although values were slightly higher on the upper reaches in 1996 when compared to 1997 (Figure 2.3).

Spatial Patterns

No dippers were observed at the mouths of any of the rivers. No dippers were observed in the lowest river reach (reach 1) of the Hoh and the Soleduck Rivers and few were detected in reach 1 on the Elwha. However, dippers were relatively common on reach 1 of the Duckabush ($\overline{X}$ = 0.59 individuals/km, Table 2.5). On the Elwha, Hoh, and Soleduck Rivers, average densities of American Dippers increased with distance from the ocean. Densities on the Duckabush River increased up to reach 4 then declined at reach 5 (Figure 2.4). Dippers were never observed on Lake Aldwell. They were observed on Lake Mills in both 1996 and 1997 with the maximum number observed during a survey being 7 individuals.

River to River Comparisons

There were significantly more American Dippers on the Elwha River than the Hoh River in 1996 ($Z = 2.88$ $p=0.004$ from a Mann-Whitney test). There were significant differences in the total number of dippers among the four rivers surveyed in 1997 ($F= 7.00$ $p=0.003$ from a one-way ANOVA). In planned multiple comparisons comparing the Elwha with the other three rivers, the mean densities of total dippers on the Elwha River was significantly lower than on the Duckabush

Figure 2.3. Mean (± SE) densities of American Dippers for five reaches of the Elwha River, 1996 (n = 7) and 1997 (n = 5). Includes sampling periods 2-8.

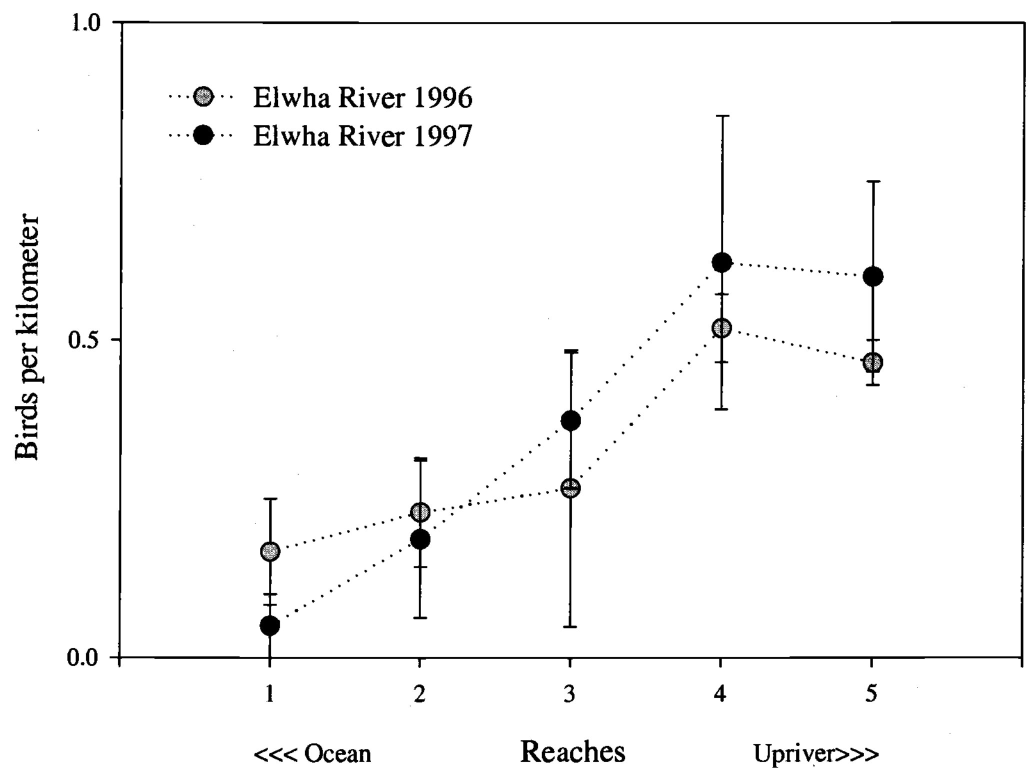
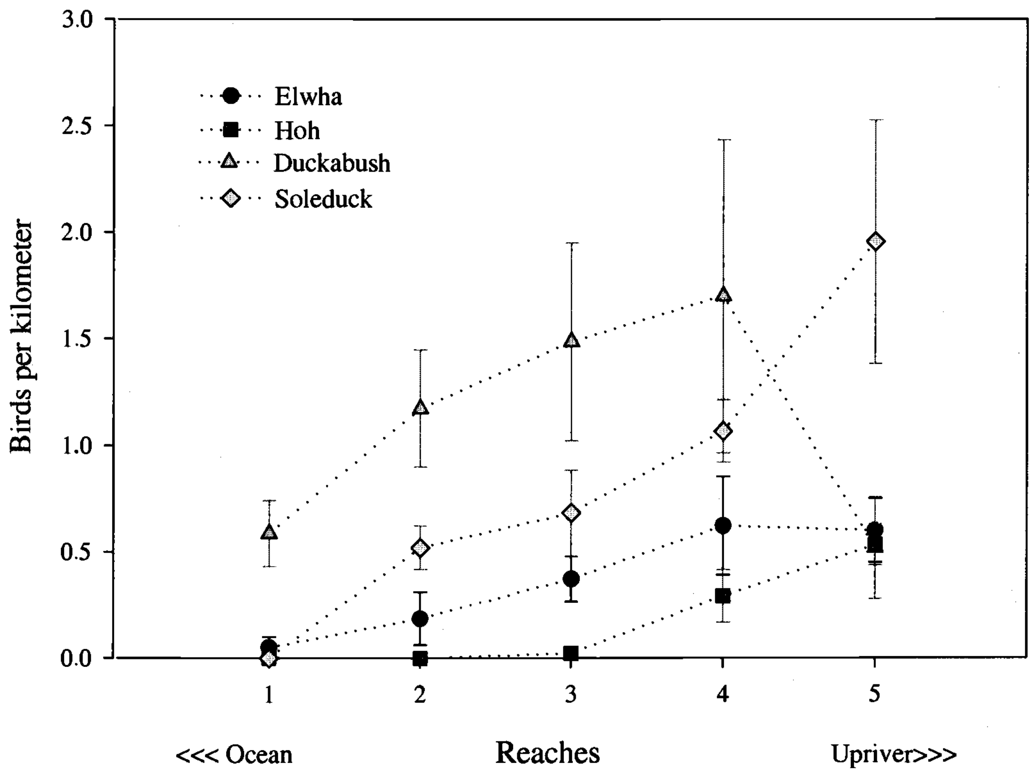


Table 2.5. Mean densities (+ SE) of total American Dippers (Individuals/km) for river reaches surveyed in 1996 and 1997. Includes survey periods 2 through 8. (N= number of surveys).

Reach		1996		1997			
		Elwha	Hoh	Elwha	Hoh	Duckabush	Soleduck
0	N	16	7	6	6	5	6
	#/km	0.00	0.00	0.00	0.00	0.00	0.00
	+SE	0.00	0.00	0.00	0.00	0.00	0.00
1	N	6	7	5	5	5	5
	#/km	0.17	0.00	0.05	0.00	0.59	0.00
	+SE	0.08	0.00	0.05	0.00	0.16	0.00
2	N	7	7	5	5	5	5
	#/km	0.23	0.00	0.19	0.00	1.17	0.52
	+SE	0.09	0.00	0.12	0.00	0.27	0.10
3	N	6	7	5	5	5	5
	#/km	0.27	0.02	0.37	0.02	1.48	0.71
	+SE	0.22	0.02	0.11	0.02	0.46	0.71
4	N	7	5	5	5	5	5
	#/km	0.52	0.11	0.62	0.29	1.70	1.07
	+SE	0.05	0.07	0.23	0.12	0.73	0.15
4.5[h]	N		6		2		
	#/km		0.41		0.67		
	+SE		0.17		0.44		
5	N	7	5	5	5	5	5
	#/km	0.46	0.21	0.60	0.53	0.52	1.96
	+SE	0.04	0.16	0.15	0.10	0.24	0.57
6[e]	N	3		1			
	#/km	0.67		1.25			
	+SE	0.17					

[e] Elwha River reach not paired with a reach on the Hoh River
[h] Hoh River reach not paired with a reach on the Elwha River

Figure 2.4. Mean (± SE) densities (n = 5) of American Dippers for each reach of the four rivers surveyed in 1997. Includes sampling periods 2-8.



River but not significantly different than on the Hoh and the Soleduck Rivers [Dunnett's t (With Control) Multiple-Comparison Test] (Table 2.6).

Productivity

Productivity of dippers is usually assessed via finding and monitoring nests (Loegering 1997, Harvey and Marti 1993), but monitoring of nests was not possible in this study, as the survey protocol required that observers keep moving through a reach rather than following adults to find nests. However, some nests were found opportunistically. Three nests were found in 1996 on the Elwha on reaches 2 and 4 respectively. They were active during sampling periods 3 through 5. One nest was found on the Hoh River in 1996 on reach 6, two nests were found on the Hoh River in 1997, on reaches 4 and 5. The nests were active during sampling periods 2 through 4. No nests were found on the Duckabush or on the Soleduck River in 1997. Dipper productivity was difficult to assess because juveniles are difficult to identify unless observed at close range, therefore counts of juveniles were somewhat unreliable. Active breeding could, however, be confirmed at some locations when juveniles were positively identified. Juveniles were positively identified on reaches 2 through 6 on the Elwha. Juveniles were seen on reaches 4 through 6 on the Hoh, on 1 through 5 on the Duckabush and on 3 through 5 on the Soleduck. Although juvenile dippers were seen as early in the season as 4 June (in 1997), late season surveys (especially sampling period 8) showed an increase in.

Table 2.6. Comparisons of mean densities (adults, females, or individuals/km) of river-dependent birds between the Elwha and the Hoh, Duckabush and Soleduck Rivers, 1997.

	American Dipper[c]		Harlequin Duck[a]		Spotted Sandpiper[b]		Belted Kingfisher[c]		Common Merganser[a]	
	$\overline{\chi}$ ±SE	P-Value[e]	$\overline{\chi}$ ±SE	P-Value[e]	$\overline{\chi}$ ±SE	P-Value[g]	$\overline{\chi}$ ±SE	P-Value[h]	$\overline{\chi}$ ±SE	P-Value[e]
Elwha	0.37±0.10		1.07±0.06		0.28±0.09		0.08±0.03		0.57±0.08	
vs. Hoh	0.15±0.02	0.970	0.21±0.03	*0.001	0.46±0.17	0.751	0.22±0.04	0.121	0.18±0.08	*0.011
vs. Duckabush	0.95±0.24	*0.012	0.71±0.22	0.117	0.26±0.11	0.997	0.08±0.04	0.121	0.21±0.07	*0.019
vs. Soleduck	0.78±0.09	0.064	0.09±0.02	*<<0.001	0.04±0.03	*0.031[g]	0.15±0.09	0.121	0.17±0.08	*0.010

[a] females, [b] adults, [c] adults and juveniles
[e] Planned comparisons of Dunnett's t Multiple-Comparison Test(2-way with control= Elwha River)
[f] Planned comparisons of Dunnett's T3 Multiple Comparison Test for unequal variance (2-way with control= Elwha River)
[g] Mann-Whitney U Non-parametric Test
[h] Kruskal-Wallis Non-parametric Test
* Significance level ≤ 0.05

juvenile dipper on the Elwha River in both seasons, on the Hoh River in 1996 only, and on the Duckabush and Soleduck Rivers in 1997

Species Summary

Monitoring American Dippers during and after the removal of the two dams on the Elwha River is recommended. There are representative populations on the four rivers examined in this study and they are relatively easy to survey; their vocalizations in flight and their behavior of flying just above, then landing in, the water make them easy to observe. Harvey and Marti (1993) have shown that American Dippers can have a strong top-down effect on macroinvertebrate prey and Ormerod and Taylor (1991) documented a correlation between macroinvertebrate densities and European Dipper densities. Loegering (1997) indicated that American Dipper habitat choice in Oregon may be more influenced by available nest sites than other habitat variables (although he did not specifically measure prey availability). It is possible, however, that nest sites may be less limited on Olympic streams because of the abundance of large downed trees, which Loegering suggests are important to American Dippers. In order to explore bottom-up effects of nutrient enrichment on macroinvertebrate populations and subsequent effects at higher trophic levels it will be important to measure macroinvertebrate composition and abundance in known foraging areas during the same seasons that American Dipper surveys are conducted. For example, in 1995 Munn et al. (1996) conducted macroinvertebrate studies on the Elwha River at sites very similar to several of the starting points of the reaches in this study. As subsequent resurveys of macroinvertebrates are planned, bird surveys could be coordinated to coincide simultaneously with them. Of particular interest would be any increases in the percent Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa and decreases in percent Diptera taxa below the dams after dam removal. Pre-dam removal studies indicate that current percent EPT are higher above the dams and Diptera and other species more tolerant to warmer temperatures and poorer water quality are present in higher percentages between and below the dams (Munn et al. 1996, Li 1990). Although Loegering did not document prey preferences, he did document that caddisflies (Order *Trichoptera*) were delivered to young on 60% of parental provisioning trips. The abundance of caddisflies and their relationship to American Dipper foraging warrants further examination and the Olympic rivers may provide an appropriate study site for such investigations.

Although I expected American Dipper density on the Elwha River to be most similar to the Duckabush River because of similar habitats (constrained rivers, forested banks, extensive bedrock and rock substrate), Duckabush River densities were greater on all reaches except Reach 5. The patterns I observed probably are related to the width, flow and gradient of the rivers at the various reaches. These variables were estimated but not measured with enough accuracy to analyze statistically. The upper Duckabush River is a narrower river than the upper Elwha River and the upper reaches probably cannot support as many American Dippers.

On the Soleduck River, the greatest number of dippers was found in reaches 4 and 5 which are similar to the Elwha and Duckabush Rivers in terms of stream width, forested banks, increased rock substrate and swifter gradient.

Harlequin Ducks

Male Harlequin Ducks leave the rivers for the ocean at the initiation of egg laying while female Harlequin Ducks remain on the rivers throughout brood rearing, therefore I used the number of females per kilometer as the population indicator for Harlequin Duck analyses. Sampling periods 1 and 8 were not included in analyses of means because populations were not stable during those times. Although pairs were present on the rivers during the first sampling period, birds were still in migration upriver and some pairs had not yet arrived on the breeding grounds. Later in August, some females and broods had begun their migration to the ocean. Therefore, only sampling periods 2 through 7 were used to avoid the sampling periods where the number of birds on the river was fluctuating due to migration.

The highest number of females/km observed during any one survey was 4 females/km (on the Elwha River, reach 5, sampling period 4 in 1996). The highest number of females/km observed on a river other than the Elwha was 3.2 females/km (Duckabush River, reach 3, sampling period 6 in 1997). Female Harlequin Duck densities for cumulative river totals range from 1.4 females/km (on the Elwha, sampling period 4 in 1996) to 0 females/km (on the Hoh River, sampling periods 4 and 9 in 1996 and the Soleduck River, sampling period 1 in 1997).

Adult Harlequin Ducks were already present on the rivers during sampling period 1 in both 1996 and 1997. Densities of female Harlequin Ducks increased from sampling period 1 to sampling period 2 on all rivers except the Duckabush. On the Elwha, densities were relatively constant from sampling periods 2-6 and began to decline during sampling period 7 (late July). Densities were low on both the Hoh and the Soleduck Rivers making temporal patterns difficult to discern.

The number of male Harlequin Ducks on the Elwha was highest during sampling period 2 in both years. Most males had left the river by sampling period 4 (beginning of June), although in 1996, a male was seen on the Elwha as late as 19 June. In 1996, some females with broods were still seen on the river during sampling period 9 (late August) in 1996, however, the number of female and juvenile Harlequin Ducks declined during sampling period 8 on all rivers, indicating that fledging and migration to the ocean had begun (Figure 2.5).

Year to Year Variation

Patterns of distribution and relative abundance were similar when comparing female Harlequin Ducks in 1996 to 1997 on the Elwha River. (Figure 2.6). So few Harlequin Ducks were found on the Hoh River that comparisons were difficult to make although reaches where juveniles were found were generally consistent from year to year.

Figure 2.5. Relative abundance of male, female and juvenile Harlequin Ducks during each sampling period on the Elwha River, 1996.

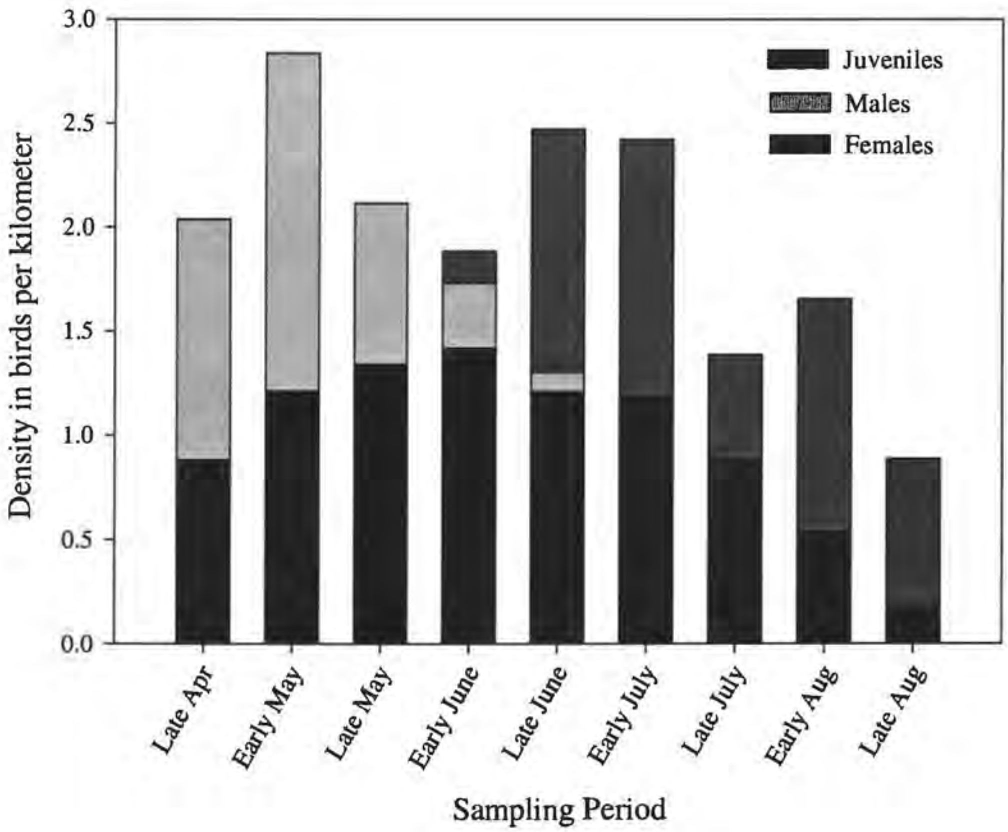
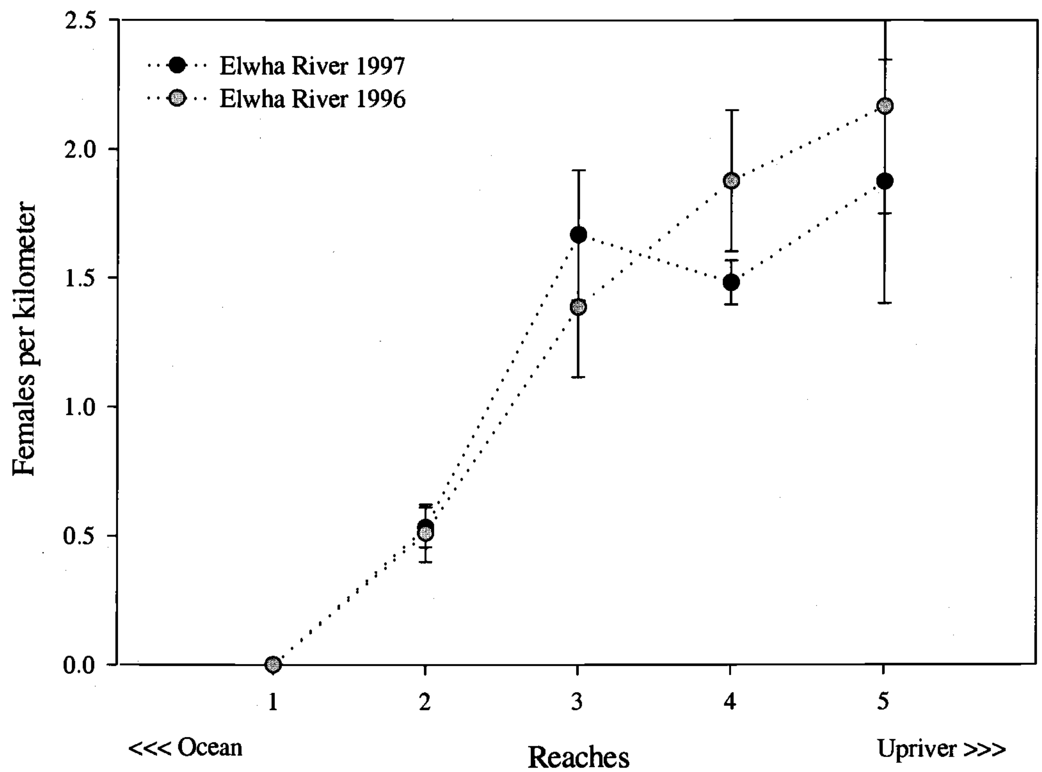


Figure 2.6. Mean (± SE) densities (n = 6 in 1996, n = 4 in 1997) of female Harlequin Ducks on the Elwha River in 1996 and 1997. Includes sampling periods 2-7.



Spatial Patterns

On the Elwha River, Harlequin Ducks were present on all river reaches except reach 1 (below the lower dam). In both years, the mean density of female Harlequin Ducks on reach 2 (the reach between the two dams) was less than half of the mean density of each of the three reaches above the upper dam (Table 2.7). In contrast, the highest harlequin densities observed on the Duckabush River in 1997 were observed in the lower two reaches. Reach 5 of the Duckabush River had only one sighting of one female harlequin during the entire field season.

Fewer Harlequin Ducks were observed on the Hoh and Soleduck Rivers than on the Elwha and Duckabush Rivers. On the Hoh, Harlequin Ducks were rarely seen on reaches 1 and 5, and they were only seen once on reach 2 in sampling period 8 when a female with a juvenile appeared to be migrating downstream. Mean densities observed in the middle reaches were rarely greater than 0.5 females/km in either year. Very few Harlequin Ducks were observed on any of the reaches of the Soleduck River in 1997. Female Harlequin Ducks were seen in low numbers on reaches 2, 3, and 5 only (Figure 2.7).

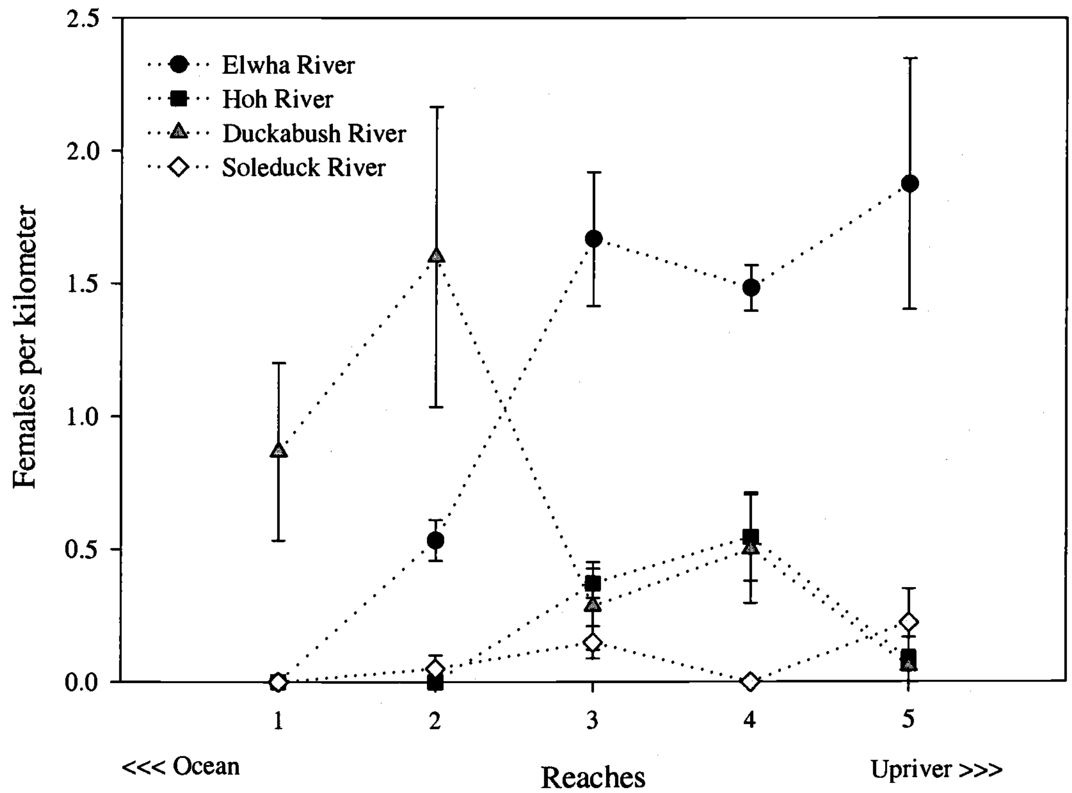
At the mouths of the rivers, there was great variation across rivers and through time. By 19 July 1997, Harlequin Ducks were no longer observed at the mouth of the Duckabush, although they had been seen there regularly through May

Table 2.7. Mean densities (± SE) of female Harlequin Ducks (Fem/km) for river reaches surveyed in 1996 and 1997. Includes survey periods 2 through 7 for 1996, and 2 through 6 for 1997. (N=number of surveys).

Reach		1996		1997			
		Elwha	Hoh	Elwha	Hoh	Duckabush	Soleduck
0	N	15	6	4	4	4	4
	Fem/km	13.3	2.80	21.50	2.00	5.33	0.00
	± SE	2.31	2.33	11.70		3.22	0.00
1	N	5	6	4	4	4	4
	Fem/km	0.00	0.06	0.00	0.00	0.87	0.00
	± SE	0.00	0.06	0.00	0.00	0.33	0.00
2	N	6	6	4	4	4	4
	Fem/km	0.51	0.00	0.53	0.00	1.60	0.05
	± SE	0.11	0.00	0.08	0.00	0.57	0.05
3	N	5	4	4	4	4	4
	Fem/km	1.39	0.34	1.67	0.37	0.29	0.15
	± SE	0.27	0.11	0.25	0.05	0.16	0.06
4	N	6	6	4	4	4	4
	Fem/km	1.88	0.00	1.48	0.55	0.50	0.00
	± SE	0.27	0.00	0.09	0.17	0.20	0.00
4.5[h]	N		5		1		
	Fem/km		0.00		0.22		
	± SE		0.00		-		
5	N	6	6	4	4	4	4
	Fem/km	2.17	0.04	1.88	0.08	0.06	0.22
	± SE	0.42	0.04	0.47	0.08	0.06	0.13
6[e]	N	3		1			
	Fem/km	1.25		0.00			
	± SE	0.38		-			

[e] Elwha River reach not paired with a reach on the Hoh River.
[h] Hoh River reach not paired with a reach on the Elwha River

Figure 2.7. Mean (± SE) densities (n = 4) of female Harlequin Ducks on each reach of the four rivers surveyed in 1997. Includes sampling periods 2-6.



(maximum number present on any visit was 20 birds seen on 13 May 1997). At the mouth of the Hoh, birds were not seen until the middle of May and began to be seen more consistently by the end of May. The maximum number of birds seen at the mouth of the Hoh River was 37 (seen on 27 May 1996), although usually fewer than ten individuals were observed. On the Elwha River, birds were seen at the mouth as early as 13 April in 1997 and were found at the mouth consistently throughout the season in both years. The maximum number of birds seen at the Elwha River was 134 (seen on 30 August 1996). No Harlequin Ducks were seen at the mouth of the Soleduck (Quillayute River) or at the confluence of the Soleduck and Quillayute Rivers.

The mean number of total Harlequin Ducks (males, females, juveniles and unknown age or gender) at the mouth of the Elwha was relatively constant from year to year: 28 in both years (N = 9 in 1996, N = 6 in 1997). The mean number of Harlequin Ducks at the mouth of the Hoh River was 8 in 1996, and 6 birds in 1997 (N = 6 in 1996, N = 6 in 1997). Harlequin Ducks were rarely observed on either lake and when observed, were located at the inlet of the river, the upstream area of the lake only.

River to River Comparisons

Mean densities of female Harlequin Ducks were significantly higher on the Elwha River than on the Hoh River in 1996 (Mann-Whitney U non-parametric test, $Z = -2.887$; $p = 0.004$). Harlequin Ducks were found on only a few occasions on a few reaches on the Hoh River system, with a mean total river density of just less than 1 female/10 km, compared to the Elwha, with a mean density of 12 females/10 km.

Mean densities of female Harlequin Ducks differed across all four rivers in 1997 ($F=15.61$ $p=<<0.001$ from one-way ANOVA). In planned multiple comparisons between the Elwha and the other three rivers, Elwha densities were significantly greater than those of the Hoh, Soleduck, but not the Duckabush River (multiple comparisons using Dunnett's t Multiple-Comparison Test with control) (Table 2.6).

Productivity

Harlequin juveniles were easy to identify as juveniles until approximately 43-45 days old (close to fledging) when they lost all their down (Bellrose 1976). At this time they were difficult to visually discern from adult females unless they attempted to fly or otherwise revealed short primary feathers. A fully-fledged juvenile, approximately 46-60 days old, was indiscernible from an adult female unless extremely close to observer (< 80 cm). Therefore, only in the early and middle stages of the breeding season were harlequin juveniles useful indicators of productivity.

Juveniles were found on all reaches of the Elwha above the lower dam (reaches 2-6). They were only found on reaches 3 and 4 of the Hoh, with the exception of the one August sighting in 1997 of the adult and juvenile that appeared to be migrating through reach 2. Harlequin juveniles were only seen on two disjunct reaches of the Duckabush, reach 1 and reach 4. Juveniles were seen only on reach 5 on the Soleduck River.

The earliest observations of broods in 1996 were on 11 June on the Elwha River. Back calculating from the estimated age of the brood (approximately 8-13 days old) puts the estimated hatch date between 29 May and 3 June. The first brood seen on the Hoh River in 1996 would have hatched no earlier than 19 June. In 1997, the earliest broods were seen on the Elwha on 6 July (estimated hatch dates 16-25 June) and on the Hoh River on 10 July (estimated hatch 13-21 June). Juveniles were still seen on all rivers during the last surveys of both years (early September in 1996, mid August in 1997) (Figures 2.8a and 2.8b).

Species Summary

Harlequin Duck abundance may be a useful indicator of ecosystem recovery of the Elwha River following dam removal, however, other aspects of their life history may obscure the picture. Because they are a species of special concern in Washington State and a candidate for threatened status in Oregon, information regarding any population response to ecosystem restoration may be useful in management decisions in the Pacific Northwest. Harlequin Ducks were found to be relatively abundant on the river in its present condition and breeding was documented on all reaches above Reach 1 (compared to the patchy breeding on the

Figure 2.8a. Number of Harlequin Duck broods and juveniles by sampling periods on the Elwha and Hoh Rivers 1996.

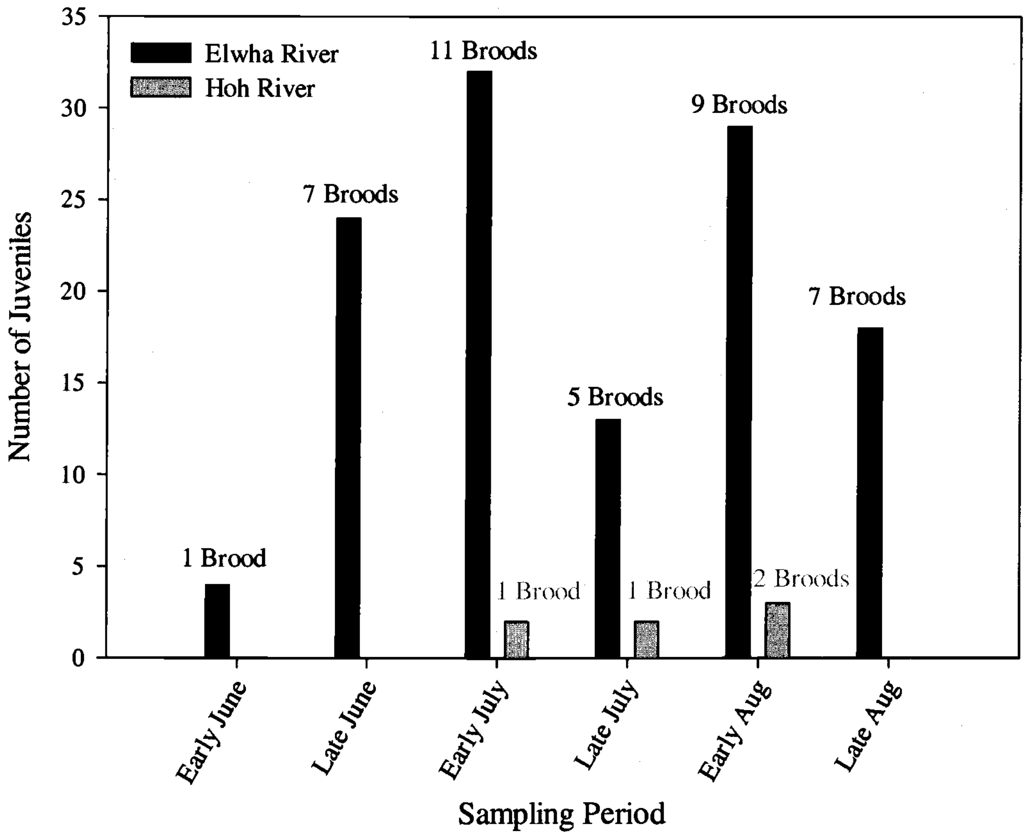
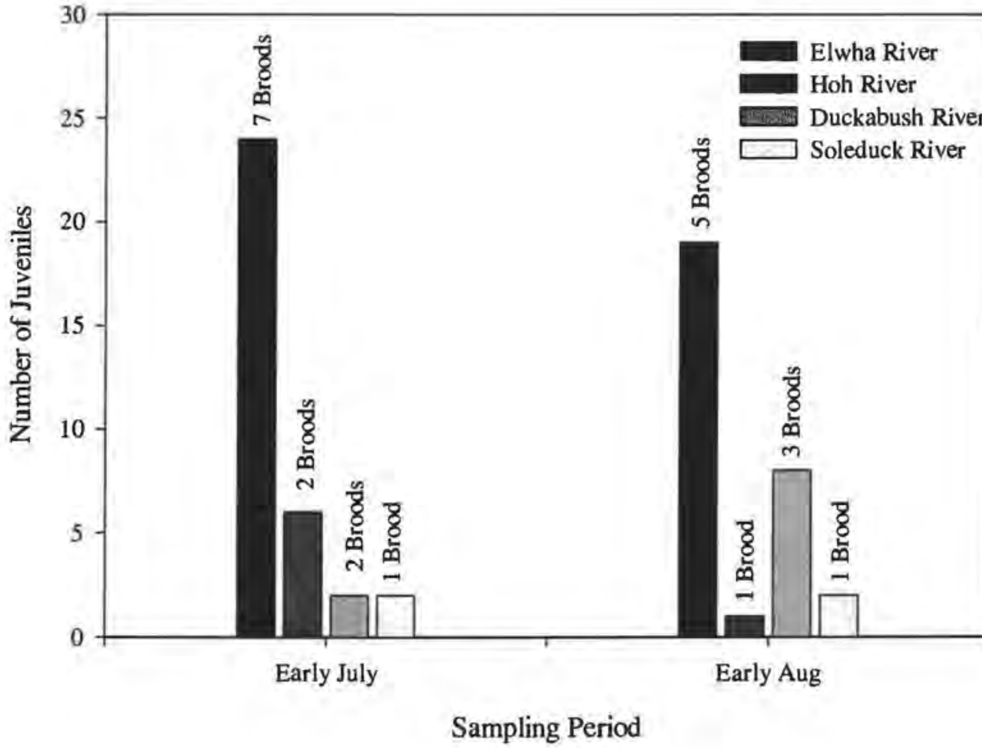


Figure 2.8b. Number of Harlequin Duck broods and juveniles by sampling periods on the Elwha, Hoh Duckabush and Soleduck Rivers 1997.



other rivers surveyed in this study). Compared to similar studies of Harlequin Duck densities along rivers in Oregon and British Columbia, the Elwha River densities are comparable to or higher than other areas in the Pacific Northwest. Harlequin Duck densities were similar from year to year during the two years of this study indicating that river populations may be relatively stable making long-term population trends more apparent should they manifest themselves after dam removal. Because of Harlequin Ducks' affinity for fast-moving river systems, colonization of reclaimed river habitat may be indicative of ecological recovery. It will be important to monitor any change in use of the lower and between-dam reaches of the Elwha by Harlequin Ducks. The significant use of the lower sections of the Duckabush suggests that if the habitat is suitable, Harlequin Ducks will use lower reaches.

Several studies indicate that food availability may be an important factor in habitat selection (Rodway and Cooke 2001, Hunt and Ydenberg 2000, Wright 1997, Bengtson and Ulfstrand 1971). Li (1990) documented higher invertebrate diversity and increased mayfly dominance in the reaches of the Elwha River above the upper dam. She suggested that increased mineral substrate availability caused by removal of filamentous algae through scouring action might contribute to the increase in diversity. Should scouring and mineral substrate increase with dam removal as predicted (along with the potential nutrient enrichment from salmon spawning), the macroinvertebrate food base for Harlequin Ducks may increase.

This may cause a trophic cascade response in Harlequin Duck use of the lower reaches. However, these reaches have the confounding factor of a higher rate of disturbance to the Harlequin Ducks resulting from easy road access and boat usage and this factor should be monitored and quantified in future studies. Also, the lowest reach in the Elwha is larger and swifter and may not be as suitable for Harlequin Duck foraging as Reach 2 regardless of enrichment or increased substrate. More habitat variables should be measured concurrently with future bird studies.

The mouth of the Elwha River was used more consistently by larger numbers of Harlequin Ducks than were those of the Duckabush, Hoh and Soleduck Rivers. After dam removal, significant increases in the amount of sediment traveling down stream will affect the sediment dynamics at the mouth (National Park Service Olympic National Park 1996). How this will affect the use of this area by ducks is unclear and would warrant monitoring. Harlequin Ducks were observed using the area both for loafing and for foraging. Dam removal will cause increased sediment load at the mouth and might temporarily discourage foraging in the area and therefore displace Harlequin Ducks. However, after removal of the dams the estuary is likely to become more extensive and foraging habitat may be improved over the long term. Also, Harlequin Ducks are known to forage on salmon roe in streams in Alaska (Dzinbal 1982) and increased anadromy in the system may encourage increased use of the mouth and estuary by Harlequin Ducks.

There is some evidence that female Harlequin Ducks are likely to return to breed on their natal stream (Robertson and Goudie 1999). This fidelity to natal stream presents a founder effect for this species whereby greater abundances may be partly due to more successful breeders producing more female offspring who return to their natal stream. This site fidelity may mask or slow any population response due to habitat quality alone.

Spotted Sandpipers

During their breeding season, Spotted Sandpiper adults can easily be distinguished from juveniles by plumage but males are indistinguishable from females, therefore, relative densities of Spotted Sandpipers were compared using adults/kilometer. Spotted Sandpipers did not arrive on the rivers in significant numbers until late June and started to leave the rivers in August so only sampling periods 3 through 8 were considered in any analyses that required averaging across sampling periods.

The maximum density of Spotted Sandpipers observed on any individual survey in the Elwha was 3 adults/km during sampling period 5 on Reach 1 in 1996 with similar densities found on Reach 3 during sampling period 6 (2.9 adults/km). The Duckabush and the Hoh River both had 1.8 adults/km on reach 1 (both rivers) in 1997 (sampling periods 2, 4 and 6). Rarely were sandpipers observed at the mouth of any of the rivers (reach 0); for example, only one individual was observed at the mouth of the Soleduck River in 1997 (Table 2.8).

Table 2.8. Mean densities (± SE) of adult Spotted Sandpipers (Ad/km) for river reaches surveyed in 1996 and 1997. Includes sampling periods 3 through 8. (N= number of surveys.)

Reach		1996		1997			
		Elwha	Hoh	Elwha	Hoh	Duckabush	Soleduck
0	N	13	6	4	4	3	4
	Ad/km	0.15	0.13	0.00	0.00	0.00	0.11
	± SE	0.15	0.13	0.00	0.00	0.00	0.11
1	N	6	6	4	4	4	4
	Ad/km	1.63	0.48	1.00	0.55	1.20	0.20
	± SE	0.50	0.18	0.25	0.43	0.41	0.20
2	N	6	6	4	4	4	4
	Ad/km	0.29	0.51	0.20	0.38	0.20	0.00
	± SE	0.12	0.12	0.12	0.20	0.13	0.00
3	N	5	4	4	4	4	4
	Ad/km	1.39	0.49	0.60	0.89	0.00	0.11
	± SE	0.49	0.19	0.17	0.26	0.00	0.07
4	N	6	5	4	4	4	4
	Ad/km	0.32	0.55	0.15	0.91	0.00	0.00
	± SE	0.08	0.22	0.10	0.34	0.00	0.00
4.5[h]	N		5		2		
	Ad/km		0.44		0.33		
	± SE		0.14		0.33		
5	N	6	4	4	4	4	4
	Ad/km	0.58	0.88	0.19	0.50	0.18	0.00
	± SE	0.19	0.10	0.06	0.15	0.11	0.00
6[e]	N	2		1			
	Ad/km	0.75		0.25			
	± SE	0.25		-			

[e] Elwha River reach not paired with a reach on the Hoh River.
[h] Hoh River reach not paired with a reach on the Elwha River

Spatial Patterns

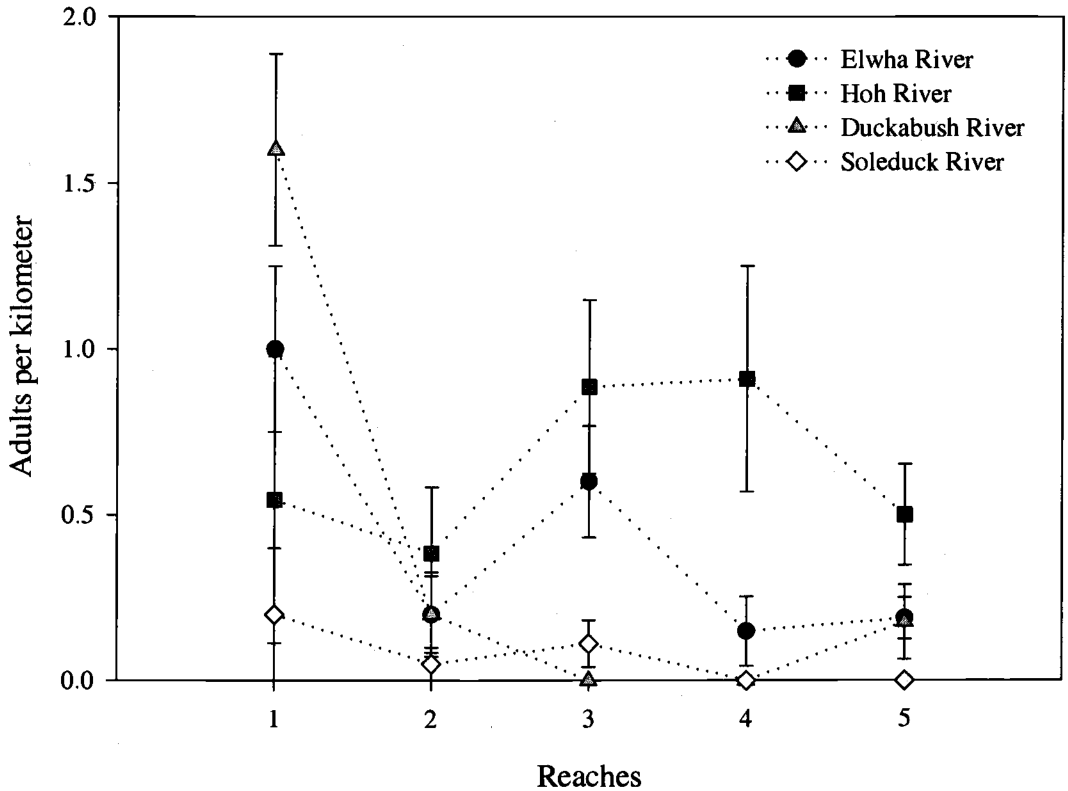
On the Elwha, reaches 1 and 3 had the highest mean densities of Spotted Sandpipers (1.6 adults/km and 1.4 adults/km in 1996). On the Hoh, densities of Spotted Sandpipers were relatively consistent across reaches and ranged between 0.5 and 0.9 adults/km. Densities on the Duckabush were greatest on reach 1 (1.2 adults/km) in 1997, but densities were low for all other Duckabush reaches. The greatest average density on the Soleduck River was in reach 1, however, the mean was only 0.2 adults/km (Figure 2.9).

River to river comparisons

In 1996, there is no evidence that mean densities of adult Spotted Sandpipers were different on the Elwha and Hoh Rivers ($t = -0.247$ $p = 0.807$ from 2-sided t-test with equal variance). The mean density of Spotted Sandpipers was slightly higher on the Hoh River by 0.3 birds per 10 km (with a wide 95% confidence interval ranging from 3 birds less to 2 birds more per 10 km).

In 1997 there were very few sightings of adult Spotted Sandpipers on the Soleduck River therefore only the Elwha, Hoh and Duckabush Rivers were included in the ANOVA. Among the three rivers, there was no evidence that the mean densities of Spotted Sandpipers were different on the Elwha, Hoh and

Figure 2.9. Mean (±SE)densities (n = 4) of Spotted Sandpipers for each reach of the four rivers surveyed in 1997. Includes sampling periods 3-8.



Duckabush Rivers (F= 0.72, 2-sided p-value = 0.501, one-way analysis of variance F-test; Table 2.6). Comparing the Elwha and Soleduck Rivers alone using non-parametric procedures, there is evidence that the rank of the mean density of Spotted Sandpipers is higher on the Elwha River than on the Soleduck River (Z-statistic = -2.163; 2-tailed p-value = 0.031, Mann Whitney Test).

Productivity

Spotted Sandpiper chicks (in their downy phase) were difficult to observe; only three sets of chicks were seen during both field seasons. However, sandpipers in juvenal plumage were readily differentiated from adults and they were very visible on the rivers. Spotted Sandpiper juveniles first appeared during sampling period 5, but most were observed during sampling periods 7 through 9. Looking at the ratio of juveniles to adults present on two rivers, 18% of all birds observed on the Elwha in 1996 were juveniles (17% observed in 1997) (average of sampling periods 6 through 9), compared with 29% on the Hoh River in 1996 (20% in 1997).

Species Summary

Because Spotted Sandpiper distributions in the Olympics are patchy and the species is not well represented on all rivers, and also because the connections between sandpiper densities along river habitat and food availability are not, as yet, well understood, this species may not be a useful indicator of ecosystem recovery after dam removal. Changes in distribution or abundance would be difficult to relate to enrichment due to anadromy. Even so, monitoring Spotted Sandpipers during and after dam removal on all rivers will be useful for monitoring population shifts of this species on broader temporal and spatial scales. On the specific reaches where they did occur, Spotted Sandpipers could be found in large enough densities that changes in populations could be potentially be observed. Spotted Sandpipers are easy to survey simultaneously while surveying other species of interest so monitoring Spotted Sandpipers could continue as a potential measure of regional population shifts regardless of their use as indicators of ecosystem response to removal of dams.

Distribution and Abundance of Piscivores

Belted Kingfisher

Female Belted Kingfishers can be distinguished from male kingfishers by the presence of a rusty bellyband; however, this was not always easy to see when birds were in flight. Similarly, juveniles can be distinguished by plumage but the differences are subtle and difficult to discern in flight or under low light conditions. Therefore, the total number of individuals per kilometer (males, females, juveniles, and unknown gender or age) is used as the population indicator for kingfishers. Belted Kingfishers are resident year round on rivers and were present on the rivers at the beginning and ending of the breeding season therefore data from all sampling periods is included in analyses involving averages across sampling periods.

Spatial Patterns

Few Belted Kingfishers were observed on the Elwha and Duckabush Rivers. On these rivers, kingfishers were mostly seen at the mouth or on reach 1. Reach 3 on the Elwha and reaches 2, 3, and 4 on the Duckabush had no occurrences of kingfishers. More birds were consistently found on more reaches on the Hoh and the Soleduck Rivers (Table 2.9, Figure 2.10).

River to river comparisons

In 1996, there was no evidence that mean densities of Belted Kingfishers on the Elwha and Hoh Rivers were significantly different ($t = -1.59$; $p = 0.138$ from 2-tailed t-test). Extrapolating to 10 km, there were nearly 2 Belted Kingfishers per 10 km on the Elwha, compared with 3 kingfishers per 10 km on the Hoh.

Densities of Belted Kingfishers did not differ among the four rivers surveyed in 1997 (Non-parametric Kruskal-Wallis statistic = 5.819; p-value = 0.121, Table 2.6). Kingfishers were found in low numbers on all rivers. Mean densities ranged from less than one individual per 10 km on the Duckabush Rivers, to just over 2 individuals per 10 kilometers on the Hoh River.

Productivity

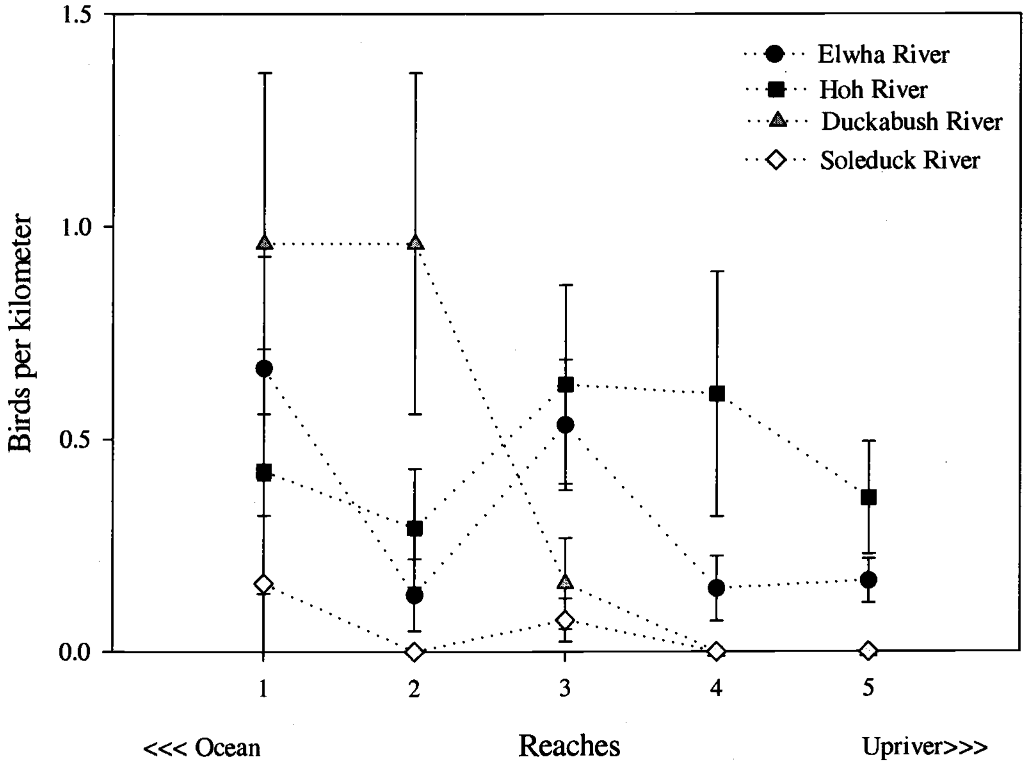
Very few juvenile Belted Kingfishers were positively identified on any river system. The maximum number of juveniles observed on any river was 4 (on the Hoh River in 1996). Different survey methods may be required to assess

Table 2.9. Mean densities (± SE) of total number of Belted Kingfishers (Birds/km) for each reach of rivers surveyed in 1996 and 1997. Includes sampling periods 1 through 9. (N=number of surveys).

Reach		1996		1997			
		Elwha	Hoh	Elwha	Hoh	Duckabush	Soleduck
0	N	22	8	6	6	5	6
	#/km	0.45	0.10	0.00	0.00	0.27	0.07
	± SE	0.18	0.10	0.00	0.00	0.27	0.07
1	N	8	8	6	6	5	5
	#/km	1.06	0.45	0.38	0.18	0.32	0.56
	± SE	0.14	0.26	0.11	0.08	0.20	0.10
2	N	9	8	6	6	5	6
	#/km	0.00	0.21	0.07	0.05	0.00	0.13
	± SE	0.00	0.05	0.05	0.02	0.00	0.10
3	N	8	7	6	6	6	6
	#/km	0.00	0.44	0.00	0.44	0.00	0.02
	± SE	0.00	0.07	0.00	0.05	0.00	0.02
4	N	9	6	6	6	6	6
	#/km	0.10	0.58	0.00	0.33	0.00	0.40
	± SE	0.10	0.14	0.00	0.12	0.00	0.19
4.5[h]	N		8		2		
	#/km		0.11		0.33		
	± SE		0.06		0.11		
5	N	9	5	6	6	5	6
	#/km	0.03	0.13	0.00	0.11	0.05	0.30
	± SE	0.03	0.08	0.00	0.04	0.05	0.22
6	N	4		1			
	#/km	0.13		0.00			
	± SE	0.13		-			

[e] Elwha River reach not paired with a reach on the Hoh River.
[h] Hoh River reach not paired with a reach on the Elwha River

Figure 2.10. Mean (± SE) densities (n = 8) of Belted Kingfishers for each reach of the four rivers surveyed in 1997. Includes sampling periods 1 – 8.



productivity of this species. Finding and monitoring nests has been used in other studies, however, the effort required to find nests by following provisioning adults back to the cavity was beyond the scope of this study.

Species Summary

Other studies have linked kingfisher (*Ceryle spp.)* densities and productivity with food availability (Siikamaki 1998, Kelly and Van Horne 1997, Wanink and Goudswaard 1994, Davis and Graham 1991), suggesting that they might be a species that would respond to enrichment via dam removal. However, their low and patchy densities on the Elwha (possibly due to nest site availability), high degree of territoriality, along with the effort needed to evaluate productivity, reduce the potential value of using this species as an indicator of ecosystem response using the survey techniques described in this study.

Common Merganser

Male Common Mergansers leave the rivers for the ocean at the initiation of egg laying but female Common Mergansers remain on the rivers throughout brood rearing. Therefore the number of females per kilometer was the population indicator used for analyses. Although large groups of female Common Mergansers were present on the lower reaches of the rivers during the first sampling period, pairs were still migrating upriver and had not yet arrived on the breeding grounds during the first sampling period. Also, near the end of the breeding season in August, some females and broods had begun their migration to the ocean.

Therefore, only sampling periods 2 through 7 were included in calculations of mean densities across sampling periods.

The greatest density of female mergansers for any reach of any river was a single observation of 14.3 females/km on the Elwha (reach 1 in sampling period 1 of 1996). The second greatest density on that reach of the Elwha was 6.8 females/km (during a second survey of sampling period 1 in 1996). The maximum density of female mergansers on a river other than the Elwha was 2.8 females/km on reach 1 of the Soleduck River (1997). Cumulative female merganser densities for rivers range from 0.7 females/km (on the Elwha, sampling period 4 in 1997) to 0 females/km (on the Duckabush and Soleduck Rivers, sampling periods 6 in 1997.

Temporal Patterns

Mergansers were present on the Elwha and Hoh Rivers in greater numbers in the early part of the field season (Figure 2.11a and 2.11b). Some adult female mergansers were still detected on the Elwha, Hoh and Soleduck Rivers in small numbers in the latest sampling periods in August. Detections of male Common Mergansers on all rivers except the Soleduck River tended to drop off after mid-May.

Figure 2.11a. Relative densities of female, male, and juvenile Common Mergansers on the Elwha River 1996.

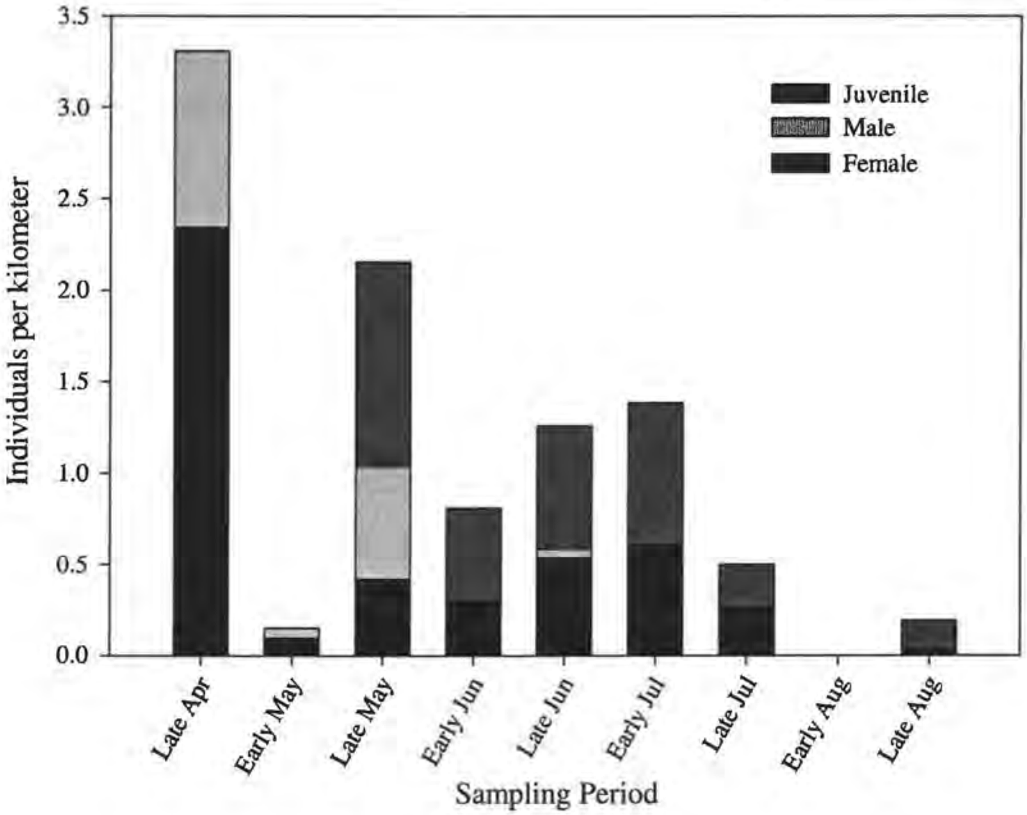
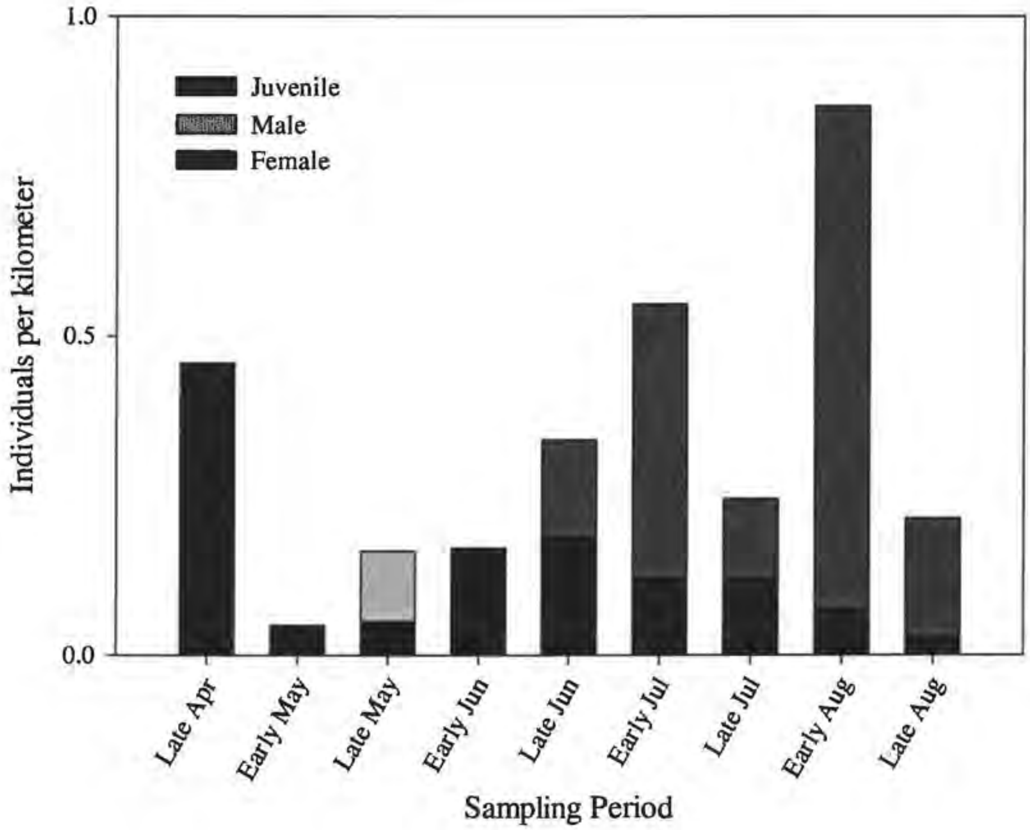


Figure 2.11b. Relative densities of female, male, and juvenile Common Mergansers on the Hoh 1996.



Common Mergansers used the mouth of the Elwha intermittently throughout both field seasons. In 1996, the number of adult mergansers observed ranged from 0-10 with the exception of 6 April 96 where 55 adult mergansers were counted. No Common Mergansers were observed on 12 of the 22 visits to the mouth of the Elwha in 1996 and a similar pattern was displayed in 1997. Broods were seen at the mouth of the Elwha during August in both years. At the mouth of the Hoh, Common Mergansers were rarely seen during either field season. The only sightings were a brood, detected on 19 August 1996, and a male observed on 7 July 1997. Common Mergansers were commonly seen at the mouth of the Duckabush through the end of June (numbers of individuals ranged from seven to 31 during the 4 sampling periods). However, Common Mergansers appeared to leave the area and were not detected during July or August of 1997. Common Mergansers were seen at the mouth of the Soleduck River during all sampling periods. Number of individuals ranged from four to 13. Broods of Common Mergansers were observed at the mouth of the Soleduck River during July and August.

Spatial Patterns

The densities of female mergansers were greatest in lower reaches and tended to decrease with distance from the ocean on the Elwha, Soleduck and Duckabush Rivers (Figures 2.12a and 2.12b). Distribution of female mergansers on the Hoh River was patchy among reaches and not consistent between years

Figure 2.12a. Mean (± SE) densities (n = 7) of female Common Mergansers for each reach on the Elwha and Hoh Rivers 1996. Includes sampling periods 2-7).

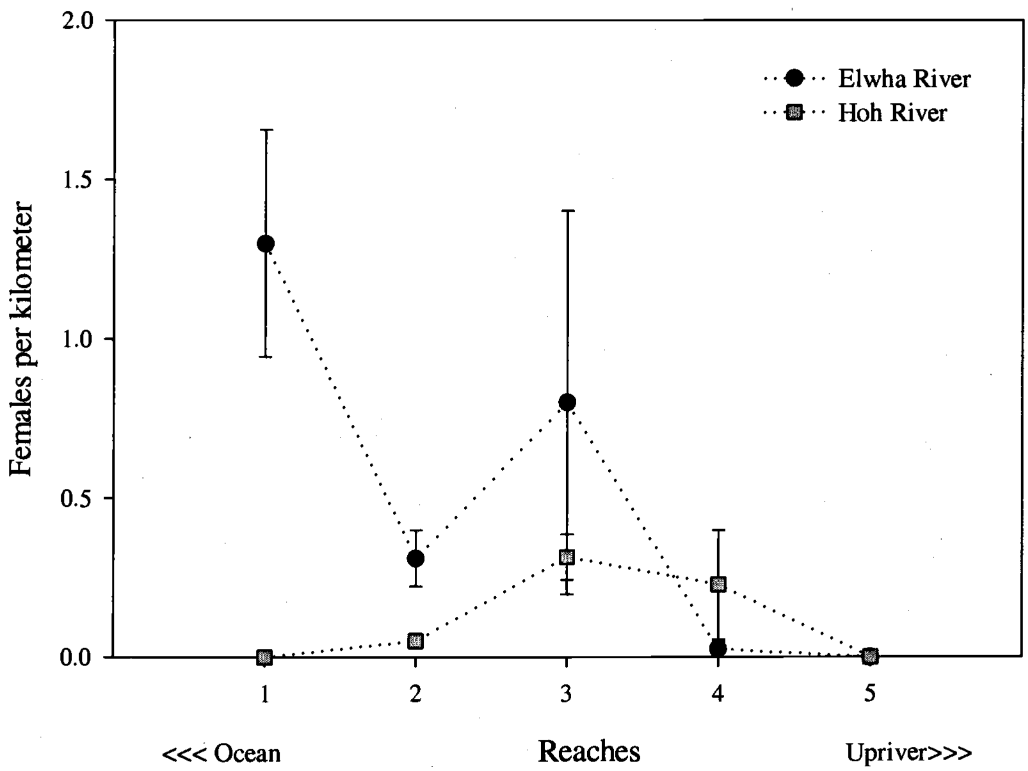
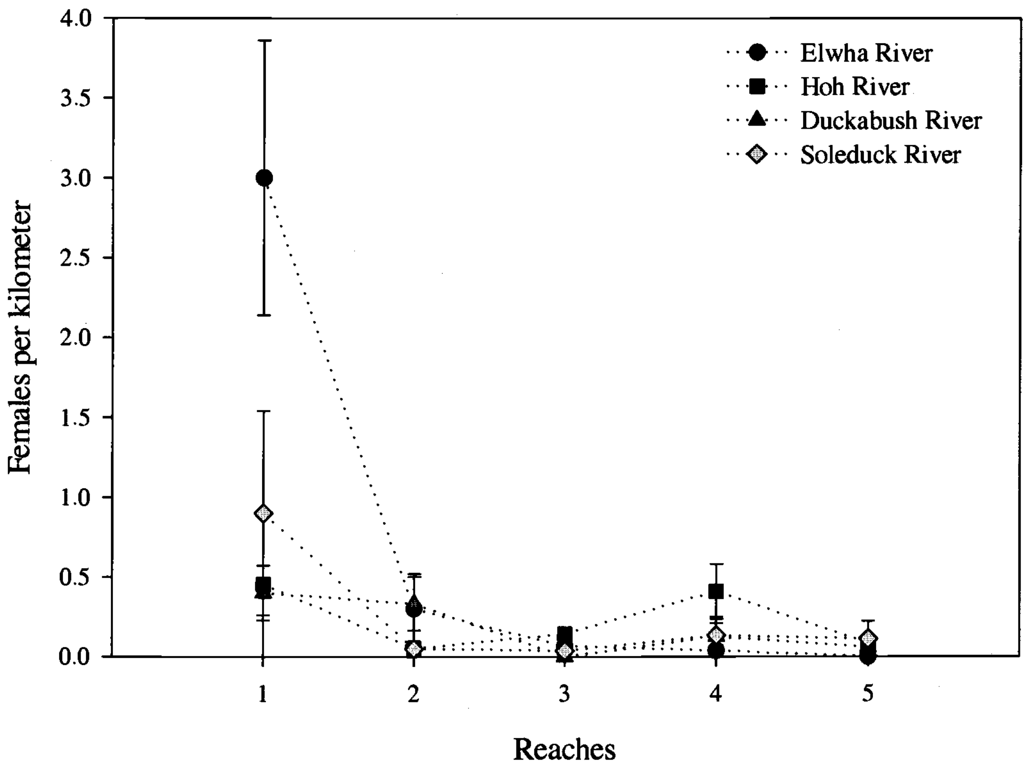


Figure 2.12b. Mean (± SE) densities (n = 4) of Common Mergansers for each reach on four rivers, 1997. Includes sampling periods 2-6.



(Table 2.10). All rivers showed most variability at the lower reach 1 where non-breeding birds are most likely to venture onto the river from the ocean.

River to river comparison

In 1996, the mean female merganser density on the Elwha River was significantly higher than on the Hoh River (p=0.018 from a two-sample t-test assuming unequal variance). Extrapolating to a value of females per 10 kilometers, the Elwha River had 2.5 more female mergansers per 10 km than the Hoh River (95% confidence interval 0.6 to 4.6 fem/10 km. Female Common Merganser densities were significantly different among the four rivers surveyed in 1997 (F=5.95 p-value =0.010 from a one-way ANOVA assuming equal variance). The Elwha River female Common Merganser density was significantly higher than the Hoh, the Duckabush and the Soleduck River densities (multiple comparisons using Dunnett's t vs. Control) (Table 2.6). Extrapolating to females per 10 kilometers, the Elwha River has 3.9, 3.5, and 3.9 more females/10km than the Hoh, Duckabush and Soleduck respectively (all confidence intervals range from 1 to 6 females/10km).

Table 2.10. Mean densities (± SE) of female Common Mergansers (Fem/km) for each reach of each river surveyed in 1996 and 1997. Includes survey periods 2 through 7 for 1996, and 2 through 6 for 1997. (N=number of surveys).

Reach		1996		1997			
		Elwha	Hoh	Elwha	Hoh	Duckabush	Soleduck
0	N	15	6	4	4	4	4
	Fem/km	1.6	0.00	2.00	0.00	8.33	1.22
	± SE	.74	0.00	2.00	0.00	3.10	0.21
1	N	7	4	4	4	3	3
	Fem/km	1.30	0.00	3.00	0.45	0.40	0.90
	± SE	0.36	0.00	0.86	0.45	0.17	0.64
2	N	14	4	4	4	3	4
	Fem/km	0.31	0.05	0.30	0.05	0.33	0.05
	± SE	0.09	0.02	0.22	0.03	0.17	0.05
3	N	7	3	4	4	4	4
	Fem/km	0.80	0.31	0.07	0.14	0.00	0.04
	± SE	0.60	0.07	0.07	0.03	0.00	0.04
4	N	1	3	4	4	4	4
	Fem/km	0.02	0.23	0.04	0.41	0.13	0.13
	± SE	0.02	0.17	0.04	0.17	0.13	0.08
4.5[h]	N		5		1		
	Fem/km		0.13		0.22		
	± SE		0.05		-		
5	N	5	2	4	4	3	4
	Fem/km	0.00	0.00	0.00	0.08	0.06	0.15
	± SE	0.00	0.00	0.00	0.05	0.06	0.15
6[e]	N	3		1			
	Fem/km	0.00		0.00			
	± SE	0.00		-			

[e] Elwha River reach not paired with a reach on the Hoh River.
[h] Hoh River reach not paired with a reach on the Elwha River

Species Summary

Common Merganser densities on all the rivers studied were relatively low with patchy distributions. Those factors will make long-term comparisons of these data difficult to interpret. It was expected that densities of female mergansers would be greatest on rivers open to anadromy, specifically the Hoh and the Soleduck Rivers, but this hypothesis is not supported by my findings.

On two occasions, it was possible to survey the lower Hoh River via raft (22 June 1996) and the lower Soleduck River by drift boat (22 May 1997). In both instances, Common Mergansers were easier to observe from the vessel than from shore and, on the Soleduck River, they appeared to occur in greater numbers than the reaches selected to survey in this study (although exact densities could not be calculated). Future investigations of mergansers should focus on the lower reaches of the rivers and should employ boats if feasible.

Anadromy may influence use of specific reaches. The highest Common Merganser density was on the lowest reach of the Elwha River, which is open to anadromy and also has a fish hatchery/rearing channel on it. Juvenile salmon released from the hatchery may locally influence the current merganser densities and distributions. If anadromous fish return to the Elwha River, it may be possible to see distributional shifts in breeding Common Mergansers as the salmon would be present in more reaches and further from the mouth.

Any increase in Common Merganser densities may cause some concern for native fish runs experiencing recovery post dam removal as mergansers are considered a significant predator of young salmon in Eastern Canada and the UK (Feltham 1995). Wood (1987a, 1987b) suggests that the impact of Common Mergansers on salmon may be minimal if the birds are taking only surplus fry or if the salmonid species does not reside in the river for more than one year. Additionally, they may have less impact on native populations when compared to hatchery fish where fry are released simultaneously and in great numbers. The current impact of Common Mergansers on Elwha River salmonid populations is not known to be of concern, however, if Common Merganser numbers increase dramatically in the lower reaches as the salmon populations begin to rebound, bird/fish management conflicts may arise. Realistic assessments of Common Merganser impacts on salmonids can be estimated using existing energetics models (Feltham 1995).

The absence of mergansers at or near the mouth of the Hoh River in light of the numbers observed up river is puzzling. It was expected that broods of Common Mergansers would be detectable at the mouths of the rivers during their migration to the sea for the non-breeding season and this seemed to hold true for the other three rivers. The high use of the lower Hoh River by fishers in drift boats (possibly causing disturbance), and the potential for poaching (Common Mergansers are seen as competitors with humans for salmonids) may be possible explanations for their absence and warrants further exploration.

Distribution and Abundance of Raptors - Bald Eagle and Osprey

Large raptors were difficult to survey from under the canopy along the river. There were few sightings along any particular reach of river in the study area and no nests were found. The maximum number of Bald Eagles and Osprey (total individuals) observed on any given reach is recorded in Table 2.11 and 2.12, respectively. Bald Eagles were regularly observed at the mouths of rivers and on reach 1, but were only occasionally observed on reaches further from the ocean. Osprey were observed in even lower numbers than Bald Eagles and on only one occasion was more than one Osprey observed on a specific reach during a specific sampling period. No Ospreys were observed at the mouths of the Hoh River or the Elwha in either 1996 or 1997.

Raptors were difficult to survey from the river bottom and were present in low numbers. These data, when compared to future surveys, may be difficult to use for comparison. One key area for surveying for raptors after dam removal would be the mouths of the rivers, where raptors were most visible and may congregate on spawned out carcasses of anadromous fish during salmon spawning seasons (which did not coincide with the bird breeding season of this study). Other key reaches to monitor in the future would be the reaches that are currently impounded by lakes (see lake data).

Table 2.11. Maximum number (MAX) of Bald Eagles for river reaches surveyed in 1996 and 1997. Includes survey periods 1 through 9 (N= number of surveys).

Bald Eagles								
Reach		1996		1997				
		Elwha	Hoh	Elwha	Hoh	Duckabush	Soleduck
0	N		8	6	6	5	6
	MAX		1	7	3	6	9
1	N	11	8	6	6	5	5
	MAX	2	2	2	3	1	4
2	N	19	8	6	6	5	6
	MAX	0	1	0	1	0	1
3	N	11	9	6	6	6	6
	MAX	0	1	0	1	0	4
4	N	5	8	6	6	6	6
	MAX	1	2	1	2	0	1
4.1[ae]	N	10					
	MAX	1					
4.2[a,e]	N	9					
	MAX	0					
4.5[h]	N		8		2		
	MAX		1		1		
5	N	10	6	6	6	5	6
	MAX	0	3	0	1	0	0
6	N	4		1			
	MAX	2		0			

[a] Reaches 4.1 and 4.2 together are equal to reach 4 but were separated when they were surveyed on separate days
[e] Elwha River reach not paired with a reach on the Hoh River
[h] Hoh River reach not paired with a reach on the Elwha River

Table 2.12. Maximum (MAX) number of Osprey for river reaches surveyed in 1996 and 1997. Includes survey periods 1 through 9. (N=number of surveys).

Reach		1996		1997			
		Elwha	Hoh	Elwha	Hoh	Duckabush	Soleduck
0	N	22	8	6	6	5	6
	Max	0	0	0	0	1	1
1	N	11	8	6	6	5	5
	Max	0	0	0	1	0	1
2	N	19	8	6	6	5	6
	Max	0	0	1	0	1	1
3	N	11	9	6	6	6	6
	Max	0	1	1	1	0	4
4	N	5	8	6	6	6	6
	Max	1	0	1	1	1	0
4.1[e]	N	10					
	Max	0					
4.2[e]	N	9					
	Max	0					
4.5[h]	N		8		2		
	Max		0		0		
5	N	10	6	6	6	5	6
	Max	0	0	1	1	1	0
6	N	4		1			
	Max	1		1			

[a] Reaches 4.1 and 4.2 together are equal to reach 4 but were separated when they were surveyed on separate days

[e] Elwha River reach not paired with a reach on the Hoh River.

[h] Hoh River reach not paired with a reach on the Elwha River

Use of the Lakes

Common Mergansers used both Lake Aldwell and Lake Mills in the largest numbers (Table 2.13); the maximum number of adult mergansers seen at any survey was 10 (on 26 July 1996). Spotted Sandpipers were regularly seen on both lakes, as were Belted Kingfishers. Bald Eagles and Osprey were occasionally seen on both lakes. and active nests of Osprey were found near both lakes. Harlequin Ducks were rarely seen on the lakes, and when observed, were located near the mouths of the river at their entry into the lakes. Dippers were never seen on Lake Aldwell in either year, but were seen occasionally on Lake Mills.

Current lake habitat will be altered most by dam removal. Displacement of birds that prefer lotic systems (e.g., dabbling ducks) can be expected and birds that prefer lentic systems (Harlequin Ducks and American Dippers) may increase their use of these areas. Species such as kingfishers, eagles, Ospreys and mergansers were present on both lentic and lotic reaches of the Elwha, and although disruption will occur during restoration phases, use of the current lake reaches after dam removal by these species should continue. It is suspected that Harlequin Duck broods may use the restored river reaches (previously lakes) to migrate to the ocean by swimming as they are known to do in some systems (Robertson and Goudie 1999, Dzinbal and Jarvis 1982), whereas currently they must fly or walk around the dams. Monitoring the bird use of the lake reaches after dam removal will potentially reveal the most dramatic changes over time.

Table 2.13. Numbers of individuals for each species observed on lakes, 1996 and 1997.

Lake	Year	Survey Date	American Dipper	Bald Eagle	Belted Kingfisher	Common Merganser	Harlequin Duck	Osprey	Spotted Sandpiper
Aldwell	96	16-Jun-96	0	0	0	6	0	0	0
Aldwell	96	24-Jun-96	0	2	1	6	0	0	3
Aldwell	96	05-Jul-96	0	0	3	6	0	0	0
Aldwell	96	26-Jul-96	0	0	1	10	0	2	4
Aldwell	96	28-Aug-96	0	0	1	7	0	1	4
Aldwell	97	12-May-97	0	1	0	1	4	0	7
Aldwell	97	03-Jul-97	0	0	3	9	0	0	5
Mills	96	30-Apr-96	0	0	0	2	0	0	0
Mills	96	15-Jul-96	0	0	2	9	1	0	4
Mills	96	26-Aug-96	3	0	3	2	0	1	2
Mills	97	11-May-97	7	0	0	7	2	2	2
Mills	97	04-Jul-97	3	0	0	0	0	2	4

Discussion

The Elwha River is a healthy, productive river for benthivorous birds such as Harlequin Ducks and American Dippers. On the Elwha, densities of Harlequin Ducks are as high as or higher than many other streams where their densities have been measured and American Dipper densities are also comparable to other known "good habitat" systems. It is a moderately productive river for the benthivorous Spotted Sandpiper and less productive for piscivorous species such as Common Mergansers and Belted Kingfishers except near the mouth of the river. Above the upper dam, densities of benthivorous species exceed those supported between the dams and below the lower dam. The relative importance of anadromy to Harlequin Ducks is unclear. At the present time, reaches closed to anadromy on the Elwha River have the highest relative abundance of Harlequin Ducks. Conversely, the reaches of the Duckabush River that are known to have anadromous fish runs have the highest relative abundance of Harlequin Ducks in that river system. The reaches of the Soleduck and the Hoh Rivers that are used by Harlequin Ducks are open to anadromy but other open reaches on these systems have very low Harlequin Duck densities. Of course, many other habitat variables are influential in determining relative abundance. However, with the removal of the dams and subsequent potential nutrient enrichment, any change in Harlequin Duck distribution and relative abundance will provide clues to any relationship between Harlequin Duck habitat selection and anadromy. Measurable increases in

Harlequin Duck relative abundances in the upper reaches of the Elwha River after dam removal along with increases in available forage would indicate strong bottom-up effects from the return of anadromy. Measurable decreases may indicate that the dams currently provide some other benefit to Harlequin Ducks such as a reduced number of mammalian nest predators such as river otter that are attracted to the river because of the lack of anadromy. Because of the unique opportunity to examine such responses in the three distinct regions of the river (above, between, and below the dams) post dam-removal survey data may be enlightening. Also, because of the conservation status of the Harlequin Duck (Eastern North American population is endangered in Canada and threatened in the state of Maine and it is considered a Species of Special Concern in Idaho and "Yellow listed" in British Columbia and Alberta (Robertson and Goudie 1999)), long-term monitoring of this species would increase understanding of long-term population trends. Although this study did not survey all rivers on the Olympic Peninsula, Washington State Fish and Wildlife surveys of Harlequin Ducks show that they may be more abundant on the Elwha River than any other river on the peninsula (Shirato pers. com.). Valuable information could be gathered on the Elwha population that will broaden our understanding of Harlequin Duck biology in general.

Following removal of the dams, monitoring must not be restricted to the Elwha River. It will be necessary to monitor other rivers to account for regional and global environmental changes that could influence river-dependent birds. No single river surveyed was an adequate match to use for comparing all species over time. However, using several rivers to compare to the Elwha would be appropriate. The lower Duckabush was the only system that had Harlequin Ducks in sufficient numbers to act as a comparison to the Elwha for that species. The Duckabush would also be useful for comparing American Dippers. The Hoh River can provide a comparison for Common Mergansers, Belted Kingfishers, Spotted Sandpipers and American Dippers. The Soleduck River was so varied in its habitat types, yet depauperate in most of the species of interest that I suggest, in the interest of efficiency, that it not be included in future surveys, except, as suggested previously, boat surveys of the lower reaches could be used for assessing abundance of piscivorous birds on the Soleduck River.

The patterns observed in these surveys can now be used to guide the formation of process-oriented questions for future hypothesis testing. It will be particularly important to fill the gaps in our understanding of the specific foraging ecology of these species before potential ecosystem enrichment could be linked to changes in productivity, abundance or distribution of these avian foraging guilds. Hopefully, these data will be useful to resource managers of Olympic National Park, not only in assessing the ecological response to dam removal, but also in providing important baseline and natural history information about river dependent bird species within Olympic National Park.

The methodology outlined in this study would be an efficient tool in evaluating the effects of dam removal on resident populations of river dependent bird species. It is easily repeatable and economically feasible to continue these surveys on a long-term basis. To compare only changes in relative abundance, the survey period could be shortened to span from mid-April through mid-June, capturing the maximum abundance of all species surveyed. However, it should be noted that, in order to strengthen the power of the comparisons of means between and among rivers, power analysis indicates that the sample size (the number of surveys conducted) should be increased to as high as 13 per breeding season for Harlequin Ducks (alpha = 0.05) when taking into account the large variability within the data (MathSoft 2000). This would most likely require that the survey area, that is the number of reaches surveyed, be reduced. Because significant time will have passed from the initiation of this study to the removal of the dams, I recommend that surveys be repeated during two breeding seasons (minimum) prior to dam removal. This will provide an updated assessment of relative abundances and distributions. Surveying multiple years will buffer against surveying a single anomalous year. Surveys should continue throughout the dam removal process in order to document any effects of disturbance and/or recovery. Following dam removal, surveys should be conducted annually to document long-term responses to dam removal in the resident populations of these avian species.

It is also recommended that other indicators of enrichment from anadromy such as the presence of marine derived nutrients in feather tissue be considered for investigation concurrently with the surveys. This promising technique could be used to non-lethally measure nutrient cycling across the aquatic boundary (Bilby pers. com., Piorkowski 1995). Testing for the presence of marine derived nutrients in avian tissue provides a different, finer scale level of information regarding enrichment.

As an alternative survey methodology, Jarvis (pers. com.) suggests surveying a reach on three consecutive days at the peak of the breeding season and using the maximum value. This would only be practical if the area surveyed was greatly reduced or the number of observers greatly increased (possibly using volunteers similar to the Christmas Bird Count efforts) such that all surveys could be done nearly simultaneously. The methodology presented here, conducting over the span of the breeding season and using the average, is a practical alternative and also provides information on productivity because survey efforts extend into July and early August. Jarvis (pers. com.) also suggests as an alternative survey method for Harlequin Ducks and Common Mergansers, using the number of offspring as an indicator of population dynamics. Females with broods are relatively easy to spot on the rivers and are less migratory than non-breeding adults. He suggests the number of juveniles provide a relative index of breeding pairs and nesting success. Obtaining such data would require as few as one survey per breeding season per river. This may be a viable alternative but reducing the number of surveys to one is risky since missing even one brood could greatly affect total numbers. However, this may be a practical alternative for resource managers balancing multi-species monitoring projects on limited budgets.

TIME ACTIVITY BUDGETS OF NON-BREEDING AND FAILED BREEDING FEMALE HARLEQUIN DUCKS ON RIVER AND ADJACENT OCEAN HABITAT ON THE OLYMPIC PENINSULA

Abstract

The feeding activity of Harlequin Ducks, *Histrionicus histrionicus*, during the breeding season was studied on both riverine and nearby coastal habitat on the Olympic Peninsula in western Washington. Time-activity budgets were described for non-breeding and failed breeding (NB/FB) female ducks on the Elwha, Duckabush and Dosewallips Rivers and at ocean feeding sites at the mouths of the Elwha River and Salt Creek. The time that NB/FB females devoted to feeding varied little from river to river (ranging from 36.4% on the Dosewallips River to 33.1% on the Elwha River). NB/FB females spent less time feeding on the Elwha River when compared to those on coastal habitat at the mouth of the Elwha (33.1% to 55.9% respectively). NB/FB female Harlequin Ducks are not constrained by chick rearing or by the early molt that males experience and can remain on rivers during the breeding season or return to ocean habitats. If Harlequin Ducks minimize energy expenditure as a life history strategy, the time that Harlequin Ducks spend foraging relative to the time available to them to forage may provide an indication of habitat quality with respect to food availability. Time-activity budgets alone cannot characterize resource availability but they may be useful tools for comparing habitat quality at coarse regional scales. They may be less informative for finer scale habitat comparisons.

Introduction

The Harlequin Duck (*Histrionicus histrionicus*) is an anadromous species that breeds in high-energy cold-water streams, feeding on benthic invertebrates, and winters in nearshore rocky saltwater habitats feeding on marine invertebrates. During the breeding season, male Harlequin Ducks leave the river habitat at the onset of incubation, presumably to molt in the more protected ocean habitat. Successful breeding females often remain on the rivers until or near fledging (when young are 42 to 56 days old) (Robertson and Goudie 1999). Female Harlequin Ducks do not breed until at least 2 years old and reproductive success is low until females are 5 years old (Robertson et al. 2000). Pair-bonding occurs during the winter while the birds are on the ocean (Robertson and Cooke 1998). Some non-breeding (immature and unmated) females also fly to freshwater systems at the advent of the breeding season (Robertson and Goudie 1999), and, along with failed breeding females, may remain on the rivers through most or all of the breeding season. Unlike males or breeding females, they are not constrained to either river or ocean habitats. Factors influencing non-breeding females' habitat selection during this period are poorly understood. Dzinbal and Jarvis (1982) and Crowley (1993) noted that breeders and non-breeders alike returned to the ocean early in the breeding season, as early as two weeks after hatching, in Prince William Sound, Alaska. They suspected that limited food resources in the relatively unproductive systems in Prince William Sound influenced the return time to the ocean (Dzinbal and Jarvis 1982). In Iceland, solo females (non-breeding and failed breeding females are indistinguishable in the field) and females with broods stay on river habitat throughout the breeding season into September (Bengtson 1972). Bengtson observed that Harlequin Duck breeding and migration periods correlated with food abundance. He hypothesized that Harlequin Duck populations are regulated by the quantity of food available on the breeding grounds (Bengtson 1972). In the Pacific Northwest, Farrell (1997) found that, on streams supporting Harlequin Ducks, benthic invertebrate densities in riffle habitats were greater than densities found on streams that did not support ducks, supporting Bengston's hypothesis. Further support is provided by Wright (1997) who observed that, in Oregon, the departure of female Harlequin Ducks with broods coincided with the pupation of the fifth instar stage of *Dicosmoecus gilvipes* caddisflies and the subsequent loss of that food resource. The timing of Harlequin Duck broods' appearance on Quartzville Creek corresponded with the predominance of fourth and fifth instars of D. gilvipes, the largest and potentially the most nutritious stages of the aquatic stages of the caddisfly's life cycle. Available food supply may also influence the amount of time that Harlequin Ducks spend feeding when compared to other activities. Pool (1961), studying Harlequin Ducks in Iceland reported that he "rarely observed harlequins feeding". Rodway and Cooke (2001) observed that Harlequin Ducks in British Columbia, Canada spent less time feeding in nearshore areas when there was a naturally occurring elevated food supply in the form of a large herring spawn. Inglis, et al. (1989) quantified the time spent feeding by Harlequin Ducks in Iceland using time-activity budgets. They suggested that the relatively low time spent feeding by pre-nesting females (7.6% of total diurnal time) when compared to other ducks might be a response to high food availability, which the researcher also measured at the feeding areas. Dzinbal and Jarvis (1982) determined that Harlequin Ducks spend a small percentage of daytime feeding (12%-15% for non-breeding individuals) in estuaries in south central AK. They suggest that the Harlequin Duck foraging strategy is one of a time-minimizer, defined as an animal whose fitness is maximized when time spent feeding to gather a fixed energy requirement, M, is minimized (Schoener 1971). Further evidence of Harlequin Ducks having a time-minimizing foraging strategy comes from a study of wintering Harlequin Ducks in the Aleutian Islands, Alaska. Female Harlequin Ducks at Shemya Island spent an average of 77.5% of the diurnal time feeding, but time spent feeding decreased as photoperiod increased (Fischer 1998). Adams et al. (2000) found that female Harlequin Ducks feeding in the Gannet Islands, Labrador in late summer fed 16.6% of the diurnal time when they were able to fly, and 8.8% of the time when they were flightless in molt. These studies provide evidence that long periods of rest are not a necessary as part of their digestive physiology and Harlequin Ducks could feed for longer periods of time if needed, suggesting that, during the breeding season at least, Harlequin Ducks are meeting a minimum energy requirement only and not trying to maximize energy intake.

Caution must be taken in using time-budget data alone to classify animals as either time-minimizers or energy-maximizers and corresponding energy budget data are needed (Hixon 1982). For example, Hunt (1998), who conducted time-budgets on Harlequin Ducks in Jasper National Park, Canada, hypothesized that, rather than a time minimizing strategy, long periods of rest were necessary in order for birds to recover from high energy exertion from feeding swift water habitats. However, Hixon states that, even in the absence of energy budget data, there can be some value in using these concepts on a relative scale, both within and between species occupying a particular habitat. With this in mind, foraging times may be useful in making predictions about Harlequin Duck habitat quality. If Harlequin Ducks are distinctly time-minimizers rather than energy-maximizers, the time required to achieve the threshold energy level M may be an indicator of food availability, quality, accessibility, or a combination of these factors. Non-breeding and failed breeding female Harlequin Ducks are unburdened by the constraints of chick rearing or early molt times. Therefore, the time that this category of female Harlequin Ducks spend feeding versus not feeding may be an indicator of habitat quality with regard to food availability. It may also influence the timing of their return to the marine environment.

Although time-activity budgets of Harlequin Ducks have been examined on both river and ocean habitats in various regions, there were no studies of foraging behavior comparing both habitats during the same season and in the same region. In this study, I measured the time spent feeding of non-breeding and failed breeding (e.g., solo) female Harlequin Ducks on three rivers and their adjacent estuaries during July and August of 1997. I focused on non-breeding and failed breeding females to avoid confounding energy constraints found in brooding females and molting males. My study was conducted from mid-June through early August when non-breeding females were identifiable from breeding females and from juveniles that had reached adult size, and before non-breeding females on the ocean had begun to molt. The proportion of diurnal time spent foraging was compared among rivers and between freshwater and marine habitats in order to discern whether this might be a useful indicator of habitat quality. If foraging time of Harlequin Ducks is indicative of habitat quality, it might be a useful indicator of ecosystem response to dam removal, which may occur on one of the rivers studied (the Elwha River).

Study Area

The Olympic Peninsula is located in northwest Washington State and includes the northwest tip of the contiguous United States (Figure 1). Its aquatic boundaries include the Pacific Ocean to the west, the Strait of Juan de Fuca to the north, and Puget Sound to the east. At the heart of the Peninsula is Olympic National Park, a 3626 km^2 roadless wilderness area with the Olympic mountain range at its core (highest elevation, Mt. Olympus at 2428 m).

Harlequin Duck populations were studied on three rivers, each originating in the mountains of Olympic National Park, and their adjacent marine estuaries. The Elwha River, 72.4 km long, flows north from the Elwha Snowfinger (an active snowfield) to the Strait of Juan de Fuca, entering 7 km west of the city of Port Angeles. It is a constrained river with forest vegetation stabilizing the banks. It has two dams located in the lower region of the river impounding two reservoirs. Harlequin Ducks were examined at the mouth of the Elwha River and at Tongue Point in Salt Creek County Park, a rocky outcrop 9 km to the west of the mouth of the Elwha. The Duckabush and the Dosewallips Rivers are neighboring east flowing rivers that enter Puget Sound near the town of Brinnon, the Dosewallips estuary is to the north and the Duckabush estuary is to the south and they are 5 km apart from each other. Both east side rivers are also constrained with forest vegetation stabilizing the banks. The Duckabush River is 41.4 km long and the Dosewallips is 47.8 km long.

Methods

Time activity budgets of Harlequin Ducks were collected from 15 June through 13 August during the 1997 breeding season. Portions of each river were designated as either lower (extended from the mouth upriver and included the lower $1/3^{rd}$ of river length) or upper (the upper 2/3 of the river). Because of the varying lengths of the rivers along with natural and anthropogenic obstacles within the river system, a proportion was used to determine lower reaches rather than a fixed distance (Table 3.1). Each river had a natural or human made barrier that separated the two regions and this barrier section was not surveyed (on the Elwha River, Rica Canyon, on the Dosewallips River, a large waterfall, on the Duckabush River, an unnamed canyon). Each sampling day was divided into three equal diurnal time periods (dawn to approximately 5.5 hours after sunrise; 5.5 hours after sunrise to approximately 5.5 hours before sunset; and 5.5 hours before sunset to sunset). Regions (upper or lower) and ocean environs (mouths of Elwha, Dosewallips estuary, Duckabush estuary, and Salt Creek) were selected randomly without replacement such that all regions and ocean areas were visited every five days during all three diurnal time periods.

Instantaneous observations of individual female ducks were taken every 30 seconds and were continually observed for 30 minutes. Observations of shorter (minimum 10 minutes) and longer durations were occasionally necessary and were included in analyses. In groups or flocks, a focal animal was selected and tracked as an individual or, if that was impossible, the flock observed as a focal flock acting together. If the focal flock separated into two or more smaller groups during an observation, observations were continued on one randomly selected

Table 3.1. Descriptions of river areas surveyed. Segments are not continuous and lengths represent distance of accessible river only.

	Description and Length of Regions		
Rivers	**Lower**	**Upper**	**Total**
Elwha	Mouth to Bridge at Altaire Campground	Krause Bottom to Hayes River.	26.0 km
	11.5 km	14.5 km	
Duckabush	Mouth to Bridge above Collins Campground	Little Hump to 4.5 km upriver of ONP boundary	15.5 km
	7.5 km	8.0 km	
Dosewallips	Mouth to Elkhorn Campground	Dosewallips Campground to Silt Creek	15.5 km
	9.5 km	6 km	

group. If the focal animal or group was out of view for more than 5 consecutive minutes, the time-activity budget was started again if the subject came back into view, or discarded if it did not. Behaviors were recorded on a tape recorder and transcribed at a later date. Although the primary behavior of interest was feeding, eighteen separate behaviors were recorded during the study. These were pooled into five general categories as described in Goudie and Ankney (1986) and Fischer (1998) (Table 3.2). Alert behavior was recorded as a behavior occurring concurrently with another behavior and not as its own distinct category. Observer bias was reduced by practicing identifying behaviors in teams of two prior to the field season.

On River Habitat

In river habitats Harlequin Ducks may use a region of a river over extended periods of time and it is possible to observe the same individual in the same location on a river as (Hunt and Ydenberg 2000, Bengtson 1972, Schoonheim and Arnheim 1995). Marking the birds was not an option for this study because much of the study area was located in a national park where mark-and-capture methods are minimized. To increase the number of different individuals observed and to reduce the chances of sampling the same individuals from visit to visit, I randomized the location of the starting point of each observation day within a

Table 3.2. Behavior categories for Harlequin Duck time-activity budget analysis.

Category	Behavior	Description
RESTING	Standing	legs/feet visible, on land/rock
	Sitting	legs hidden
	Sleeping	eyes closed or head tucked
	Floating	resting, not a pause
FEEDING	Diving	underwater
	Pausing	at surface between dives; <2 minutes long
	Head-dipping	head underwater searching
	Dabbling	feeding at water surface
LOCOMOTION	Flying	on the wing
	Swimming	relocating, against the current
	Walking	feet touching land or rocks
	Coasting	relocating, using the current
COMFORT BEHAVIORS	Bathing	splashing with intent
	Preening	feather maintenance
	Stretching	wing or leg fully extended
SOCIAL INTERACTIONS	Agonistic	negative interactions
	Courtship	male female + interactions
ALERT (was an activity that was concurrent with other behaviors, not tallied in its own category)	Alert	neck extended, attentive

region of a river (upper or lower). For each visit, a river kilometer marker was randomly chosen as a starting point. Observers walked upriver from the random starting point until the first solo female or group of females was encountered. At the end of an observation session (when the animal moved out of sight or the maximum time was reached) the observer moved upstream until the next animal was located and so on until the region was surveyed or the time period was up, returning to downriver areas as necessary. Because of the large distances, it was often necessary to survey adjacent river regions when changing from one diurnal time period to another, rather than shifting to a different river system. When no new non-breeding/failed breeding females could be found during a given time period on a given area, time activity budgets were collected on breeding females.

On Ocean Habitat

At the ocean sites, all potential animals could be observed simultaneously from distinct vantage points. Birds were chosen by assigning a number to each solo female or group of females in view, then selecting the numbers randomly without replacement until all potential groups or birds had been observed, or until the diurnal time period was completed. Because males were also present on the ocean and feeding in the same areas, some of the focal females were in mixed groups of males and females and this was noted.

Statistical Analyses

Although all river and ocean regions were visited during all three time periods equally, the number of birds observed within each time period varied greatly from region to region. This resulted in differing sample sizes of time-activity budgets collected during the different time periods and at different river or ocean regions. A total of 211 time-activity budgets were obtained. However, after removing observations of 45 breeding females and nine males, as well as any that were less than ten minutes long, 154 time-budgets, representing 124 hours of observation time, were used in the analyses. Comparisons were made only on sets of data where there were ample time-activity budget samples in all categories. Some regions had too few birds observed to include in any analyses.

Time-activity budgets were analyzed using parametric statistics after subjecting non-normal percentage data to the logit transformation when assumptions of normality were met. Group differences were examined using t-tests, analysis of variance, and multiple comparison of mean time spent feeding. A randomization test was used to compare odds ratios when assumptions of normality were not met.

Results

Diurnal Time Period Comparison

The upper region of the Elwha River was the only river area where there were enough samples in each time period to analyze differences between early, middle and late time periods. Although the average amount of time spent feeding decreased in the late period of the day, there was no statistical difference among periods (One-way ANOVA on logit transformed data F=0.82; p-value = 0.450). Two ocean regions had enough time activity data to make the comparisons. Time spent feeding at the mouth of the Elwha varied little among the three diurnal time periods. At Salt Creek, although birds spent less time feeding later in the day means were not significantly different (F = 0.79, p-value = 0.463). Because no significant differences among diurnal time periods were detected, time activity samples were pooled across time periods for subsequent analyses. It is noted here that through a power analysis (MathSoft Inc. 2000) it was determined that this analysis may have shown a significant difference if the sample size, n, for each category had at least 50 time budgets per category. The original study design anticipated that many time budgets however, it was not possible to obtain that many in all categories.

Ocean Site Comparisons - Salt Creek Compared to Mouth of Elwha

All four ocean locations were visited equally. However, Harlequin Ducks that frequented the mouths of the Dosewallips and the Duckabush Rivers earlier in the season had left these areas by mid-July, when this study began. Since only one time-activity budget was obtained from either of these sites during the entire study, these two areas could not be included in the comparisons. Harlequin Duck time-activity budgets observed at the mouth of Salt Creek were compared with time-activity budgets from the mouth of the Elwha. Harlequin Ducks spent more time feeding at the mouth of the Elwha River than at the mouth of Salt Creek (2-tailed t test on transformed data $t = 2.05$; two- sided p-value = 0.044). Birds spent 55.9% of the time feeding at the mouth of the Elwha compared with 34.8% at the mouth of Salt Creek. Because this significant difference in time spent feeding at the different areas was found, I did not pool these data into one ocean value.

Upper to Lower Region Comparison on the Elwha River

The upper and lower regions of all three rivers, the Elwha, Duckabush and Dosewallips Rivers were visited equally throughout the study, however, the upper Duckabush River and the lower Dosewallips had very few Harlequin Ducks yielding too few time activity budgets to allow comparisons of upper and lower regions on those rivers. Therefore, to compare Harlequin Duck time spent feeding between lower and upper regions, only the Elwha regions were analyzed statistically.

Although birds lower in the river system spent less time feeding than birds in the upper region, means did not differ statistically (2-tailed t test on transformed data $t = -.538$; p-value = 0.592). Similar means were found for birds on the lower Duckabush River and birds on the upper Dosewallips and time activity budgets were pooled from upper and lower regions.

River Comparisons – Elwha, Duckabush and Dosewallips Rivers

Time-activity budgets from the Elwha, Duckabush, and Dosewallips Rivers were pooled across diurnal time periods and upper and lower regions. Mean percent of time spent feeding was similar for all three rivers, Elwha - 33.1% (n = 43); Duckabush - 33.2 % (n = 12); Dosewallips – 36.4% (n = 11)) with no statistical differences among rivers (one way ANOVA on the logit transformed data F= 0.63; two-sided p-value = 0.54) (Figure 3.1).

Elwha River System Comparison

To compare the percent time that Harlequin Ducks spend feeding on their river habitats with nearby and accessible saltwater habitat, it was only possible to compare the regions of the Elwha River and the mouth of the Elwha. Since essentially no Harlequin Ducks remained at the mouths of the other two rivers, the Duckabush and the Dosewallips Rivers were not included in this analysis. Harlequin Ducks spent a significantly greater proportion of time feeding at the mouth of the Elwha River (55.9%) than on river habitat alone (33.1%) (randomization test on empirical logit transformed data, p = 0.016) (Figure 3.2).

Behavior Category Comparisons

When comparing other behaviors with feeding behavior, as feeding time decreases, resting time increases (Figure 3.3). Resting and comfort behaviors, which include preening, were the most likely behaviors to increase as feeding time decreased. Locomotion seemed to increase slightly with an increase in feeding

Figure 3.1. Comparison of mean (± SE) time spent feeding by non-breeding and failed-breeding female Harlequin Ducks on the Elwha Duckabush and Dosewallips Rivers, 1997.

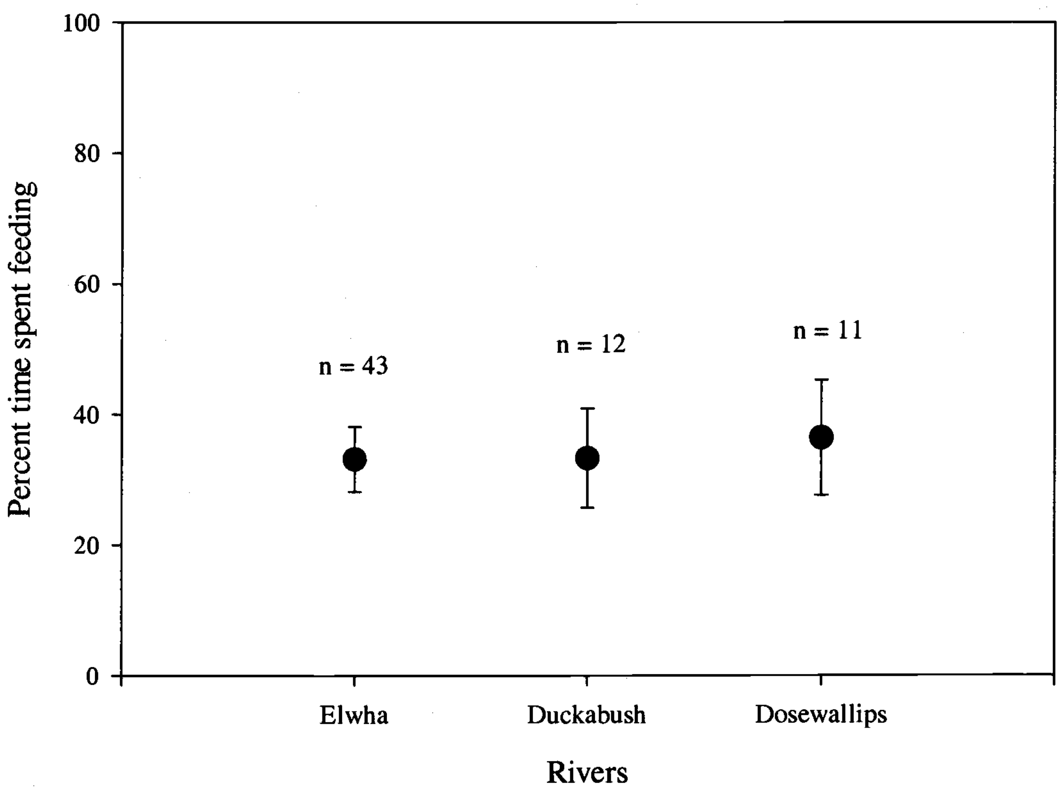


Figure 3.2. Comparison of mean (± SE) by non-breeding and failed-breeding female Harlequin Ducks on the time spent feeding (with Elwha River and its adjacent ocean area, 1997.

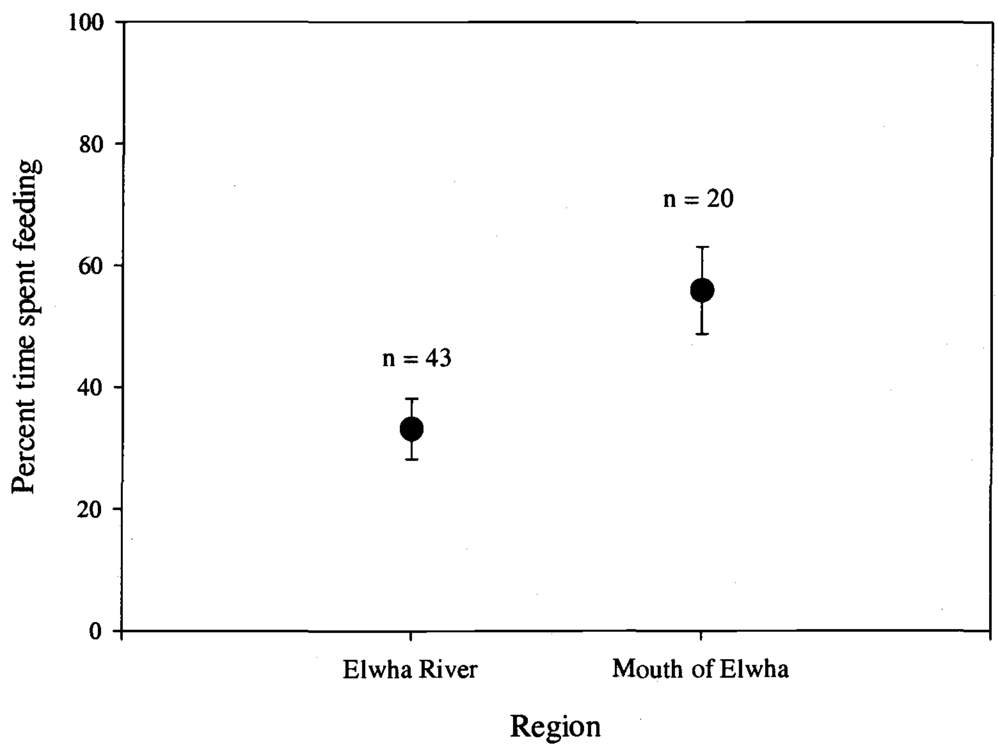
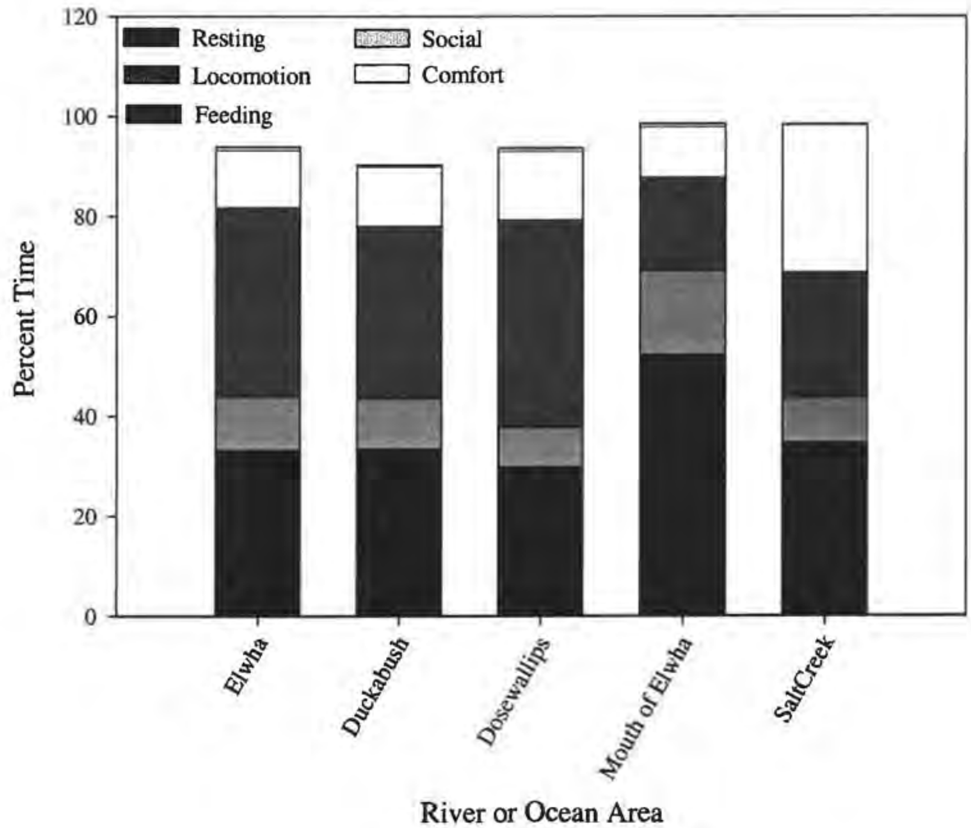


Figure 3.3. Percentages of all behaviors of non-breeding and failed breeding Harlequin Ducks on four rivers and two ocean areas on the Olympic Peninsula, 1997.



behavior. This is more evident on the ocean and is probably because flying is relatively more observable on the ocean, when birds flew on river habitat they most likely flew out of sight.

Group Size Comparisons - Solo Birds to Birds in Groups

Some time-activity budgets were taken on individual birds that were part of a group of birds, while other time-activity budgets were taken on solo individuals. The effect of group status on feeding time was analyzed using the Elwha River data and the mouth of the Elwha data separately. Group status did not influence the time spent feeding (2-tailed t-test $t = -0.507$; p-value = 0.614) for birds observed on the Elwha River. Female Harlequin Ducks in groups had a mean time spent feeding of 36.5% ($n = 28$) whereas, solo females had a mean time spent feeding of 30.8% ($n = 33$). At the mouth of the Elwha, on salt water, there was slight but inconclusive evidence that group size might positively influence feeding time (2-tailed t-test $t = 1.78$; $p = 0.085$). Although birds were rarely found feeding alone on the ocean, mean percent time feeding for solo birds was 87.8% ($n = 5$) and for birds in groups 46.6% ($n = 30$)).

Discussion

On a broad geographic scale, time activity budgets may reveal information about foraging quality of Harlequin Duck habitat as well as about life history choices; however, time-activity budgets may be less useful when examining finer geographic scales. In this study, Harlequin Ducks foraged less time on river habitat than on adjacent ocean habitat during the same season, however, time spent foraging was similar among the different river habitats. The similarities among rivers may be indicating that food resources are similar among the rivers, however, it may also be that the differences in food resources among rivers is less detectable at the predator level when compared to the difference between ocean and river food sources, which is a broader geographic scale.

Because the birds observed in this study were not marked, it was impossible to tell whether failed or non-breeding Harlequin Ducks on the Elwha River migrated to the mouth of the Elwha or to the Salt Creek area. It would be feasible for birds of the lower river to travel to the mouth of the Elwha even temporarily. Even so, the mouth of the Elwha and other marine areas were certainly accessible to all the non-breeding and failed breeding females and they could choose to leave the river habitat at any time during the breeding season, yet many remained on the river. The greater foraging time observed on ocean habitats suggests that food availability may be a factor. It is reasonable that non-breeding and failed breeding females remain on river habitats where food availability is greater (or energy expenditure to acquire food is less) than on ocean. This would explain why Dzinbal and Jarvis (1982) observed all Harlequin Ducks, breeding and non-breeding, leaving the rivers shortly after hatching on what they described as relatively unproductive rivers in southeast Alaska. Harlequin Ducks may be taking advantage of a seasonally abundant food source of macroinvertebrates in summer streams. If diversity is high and hatches of larvae and nymphs are asynchronous, then female ducks may be inclined to stay on the rivers longer.

Other studies have found associations between macroinvertebrates and Harlequin Ducks. Wright (1997) noted that Harlequin Ducks tended to leave Quartzville Creek, Oregon, shortly after the hatch of the *Dicosmoecus gilvipes* instars, a seasonal component of their diet. He also found a spatial correlation between Harlequin Duck distribution and densities of the caddisfly. Farrell (1997) compared invertebrate densities from stream data collected on streams with known Harlequin Duck populations and those without and found invertebrate densities to be greatest on rivers with Harlequin Ducks. In Labrador, Canada, (Rodway 1998b) also found greater macroinvertebrate abundance in areas where Harlequin Ducks were found than where they were absent. Hunt (1998) found a positive correlation between the quantity of benthic macroinvertebrate prey and the daily abundance of Harlequin Ducks in Jasper National Park, Canada. In Iceland, Gardarsson and Einarsson (1994) found that Harlequin Duck productivity was positively correlated with food abundance represented by chironomid and simuliid dipteran larvae.

Although food resources are likely to be an important factor in habitat selection, other factors need to be considered. Nest site and in-stream loafing site availability may be factors, as well as predator abundance. Bruner's (1997) research with radio transmitters on female Harlequin Ducks in the Cascades of Oregon suggests that Harlequin Ducks have wide amplitude in their nest site preference. Although concealing cover was an important factor at 95% of the nests found, nest sites were found on first through fifth order streams in forests ranging from 30 to 300 years old and both on floodplain and above it. Little is known about predation pressure on Harlequin Ducks on rivers although mammals have been suspected predators of nests (Bruner 1997) and avian predators have also been implicated (Cassirer et al. 1993b). Quantification of predator abundance on streams used by Harlequin Ducks seems to be lacking in the literature. These factors may influence habitat choice by Harlequin Ducks and warrant further study, however, currently more evidence points to food abundance and availability as a key factor.

Patterns of time allocation among specific behaviors may provide insight into the importance of food availability in habitat selection. If harlequins are time-minimizers, high food abundance and availability should decrease time spent feeding. Adams et al (2000) suggested that the relatively low time allocated to feeding by Harlequin Ducks on saltwater in Labrador during late summer could be attributed to ducks conserving energy by reducing physical activity, rather than increasing energetically expensive activities in order to meet the energy demands of molting.

Time-activity information will be more useful when Harlequin Duck energetics are better understood. It would be useful to understand the comparative energy demands of foraging in the fast moving water of river habitats and high-energy coastal feeding areas. More information is needed on prey preference versus availability in both fresh and saltwater habitats. Although Harlequin Ducks seem to have relatively general food preferences, they have been known to focus on specific prey items such as caddisflies in Oregon (Wright 1997) and salmon eggs in Prince William Sound (Dzinbal 1982). Crowley (1993) found that Harlequin Ducks prefer streams with spawning salmon (which provide a food source in salmon roe) to those without salmon. Studies of the relative abundance and energy quality of prey items from ocean and river habitats might provide a better understanding of the factors influencing persistence of non-breeding and failed breeding females on river habitat prior to molt. Crustaceans and gastropods and are dominant prey items of Harlequin Ducks on salt water (Fischer 1998, Gaines and Fitzner 1987, Vermeer 1983), whereas, insect larvae dominate their diet on freshwater (Bengtson 1972, Rodway 1998b, Cassirer et al. 1993a). Comparing these distinct food sources for nutritional quality may reveal whether food quality affects timing of migration decisions.

Non-breeding/failed breeding female ducks spent similar amounts of time feeding on the three study-rivers, suggesting that the foraging quality of each is similar. However more information is needed on prey abundance and availability before any conclusions can be drawn. The relative density of Harlequin Ducks was similar on the areas of rivers studied (see Chapter 1). In 1997, the mean density of female ducks on a representative reach in the upper Elwha was 1.8 females/km and on one reach of the lower Duckabush, 1.6 females/km. These two sections are the areas where most of the time-activity budgets were taken for this study. It cannot be ruled out that Harlequin Ducks may be choosing sites with similar prey availability and avoiding sites with less availability, which would account for the similar portion of time spent feeding on the areas where Harlequins were found. It may not be possible to observe significant differences in foraging time if there is an adequate amount of high quality habitat available to the population.

Harlequin Ducks on rivers of the Olympic Peninsula seem to forage a greater percent of the time than birds on other systems. Few other studies have specifically looked at failed breeding and non-breeding (NB/FB) females but Rodway (1998a) reported NB/FB females foraging 25.4% of the time, compared to 33.1% - 36.4% on rivers on the peninsula. Differences in methods could account for the differences, as Rodway did not include head-dipping (which he considered "searching") as feeding behavior. Dzinbal and Jarvis (1982) found females (not distinguished between breeding and non-breeding) feeding 21% of the time. This value was obtained during the summer but in coastal habitats, not on rivers. Their total feeding value also did not include the pause time between dives or head-dipping, whereas this and other studies included both activities as feeding. The differing methodologies of the studies make comparisons between studies less useful.

In summary, non-breeding and failed breeding females seem to spend less time feeding on rivers than on coastal habitats. This finding is consistent with other studies that have suggested that Harlequin Ducks have a time-minimizing strategy of survival that buffers them against high variability in fluctuating environments (Dzinbal and Jarvis 1982). This difference in foraging time may reflect food abundance and availability. However, such a conclusion must await a better understanding of the relationship of feeding behavior to energy requirements and food availability. To gain this knowledge, studies of prey availability, diet composition, and feeding behavior would need to be conducted simultaneously within specific study areas. At present, time-activity budgets may be most useful at coarse scales such as comparing ocean habitat to river habitat in the same geographic region. They may be less useful when looking at finer scales such as river-to-river comparisons within the same region, or in assessing ecosystem recovery following removal of dams.

CONCLUSION

River-dependent birds such as Harlequin Ducks, Common Mergansers, American Dippers, Belted Kingfishers and Spotted Sandpipers can provide insight into the linkages between terrestrial and aquatic ecosystems. The unique opportunity to examine this connection as a result of the removal of two hydroelectric dams should not be overlooked. Population fluxuations of piscivorous and benthivorous birds may be quantified during the dam removal process and subsequent ecosystem recovery phase and foraging behavior of select species can be monitored. With some modification of the methodology presented here to include larger sample sizes and a more refined study area, along with better coordination with concurrent ecological studies in the area, river-dependent bird populations and behavior may reveal important relationships between aquatic and terrestrial food webs.

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