DEVELOPMENT OF A BIRD PREDATION INDEX

Annual Report 1998

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EXECUTIVE SUMMARY

Avian predation on juvenile salmonids in the Yakima River was studied from fall 1997 to summer 1998 with emphasis on spring chinook rearing areas. Index sections were established in free-flowing stretches to determine abundance of avian predators in each chinook rearing area. Predation "hot spots" were studied during spring to determine the impact of piscivorous birds on juvenile salmonids during outmigration. "Hot spots" are areas such as irrigation diversion dams and irrigation canal smolt bypass outfalls where fish become concentrated and disoriented. Finally, to determine which birds respond most readily to high concentrations of fish in different parts of the river, hatchery salmonid acclimation sites were studied.

Floats through index areas indicated that avian predation was low in the lower river during the spring smolt outmigration. Summer observations in the upper river suggested that common mergansers and their broods may consume large numbers of non-migrating chinook fry. Fall and winter observations suggested that mergansers were the major avian predator of rearing spring chinook.

Numerous hot spots were studied, but predation was highest at the Chandler Canal bypass outfall and at Horn Rapids Dam. Both sites are in the lower 50 km of the river. The primary predators at both sites were California and ring-billed gulls. Estimated consumption by gulls was 2,607 (SE 501) salmonids at Chandler Canal bypass outfall or 1.1% of the salmonids that passed through the outfall during the study period. At Horn Rapids Dam, estimated consumption by gulls was 20,987 (SE 2,285) salmonids or 1.7% of the salmonids that passed over the dam during the study period. Assuming that all fish were consumed by gulls in proportion to their relative abundance, consumption at Chandler Canal bypass outfall was 174 (SE 33) spring chinook or 0.20% of the spring chinook that passed through the outfall during the study period. Under the

same assumption, gull consumption at Horn Rapids Dam was 1316 (SE 143) spring chinook or 0.52% of the spring chinook that passed over the dam during the study period. There was a significant relationship between gull foraging and river flow such that at high flows, foraging was precluded.

The large concentrations of fish found at acclimation sites attracted avian predators. Gulls were the primary avian predator at an acclimation site in the lower Yakima River, great blue herons and common mergansers were the primary avian predators at an acclimation site in the middle Yakima River, and mergansers were the primary avian predator at an acclimation site in the upper Naches River. The merganser predation observed at the upper Naches River acclimation site suggests that mergansers will be the main avian predator at a newly started upper Yakima River hatchery designed to supplement the natural spring chinook salmon population.

Several options exist to reduce avian predation at the Chandler Canal bypass outfall and Horn Rapids Dam. The Chandler Canal bypass fish return pipe could be redesigned to eliminate a 90° upward bend at the terminus that pushes fish to the surface, making them vulnerable to avian predators. In addition, Horn Rapids Dam could be redesigned to eliminate the recirculating motion at the base of the dam that rolls fish to the surface where they are vulnerable to avian predators. Another option for both sites is to erect arrays of overhead lines so that gulls are not able to access the vulnerable fish. Assuming that foraging gulls are commuting from three nearby Columbia River island colonies, reduction in the size of the colonies could also lower gull predation. This reduction could be accomplished by making the islands unsuitable for nesting by planting dense vegetation or by encouraging terrestrial animal or raptor predation on nesting gulls. Under the higher than average spring flow conditions of 1998, avian predation does not appear to be a significant limiting factor of salmonid production in the Yakima River.

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LIST OF ABBREVIATIONS

BOR United States Bureau of Reclamation

BPA Bonneville Power Administration

cfs cubic feet per second

CI confidence interval

cm centimeter

CRITFC Columbia River Inter-Tribal Fish Commission

hr hour

km kilometer

ln natural log

m meter

min minute

ODFW Oregon Department of Fish and Wildlife

OSU Oregon State University

RKM river kilometer

sec second

sqrt square root

USGS United States Geological Survey

WDF Washington Department of Fisheries

WDFW Washington Department of Fish and Wildlife

YFP Yakima Fisheries Project

YIN Yakama Indian Nation

YRBWEP Yakima River Basin Water Enhancement Project

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INTRODUCTION

Many salmonid populations in the Pacific Northwest are either extinct or have experienced significant declines in abundance (Nehlsen et al. 1991, Washington Dept. of Fisheries [WDF] et al. 1993). Factors such as hydropower, fishing, logging, mining, agriculture, urban growth and poorly designed hatchery programs have caused extensive losses in salmon and steelhead populations (Nehlsen et al. 1991, WDF et al. 1993). Historically, the Columbia River watershed was a major producer of salmonids with an estimated 5-11 million fish returning annually to the portion of the watershed now above Bonneville Dam (CRITFC 1996). Today, fewer than 500,000 fish return above Bonneville Dam and approximately 80 percent of those fish originate in hatcheries (CRITFC 1996). Historically, all five native eastern Pacific salmon species (*Oncorhynchus* spp.) and steelhead (*O. mykiss*) returned to the Columbia River. Out of over 200 distinct anadromous stocks of salmon in the Columbia River, 69 are extinct, including most chum (*O. keta*), pink (*O. gorbuscha*) and wild coho (*O. kisutch*) stocks, and 75 others are at risk of extinction (Nehlsen et al. 1991). Many Columbia River salmon stocks have been afforded protection as “threatened” or “endangered” species under the Endangered Species Act; however, Nehlsen et al. (1991) point out that “in most cases, enough of the native resource remains to allow a variety of remedial actions.” Where necessary, those actions may include steps to limit predation on juvenile salmonids, whether by piscivorous fish, birds, or other animals (Northwest Power Planning Council 1994, Busack et al. 1997).

Piscivorous birds can be a major source of mortality for juvenile salmonids (Mills 1967), in part because they congregate in areas where fish are concentrated (Sealy 1973, Hoffman et al. 1981). Wood (1985*a* & *b*) documented increases in common merganser (*Mergus merganser*) numbers in hatchery salmonid release areas, while other researchers have recognized the impact of avian predation at hatcheries. Parkhurst et al. (1987) surveyed hatchery managers at 336 fish-rearing facilities in the eastern United States and found that over half of the predator species the managers identified were birds. In subsequent observations, the researchers found that seven species of piscivorous birds consumed between 1,550 and 773,530 fish at each of 10 trout hatcheries in central Pennsylvania (Parkhurst et al. 1992). In a different study at Midway and Springville trout hatcheries in Utah, researchers concluded that the total loss to six species of avian predators was 7.1% and 0.5%, respectively (Pitt and Conover 1996).

Other investigations have demonstrated that piscivorous birds may consume significant numbers of juvenile salmonids in rivers and estuaries. Wood (1987*b*) studied common merganser predation on juvenile coho salmon in streams on Vancouver Island, British Columbia. He concluded that between 10 June and 25 August 1980-1982, mergansers consumed 82,000-131,000 fry, or 24-65% of the observed wild smolt production from the Big Qualicum River system, assuming that these fry would otherwise have survived as well as uneaten fry. An earlier study on the same river estimated that piscivorous birds consumed 20-40% of the chinook salmon (*O. tshawytscha*) and 3-5% of the coho salmon released from the Big Qualicum Hatchery (Mace 1983). Alexander (1979) estimated that avian predators consumed 20-24% of the total annual production of trout in the North Branch of the Au Sable River, Michigan, and Kennedy and Greer (1988) found that European cormorants (*Phalacrocorax carbo*) predation could account for a minimum of 51-66% of the total wild Atlantic salmon (*Salmo salar*) smolt run and 13-28% of the hatchery smolt release on the River Bush in Northern Ireland. Many additional investigations in a variety of situations have also shown that avian predators consume large numbers of salmonids (White 1936, Huntsman 1941, White 1957, Elson 1962, Feltham 1995, Modde and Wasowicz 1996).

Colonial nesting and social interactions among birds may help them to exploit fluctuating food resources (Alcock 1968, Ward and Zahavi 1973). Götmark et al. (1986) found that individual fishing success of black-headed gulls (*Larus ridibundus*) increased with flock size up to at least eight birds. Forbes (1986) studied arrivals and departures of great blue herons (*Ardea herodias*) at a colony in southeastern British Columbia, finding that herons departing from the colony #2 min apart followed in the same direction as the previous heron significantly more often than herons > 2 min apart. He concluded that the two strongest hypotheses to account for this behavior were flock recruitment (e.g., predator avoidance) and use of the colony as an information center to aid in finding food. Greene (1987) documented that colonial ospreys (*Pandion haliaetus*) nesting in Cow Bay estuary, Nova Scotia, Canada, discriminate visually among fish species brought back by other colony members and respond only to schooling prey species. Non-fishing birds at the colony were more likely to begin fishing after the arrival of a successful forager carrying a schooling alewife (*Clupeus harengus*), pollock (*Pollachius virens*), or smelt (*Osmerus mordax*) than they were after the arrival of an unsuccessful forager, a successful forager carrying a non-schooling winter flounder (*Pseudopleuronectes americanus*), or during periods when no ospreys had returned to the colony for at least half an hour. Furthermore, the departing birds flew in the direction from which the successful forager of schooling prey had arrived. As a result of social interaction in birds, avian predator abundance may increase over time at hatchery release sites, dams, and smolt bypass outfalls as more birds discover that these locations offer high prey density or vulnerable fish.

Several studies of avian predation on salmonids have been conducted on the Columbia River. Ruggerone (1986) documented large numbers of gulls (*Larus* spp.) foraging on juvenile salmonids below Wanapum Dam in 1982. He estimated that they consumed between 111,750 and 119,250 fish during the 25 days of peak outmigration, or 2% of the spring salmonid outmigration past the dam. Avian predators, especially gulls, are also abundant at other Columbia River dams such as John Day, The Dalles, and Bonneville (Jones et al. 1996, 1997, 1998). An ongoing study by Roby et al. (1998) found that Caspian terns (*Sterna caspia*) nesting on Rice Island in the Columbia River estuary consumed an estimated 6 to 25 million juvenile salmonids in 1997, or 6 to 25% of the 100 million juvenile salmonids that reached the estuary that year. This level of consumption does not include predation by the double-crested cormorants (*P. crocorax*), glaucus-winged/western gull hybrids (*L. glaucescens X L. occidentalis*), and ring-billed gulls (*L. delawarensis*) that also breed and forage in the estuary (Roby et al. 1998).

STUDY SITE

The Yakima River joins the Columbia River at the cities of Richland, Kennewick, and Pasco, about 17 km above the confluence of the Columbia with the Snake River. Historically, an estimated 600,000 to 960,000 adult salmonids returned to the Yakima River Basin (BPA 1990b) whereas recent returns have been less than 7,000 (Table 1) (BPA et al. 1996). The indigenous stocks of summer chinook, sockeye (*O. nerka*) and coho salmon are considered extinct (Nehlsen et al. 1991) and steelhead and bull trout (*Salvelinus confluentus*) have been listed as threatened under the Endangered Species Act (T. Tynan, Washington Department of Fish and Wildlife [WDFW], pers. comm.).

Production and distribution of the remaining stocks of salmon are greatly reduced from historic levels (Nehlsen et al. 1991). For example, chinook once occurred throughout the Yakima River Basin from small upriver tributary streams to the lower mainstem. Now, spring chinook spawn only in the upper Yakima and Naches Rivers and certain tributary streams (WDF et al. 1993). Fall chinook are currently found only in the lower Yakima River from Sunnyside Dam to the mouth and in Marion Drain, an irrigation return canal (WDF et al. 1993). Steelhead were once widely distributed in the Basin, spawning in streams of every size, from the mainstem Yakima River to small tributary creeks with intermittent flow. Currently, steelhead production is much lower with limited spawning in the upper Yakima and Naches Rivers and several tributary streams (WDF et al. 1993). The few adult coho that now return to the Basin are a result of non-native hatchery smolt releases conducted under the Columbia River Salmon Management Plan. Scattered spawning has been observed in several lower river tributaries (YRBCAG 1997, SOAC 1998) and in parts of the mainstem Yakima River (B. Watson, Yakama Indian Nation [YIN], pers. comm.).

Recovery efforts for Yakima River salmonids include the Yakima Fisheries Project (YFP). This project is aimed at restoring the critically depressed spring chinook salmon run by using, in part, a supplementation hatchery which has been constructed near Cle Elum. The hatchery released its first brood of spring chinook smolts in the spring of

1999. The objective is to rebuild the spring chinook run by raising and releasing artificially propagated fish into streams. These fish will spawn naturally, thereby increasing natural production. The goal of the project is to increase the numbers of naturally spawning fish, while maintaining the long-term genetic fitness of the population being supplemented and keeping adverse genetic and ecological interactions with non-target species or stocks within acceptable limits. The ultimate goal is to produce enough naturally spawning spring chinook with a high enough survival rate to be able to phase out artificial propagation (BPA et al. 1996).

While avian predation and abatement measures, such as propane cannons, pyrotechnics, water sprinklers, water cannons, and arrays of overhead cables (Steuber et al. 1993; Jones et al. 1996, 1997, 1998), have been studied on the mainstem Columbia and Snake rivers, there has been little research on the impact of avian predation in Columbia River tributaries. The need to investigate possible limitations to the success of the YFP (Busack et al. 1997) and concerns about adverse impacts on resident fish (BPA 1990b), led to studies of species interactions in the Yakima River Basin, beginning in 1989 (Hindman et al. 1991). Piscivorous birds were identified as an interactor guild capable of limiting the success of the YFP (Busack et al. 1997).

AVIAN PREDATORS

COMMON MERGANSERS

Common mergansers are found year-round in the Columbia River and the population in Washington is increasing (Sauer et al. 1997). Mergansers have frequently been associated with significant predation of fish populations (White 1936, Lindroth 1955, Meigs and Rieck 1967, Wood 1987*b*) and are known to take advantage of hatchery releases (Wood 1985*a*) and the disorienting effect of dams (Timken and Anderson 1969). In the Columbia River, Jones et al. (1996) noted mergansers feeding in the tailraces of two lower river dams.

Parts of the Yakima River have been surveyed during winter for merganser abundance and it appears that numbers have declined since the early 1990s (T. Hames, YIN, pers. comm.). However, they are still commonly seen feeding in the river and are known to breed in the upper river and its tributaries (Smith et al. 1997, T. Hames, YIN, pers. comm.). Several shot on the Yakima River by WDFW in the past contained salmonids in their stomachs (G. McMichael, WDFW, pers. comm.).

GULLS

Gulls are likely the most abundant predators on juvenile salmonids throughout the Columbia Basin. California (*L. californicus*) and ring-billed gulls are the most common species found in the vicinity of the Yakima River (Conover et al. 1979; Thompson and Tabor 1981; Ruggerone 1986; Jones et al. 1996; 1997, 1998; Roby et al. 1998). Populations of both species are increasing in the United States (Conover 1983, Ryder 1993, Winkler 1996) and, while the locations of nesting colonies have shifted, the number of these gulls has been steadily increasing near the Yakima River at an average rate of 5-8% per year (Conover et al. 1979, Thompson and Tabor 1981, Roby et al. 1998). This increase has been attributed to creation of nesting habitat by dam impoundments (Conover 1983), the proliferation of irrigation-based agriculture, and increased availability of refuse at garbage dumps (Conover et al. 1979, Conover 1983).

California and ring-billed gulls nest on three Columbia River islands within foraging distance of most of the lower Yakima River: Crescent Island, approximately 18 km downriver from the mouth of the Yakima River, supports about 5,800 nesting pairs of gulls; Richland Island (Island 20), approximately 8 km upstream of the mouth of the Yakima, supports about 18,800 nesting pairs; and Island 18, approximately 12 km upstream of the mouth of the Yakima, supports about 14,500 nesting pairs (Roby et al. 1998). The total number of nesting California and ring-billed gulls in the vicinity of the Yakima River is therefore nearly 80,000 individuals. Each pair of gulls typically lays one to three eggs, so after hatching the number of birds being fed is much higher than the number of adults nesting in the area (Thompson and Tabor 1981, Chudzik et al. 1994, Winkler 1996). Examination of Figure 1 reveals that, because of the geography of the area, much of the lower Yakima River is within a short overland distance of the colonies at Richland Island and Island 18. In 1997, gulls had laid eggs by early April and most young hatched during June, with fledging taking place in early July (Roby et al. 1998). This timing corresponds to the spring outmigration of juvenile salmonids.

Gulls are known to congregate below dams where juvenile salmon are disoriented and vulnerable to predation after passing over the dam (Ruggerone 1986, Steuber 1993, Jones et al. 1996,1997,1998). In addition, they will congregate to feed in areas with locally high fish concentrations such as those created by irrigation canal bypass outfalls and hatchery releases (Jones et al. 1996, 1997, 1998). In the past, gulls have been seen foraging at both Horn Rapids Dam and Chandler Canal bypass outfall in the lower Yakima River (Seiler 1992; T. Pearsons, WDFW, pers. comm.), but their impact on fish has not been studied.

TERNS

Terns are commonly found in the Columbia Basin. The first breeding populations of Caspian terns became established in the 1930s (Alcorn 1958) and, since that time, Pacific Coast populations have expanded dramatically (Gill and Mewaldt 1983). Roby et al. (1998) reported a breeding colony of nearly 2,000 Caspian terns on Crescent Island in the Columbia River during a 1997 survey. Thompson and Tabor (1981) reported Forster’s terns (*S. forsteri*) nesting on Richland Island (126 nests), Island 19 (50 nests), and Island 18 (228 nests) in 1977 and 1978. No mention of these Forster’s terns were made by Roby et al. (1998) so its unclear whether they still nest in the vicinity of the Yakima River. These nesting areas are within a short distance of the Yakima River (Figure 1) and tern nesting chronology places them on the colonies from mid-April through mid-July (Thompson and Tabor 1981), corresponding to outmigration of juvenile salmonids.

Although terns have been reported as major salmonid predators in the Columbia River estuary (Roby et al. 1998), there is no mention of tern predation in studies conducted further upriver. However, anecdotal reports indicate that terns do prey on juvenile salmon in the lower Yakima River (T. Pearsons, WDFW, pers. comm.).

DOUBLE-CRESTED CORMORANTS

Double-crested cormorant (*P. auritus*) numbers have been increasing across their range for the past 20 years (Hatch 1995) and the Western United States is no exception (Carter et al. 1995, Sauer et al. 1997). Cormorants are common in the Columbia River estuary (Roby et al. 1998) and they also nest in the Washington interior. The most recent breeding colony data compiled for Washington shows six confirmed breeding sites and another nine probable sites within the interior. One confirmed site is on the Columbia River on a small, wooded island near the mouth of the Snake River in the McNary National Wildlife Refuge (Smith et al. 1997, D. Roby, OSU, pers. comm.) and five possible sites are on or near the lower Yakima River below Prosser (Smith et al. 1997).

In the Yakima River, a colony with 25-30 nests has become established in a grove of trees between Granger and Mabton and cormorants can be found in the area all year (T. Hames, YIN, pers. comm.). In addition, they are commonly seen feeding in the lower Yakima River during the spring (T. Pearsons, WDFW, pers. comm.).

HERONS

Both great blue herons and black-crowned night herons (*Nycticorax nycticorax*) are common in the Columbia Basin (Thompson and Tabor 1981). Great blue heron populations may be slowly increasing on the Columbia Plateau (Sauer et al. 1997), but black-crowned night heron populations are more limited than in the past (Smith et al. 1997). Great blue herons have been documented feeding below Columbia River dams (Jones et al. 1996) and they are commonly seen feeding throughout the Yakima River (T. Pearsons, WDFW, pers. comm). A survey from Union Gap to Mabton in 1993 identified approximately 600 nests (T. Hames, YIN, pers. comm). Black-crowned night herons can also be found in the Yakima River and are known to breed near Selah and in the Toppenish National Wildlife Refuge (Smith et al. 1997). They have been seen taking advantage of lighting to feed on fish at the bypass screens on Chandler Canal (M. Johnston, YIN, pers. comm.).

BELTED KINGFISHERS

Belted kingfisher (*Ceryle alcyon*) populations in Washington appear to be at least stable, but may be slowly increasing (Sauer et al. 1997). Kingfishers commonly prey on fish at hatcheries (Schaeffer 1992) and in rivers (White 1936, 1937, 1953; Salyer and Lagler 1946) and have been considered significant predators of salmonids by some researchers (White 1939), but not by others (Salyer and Lagler 1946). Data on kingfisher abundance on the Yakima River are not available, although the birds are present and are known to breed in the Basin (Smith et al. 1997).

STUDY OBJECTIVES

This report was designed to explore the level of avian predation on mainstem Yakima River salmonids, emphasizing possible impacts on juvenile spring chinook. More specifically, the objectives were to:

- Identify the avian predators in the river.
- Index the abundance of major predators at different times of the year.
- Locate the areas of heaviest avian predation on juvenile salmonids.
- Estimate the number of juvenile salmonids consumed by the avian predators in the river.
- Determine how avian predators respond to unusually high prey densities in different parts of the river.
- Determine the best method for estimating avian consumption at predation “hot spots”, areas such as dams and irrigation canal bypass outfalls where fish become concentrated and/or disoriented, making them vulnerable to predation.

Table 1. Historical and recent run sizes of salmon and steelhead populations in the Yakima River, Washington.

Species/Race	Pre-1900 Run	Recent Range	Recent Average
Spring Chinook	200,000	645-9,300	3,800
Summer Chinook[a]	68,000	0	0
Fall Chinook	132,000	2,000-4,000	1,200
Coho[b]	110,000	NA	240
Summer Steelhead	80,500	204-2,601	1,100
Sockeye[a]	200,000	0	0

Source: BPA et al. 1996

[a]native population considered extinct
[b]native population considered extinct – recent spawners are non-native

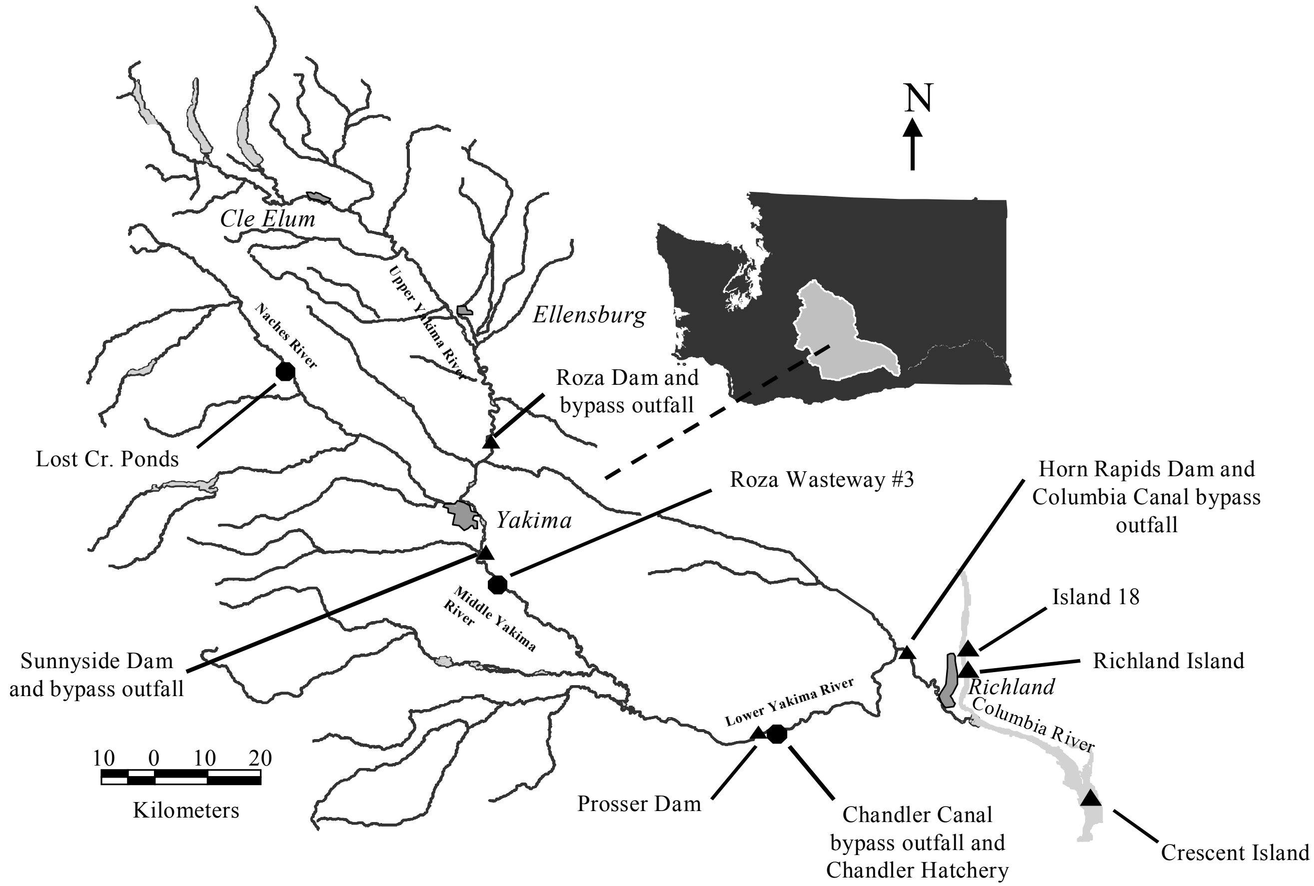


Figure 1. Map of the Yakima River Basin showing the location of hot spots, acclimation sites and three gull nesting colonies on the Columbia River.

METHODS

In studying avian predation on juvenile salmonids in the Yakima River, I emphasized spring chinook because they are the subject of intensive restoration efforts, primarily by the YFP, and the impetus behind this project. I focused my field effort in areas where juvenile spring chinook are found at a given time of the year. Spring chinook spawn in the upper Yakima River, primarily above the Teanaway River, and in the Cle Elum River (Fast et al. 1986). The juvenile fish then gradually migrate downriver throughout the year. In the late spring and summer, fry (age 0+) are most concentrated upriver from Ellensburg; during the fall and winter, parr are abundant between Ellensburg and Granger. The following spring, the smolts, now age 1+, migrate out of the Yakima on their way to the Pacific Ocean.

For the purpose of this report, the following definitions apply:

- **Upper Yakima** - the Yakima River upstream of Roza Dam (river kilometer [RKM] 205.8)
- **Middle Yakima** - the Yakima River between the high voltage power lines downstream from Granger (RKM 129.1) and Roza Dam
- **Lower Yakima** - the Yakima River between the Columbia River confluence and the high voltage power lines downstream from Granger.

Given staffing constraints, a lack of historical information about avian predation on the Yakima River, and the need to conduct a broad survey of predation, my sampling protocol can best be described as opportunistic, yet closer to random than systematic. I attempted to float index sections (described below) at least every 2 months, but was not always successful. During spring 1998, the sampling effort was intense, although broadly distributed. Hot spots and hatchery coho and fall chinook acclimation and release areas (described below) were visited frequently, but not on fixed schedules.

ABUNDANCE ESTIMATION

Piscivorous bird counts were made from October 1997 through August 1998 and once in December 1988 in free-flowing index sections and at hypothesized predation "hot spots".

FREE-FLOWING INDEX AREAS

Index areas -- free-flowing stretches judged to be representative in character of different parts of the upper, middle, and lower Yakima River -- were established to index abundance of avian predators in each chinook rearing area. The index sections were as follows (Figure 2):

- **Cle Elum** – from the WDFW boat ramp near Ensign Ranch to the Teanaway WDFW boat ramp (RKM 311.0 to 284.0).
- **Canyon** – from Reinhart Park boat ramp to the Roza USBLM boat ramp (RKM 247.4 to 209.5).
- **Selah** – from the lower end of Yakima Canyon to the boat ramp in Selah (RKM 200.0 to 180.8).
- **Granger** – from the WDFW boat ramp just below Roza Wasteway #3 to the town boat ramp in Granger (RKM 165.8 to 133.3).
- **Benton** – from Chandler Power Plant to the WDFW boat ramp in Benton City (RKM 57.6 to 47.8).
- **Horn** – from the WDFW boat ramp in Benton City to the boat ramp just above Horn Rapids Dam (RKM 47.8 to 30.1).
- **Vangie** – from the access point at the end of Snively Road to the Van Giesen Street bridge in West Richland (RKM 26.1 to 13.5).

The numbers of piscivorous birds were counted by two observers floating downriver in an aluminum drift boat or small hypalon raft. All floats were started between 08:00 and 14:30. The time required for each float varied with the length of the index section and river flow, but we generally completed the floats within 150 min. One person rowed the craft while the other sat in the front using Swift Trilyte 10 X 42 binoculars to scan the river downstream from the boat. Attempts were made to identify all piscivorous birds encountered, but they occasionally flew away before we got close enough for identification. Birds were judged to be using the river if they were swimming on the river, resting on the riverbank, perched in a tree overlooking the river, or hovering over the river. The observer recorded species, number, sex (for sexually dimorphic birds), time, activity at time of observation (e.g. swimming, sitting on bank, flying, etc.), and direction of flight when disturbed for each bird or group of birds encountered. In addition, the location of each bird sighting was noted with the use of a Magellan Systems, Model 2000, GPS (Global Positioning System). If birds flew downriver when frightened and a group with the same composition (species, number, sex) was subsequently sighted within a short distance downriver, that group was judged to be a repeat sighting and was not re-recorded.

Floats were made in each index area during the time of year that juvenile spring chinook were abundant in that section of river (Table 2). Late-spring predation on spring chinook fry was not evaluated because my effort at that time of year was concentrated on smolt outmigration in the lower river. The Granger and Canyon index sections were both quite long (32.5 km and 37.9 km, respectively); therefore, different intermediate put-in and take-out points were frequently selected to reduce the distance. The shortest float was 3 km.

For each species, the number of birds observed was divided by the length of the float to determine the number of birds per kilometer in each index section. When only a subsection of the index section was floated, I assumed that this density was representative of the entire index section. Birds that were flying up- or down-river during the float were not considered to be using the river in the index section and were therefore excluded from the calculations. I used Mann-Whitney tests to compare bird abundance between seasons for the Canyon, Selah, and Granger index areas.

HOT SPOTS

Dams and irrigation canal bypasses concentrate and disorient outmigrating fish (Ruggerone 1986, Northwest Power Planning Council 1994, ODFW 1998), increasing their vulnerability to the various piscivorous birds that often congregate in such places (Ruggerone 1986; Mesa 1994; Jones et al. 1996, 1997, 1998). These locations have the potential to become "hot spots" for predation. At low-head irrigation diversion dams, the water passing over the structure becomes violent and aerated, disorienting fish. In addition, each irrigation canal has a series of screens to remove fish from the canal and funnel them back into the river. Generally, the fish pass through a pipe, re-entering the river at a single point location. At this point the fish are concentrated into a small area and likely disoriented by the journey through the bypass system.

I identified the following potential hot spots for consideration (Figure 1):

- **Roza Dam and Roza Canal bypass outfall** (both at RKM 205.8) – the bypass outfall is located along the right bank.
- **Wapato Dam and Wapato Canal bypass outfall** (both at RKM 171.6) – the bypass outfall is located along the right bank
- **Sunnyside Dam (RKM 167.0) and Sunnyside Canal bypass outfall** (RKM 166.8) – the bypass outfall is located along the left bank.
- **Prosser Dam** (RKM 75.8) **and Chandler Canal bypass outfall** (RKM 46.8) – the bypass outfall is located approximately 8 m out from the left bank.
- **Horn Rapids (Wanawish) Dam and Columbia Canal bypass outfall** (both at RKM 29.0) – the bypass outfall is located along the right bank.

Since Sunnyside Dam and Sunnyside Canal bypass outfall are quite close to Wapato Dam and Wapato Canal bypass outfall, I made the assumption that the predation at Sunnyside Dam and Sunnyside Canal bypass outfall would be representative of the predation at Wapato Dam and Wapato Canal bypass outfall. For this reason, I did not make observations at Wapato Dam or Wapato Canal bypass outfall.

All hot spot observations throughout the season were made between sunrise and sunset. Observations were made on 22 November 1997 at Sunnyside Dam, Sunnyside Canal bypass outfall, and Prosser Dam and on 23 November 1997 at Roza Dam and Roza Canal bypass outfall; on 14 February 1998 at Sunnyside Dam, Sunnyside Canal bypass outfall, Prosser Dam, Chandler Canal bypass outfall, Horn Rapids Dam, and Columbia Canal bypass outfall; and on 15 February 1998 at Roza Dam and Roza Canal bypass outfall (Table 3). Between 24 March 1998 and 24 June 1998, observations were frequently made at all of the listed hot spots. Finally, all hotspots except for Roza Dam and Roza Canal bypass outfall were observed on 16 July 1998. I chose these dates so that I would have data from fall and winter when salmonid outmigration was low and data for spring when outmigration was high.

Observations at Roza Dam and Roza Canal bypass outfall between 24 March 1998 and 24 June 1998 were made by staff members of the WDFW Species Interaction Study, while all other locations were monitored by me and a WDFW observer. At each location, observations were made over a 200 m length of river that included 50 m upstream and 150 m downstream of the hot spot.

At each visit, instantaneous "snapshot" descriptions of avian presence and activity were made at a hotspot by scanning the 200 m area of river around the hotspot. With large numbers of birds milling about in a small area, it was often difficult to make an accurate count. I discovered that if ten or fewer birds of a species were present, a single count was accurate. However, as bird numbers increased above ten, my confidence in counting decreased. Therefore, I began to make multiple, successive counts which were averaged to obtain the snapshot abundance. In this case, three-to-five counts were made, pausing only long enough to record numbers between successive counts (about 2 sec). During the counts, each bird of a particular species was categorized as to its location (on water, on land, or in flight) and its activity (feeding or non-feeding). The instantaneous counts were made at 15 to 45 min intervals throughout the observation period. Observation periods ranged from 15 min to 8 hr with from 1 to 25 counts per day. No attempt was made to separate gull counts by species; however, the only species observed were California and ring-billed gulls.

Based on early observations of the predation levels at various sites, emphasis was placed on Horn Rapids Dam and Chandler Canal bypass outfall, where avian predation was most intense. The other sites were monitored for predation, but less intensively. Therefore, most of my results concern Horn Rapids Dam and Chandler Canal bypass outfall, with notes on predation at the other hot spots.

HATCHERY SALMONID ACCLIMATION AND RELEASE SITES

Avian predation was monitored at acclimation sites for hatchery-reared coho smolts and fall chinook fry that were to be released into the Yakima River. One site was on the upper Naches River while the other three were on the Yakima River. In addition, bird activity was noted during the time of release at the point where the fish reached the river. In both cases, observations were made as described for hot spots; however, visiting an acclimation site frightened all of the birds so only one count was made per visit. The acclimation and release sites were:

- **Lost Creek Ponds** (RKM 62.3, Naches River)
  - Coho acclimation site
  - No observations during releases
- **Yakima Greenway** (RKM 177.3)
  - Coho acclimation site
  - No observations during releases
- **Roza Wasteway #3** (RKM 157.7)
  - Coho acclimation site
  - No observations during release
- **Chandler Hatchery** (RKM 46.9)
  - Fall chinook acclimation site
  - Observations only during release

FEEDING AND DIET

GULLS

Intensive observations of feeding gulls were made at hot spots between 24 March and 24 June to determine predation and success rates, although I did not observe feeding every day the hot spot was visited for collection of bird abundance data. One of the goals of this project was to determine the best method for conducting observations of avian feeding. I tried two different methods: 1) observing predation for the aggregate of California and ring-billed gulls present at a hot spot and 2) focusing on individual birds within the aggregate group. For aggregate observations, the sampling unit was the total number of gulls feeding during the observation period while for individual focal observations, the sampling unit was one bird selected randomly from within the group. I realized that a single bird might have been included more than once during aggregate observations; however, the major focus of the feeding observations was to estimate the numbers of fish caught, whether by one or many birds. I defined the predation rate as the number of fish eaten per bird per hr and the success rate as the percentage of total feeding attempts that were successful

At the beginning of an aggregate observation, the gulls at the hot spot were counted as previously described. Then, predation was observed for 15 min followed by another bird count. During the predation observation, both the total number of feeding attempts and the number of successful feeding attempts were recorded with the aid of 10 x 42 binoculars by scanning for feeding attempts by any of the gulls foraging at the hot spot. When a feeding attempt took place, the observer focused on the gull making the attempt to determine if that attempt was successful. In addition, 15-min observations were made for individual gulls by focusing on a specific bird within the aggregate group. That focal bird was followed for the entire 15-min observation period and only feeding attempts and successes by that bird were recorded. The observer chose a gull for focal observation by selecting the bird flying closest when the 15-min period began.

For both types of observations, I defined a predation attempt as the incidence of a gull diving into the water or hovering over the water and submerging its beak. If a bird was seen emerging from the water with a fish and subsequently swallowing the fish, I considered the attempt successful. If no fish was captured, a captured fish escaped or it was not possible to determine whether a fish had been captured, I considered the attempt unsuccessful.

Whenever possible a note was made as to the type of fish caught by the predators. The best I could do was a simple distinction between probable salmonid or non-salmonid because the distance from observer to the gull was often 50 m or more, a gull that had captured a fish was rapidly swarmed and harassed by other gulls, and the fish were generally quickly consumed. A fish was classified as a probable salmonid if it was silvery and a non-salmonid if it was darkly colored. It is possible that in some cases the dark color was simply the dorsal side of a smolt.

TERNS

Tern feeding observations were made at hot spots as described for gulls; however, at no point was more than one tern present at a time. Consequently, all feeding observations were for individual terns. Again, captured fish were identified as salmonid or non-salmonid.

DOUBLE-CRESTED CORMORANTS

Feeding observations were also made in the spring for cormorants at the hot spots over 15-min intervals with counts before and after each period, as described for gulls and terns. For cormorants, instances of the bird diving completely underwater were considered predation attempts. When cormorants dove and swam underwater it was impossible to keep track of individual birds. Therefore, the sampling unit for feeding cormorants was the aggregate number of birds present (i.e., individual bird observations were made when only one cormorant was present and group observations were made when more than one cormorant was present). After a bird dove, the observer scanned the area where the cormorant was feeding without the aid of binoculars until the bird surfaced. Since cormorants swallow their prey above water (Van Dobben 1952), the bird was then quickly located in the binoculars to determine if a fish had been caught. Fish were sometimes rapidly swallowed upon surfacing so it was not always possible to determine the success of an attempt. An attempt was considered successful if the bird was seen surfacing with a fish and subsequently swallowing the fish. If it was apparent that no fish was captured, a captured fish escaped or it was not possible to determine whether a fish had been captured, the attempt was counted as unsuccessful. The total number of attempts and the number of successful attempts were recorded and prey species identification was made as previously described.

Stomach contents were available from three cormorants shot by WDFW personnel in spring 1998, two from the Granger index section and the other from the Vangie index section. Location and time of day were recorded for each sacrificed bird. The foregut (esophagus, proventriculus, and gizzard) had been removed and placed in a labeled plastic bag for the two samples from the Granger section, while only the intact prey items were provided for the sample from the Vangie section. The samples had been initially preserved on ice until they could be frozen later (within 4 hr).

COMMON MERGANSERS

Much like cormorants, common mergansers feed by diving and swimming underwater. However, they frequently swallow their prey while still submerged (Lindroth and Bergstrom 1959). This makes it impossible to determine consumption simply by observing the feeding birds. To study the diet of mergansers, 20 were shot opportunistically by WDFW personnel in various river reaches at the time of year that a given reach was presumed to be inhabited by juvenile spring chinook (see method section on free-flowing index areas). Sex, weight (when a scale was available), location, and time of day were recorded for each sacrificed bird and the samples were treated as described above for cormorants.

OTHER SPECIES

Several other species of avian predators were seen on the Yakima River, including belted kingfishers, herons, ospreys, bald eagles (*Haliaeetus leucocephalus*), grebes (*Aechmophorus occidentalis* and *Podiceps* spp.), and common loons (*Gavia immer*). These were judged to have a relatively minor impact on salmonids and their diet and feeding was not studied.

ANALYSIS OF STOMACH CONTENTS

Stomach contents of the 20 mergansers and three cormorants were analyzed to determine taxonomic composition of the diet. Samples were thawed and cut open to remove the contents of the foregut. Materials were separated into major food categories: fish, aquatic invertebrates, insects, and plant material. Items from each taxonomic group were enumerated. Whenever possible, fish were further identified to genus and species. Whole or nearly whole fish were weighed and measured for fork length, tail length, or standard length (in that order of preference), depending on stage of digestion. These fish were then placed into labeled jars containing 70% ethanol.

Many of the samples contained fully digested (only bones remaining) and semi-digested fish. The semi-digested fish matter was artificially digested using methods adapted from Peterson et al. (1990, 1991). The sample was placed into a jar containing a digestive enzyme solution prepared using 65 ml tap water, 35 ml saturated borate solution, and 1 g porcine pancreatin (A. Fritts, WDFW, pers. comm.). The samples were maintained at about 40 ºC until most of the flesh had been digested. The contents were then poured through a sieve and rinsed with tap water. A dissecting scope was used to locate and separate diagnostic bones that were then identified to the lowest possible taxon (Hansel et al. 1988, USGS 1992, Frost et al. 1993), measured, paired to enumerate prey fish consumed, and preserved in labeled jars containing 70% ethanol. Regression tables were used to estimate the length of the prey consumed (Hansel et al. 1988, Vigg et al.

1991). The taxonomic composition of the diet was expressed as percentage of total prey items by number and as percentage of bird stomachs containing a particular prey item.

DATA ANALYSIS FOR GULL CONSUMPTION

DAILY GULL-HOURS OF PREDATION

To determine potential diurnal patterns in feeding activity, I split gull observations at Horn Rapids Dam into four shifts by dividing the day into four equal time-periods from sunrise to sunset. Since the days grew longer throughout the study, the time periods changed each day, but a rough approximation of the periods would be as follows: from sunrise to about 08:00; from 08:00 to about 12:00; from 12:00 to about 16:00; from 16:00 to sunset. Sunrise and sunset data for West Richland were obtained from the U.S. Naval Observatory, Astronomical Applications Department, Washington, D.C. After the counts were categorized and normality was improved with a square root transformation of gull count, I used one-way ANOVA of gull count to infer that there was a time of day effect for Horn Rapids Dam ($F=13.055$, $df=748$, $p<0.001$) such that gull abundance in the latter three periods was likely to be equal (Tukey test, $p>0.7$), but abundance in the earliest period was significantly higher (Tukey test, $p<0.001$) (Zar 1996). The morning gull abundance was estimated to average 2.3 times that of the remainder of the day (Figure 3). Therefore, the counts each day for the latter three periods were pooled and referred to as Period 2; the morning period was referred to as Period 1.

The number of bird-hours of predation by gulls was then calculated for each day in the study period. I defined a bird-hour as a bird continuously feeding at a hot spot for an hour. A gull-hour is simply a bird-hour for gulls. I realize that any individual gull likely does not feed continuously all day, but the presence of feeding gulls during the entirety of the day would still result in fish being consumed during daylight hours. When there was more than one bird count for a given time-period in the day, I averaged the counts. The average bird count for each time-period was then multiplied by the number of hours in the time-period for that particular day. The gull-hours in each time-period were summed to determine gull-hours of predation per day.

When a day did not have observations in both time-periods, I used the mean count from the other time-period that day to estimate the mean gull count for the unobserved time-period (Figure 4). The expansion factor (2.3) indicated by the ANOVA for time of day effect was used. For example, if counts were only made in Period 2 on a day, the Period 1 average gull count was estimated at 2.3 times the Period 2 count. Conversely, if counts were only made during Period 1, the Period 2 average gull count was equal to the Period 1 average divided by 2.3. If a day did not have any observations, the average of the bird counts in each time-period of the previous and following day was used. The results were expressed as gull-hours of predation per day. Thus, gull-hours of predation per day was the extrapolated gull feeding time.

Variance in gull-hours of predation per day was also calculated. I identified three main sources of variation for the bird abundance estimates, two of which were relatively minor in comparison to the third. To illustrate the magnitudes of the three sources of variation, I calculated the coefficient of variation (CV) for each:

$$CV = \frac{S}{0} \cdot 100 \qquad (1)$$

where

CV	=	coefficient of variation
S	=	standard deviation
0	=	mean.

The first minor source of variation was in counting the birds. The CV for counting error was calculated for all observations of more than 10 birds for which multiple counts were averaged. The CV was relatively constant at 5.1% (Figure 5). The second minor contributor to the variance was inter-observer variation in the counts between the two observers (myself and a WDFW-employed scientific technician, Aaron Hird). On one occasion, two separate snapshot counts of approximately 25 gulls were made concurrently by both observers. Neither of the two average counts differed from its pair by more than 5% and the CV for the mean of each of the pairs was less than 3%. The major variance source proved to be the within-day variation in gull abundance. Figure 6 shows the variability of gull abundance for two typical days at Horn Rapids Dam. The graph for 3 June 1998 shows only abundance variability within Period 2, while the graph for 9 June 1998 has both Periods 1 and 2. The CVs are 40.5%, 37.7%, and 57.9%, respectively. Overall, the CV for days with actual observations ranged from 0 to 346.4%, averaging 48.2%. Therefore, to simplify variance calculations while still accounting for the majority of the variation, I only took into account the within-day variation in gull abundance. Consequently, confidence interval estimates are judged to be on the low side, but not greatly so.

The variance of the mean gull count for time-periods with actual observations is:

$$V_{ca} = \frac{n \cdot \sum x^2 - (\sum x)^2}{n^2 \cdot (n-1)} \qquad (2)$$

where

V_{ca} = variance of actual mean gull count per time-period

x = gull count

n = number of observations.

For days with counts in only one time-period where counts for the other time-period were calculated with the ANOVA expansion factor, the variance of the estimated mean count is:

$$V_{ce} = f^2 \cdot V_{co} \qquad (3)$$

where

V_{ce} = variance estimated from the other time-period that day

f = expansion factor appropriate for the time-period being estimated

Period 1 estimated = 2.3

Period 2 estimated = 1 ÷ 2.3

V_{co} = variance from the other time-period on the same day.

For days with no counts where the count for each time-period was interpolated from the most recent past and following day, the variance is:

$$V_{ci} = \frac{V_{cp} + V_{cf}}{2^2} \quad (4)$$

where

V_{ci} = interpolated variance for a time-period

V_{cp} = variance from the previous day for the same time-period

V_{cf} = variance from the following day for the same time-period.

For all three of the above methods for calculating the variance of a time-period, the variance in gull-hours per time-period becomes:

$$V_p = h^2 \cdot V_c \quad (5)$$

where

V_p = variance of gull-hours of predation per time-period

h = number of hours in the time-period

Period 1 = 0.25·day length

Period 2 = 0.75·day length.

n = variance of the actual, estimated, or interpolated mean gull count.

Finally, the variance in gull-hours of predation per day is:

$$V_g = V_{p1} + V_{p2} \qquad (6)$$

where

V_g = variance of gull-hours of predation per day

V_{p1} = variance of gull-hours of predation in time-period 1

V_{p2} = variance of gull-hours of predation in time-period 2.

The number of days with gull predation at Chandler Canal bypass outfall was small. Therefore, I did not attempt to stratify the gull abundance into time-periods. Instead, I averaged the gull counts for each day and expanded those counts to gull-hours of predation per day by multiplying this average by the total hours of daylight in the day. If a day did not have any observations, the average of the bird counts of the most recent previous and following day with counts was used (Figure 7).

The calculation of variance in gull-hours of predation per day at Chandler Canal bypass outfall was similar to that for Horn Rapids Dam. Equation (2) now calculates the variance of the actual mean gull count *per day* and equation (4) calculates the variance for days with no counts where interpolation was used. Finally, equation (5) gives the variance of gull-hours per day. Equations (3) and (6) are not necessary.

CONSUMPTION PER GULL-HOUR

Due to initial uncertainty about the best way to collect consumption data, I started this project by performing feeding observations for both the aggregation of gulls present and by focusing on individual gulls within the aggregate. I quickly realized that individual focal gull observations were problematic. First, it was difficult to observe the same bird for 15 min when there were many gulls milling around in a small feeding area.

Second, the gulls frequently left the hot spot by flying up- or downriver and out of sight before the 15-min observation period was complete. Third, when a gull captured a fish it was often attacked and harassed by several other gulls in the feeding area. The ensuing melee made it difficult to distinguish one gull from another so the focal gull was lost. Fourth, the bird stopped feeding by landing on the water or on the bank. At Horn Rapids Dam, out of 119 observations that were begun for individual focal gulls, 80 (67.2%) were aborted before the 15-min period had expired. On the other hand, only 4 out of 154 (2.6%) aggregate observations were aborted before the 15-min period was complete. Therefore, I chose to use the aggregate observation method. The following calculations, results, and discussion are based on aggregate consumption observations.

Shortly after feeding observations began, it became apparent that there was a discrepancy between the two observers as to what was considered to be a gull feeding attempt. One observer only counted gull plunge dives as attempts, ignoring the attempts where gulls hovered over the water and submerged their beaks while still flapping their wings. This was remedied by conducting a joint observation session where both observers independently counted feeding attempts and successes. Based on this session, correction factors were applied to the feeding data collected by one observer before the joint session. The number of feeding attempts recorded by the observer that ignored hovering attempts was multiplied by 2.0 and the number of successful attempts was multiplied by 1.44. This correction factor affected data collected on 6 out of 30 days of feeding observations.

For data analysis, I first eliminated all uncompleted observations, leaving only consumption counts for complete 15-min periods. Then the number of probable salmonids eaten per gull per 15-min observation period was calculated by dividing the aggregate consumption by the average number of gulls feeding during that 15-min observation. This figure was expanded to salmonids eaten per gull-hour by multiplying by four to make it compatible with the bird abundance calculations. The few fish that were classified as non-salmonids were excluded from the calculations. Next, I calculated daily consumption per gull-hour by averaging all of the feeding observations in a day.

Finally, the mean of the daily averages was calculated separately for the gulls at Horn Rapids Dam and Chandler Canal bypass outfall to yield the seasonal mean salmonids eaten per gull-hour. I calculated variance in mean seasonal salmonids eaten per gull-hour by using equation (2).

SEASONAL FISH CONSUMPTION BY GULLS

Seasonal fish consumption by gulls was calculated separately for both Horn Rapids Dam and Chandler Canal bypass outfall. I did this by multiplying the mean seasonal salmonid consumption per gull-hour by the daily number of gull-hours of predation. The daily consumption figures were then summed to yield the seasonal salmonid consumption by gulls at each of the sites.

The variance in daily salmonid consumption is:

$$V_{sd} = G^2 \cdot V_f + F^2 \cdot V_g \quad (7)$$

where

V_{sd} = variance in daily salmonid consumption

G = gull-hours of predation per day

V_f = variance of mean seasonal salmonid consumption per gull-hour

F = mean seasonal salmonid consumption per gull-hour

V_g = variance of gull-hours or predation per day.

Next, the variances in daily salmonid consumption were summed to yield the variance of the seasonal salmonid consumption by gulls at each site. Finally, the square root of this variance gave the standard error, which was then used to calculate a 95% confidence interval around the seasonal consumption figures.

SUCCESS RATE

Rate of success of salmonid capture was also calculated for gulls foraging at Horn Rapids Dam and Chandler Canal bypass outfall. For each complete 15-min feeding observation, the number of fish caught was divided by the number of feeding attempts. In addition, I calculated the daily and seasonal average success rates for each site.

DATA ANALYSIS FOR TERN CONSUMPTION

I rarely saw terns at any of the hot spots so consumption estimates could not be calculated. However, success rates were calculated for the limited number of feeding observations.

DATA ANALYSIS FOR DOUBLE-CRESTED CORMORANT CONSUMPTION

Double-crested cormorant abundance was low at the hot spots so I was unable to make many feeding observations. Success rates were calculated for the limited number of feeding observations that were made. In addition, since only three stomach samples were obtained it was not possible to quantify species composition of the cormorant diet.

DATA ANALYSIS FOR COMMON MERGANSER CONSUMPTION

Common merganser stomach content data was divided into three groups based on location and time of year: fall/winter in the Canyon and Selah sections, spring in the Canyon and Selah index sections, and spring in the Granger section. Data were then expressed as percentage of stomachs containing a prey item and percentage by number of prey items.

CORRELATIONS FOR GULL ABUNDANCE AND CONSUMPTION

Data on river flow, turbidity, air temperature, water temperature, wind speed, and salmonid outmigration were gathered to investigate correlations and trends with predation level (gull-hours), daily consumption, and success rate of predators. Daily mean river flow data were obtained from Hydromet, a network of stream gauges operated by the United States Bureau of Reclamation (BOR). The Yakima River gauge at Kiona is the closest available flow reading to Horn Rapids Dam while flow at Chandler Canal bypass outfall is obtained by subtracting the flow into Chandler Canal from the flow at Grandview, just above Prosser Dam. In addition, daily average water temperature at Prosser Dam was obtained from Hydromet. Turbidity readings were taken by BOR at Prosser Dam with an HF Scientific, model BW 200 turbidity meter attached to a Rustrack Ranger III Data Logger. Mean daily air temperatures and mean daily wind speeds were obtained from AgriMet, a satellite-based network of automated agricultural weather stations operated and maintained by BOR. I used data from the Le Grow Station, approximately 45 km southeast of Horn Rapids Dam.

Daily fish passage was estimated by YIN at Chandler Juvenile Monitoring Facility (CJMF) which intercepted a sub-sample of the fish passing through Chandler Canal bypass outfall. Daily sub-sample retention rates were expanded to total daily downriver fish passage using the sub-sample rate, species- and flow-specific entrainment rates for Chandler Canal, and species- and flow-specific mortality rates within Chandler Canal. The retained fish were enumerated each morning, then held and released at night to minimize predation. Non-retained fish continued through CJMF and re-entered the river from Chandler Canal bypass outfall without delay, providing an accurate daily account of the fish available to predators foraging at Chandler Canal bypass outfall. In order for CJMF fish passage data to be representative of passage over Horn Rapids Dam, the daily fish counts must be lagged to allow for fish to migrate the additional 17.8 km. Fall chinook data were lagged 3 days (Seiler 1992) while coho, spring chinook, steelhead, and sockeye were lagged 1 day (B. Watson, YIN, pers. comm.). Of course, fish will move at varying speeds depending on time of year and water conditions, but I considered this to be the most likely representation of fish abundance at Horn Rapids Dam. Estimates of fish passage at Horn Rapids dam would also be influenced by juvenile mortality between CJMF and the dam. This mortality was not factored into the analysis. An additional confounding factor for fish passage estimates over Horn Rapids Dam is the fact that the majority of fall chinook spawn below Prosser Dam (Seiler 1992) and 1.2 million fall chinook were released from Chandler Hatchery (below Prosser Dam) on 30 May. Therefore, this production and the hatchery release was not represented in the CJMF fish counts. Since the predation at Chandler Canal bypass outfall occurs at the outfall pipe, the daily numbers of non-retained fish were used for Chandler Canal bypass outfall correlations.

GULL ABUNDANCE

Plots were made with daily gull-hours of predation vs. each of the additional parameters and Pearson correlations were calculated after normality was assessed using histograms and q-q plots (Zar 1996). Where appropriate, partial correlations were calculated to control for highly correlated parameters. When necessary, I used transformations to improve normality (Table 4). Linear piecewise regression was used to develop separate models to predict gull-hours of predation at both Horn Rapids Dam and Chandler Canal bypass outfall (Neter et al. 1996). For both models, only observations after the first sighting of gulls at the respective hot spot were used. First, stream flow, fish passage, and a piecewise indicator variable were entered into the model. Then, a forward selection procedure was used to choose other significant predictor variables (Neter et al. 1996). I also plotted daily gull-hours and all of the additional parameters vs. date to look for trends.

CONSUMPTION

I made plots for observational and daily consumption and success rates vs. each of the additional parameters for both Horn Rapids Dam and Chandler Canal bypass outfall. Feeding observations were not made each day a site was visited; therefore, the transformations used above were not necessarily appropriate. For many of the variables, such as gull-hours of predation, turbidity, flow, and wind, I was not able to find an appropriate transformation. I elected to use non-parametric bivariate Spearman correlations (Neter et al. 1996, Zar 1996) instead of transforming the data. In addition, I used Mann-Whitney tests to compare consumption and success rates between Horn Rapids Dam and Chandler Canal bypass outfall (Zar 1996)

Table 2. Number of floats made in each free-flowing index area and spring chinook abundance by month.

	1997				1998							
Index Area	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Cle Elum							X			X(2)	X	
Canyon		X(5)	X(2)	X(3)				X	X(3)	X(2)		
Selah		X	X			X		X(2)		X		
Granger		X	X			X		X(4)	X(3)	X		
Benton								X(2)	X(2)	X		
Horn								X(3)	X(2)	X		
Vangie								X(3)	X(2)	X		

spring chinook abundant

spring chinook present but not highly abundant

X - indicates that the index section was floated during the month.

( ) - indicates the number of times floated during the month, if greater than 1.

Table 3. Observation dates at Yakima River predation hot spots.

Date	RD	RCO	WD	WCO	SSD	SSCO	PD	CCO	HRD	CCB
11/22/97					X	X	X			
11/23/97	X	X								
02/14/98					X	X	X	X	X	X
02/15/98	X	X								
3/24/98 - 6/24/98	X(8)	X(8)			X(51)	X(51)	X(71)	X(70)	X(63)	X(63)
07/16/98					X	X	X	X	X	X

RD = Roza Dam
RCO = Roza Canal bypass outfall
WD = Wapato Dam
WCO = Wapato Canal bypass outfall
SSD = Sunnyside Dam
SSCO = Sunnyside Canal bypass outfall
PD = Prosser Dam
CCO = Chandler Canal bypass outfall
HRD = Horn Rapids Dam
CCB = Columbia Canal bypass outfall

X - indicates that observations were made at the hot spot on that date

( ) - indicates the number of days with observations, if greater than 1.

Table 4. Normality transformations of parameters used in analysis of gull-hours of predation at Horn Rapids Dam and the Chandler Canal bypass outfall.

Original Parameter	**Transformation**
CCO bird-hours	natural log (+ 1)
HRD bird-hours	square root
CCO fish passage	natural log
HRD fish passage	square root
stream flow at Kiona	square root
stream flow at Chandler	square root
turbidity	natural log
mean wind speed	natural log
mean water temperature	untransformed
mean air temperature	untransformed

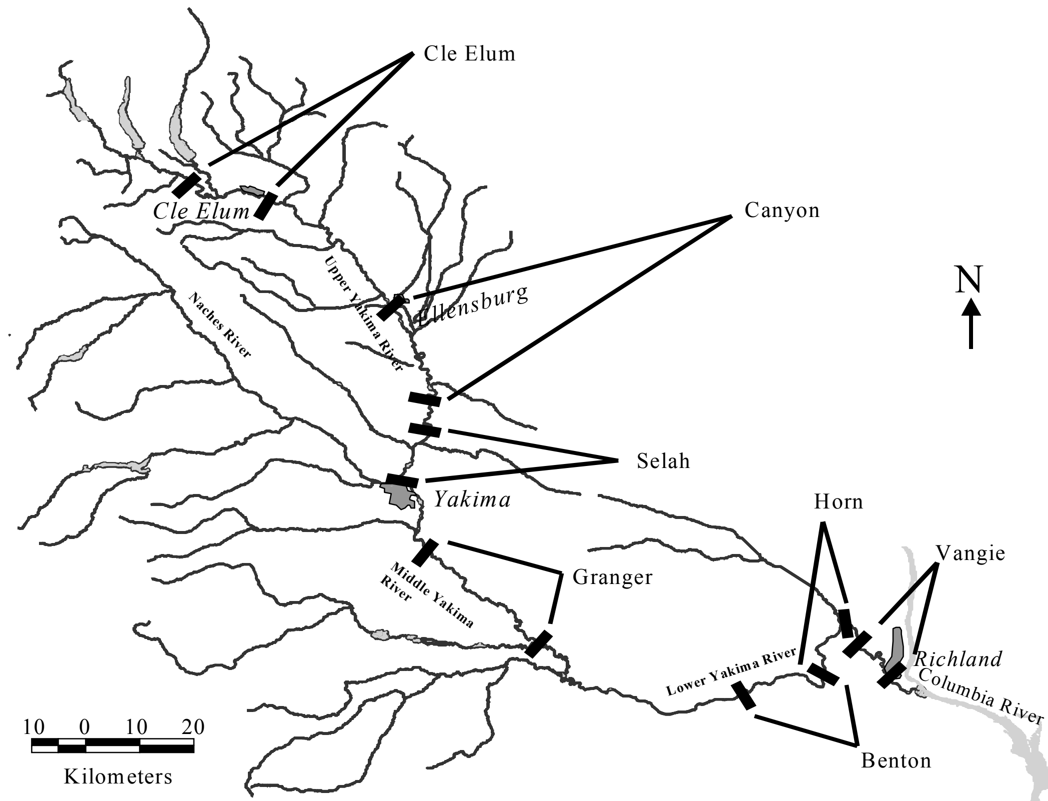
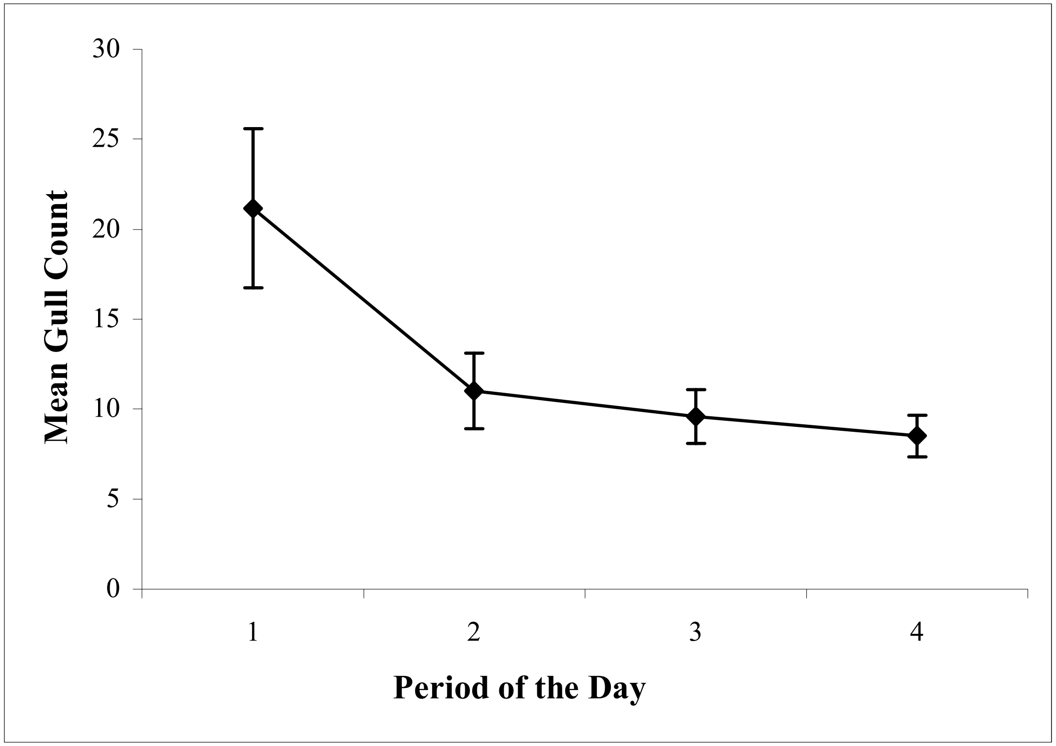


Figure 2. Map of the Yakima River Basin showing the seven free-flowing index areas



Error bars represent 95% confidence intervals.
period 1: n = 63
period 2: n = 183
period 3: n = 206
period 4: n = 295

Figure 3. Seasonal mean gull count at Horn Rapids Dam for each of four daily time-periods. Actual time-periods changed with day length, but they were approximately: 1 - sunrise to about 08:00; 2 - 08:00 to about 12:00; 3 - 12:00 to about 16:00; 4 – 16:00 to sunset.

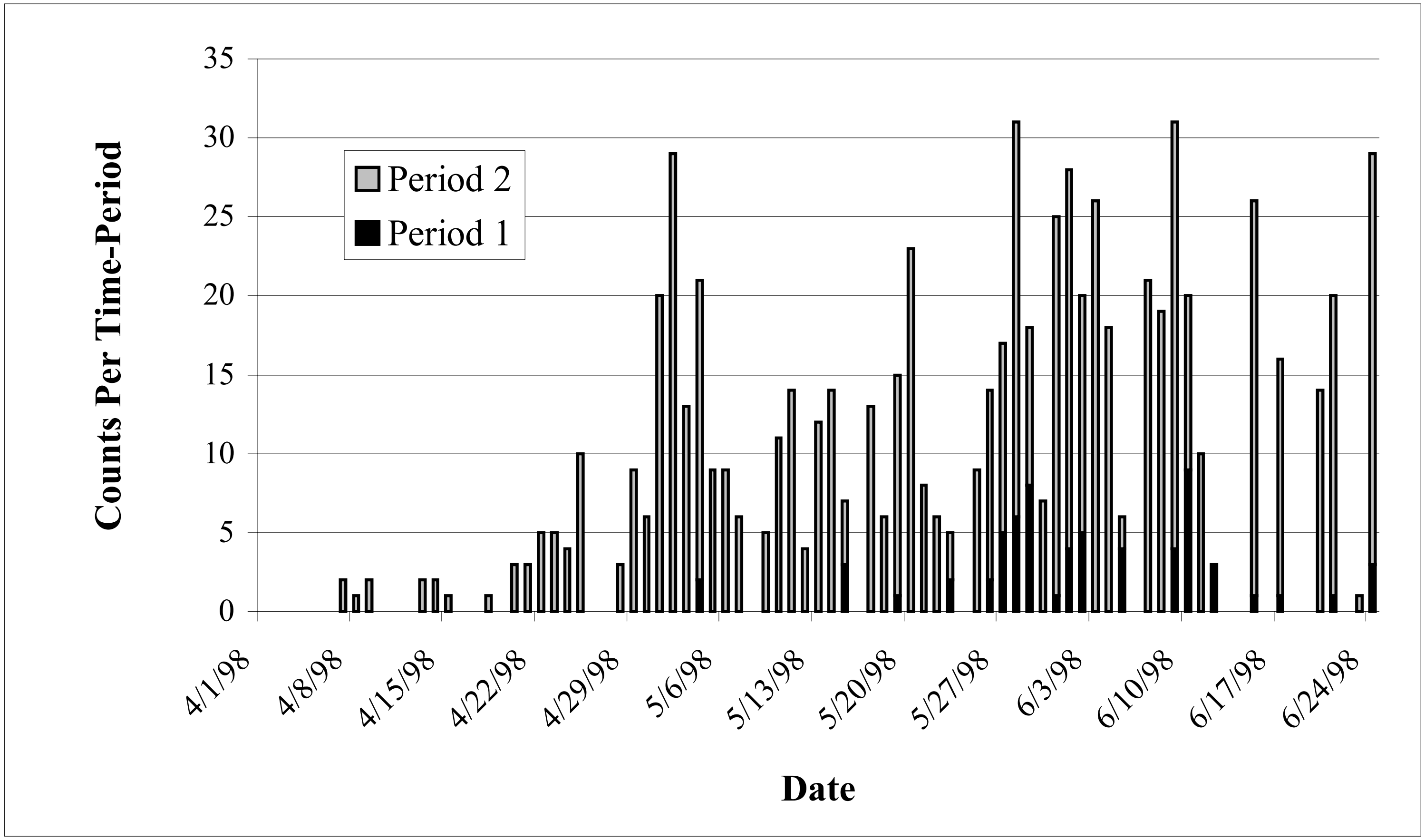


Figure 4. Number of gull counts per time-period at Horn Rapids Dam from 1 April to 24 June 1998. Actual time periods changed with day length, but they were approximately: 1 - sunrise to about 08:00; 2 - 08:00 to sunset.

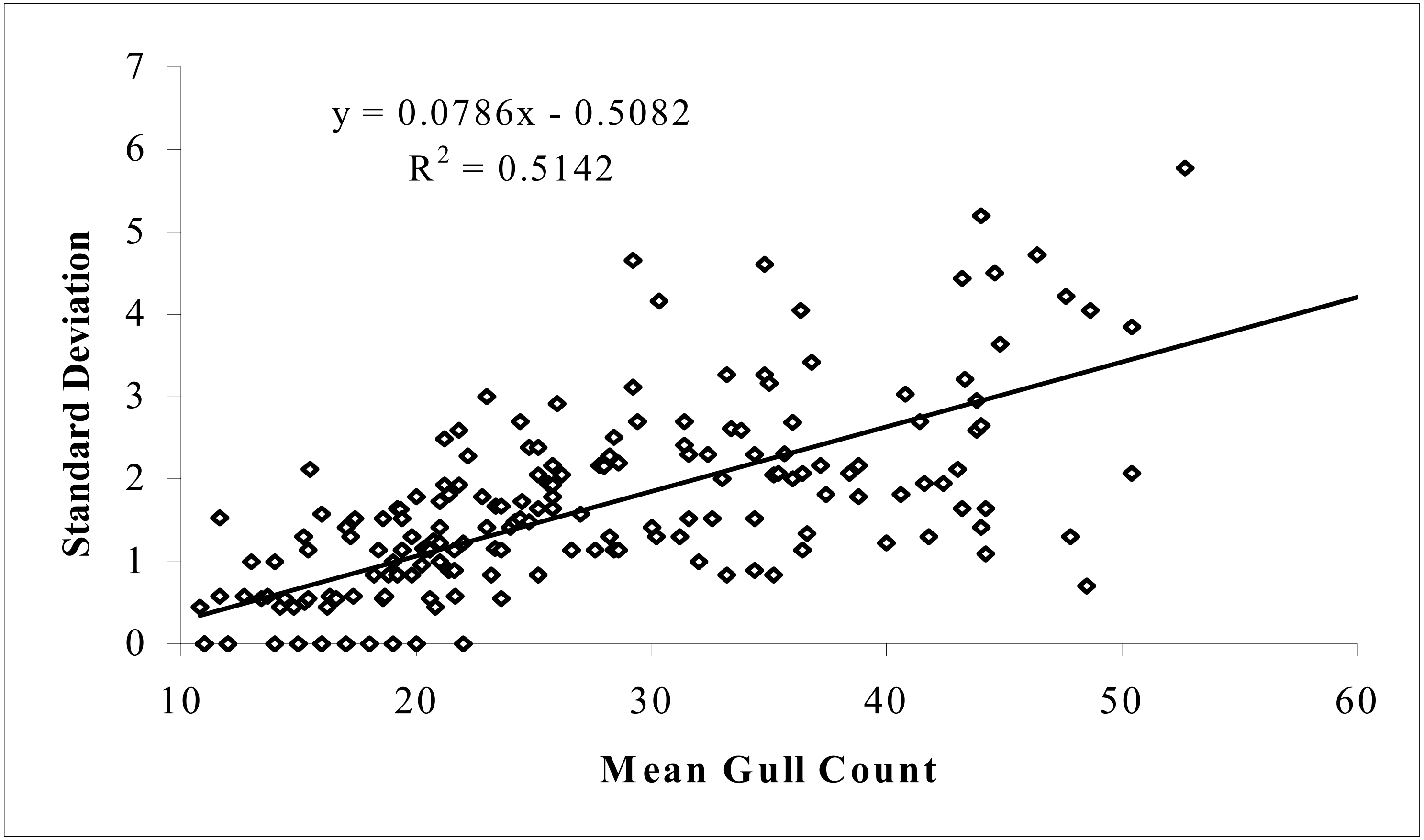


Figure 5. Mean gull count vs. standard deviation at Horn Rapids Dam for all observations of more than ten birds for which multiple counts were averaged.

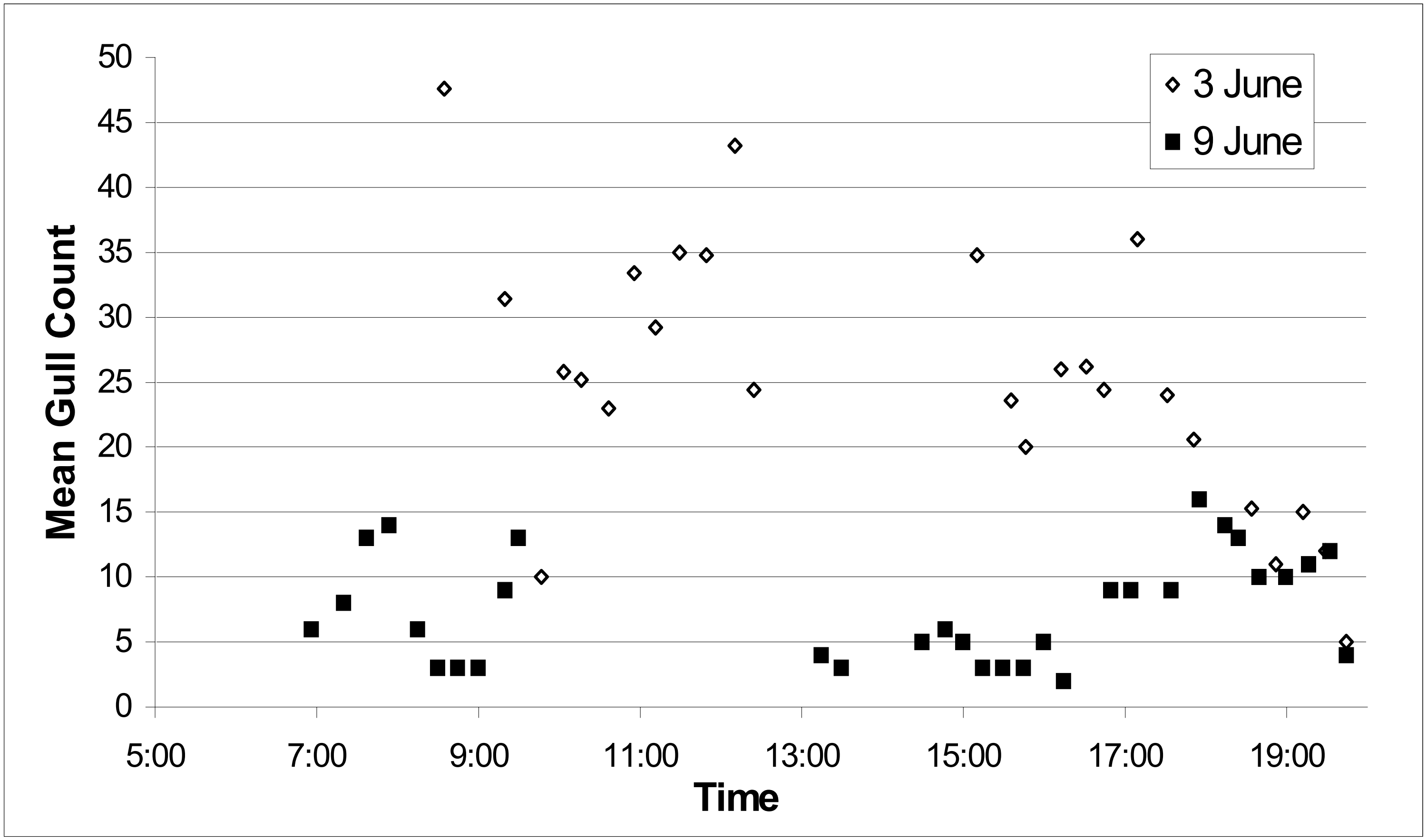


Figure 6. Gull count vs. time of day at Horn Rapids Dam on 3 and 9 June 1998.

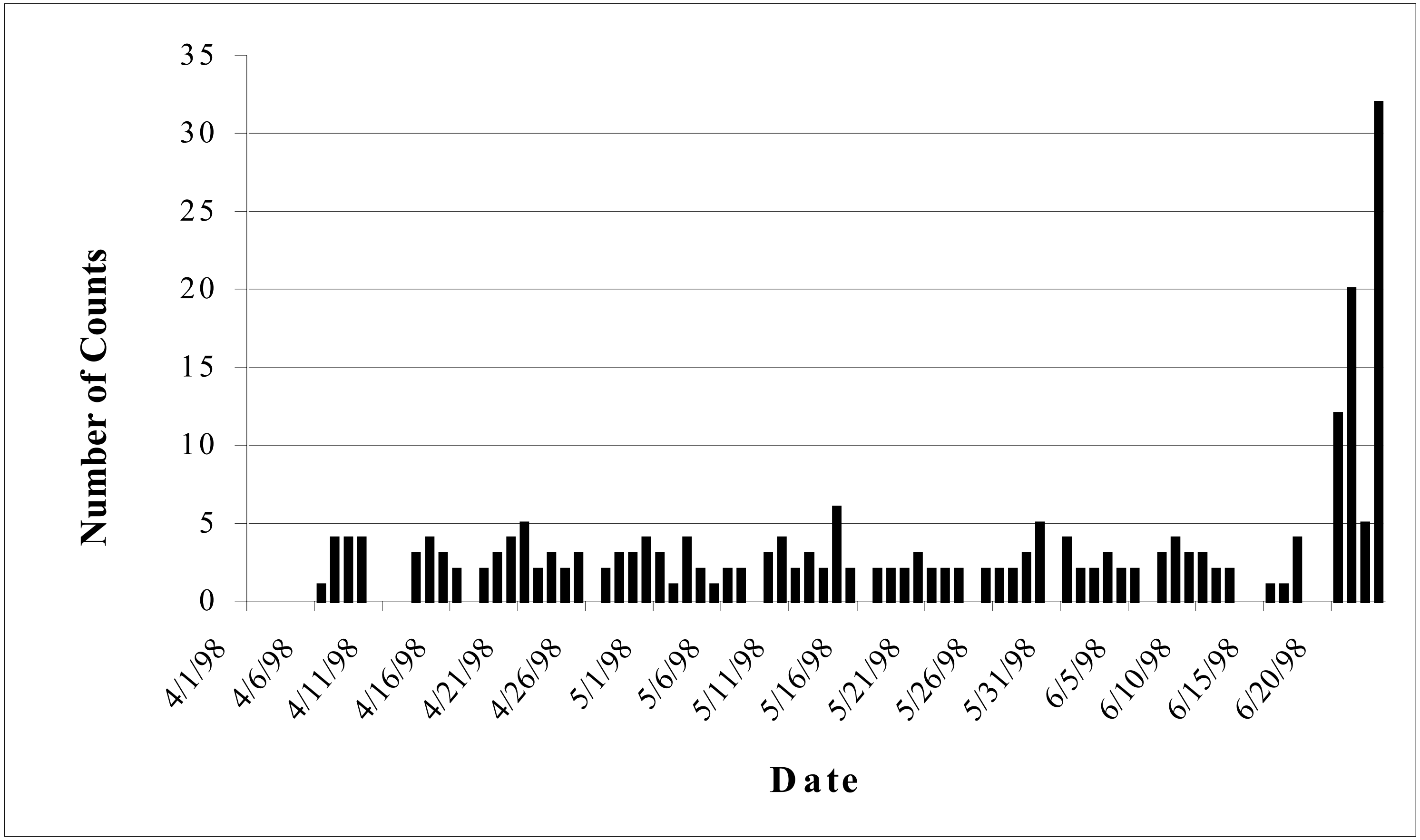


Figure 7. Number of gull counts per day at the Chandler Canal bypass outfall from 1 April to 23 June 1998.

RESULTS

FREE-FLOWING INDEX AREAS

CLE ELUM

This index area was floated once in early spring (13 March) and three times during the summer (16 June, 22 June, and 17 July) (Table 2). Mergansers were always the most abundant avian predator in the area, ranging from 0.30 per km on 17 July to 0.57 per km on 13 March (Figure 8). This index section was one of two areas where juvenile mergansers were seen in the summer. There were 1.1 juveniles per km on both 16 June and 22 June, and more than twice that on 17 July when 2.4 per km were seen. Kingfishers and great blue herons were uncommon in this index area with a maximum of three kingfishers (0.11 per km) and one heron (0.04 per km) seen during the summer. No herons and only one kingfisher were seen in early spring. Osprey were observed in this section with three (0.11 per km) seen on both 16 June and 22 June, and one (0.04 per km) on 17 July; however, no osprey were observed in early spring. There were no gulls, terns, cormorants or night herons observed on any of the floats in this index section.

CANYON

Portions of this index area were floated five times in October, twice in November, three times in December (1997), once in April, three times in May, and twice in early June (1998) (Table 2). A final float was done on 12 December 1998, for a year-to-year check on abundances. No mergansers were seen on the first two floats in October, but numbers increased toward the end of October with as many as two mergansers per km (Figure 9). In November, abundance decreased only to increase again to 2.2 per km in December. The average fall/winter merganser count was 0.89 per km (SE 0.26). In the spring, merganser abundance peaked at 2.5 per km on May 9 with an overall spring average of 1.27 per km (SE 0.23). The average fall/winter and spring abundances were not significantly different (Mann-Whitney test, p = 0.227, two-tailed). The float on 12 December 1998 had 0.72 mergansers per km which is within the range of the fall/winter 1997 counts and near the 1997 fall/winter average.

Great blue heron abundance ranged from zero on 15 October to 0.67 per km on both 12 October and 31 October with a fall/winter average of 0.26 per km (SE 0.063). Spring heron numbers were lower with zero on 22 May and a maximum of 0.23 per km on 1 June. The spring average of 0.11 per km (SE 0.033) was not significantly different from the fall/winter average (Mann-Whitney test, p = 0.130, two-tailed). Belted kingfishers were also seen on Canyon floats in the fall/winter with an average of 0.45 per km (SE 0.33), however the range was quite wide (zero to 0.53 per km). During the spring, kingfishers were not seen on any of the floats. Ospreys were also rare in this index area with one observed on 25 October (0.09 per km) and on 1 June (0.08 per km). One common loon was seen on 16 June but no cormorants, gulls, terns, or night herons were observed in the Canyon index area.

SELAH

The Selah index section was floated in the fall and winter on 25 October, 23 November, and 15 February, and in the spring on 3 April, 16 April, and 8 June (Table 2). In the fall/winter, merganser abundance ranged from 0.25 to 0.33 with an average of 0.30 per km (SE 0.027) while in the spring, it ranged from 0.41 to 1.39 with an average of 1.06 per km (SE 0.33). The fall/winter average was significantly lower than the spring average (Mann-Whitney test, p = 0.043, two-tailed) (Figure 10).

The fall/winter great blue heron abundance ranged from 0.25 per km on 23 November and 15 February to 0.33 per km on 25 October. In spring, abundances were lower with a range from zero on 16 April to 0.08 per km on 8 June, corresponding to one bird observed. The fall/winter average of 0.27 per km (SE 0.027) was not significantly larger (Mann-Whitney test, p = 0.105, two-tailed) than the spring average of 0.11 per km (SE 0.072). In the fall/winter, between 0.08 and 0.49 kingfishers per km were seen and in the spring between 0.16 and 0.33 per km were seen. The fall/winter average of 0.22 per km (SE 0.14) was not significantly smaller (Mann-Whitney test, p = 0.507, two-tailed) than the spring average of 0.25 per km (SE 0.047).

One osprey was observed in both the fall (25 October) and the spring (8 June) for a density of 0.08 per km. No cormorants, gulls, terns, or night herons were observed using this index section; a bald eagle was spotted on 3 April.

GRANGER

The Granger index area, or parts of it, were floated in the fall/winter on 26 October, 19 December, and 14 February and during the spring in April (2, 15, 19, and 30), May (3, 12, and 27), and on 10 June (Table 2). The fall/winter merganser abundance varied from zero on 26 October to 0.23 per km on 14 February, averaging 0.13 per km (SE 0.067). Mergansers were more abundant in spring, ranging from 0.15 (3 May) to 2.40 per km (12 May) with an average of 0.96 per km (SE 0.25). The difference in abundance between fall/winter and spring was significant (Mann-Whitney test, p = 0.032, two-tailed) (Figure 11).

Similarly, great blue herons were significantly more abundant in spring than in fall/winter (Mann-Whitney test, p = 0.014, two-tailed). Fall/winter numbers ranged from 0.12 (26 October) to 0.23 per km (19 December and 14 February), averaging 0.19 per km (SE 0.034) while spring density ranged from 0.31 (3 May) to 1.12 per km (10 June), averaging 0.73 per km (SE 0.093). Kingfishers were also present in the Granger section in fall/winter and spring. The fall/winter abundance ranged from 0.15 to 0.61 per km (14 February and 19 December, respectively) with an average of 0.42 per km (SE 0.14) and the spring abundance ranged from zero (30 April, 3 May, 27 May) to 0.57 per km (April 15) with an average of 0.19 per km (SE 0.085). The difference in abundance was not significant (Mann-Whitney test, p = 0.149, two-tailed).

I did not see any cormorants in the fall, but I did in the spring. Spring numbers were highly variable, ranging from zero on 19 April and 3 May to 0.76 per km on 27 May. The average in spring was 0.33 per km (SE 0.12). Other piscivorous birds observed included a single osprey on two different spring floats, a red-necked grebe (*P. grisegena*) on 19 April and a Caspian tern on 10 June. I did not see any gulls or night herons using this section.

BENTON

Floats were made in the Benton index area on 18 April, 22 April, 10 May, 13 May, and 2 June (Table 2). Common mergansers were observed on the first two floats (0.10 and 0.20 per km, respectively) but were not seen after that (Figure 12). Great blue heron abundance ranged from zero (22 April and 10 May) to 0.31 per km (2 June) with an average of 0.14 (SE 0.06) and a single night heron was seen on two floats (0.10 per km; 22 April and 2 June). Cormorant abundance in this section ranged from zero (22 April and 13 May) to 0.31 per km (10 May) with an average of 0.12 per km (SE 0.059). In addition, between one and four cormorants were observed flying up- or downriver on each float (mean 1.2, SE 0.58). No gulls, terns or kingfishers were seen using the Benton index section.

HORN

This index area was floated three times in April (7, 20, and 23), twice in May (10 and 13), and on 2 June (Table 2). Common mergansers were only seen on 23 April when three were observed (0.17 per km) (Figure 13). Both great blue herons and night herons were present in this index area. Great blue heron abundance ranged from zero to 0.17 per km with an average of 0.07 (SE 0.022). On 7 April and 2 June, numbers of night herons observed were 0.06 and 0.11 per km, respectively. Cormorant abundance ranged from zero to 0.11 per km, averaging 0.07 per km (SE 0.023) and two birds were observed flying upriver on 7 April. Kingfishers were only seen on 20 April when two were observed (0.11 per km). Ospreys were seen twice in the Horn section with one spotted on 20 April and two seen on 10 May. We did not see any terns while floating this index area.

VANGIE

Like the Horn section, this index area was floated three times in April (9, 21, and 24), twice in May (12 and 18), and on 9 June (Table 2). Four mergansers were seen on 9 April (0.32 per km), but none were seen on three floats and only one was seen on each of the other two floats (0.08 per km) (Figure 14). Great blue herons were observed on all but one float with an average of 0.13 per km (SE 0.07), however this average is influenced by a large count of six on 9 April (0.48 per km). Night herons were also occasionally found in this index area with one seen on 12 May and two seen on 9 June. Cormorants were observed on all but one float with a peak of 16 (1.27 per km) on 18 May and an average of 0.39 per km (SE 0.19). In addition, we saw an average of 2.5 (SE 0.43) cormorants flying up- or downriver on each float. One to two kingfishers (0.08 and 0.16 per km, respectively) were observed on three floats, but none were seen on the other three floats. Osprey were present in April (0.08 to 0.16 per km), but were not seen in May or June. In addition, two terns that were seen flying over the river on 9 June appeared to be searching for fish.

HOT SPOTS

ROZA DAM AND ROZA CANAL BYPASS OUTFALL

Roza Dam and Roza Canal bypass outfall had little avian predation. Checks on 23 November, 15 February, 1 April, and 14 April found no birds foraging above or below the dam and no birds at the bypass outfall. However, on 30 April one great blue heron was observed on the right bank about 75 m below the dam. Other observations were made intermittently by WDFW personnel. They found no evidence of avian predation (T. Pearsons, WDFW, pers. comm.). Observations were not made frequently enough to estimate bird-hours of predation at Roza Dam or Roza Canal bypass outfall.

SUNNYSIDE DAM AND SUNNYSIDE CANAL BYPASS OUTFALL

Like the Roza hot spots, Sunnyside Dam and Sunnyside Canal bypass outfall had little avian predation. During 70 min of observation on 22 November, I saw one drake merganser approximately 50 m above the dam, but no feeding attempts were observed. A short time later this merganser was joined by two other drake mergansers and all three began feeding between 150 and 200 m above the dam, out of the study area. One great blue heron was seen within the study area for Sunnyside Canal bypass outfall sitting on an old railroad bridge but no feeding attempts were observed. A check on 14 February found no avian predators within site of these hot spots.

More intensive monitoring was begun on 24 March, continuing through 24 June. At least one count per day was made on 1 day in March, 20 days in April, 21 days in May, and 9 days in June. The March observation found no predators at either hot spot; however, the observations in April, May, and June indicated that great blue herons fed at the dam, but not in large numbers. At least one heron was observed feeding within the Sunnyside Dam index on 13 out of 20 days in March (65%), 13 out of 21 days in April (62%), and 5 out of 11 days in June (45%). On 90% of these days, only one heron was observed and the maximum number was three, seen only on 10 June. The favored place for heron feeding was a small, mid-river island approximately 15 m below the dam. A final check on 14 July found no birds present.

Counts were made at Sunnyside Canal bypass outfall on the same days as Sunnyside Dam. There was little predation at the outfall with one common merganser seen on 22 April near the right bank at the lower end of the hot spot section, one heron on three occasions near the right bank within the section, and one kingfisher within the section flying along the right bank. The bypass outfall is located along the left bank so all of the piscivorous birds I observed were well away from the immediate area of the outfall and not in position to be able to take advantage of its effects on the fish passing through it. A final check on 16 July found no birds present. Observations were not made frequently enough to estimate bird-hours of predation at Sunnyside Dam or Sunnyside Canal bypass outfall.

PROSSER DAM

Prosser Dam was observed for 85 min on 23 November when up to four common mergansers were seen feeding in the foredam. However, these birds never moved downriver far enough to be within the designated study area. In addition, one great blue heron was standing at the water's edge within the downstream section of the hot spot. No piscivorous birds were seen when Prosser Dam was visited on 14 February. Frequent observations were made between 24 March and 24 June with at least one count per day on 2 days in March, 23 days in April, 28 days in May, and 18 days in June. Observations indicate that predation was light at Prosser Dam. A single female common merganser was seen on 2, 3, 8, and 9 April, but these are the only days that mergansers were observed at the dam. The first two days, it was feeding within the 50 m hot spot stretch above the dam while on 8 April it was swimming around below the dam and on 9 April it was sitting on a rock below the dam. A single cormorant was seen above the dam on 7 April and its feeding was observed for 15 min. The cormorant made 17 dives, some within 5 m of the dam crest, but no fish were seen consumed. A short time after the 15-min observation the cormorant flew upriver. The only other time a cormorant was seen at Prosser Dam was on 29 April when one was sitting on a rock below the dam.

Great blue herons were the most abundant of the piscivorous birds at Prosser Dam and when observed were always in the stretch below the dam. In April, herons were seen on 10 of 23 days (43%) with a maximum of three at one time on 22 April. Abundance was lower in May and June with herons seen on only 2 out of 28 days (7%) and 2 out of 18 days (11%), respectively. One of the herons in June was resting on the rocks with its head tucked down and was not considered to be feeding. Gulls were occasionally seen resting on parts of the dam structure where they were far enough from the water that I did not consider them to be feeding. A final observation on 16 July found only a single gull sitting on the dam structure.

CHANDLER CANAL BYPASS OUTFALL

Chandler Canal bypass outfall was visited at 14:50 on 14 February and no birds were observed in the area. Frequent observations were made from 25 March through 23 June with at least one count per day made on one day in March, 23 days in April, 28 days in May, and 18 days in June. With the exception of 25 March, 15 June, and 16 June, Chandler Canal bypass outfall was visited at least twice on each observation day (Figure 7). Gulls were by far the most abundant predators at Chandler Canal bypass outfall; however, great blue herons, night herons, cormorants, and mergansers were occasionally observed in the area. No great blue herons were seen in March, but they were seen on 11 of 23 days in April (48%), 3 of 28 days in May (11%), and 4 of 18 days in June (22%). On 8 of these days, the herons were near the left bank below the outfall in a position to take advantage of the concentrated fish. In addition, night herons were seen once in May and twice in June. On days with heron sightings (either species) there was generally only one bird in the area at a time. As many as three cormorants were observed on 8 April and two were observed on 15 April within the designated study area. On several other days, cormorants were observed either just above or below the hot spot section. On two occasions in April, common mergansers were seen near Chandler Canal bypass outfall. One female was on the left bank on 23 April and two females were in the left bank shallows below the outfall on 25 April. There were no terns sighted during the spring observations.

Gulls were first sighted at Chandler Canal bypass outfall on 8 April when one was observed circling the outfall and two were seen sitting on the right bank later the same day. The next time gulls were seen was on 14 April when one was at the outfall. The highest count in April was five gulls at 17:50 on the 19th. In total, gulls were seen on 6 days in April. The only sighting of feeding gulls in May was of two on the 31st at 11:50. After that, gulls were more frequent visitors to Chandler Canal bypass outfall with gulls feeding on 13 out of 18 observation days in June (72%). The peak count of feeding gulls was 26 on 23 June at 16:43. In 1998 the total gull-hours of predation for the spring observation period was estimated to be 807 (SE 73), varying between zero on many days and 139 (SE 21) on 23 June (Figure 15). The only species of gulls seen at Chandler Canal bypass outfall were California and ring-billed.

During a final observation on 16 July, the maximum count of feeding gulls was two at 12:20. In addition, two Caspian terns were flying around in the area of the outfall that day. Given the rising average gull counts when observations ceased on 23 June, it is likely that gulls foraged at Chandler Canal bypass outfall in the period between 23 June and 16 July.

Bivariate Pearson correlations were used to investigate possible relationships between daily gull-hours of predation at Chandler Canal bypass outfall and river flow at Chandler, turbidity, wind speed, fish passage, air temperature, and water temperature. For the entire observation period (25 March – 23 June), predation was significantly correlated with river flow ($r = -0.393$, $p<0.001$), turbidity ($r = -0.235$, $p = 0.025$), water temperature ($r = 0.606$, $p<0.001$), and air temperature ($r = 0.489$, $p<0.001$), but not significantly correlated with fish passage through CJMF ($r = 0.112$, $p = 0.290$) or wind speed ($r = -0.059$, $p = 0.577$). Bivariate Pearson correlations for all observations after the first sighting of gulls at Chandler Canal bypass outfall (8 April) resulted in little change in the correlations (Table 5). Since stream flow at Chandler was highly correlated with turbidity ($r = 0.893$, $p<0.001$), I also calculated the partial correlation of gull-hours with flow while holding turbidity constant ($r = -0.385$, $p = 0.001$) and for gull-hours with turbidity while holding flow constant ($r = -0.220$, $p = 0.058$) (Neter et al. 1996, Zar 1996).

Examination of a plot of water and air temperatures over time revealed that both increased steadily throughout the spring, while predation remained nearly nonexistent until 14 June when it increased rapidly (Figures 16 and 17). Thus, these significant correlations appear biologically meaningless. Conversely, the significant correlation with flow appeared to have merit (Figures 18 and 19). Gull abundance was low near the beginning of the spring but began to increase slightly by 19 April. Shortly after this, flow increased to more than 4,000 cfs, remaining above this level until mid-May. When the flow began to drop, gull abundance increased, especially when flows approached 3,000 cfs. Immediately after this point, the flow spiked up over 4,000 cfs and gull abundance dropped. This pattern was repeated again in early June. Finally, in mid-June the flow dropped well below 4,000 cfs and abundance rapidly increased. Gull abundance was still rising when observations ended.

Examination of Figure 19 shows that predation decreased linearly with increasing flow until about 7,000 cfs when predation ceased. A piecewise regression model using flow, fish passage, water temperature and an indicator variable to allow a slope change at 7,000 cfs was created to predict gull abundance at the Chandler Canal bypass outfall. The model was:

$$Y = -7.07 - 0.051\,X_1 + 0.042[(X_1 - \sqrt{7000})X_2] - 0.173\,X_3 + 0.219X_4$$

$$(F = 29.215,\ p =<0.001,\ R = 0.787,\ R^2_{adj} = 0.598)$$

where

Y	=	ln gull-hours predation	
X_1	=	sqrt stream flow at Chandler ($t = 5.837$, $p<0.001$)	
X_2	=	1	if $X_1 >$ sqrt 7000 ($t = 2.018$, $p = 0.047$)
		0	otherwise
X_3	=	ln fish passage ($t = -1.378$, $p = 0.172$)	
X_4	=	water temperature ($t = 8.509$, $p<0.001$).	

Turbidity and stream flow were highly correlated ($r = 0.893$, $p<0.001$), although partial correlation showed that each was still correlated with gull-hours of predation when the other was held constant, so I chose to use stream flow in the model.

HORN RAPIDS DAM AND COLUMBIA CANAL BYPASS OUTFALL

The first observation at these two hot spots was made on 14 February. There were no birds observed at that time. Intensive observations began on 25 March, continuing through 24 June with at least one count made 1 day in March, 17 days in

April, 28 days in May, and 17 days in June. Counts were made at least twice on each observation day, with the exception of 25 March, 2, 8, 15, and 18 April, and 23 June (Figure 4). I did not see any predation take place at Columbia Canal bypass outfall; however, at times predators were abundant at Horn Rapids Dam.

Herons were rarely seen at Horn Rapids Dam, with only one great blue heron observed on three separate days (7 April, 11 May, and 29 May). Terns were occasionally seen feeding below the dam. These were Caspian terns, with the exception of one sighting of a Forster's tern on 21 May. Caspian terns were seen on 26 May and 9, 10, 12, 15, 17, 20, and 24 June, but they generally did not remain in the area for long. On two separate occasions, a Caspian tern was observed capturing a salmonid and both times the tern was harassed by gulls trying to steal the fish.

Cormorants visited Horn Rapids Dam more frequently than did terns, with sightings on 8 of 17 days in April (47%), 15 of 28 days in May (54%), and 14 of 17 days in June (82%). The most seen feeding at any one time was five on both 29 April and 15 June; however, more typically there were one or two at a time. On about 4 June, a float was placed approximately 150 m above the dam in the middle of the river to warn boaters about the dam. This float quickly became a common resting spot for cormorants that had been feeding above or below the dam.

As at Chandler Canal bypass outfall, the most abundant predators at Horn Rapids Dam were California and ring-billed gulls; however, the first gull was seen later than at Chandler Canal bypass outfall. Gulls first appeared in low numbers at Horn Rapids Dam on 19 April, building to as many as 23 feeding at one time on 1 May before dropping off again. No gulls were seen from 4 May through 10 May and gulls were rarely seen from 11 May through 18 May. On 19 May, abundance again began to increase, peaking for the season with 90 birds feeding at 10:00 on 22 May. After this, abundance varied around an average count of approximately 10 gulls. On several occasions, gulls were seen feeding on insects on the right-bank access road to Horn Rapids Dam. These were mostly ring-billed gulls with as many as 70 on the road within the 150 m downstream study area of the Horn Rapids Dam hot spot. The total gull-hours of predation for the spring observation period at Horn Rapids Dam was estimated to be 10,602 (SE 225), with daily variations between zero on numerous days and a maximum of 827 (SE 156) on 26 May (Figure 20). A final observation was made at Horn Rapids Dam and Columbia Canal bypass outfall on 16 July. No gulls were feeding at either hot spot, but one Caspian tern was feeding below Horn Rapids Dam. In addition, one cormorant was on the mid-river buoy above Horn Rapids Dam.

The gulls at Horn Rapids Dam primarily fed immediately below the dam in the backwash created by the water flowing over the lip of the dam. Gulls fed by plunge diving into the water at the base of the dam and by hovering down into the froth while continuing to flap their wings. In addition, gulls occasionally fed in the riffle approximately 25 m downriver from the dam. During most of the observation period, the rocks that form this riffle were underwater and the gulls fed from the air. However, near the end of my observation period when the water was low, rocks became exposed and gulls frequently rested on them. At lower water levels, gulls may begin to feed in this area from the rocks.

The daily gull-hours of predation at Horn Rapids Dam was highly variable. For the entire study period (25 March – 24 June), bivariate Pearson correlations relating gull-hours of predation to turbidity ($r = -0.015$, $p = 0.887$), wind speed ($r = 0.092$, $p = 0.378$), and fish passage ($r = 0.169$, $p = 0.106$) were not significant, but water temperature and air temperature were positively correlated with predation ($r = 0.589$, $p<0.001$; $r = 0.442$, $p<0.001$, respectively) (Table 6). Gull-hours was weakly, but not significantly correlated with stream flow at Kiona ($r = -0.202$, $p = 0.052$). When I eliminated the time before gulls were first sighted at Horn Rapids Dam (19 April), several of the bivariate correlations changed. Correlation with turbidity ($r = -0.376$, $p = 0.002$) and stream flow at Kiona ($r = -0.385$, $p = 0.001$) became significant while air temperature became non-significant ($r = 0.042$, $p = 0.737$) and the relationship with water temperature weakened ($r = 0.264$, $p = 0.031$). Correlation with wind speed ($r = 0.035$, $p = 0.780$) and fish passage ($r = -0.141$, $p = 0.256$) remained non-significant. Since stream flow at Kiona and turbidity were highly correlated ($r = 0.866$, $p<0.001$), I also calculated the partial correlation of gull-hours with flow while holding turbidity constant ($r = -0.123$, $p = 0.304$) and for gull-hours with turbidity while holding flow constant ($r = -0.092$, $p = 0.463$).

Although some correlations were not significant, examination of Figure 21 suggests that there was a relationship between daily gull-hours of predation and flow, turbidity, and fish passage. Looking at only the period between 21 April, when birds first arrived, and 9 June, when fish passage dropped off, a likely relationship is apparent. In section 1 of the figure, bird predation followed increasing, then decreasing fish numbers. At the end of section 1, both fish numbers and predation began to increase until the flow reached approximately 8,000 cfs at which point predation dropped down to zero, staying there throughout section 2. This happened even though fish numbers continued to increase. At the end of section 2, the flow again dropped below about 8,000 cfs. When this happened (section 3), bird predation began to increase and remained high until flow rose again toward 8,000 cfs. Throughout the remainder of section 3, predation and flow were negatively related. At the end of section 3, fish passage and predation dropped to a low level. Both remained low throughout section 4 as flow decreased.

Examination of Figure 22 showed that predation increased with flow until approximately 8,000 cfs where it began to decrease. A piecewise regression model using flow, fish passage, water temperature, and an indicator variable to allow a slope change at 8,000 cfs was created to predict bird abundance at Horn Rapids Dam. The model was:

$$Y = -33.4 + 0.073\,X_1 - 0.692[(X_1 - \sqrt{8000})X_2] + 0.020\,X_3 + 0.620X_4$$

$$(F = 7.801,\ p =< 0.001,\ R = 0.579,\ R^2_{adj} = 0.292)$$

where

Y	=	sqrt gull-hours predation
X_1	=	sqrt stream flow at Kiona ($t = 0.906$, $p = 0.368$)
X_2	=	1 if $X_1 >$ sqrt 8000 ($t = 3.958$, $p<0.001$)
		0 otherwise

X_3 = sqrt fish passage ($t = 1.428$, $p = 0.158$)

X_4 = water temperature ($t = 2.305$, $p= 0.025$).

Turbidity and stream flow were highly correlated ($r = 0.866$, $p<0.001$) and partial correlation showed that each was non-significantly correlated with gull-hours of predation when the other was held constant. I chose to use stream flow in the model.

HATCHERY SALMONID ACCLIMATION AND RELEASE SITES

LOST CREEK PONDS

This site was visited on 10 days throughout the spring observation period. The YIN personnel responsible for feeding the coho were present during daylight hours and their activity and that at several nearby houses probably disturbed the avian predators. On only one day did I arrive before YIN personnel. On this visit I saw one great blue heron. The YIN personnel indicated that they frequently observed a heron at the ponds when they arrived in the morning. Also, my limited observations indicated that common mergansers frequently fed in the ponds. On 7 of the 10 days on which counts were made, mergansers were seen either in the ponds or in the Naches River near the ponds. On the one morning that I arrived before the YIN personnel, ten mergansers were in the ponds consuming coho.

YAKIMA GREENWAY

I visited this acclimation site on 5 days and saw no piscivorous birds on any of the visits.

ROZA WASTEWAY #3

Coho were put into this acclimation site at the end of March and avian predators quickly keyed in on the concentration of fish. The first observation was made on the evening of 6 April, slightly more than 1 week after the fish arrived at the wasteway; 15 great blue herons and one great egret (*Casmerodius albus*) were seen at the wasteway.

The peak heron count was 29 on the morning of 14 May. On several occasions, I saw up to two kingfishers in the ponds. In addition, common mergansers preyed on the coho. One evening, I observed 18 mergansers flying out of the acclimation site and smaller groups were seen on other days.

Roza Wasteway #3 was visited by YIN personnel responsible for feeding the coho. In addition, the site was in a cattle rancher's field; cows and the farmer frequently moved around near the wasteway during the day. This daytime activity allowed the herons to feed only at night. As dusk neared, herons would begin to arrive from the direction of the Yakima River and were not seen leaving as it grew dark. Visits at dawn frightened herons out of the wasteway and they flew back toward the Yakima River. Mergansers appeared to be bothered less by the intermittent activity at or near the wasteway and were seen flying in and out of the acclimation site at all times of the day.

CHANDLER HATCHERY

The 1.2 million fall chinook fry that were acclimated at Chandler Hatchery were protected from avian predation by bird netting over the ponds except at the time of release. The three acclimation ponds are connected to the Yakima River by a small outflow creek approximately 1 m wide by 75 m long. The screens on all three ponds were pulled on the afternoon of 29 May and fish were allowed to leave until the following day when the remaining fish were forced out of the ponds in the afternoon. It appeared that the majority of chinook remained in the ponds until forced out.

Gulls responded quickly to the concentration of fish leaving the hatchery. At 10:20 on the morning of 30 May there were 18 gulls feeding from the air at the point where the hatchery creek joined the river. In addition, one great blue heron and two night herons were at this confluence feeding on fry. At 13:00 there were 40 gulls feeding from the air at the confluence and another 20 either on the bank or in the shallows. Some of the gulls on the ground were also feeding on fry. A short time later the number of gulls in the area had increased to about 125. The next day, after all fish had been forced from the ponds, there were no gulls at the outlet creek.

FEEDING AND DIET

GULLS

Gull feeding observations were made at both Horn Rapids Dam and Chandler Canal bypass outfall. No distinction was made between California and ring-billed gulls. Feeding observations at Chandler Canal bypass outfall were made each day from 20 June to 23 June for a total of 7.75 hr for all completed 15-min aggregate observations (Figure 4). Observations at Horn Rapids Dam were more frequent, spanning from 25 April to 24 June. Gull consumption was observed on 2 days in April, 13 days in May, and 15 days in June (Figure 7). Total feeding observation time at Horn Rapids Dam was 37.5 hr for all completed 15-min aggregate observations.

At Horn Rapids Dam, the daily average success rate for feeding gulls ranged from 9.1% on 26 May (SE 2.7%) to 36.2% on 1 May (SE 1.6%) with an overall seasonal average of 22.7% (SE 1.2%). The daily average number of salmonids consumed per gull-hour of predation ranged from 0.24 on 28 May (SE 0.12) to 5.33 on June 20 (SE 1.71) with an overall seasonal average consumption of 2.0 (SE 0.2) fish per gull-hour of predation. Therefore, the estimated total number of salmonids consumed during spring at Horn Rapids Dam was 20,987 (SE 2,285; 4,479, 95% CI), representing 1.7% of the salmonids that passed Horn Rapids Dam (as expanded from CJMF counts and lagged to allow for travel time from Prosser Dam to Horn Rapids Dam) between 25 March and 24 June, the intensive observation period. This consumption was 1.9% of the fish that passed between 19 April (first gulls sighted at Horn Rapids Dam) and 24 June. When only days during which gulls foraged at Horn Rapids Dam were considered (i.e., excluding fish that passed during high water events when no gulls fed at Horn Rapids Dam), that proportion rose to 2.6% of the fish that passed Horn Rapids Dam during that time period. The proportion of spring chinook in the total number of salmonids passing Horn Rapids Dam changed daily and gull predation at Horn Rapids Dam was estimated on a daily basis. Therefore, when the assumption was made that daily gull consumption of all species of fish was in proportion to their relative abundance, spring chinook consumption for the three scenarios above became 0.52%, 1.0%, and 1.2%, respectively, with a total of 1,316 (SE 143; ± 280, 95% CI) eaten during the study period.

The average daily success rate for gulls foraging at Chandler Canal bypass outfall was 28.2% on 20 June, 30.0% on 21 June, 37.8% on 22 June, and 23.2% on 23 June (SE 4.4%, 10.7%, 0%, and 2.7%, respectively). The seasonal average success rate of 29.8% (SE 3.0%) was somewhat larger than that of Horn Rapids Dam (Mann-Whitney test, $p = 0.054$, two-tailed). At Chandler Canal bypass outfall, daily average consumption per gull-hour of predation on the 4 days of feeding observations was 2.76, 2.47, 4.86, and 2.84 (SE 0.89, 0.93, 0, and 0.56, respectively) with a seasonal average 3.23 (SE 1.20) fish consumed per gull-hour of predation. Consumption per gull-hour was significantly higher at Chandler Canal bypass outfall than at Horn Rapids Dam (Mann-Whitney test, $p = 0.016$, two-tailed). The total number of salmonids consumed by gulls at Chandler Canal bypass outfall was 2,607 (SE 501; ± 982, 95% CI), representing 1.1% of the fish that passed unhindered through CJMF (i.e. not retained in the sub-sampler for daily fish passage estimates) between 25 March and 23 June. This proportion increased to 1.2% of the fish that traveled through the bypass between 8 April (first gulls sighted at Chandler Canal bypass outfall) and 23 June and to 3.1% of the fish that passed on days during which gulls foraged at Chandler Canal bypass outfall. The proportion of spring chinook in the total number of salmonids passing unhindered through CJMF changed daily and gull predation at Chandler Canal bypass outfall was estimated on a daily basis. Therefore, when the assumption was made that gulls captured all species of fish in proportion to their relative abundance, spring chinook consumption for the three scenarios above became 0.20%, 0.25%, and 0.72%, respectively with a total of 174 (SE 33; ± 65, 95% CI) eaten during the study period.

Spearman correlations were used investigate the relationship between feeding, gull abundance, and environmental factors. The success rate as estimated from each 15-min group observation of gulls at Horn Rapids Dam was negatively correlated with the number of gulls observed feeding ($r = -0.226$, $p = 0.006$), but the average daily success rate was not significantly correlated with the gull-hours of predation per day ($r = -0.278$, p = 0.136). The 15-min observational success rate was not correlated with time of day (r = 0.010, p = 0.900), and the average daily success rate was not correlated with time of the year (r = 0.305, p = 0.101). In addition, neither measure of success rate (15-min observational or daily) was significantly related to turbidity (r = -0.007, p = 0.934; r = -0.046, p = 0.809, respectively), flow (r = 0.025, p = 0.762; r = -0.056, p = 0.769, respectively), fish number (r = -0.139, p = 0.092; r = -0.178, p = 0.347, respectively), or wind speed (r = -0.138, p = 0.094; r = -0.256, p = 0.172, respectively).

At Horn Rapids Dam, the number of fish consumed per gull-hour during each 15-min feeding observation increased later in the day (r = 0.230, p = 0.004) and was negatively correlated with the number of birds observed feeding (r = -0.193, p = 0.016). In addition, 15-min observational fish consumption per gull was related to turbidity and flow (r = -0.239, p = 0.003; r = -0.228, p = 0.004, respectively), but not to fish abundance or wind (r = -0.066, p = 0.415; r = -0.140, p = 0.084, respectively). Similarly, the average daily fish consumption per gull-hour of predation was negatively correlated with turbidity and flow (r = -0.355, p = 0.054; r = -0.392, p = 0.032, respectively), but unrelated to time of year (r = 0.281, p = 0.132), fish (r = -0.091, p = 0.633), wind (r = -0.279, p = 0.135), or gull-hours of predation per day (r = 0.028, p = 0.884). Predation at Chandler Canal bypass outfall was limited and I only made feeding observations on 4 consecutive days; therefore, I did not investigate correlations as I did for Horn Rapids Dam.

TERNS

Terns were uncommon visitors to the sites I monitored. Feeding observations of Caspian terns were limited to 3 days at Horn Rapids Dam for a total of 74 min, including four 15-min periods, one 10-min period, and one 4-min period. In all, eight feeding attempts were made, two of them successful. Both of the captured fish appeared to be salmonids and both times the fish were caught below the dam. After capturing the fish, the terns were harassed by gulls trying to steal the fish and the terns left the area.

CORMORANTS

Cormorants were only seen consistently on the index area floats and at Horn Rapids Dam. Unfortunately, I was not able to get close enough to them while on index floats to observe predation so the observations were made at Horn Rapids Dam, with two exceptions. As previously mentioned, one cormorant was observed for 15 min at Prosser Dam on 7 April. No fish were caught during 17 attempts. In addition, at Chandler Canal bypass outfall one cormorant was observed making 12 attempts over a 6-min period on 15 April. This bird caught what appeared to be a 10 to 15 cm salmonid.

At Horn Rapids Dam, cormorants were observed on 18 different days for a total of 148 min, including periods of less than 15 min. Although only 3 of 24 observations were for a full 15-min period, I combined data from all 24 for the purpose of this discussion. Over the 148 min of observation, a total of 231 feeding attempts were observed with 15 fish caught. Only three of the fish were identified by the observers as probable salmonids; 11 were non-salmonids and one lacked an identification. All of the fish classified as non-salmonids were judged to be larger than 25 cm and some were quite obviously darkly colored, unlike the silvery salmonids. While it was not possible to calculate meaningful average success rates for cormorants, it should be noted that they appeared to be highly variable. On one occasion, a cormorant made 41 dives over 15 min with no fish captured. However, another time a cormorant landed just below the dam, made one dive, captured and consumed a large non-salmonid, and flew downriver. The total elapsed time was about 30 sec. Behavior such as this makes the 15-min observation period inadequate for assessing cormorant predation.

For the cormorant obtained on 26 May in the Vangie index section, only the intact contents of the stomach were provided. This consisted of a smallmouth bass that was 190 mm total length and weighed 92.2g. Two samples were obtained from the Granger index section, one each on 26 May and 27 May. The first stomach contained only a partially digested chiselmouth (*Acrocheilus alutaceous*) with fork length of 174 mm. The other contained numerous fish and bones. There were three chiselmouth, one of which was intact. The intact chiselmouth had a fork length of 158 mm and weighed 40.9g. This cormorant also had bones from two mountain whitefish (*Prosopium williamsoni*), three suckers (*Catostomus* spp.), and two northern pikeminnow (*Ptychocheilus oregonensis*). There were no salmonids in any of the stomachs.

MERGANSERS

Twenty common merganser stomachs were collected by WDFW from 25 October 1997 through 11 June 1998 (Table 7). The fall/winter samples were taken in the Canyon and Selah index sections while the spring samples were taken in the Canyon, Selah, and Granger sections. One additional sample was collected in the Canyon section on 12 December 1998; it has been combined with the fall/winter Canyon and Selah samples. I examined the data in three separate groups: fall/winter in Canyon/Selah (n = 9); spring in Canyon/Selah (n = 7); and spring in Granger (n = 4). During fall/winter, salmonids made up 42% of the fish and were found in 40% of the stomachs with rainbow trout being the most common salmonid (Table 7). In the same sections in spring, sculpins were the most commonly eaten fish. They were found in 50% of the stomachs and made up 72% of the prey items found. A merganser taken on 6 April had bones from nine sculpins in its stomach. Salmonids occurred in 25% of the stomachs, making up 6% of the prey items found (Table 7). In the Granger section during spring, the most common prey items were chiselmouth, found in 50% of the stomachs and making up 50% of the fish found. Salmonids occurred in 17% of the stomachs, making up 17% of the prey items found; however, this only represents one salmonid found in one stomach (Table 7).

Table 5. Bivariate Pearson correlations for gull-hours of predation at the Chandler Canal bypass outfall.

	Bivariate Pearson Correlation (significance)			
Parameter[a]	Entire Period[b]		After Gull Arrival[c]	
river flow at Chandler	-0.393	(<0.001)	-0.426	(<0.001)
turbidity	-0.235	(0.025)	-0.291	(<0.001)
mean wind speed	-0.059	(0.577)	-0.074	(0.523)
fish passage	0.112	(0.290)	0.087	(0.453)
mean air temperature	0.489	(<0.001)	0.441	(<0.001)
mean water temperature	0.606	(<0.001)	0.595	(<0.001)

[a] variables transformed according to Table 4
[b] for period 25 March – 23 June 1998
[c] for period 8 April – 23 June 1998

Table 6. Bivariate Pearson correlations for gull-hours of predation at Horn Rapids Dam.

	Bivariate Pearson Correlation (significance)			
Parameter[a]	Entire Period[b]		After Gull Arrival[c]	
river flow at Kiona	-0.202	(0.052)	-0.385	(0.001)
turbidity	-0.015	(0.887)	-0.376	(0.002)
mean wind speed	0.092	(0.378)	0.035	(0.780)
fish passage	0.169	(0.106)	-0.141	(0.256)
mean air temperature	0.442	(<0.001)	0.042	(0.737)
mean water temperature	0.589	(<0.001)	0.264	(0.031)

[a] variables transformed according to Table 4
[b] for period 25 March – 24 June 1998
[c] for period 19 April – 24 June 1998

Table 7. Contents of common merganser stomachs expressed as percentage by number of prey items and as percentage of stomachs containing a prey item. Sample sizes are given in parenthesis.

Species	Fall/Winter Canyon and Selah (9)				Spring Canyon and Selah (7)				Spring Granger (4)			
	% stomachs		% by number		% stomachs		% by number		% stomachs		% by number	
chinook	6.7	(1)	15.8	(3)								
rainbow trout	26.7	(4)	21.1	(4)	12.5	(1)	3.1	(1)				
unidentified salmon	6.7	(1)	5.3	(1)	12.5	(1)	3.1	(1)	16.7	(1)	16.7	(1)
Total salmonids	**40.1**	**(6)**	**42.2**	**(8)**	**25.0**	**(2)**	**6.2**	**(2)**	**16.7**	**(1)**	**16.7**	**(1)**
sculpin (*Cottus* spp.)	13.3	(2)	10.5	(2)	50.0	(4)	71.9	(23)				
dace (*Rhinichthys* spp.)					12.5	(1)	18.8	(6)	16.7	(1)	16.7	(1)
smallmouth bass (*Micropterus dolomieui*)	6.7	(1)	5.3	(1)								
northern pikeminnow (*Ptychocheilus oregonensis*)	13.3	(2)	10.5	(2)					16.7	(1)	16.7	(1)
redside shiner (*Richardsonius balteatus*)	6.7	(1)	15.8	(3)								
sucker (*Catostomus* spp.)	13.3	(2)	10.5	(2)								
chiselmouth (*Acrocheilus alutaceus*)									50.0	(3)	50.0	(3)
crayfish (*Pacifastacuss* spp.)	6.7	(1)	5.3	(1)	12.5	(1)	3.1	(1)				
GRAND TOTAL				**(19)**				**(32)**				**(6)**

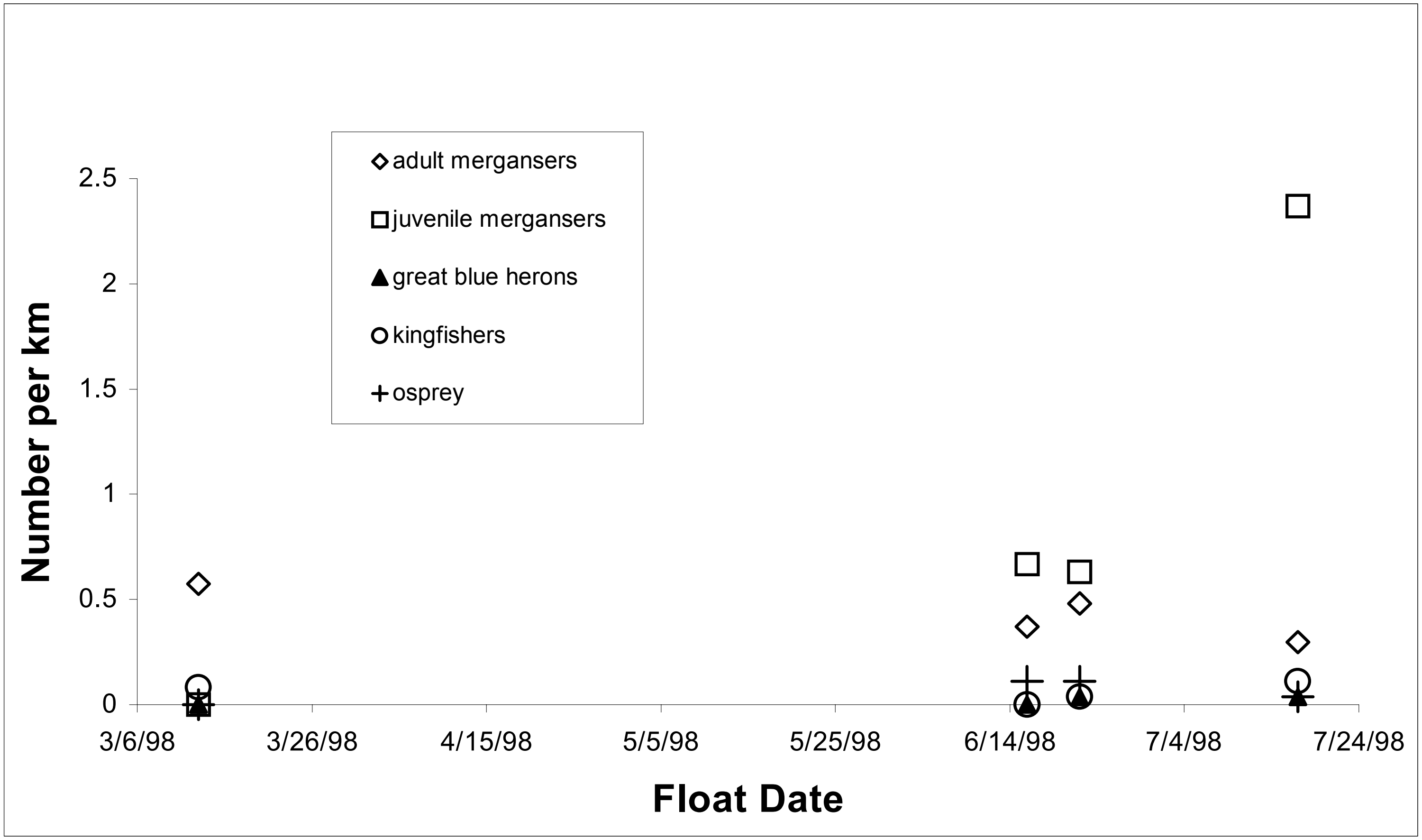


Figure 8. Piscivorous bird abundance in the Cle Elum index section.

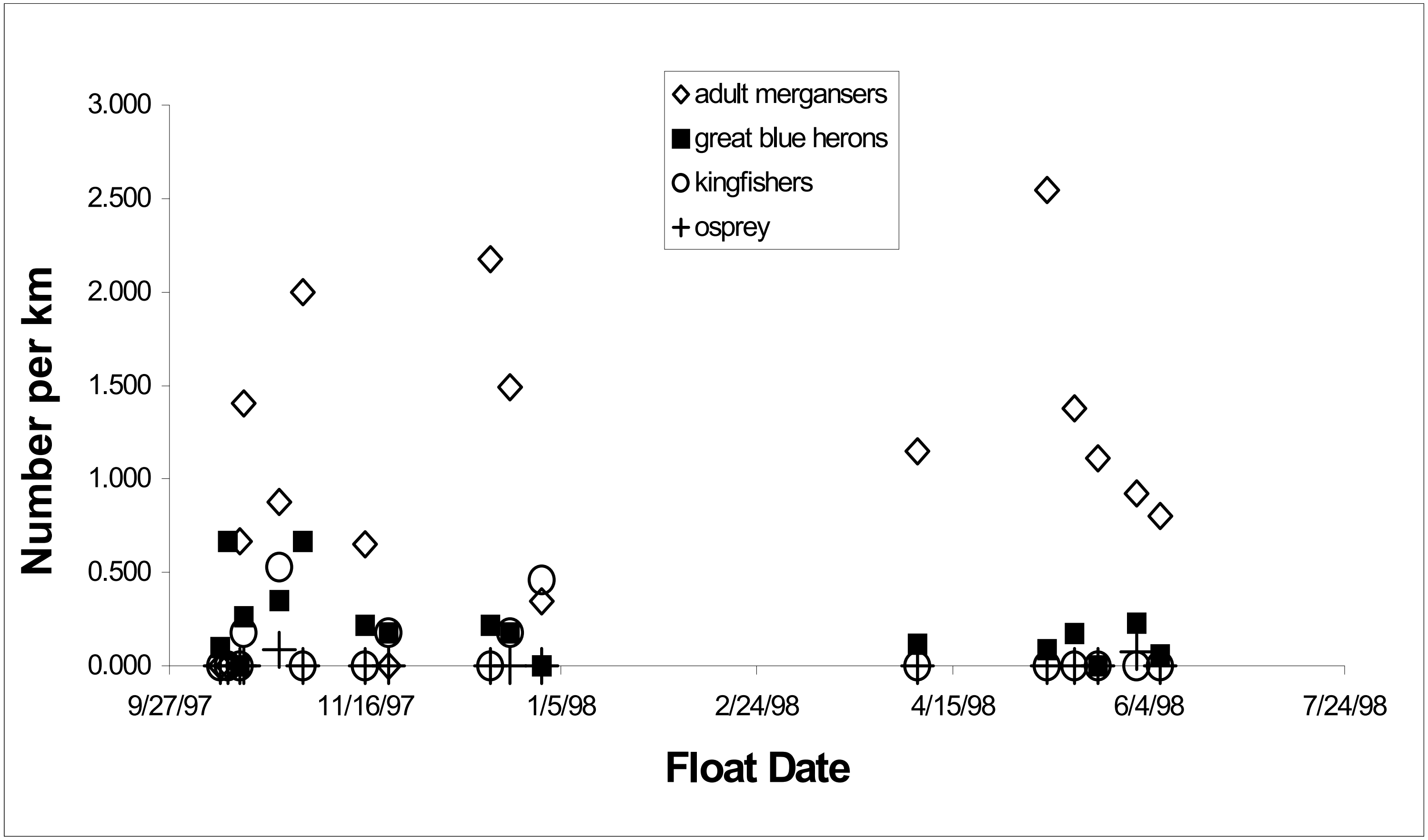


Figure 9. Piscivorous bird abundance in the Canyon index section.

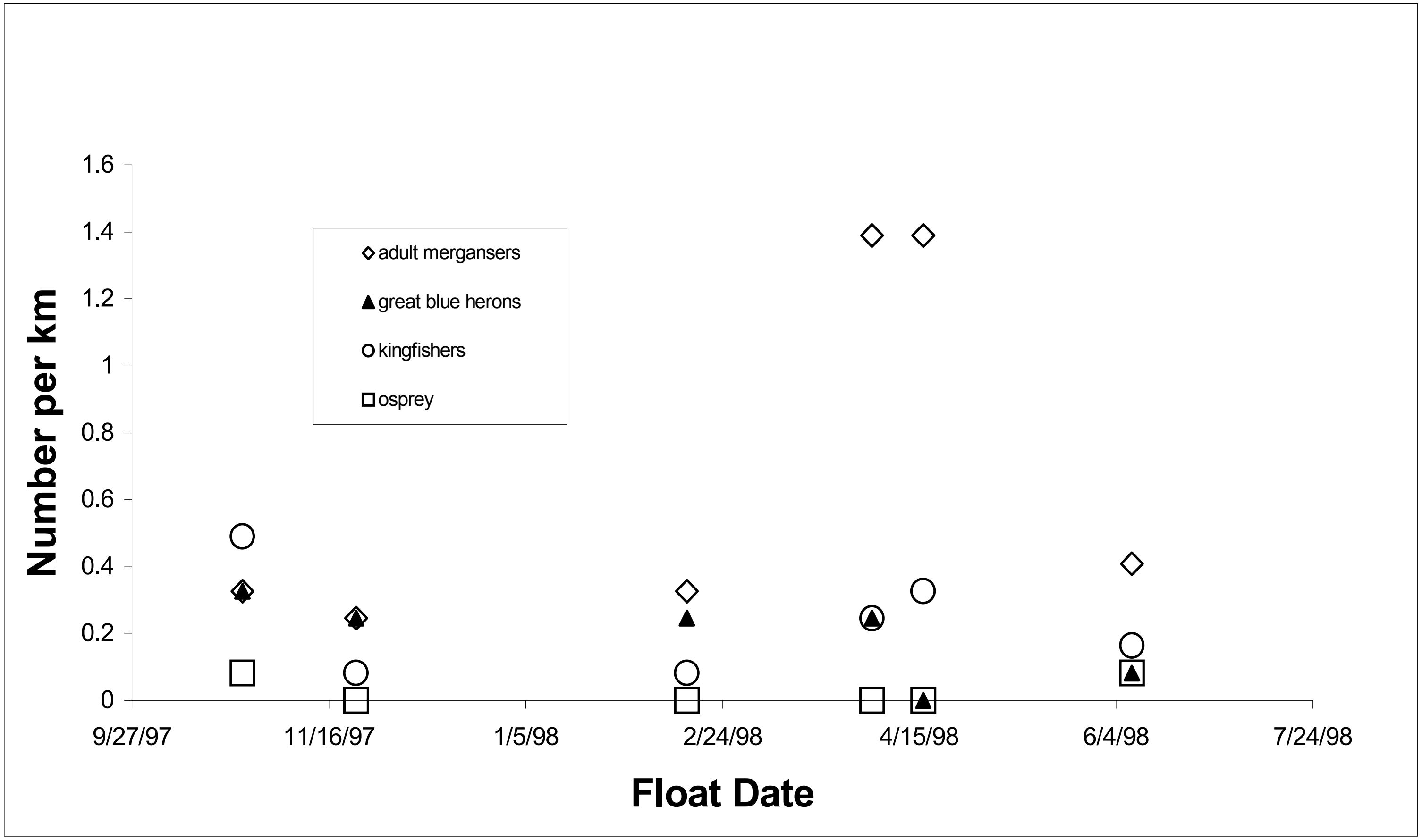


Figure 10. Piscivorous bird abundance in the Selah index section.

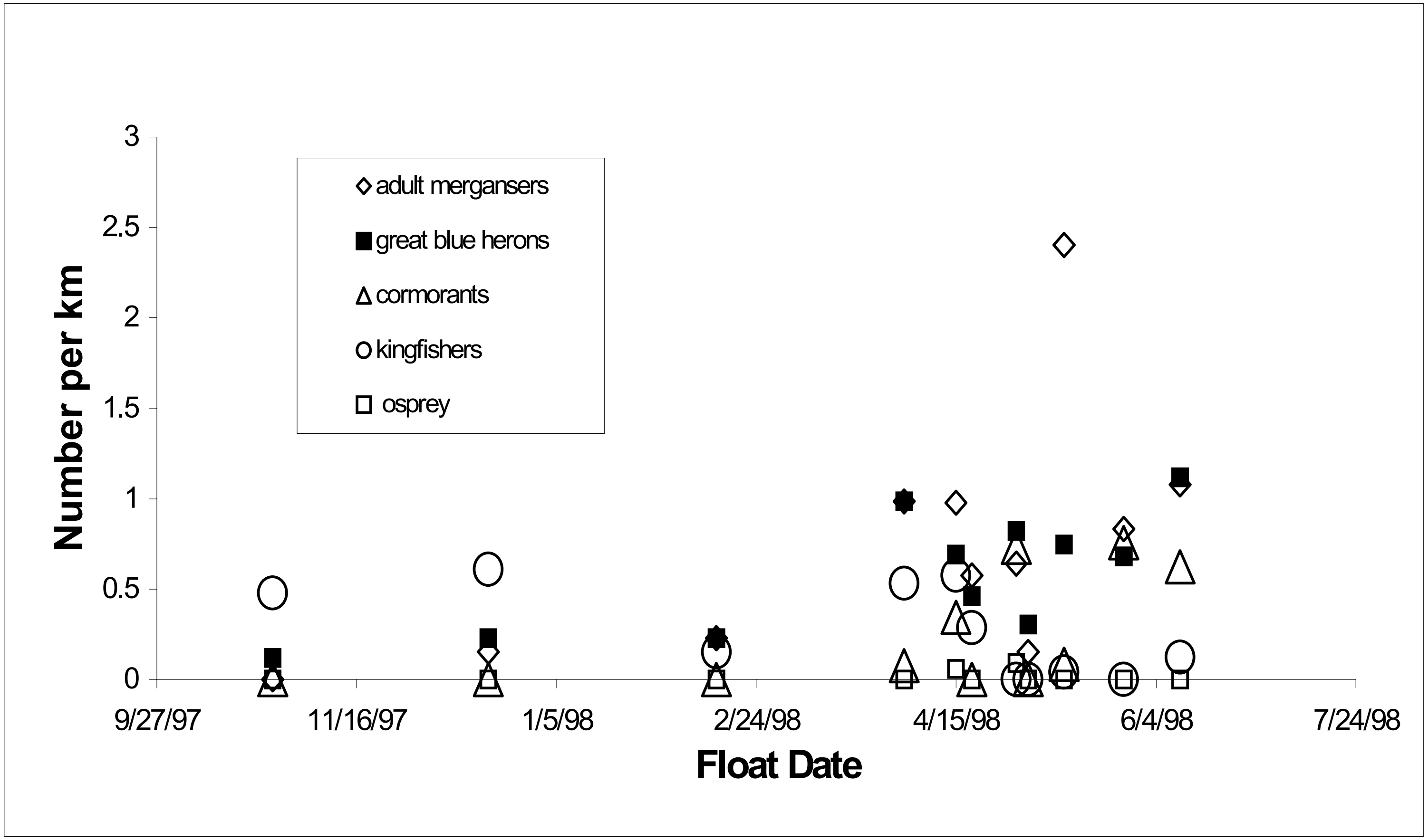


Figure 11. Piscivorous bird abundance in the Granger index section.

Figure 12. Piscivorous bird abundance in the Benton index section.

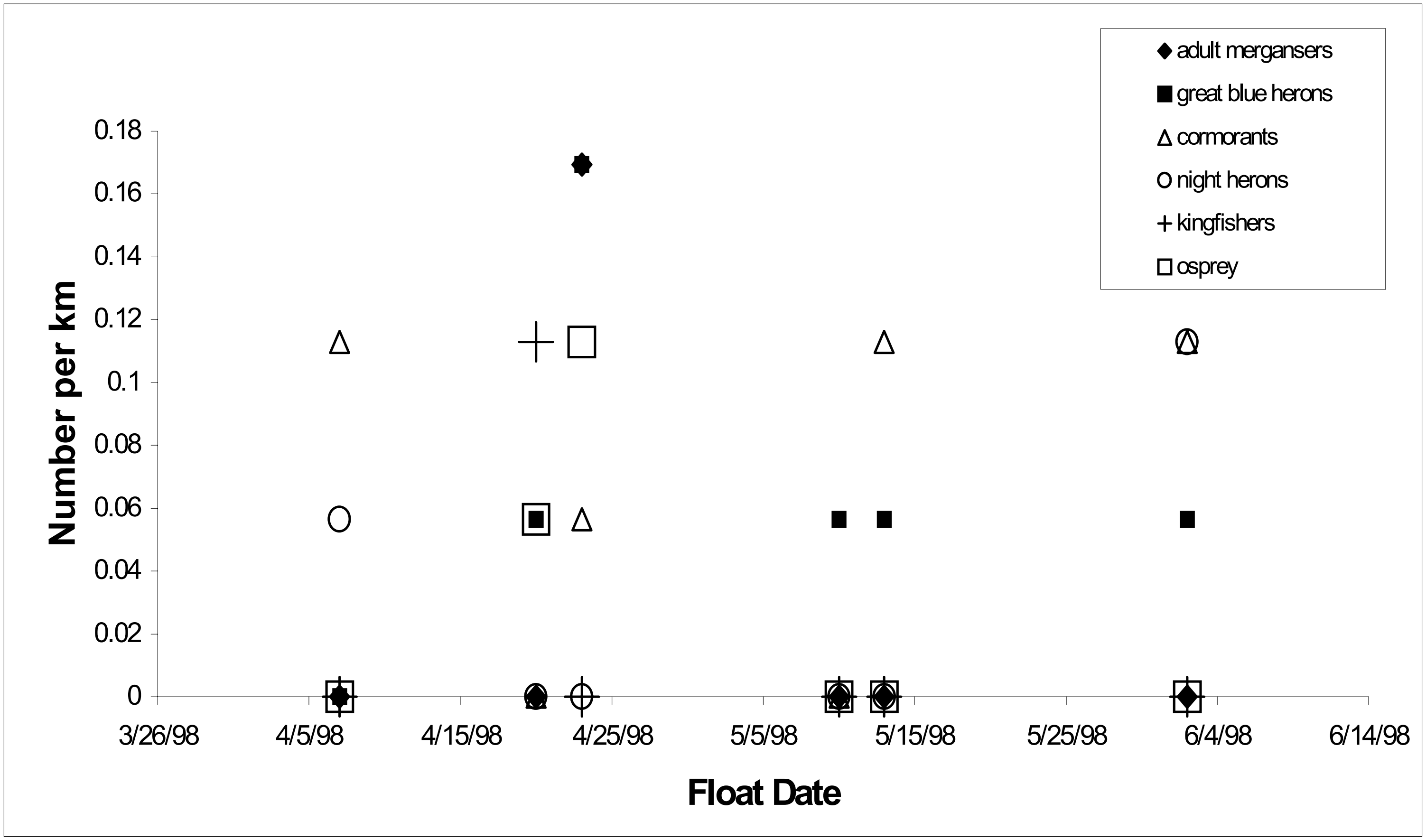


Figure 13. Piscivorous bird abundance in the Horn index section.

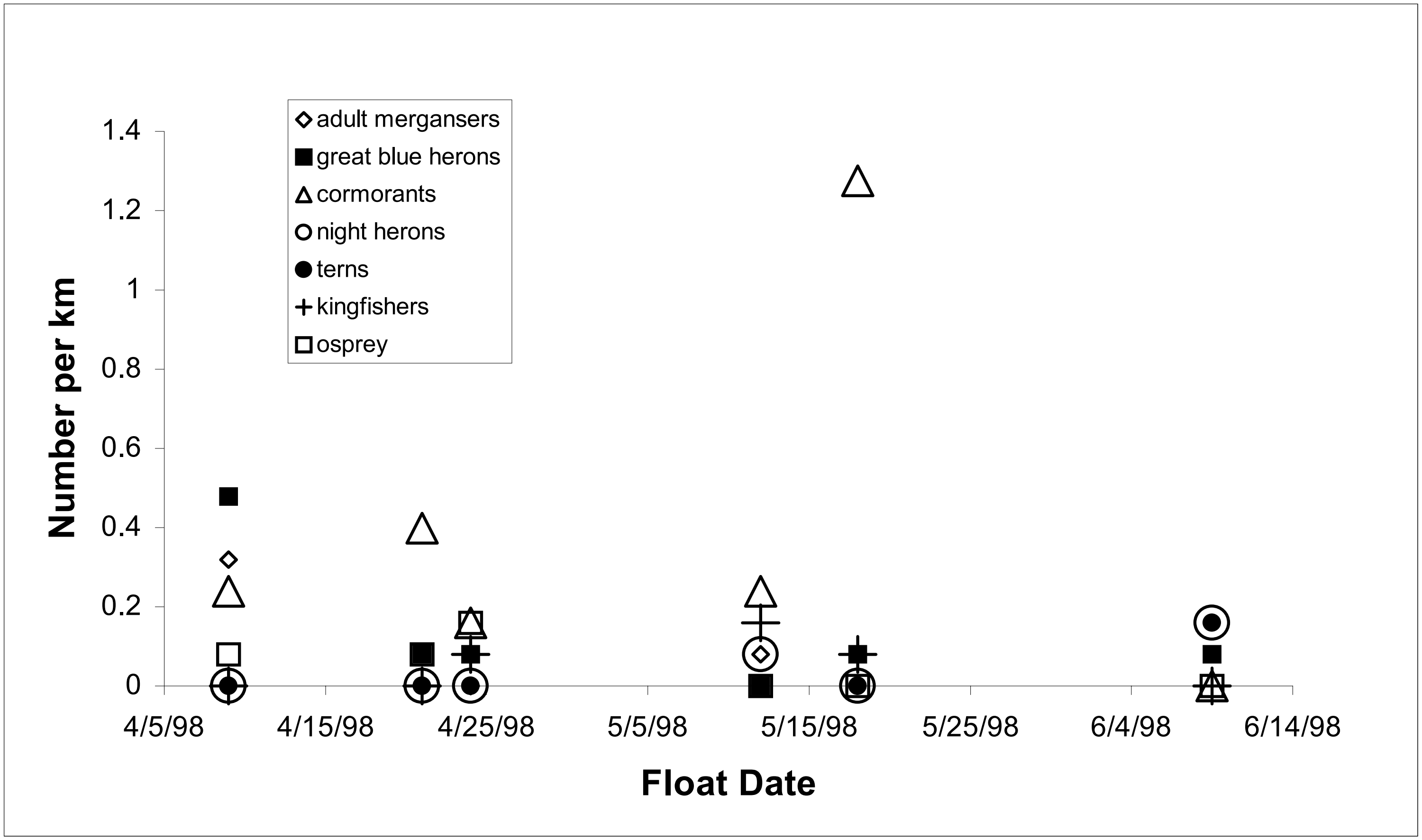


Figure 14. Piscivorous bird abundance in the Vangie index section.

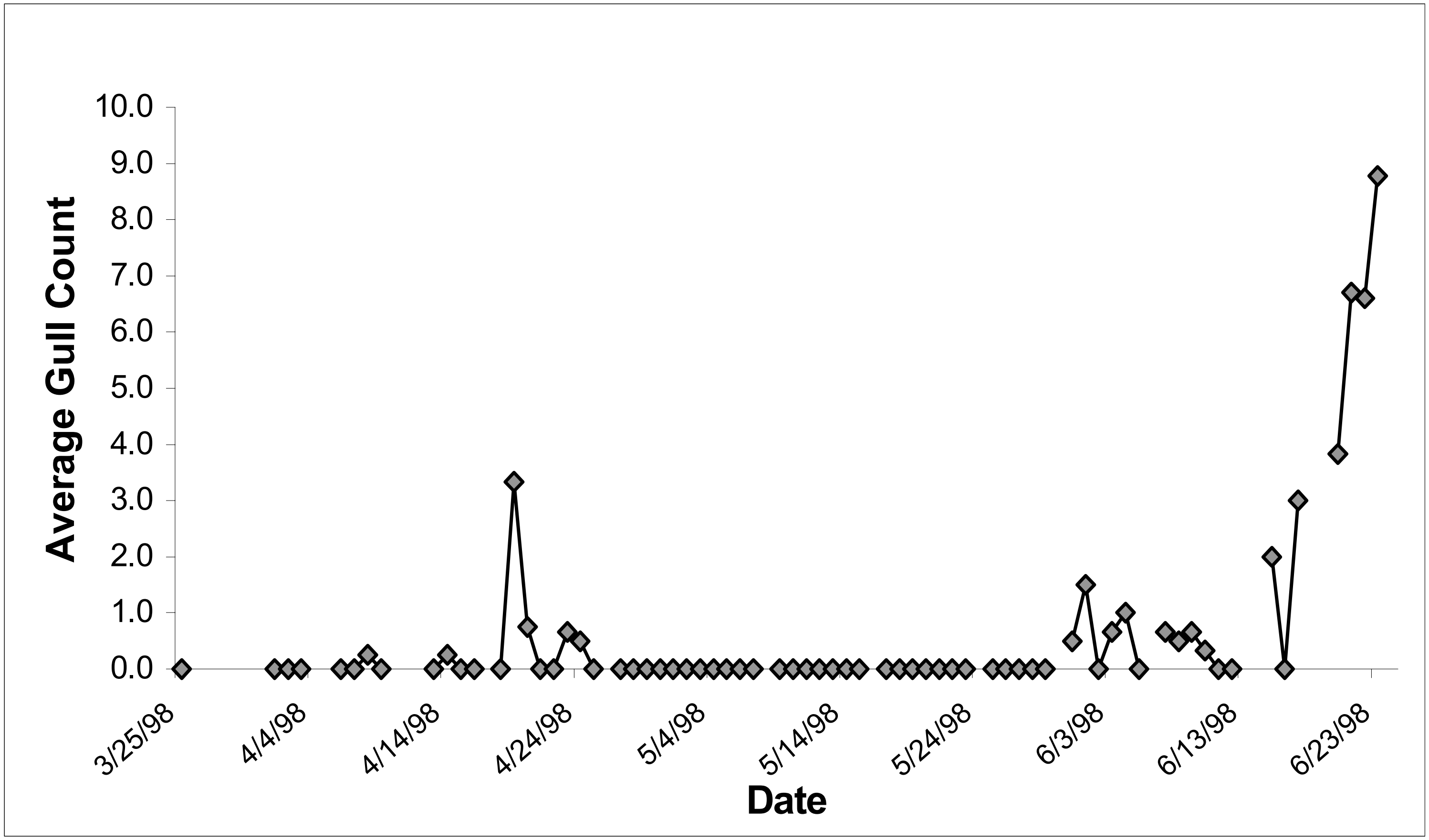


Figure 15. Daily average gull abundance at the Chandler Canal bypass outfall from 25 March through 23 June with blanks for days with no data.

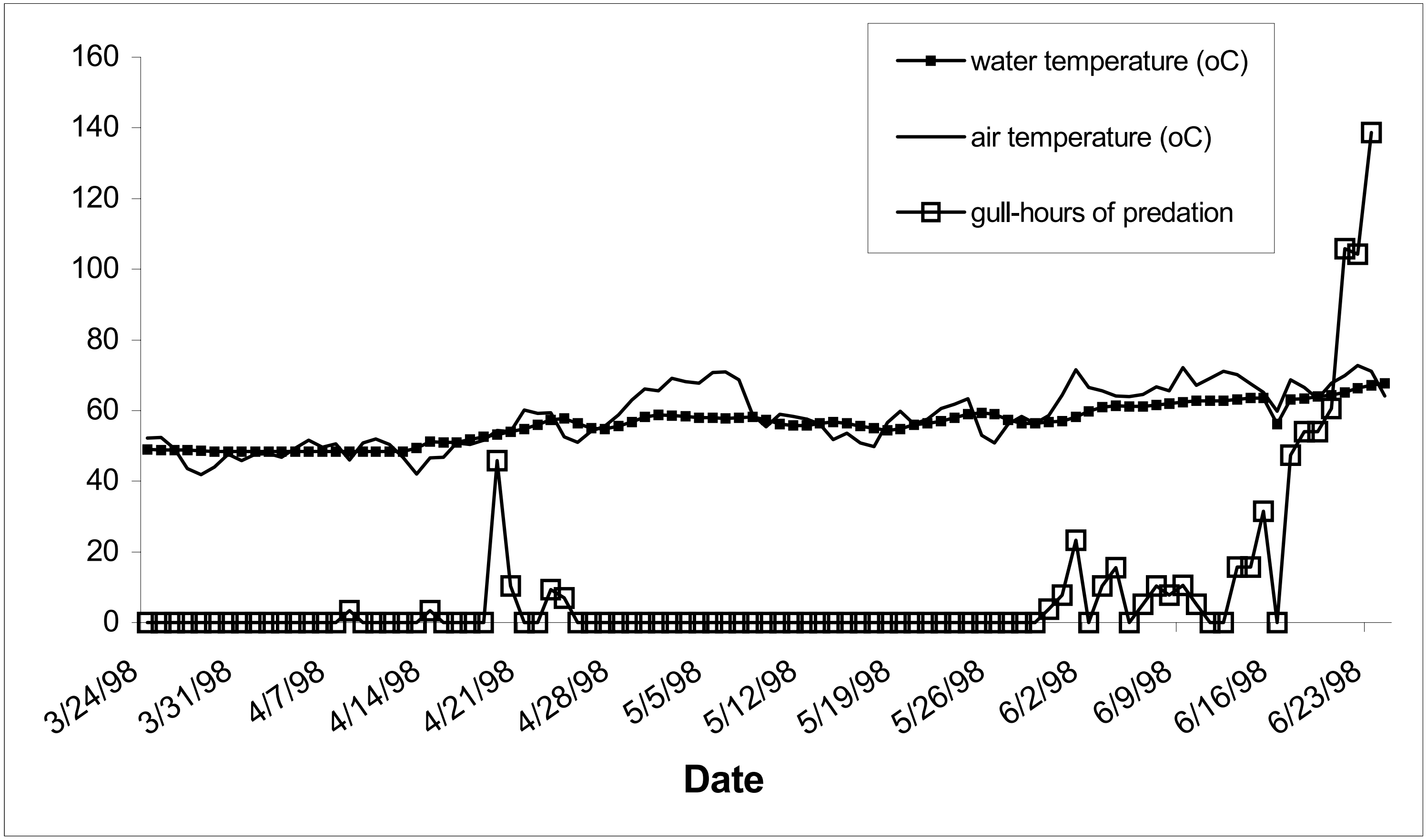


Figure 16. Daily gull-hours of predation, water temperature, and air temperature over the study period at the Chandler Canal bypass outfall.

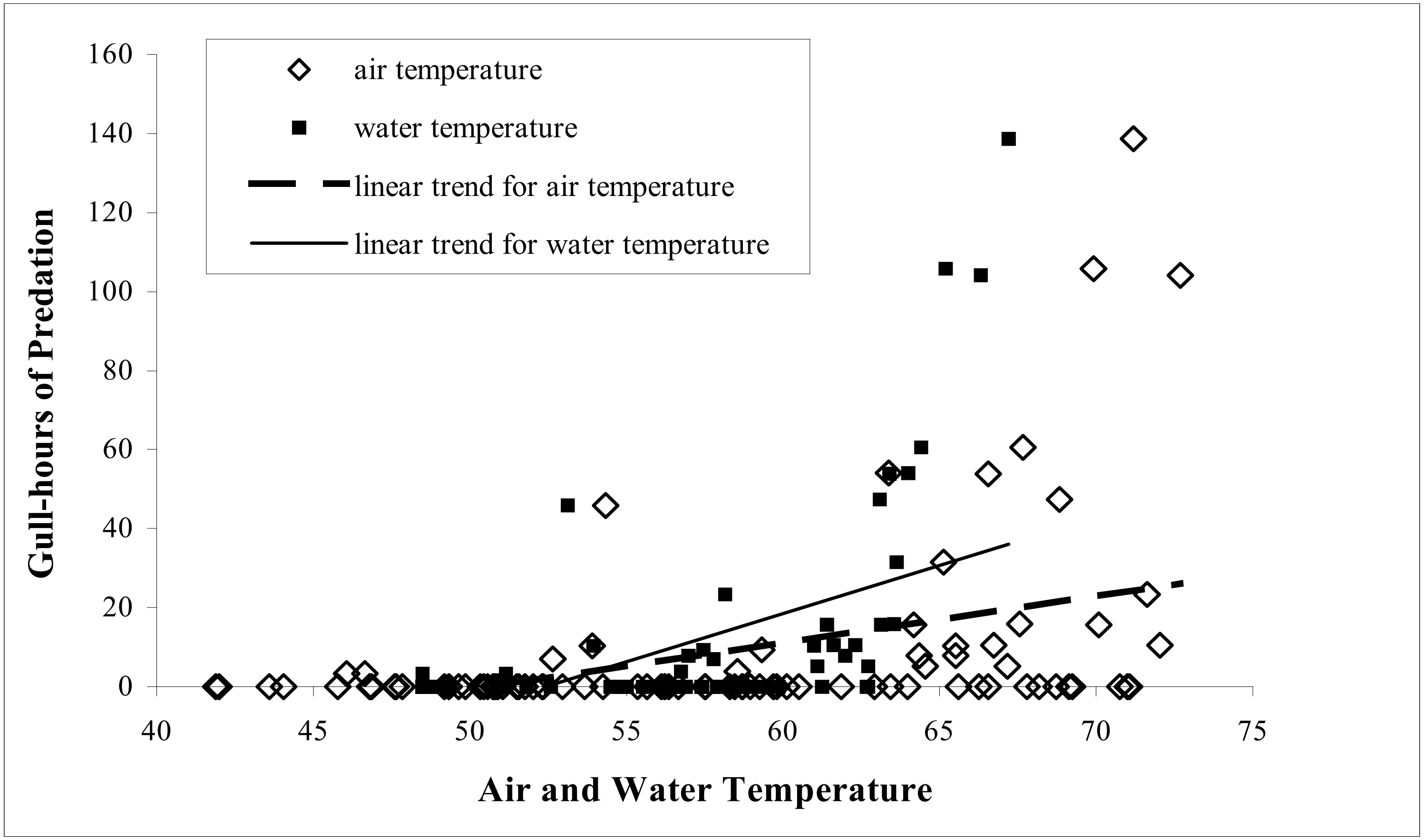


Figure 17. Air and water temperature vs. gull-hours of predation at the Chandler Canal bypass outfall. Trendlines are simple linear regressions.

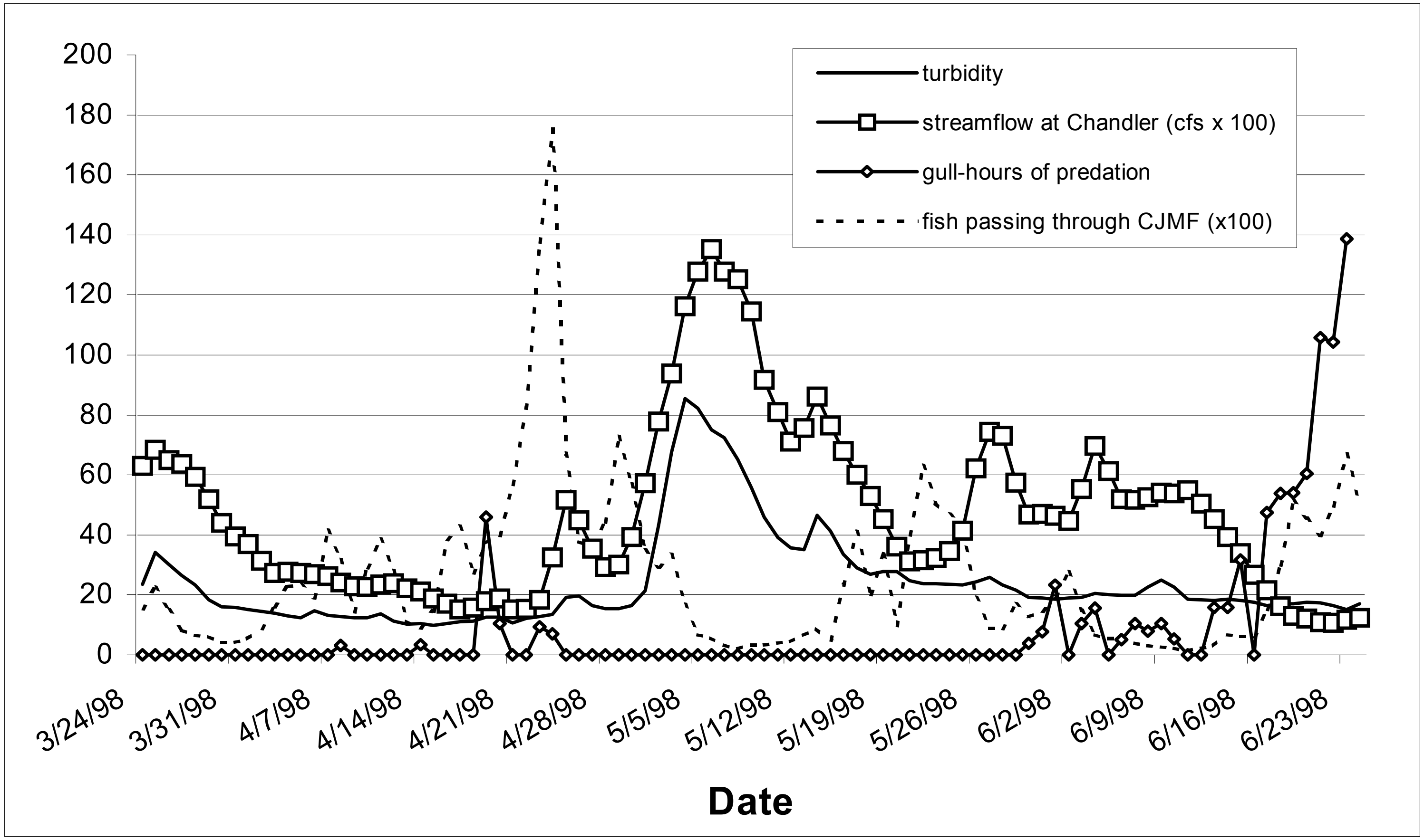


Figure 18. Daily gull-hours of predation, turbidity, streamflow, and fish passage over the study period at the Chandler Canal bypass outfall.

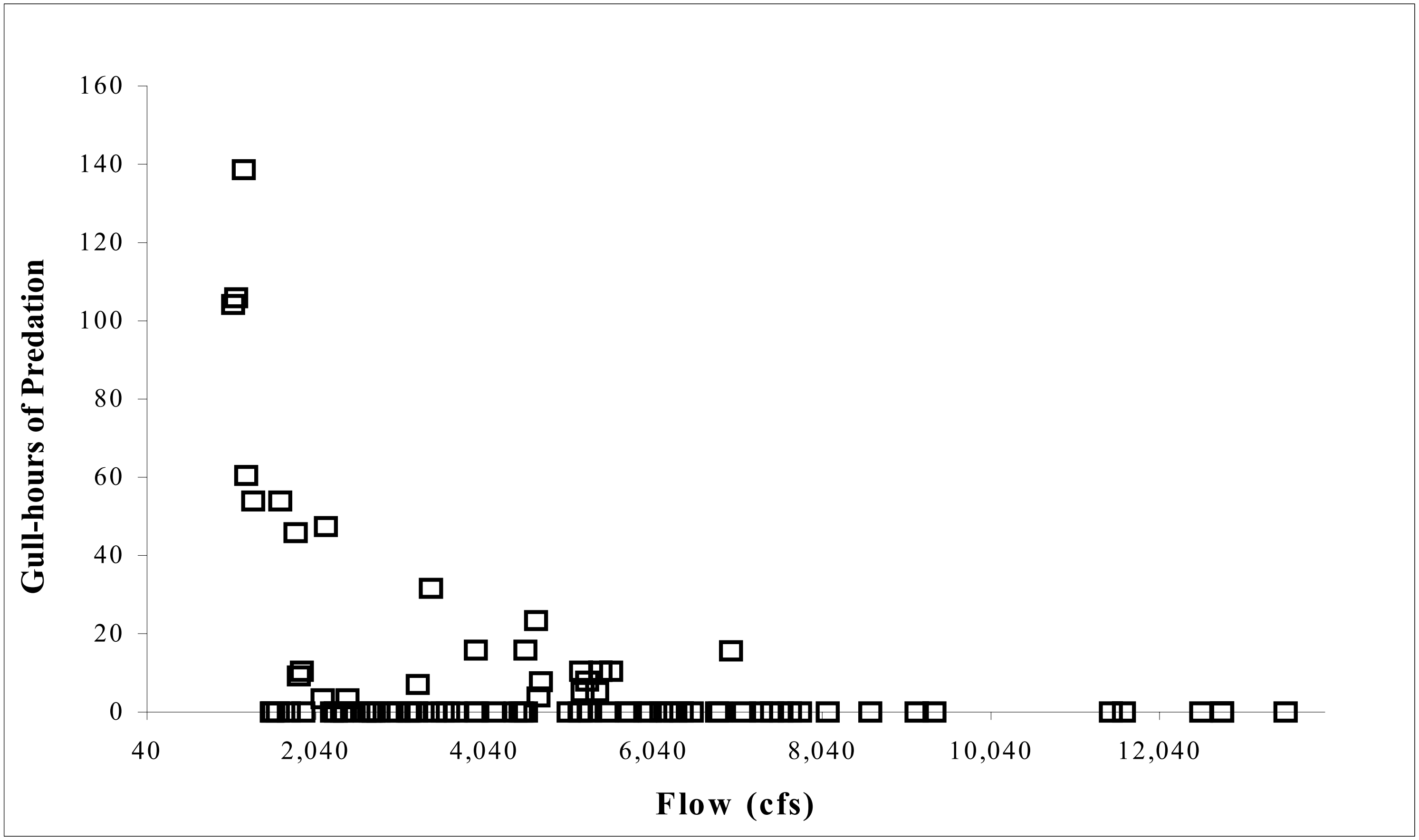


Figure 19. Daily gull-hours of predation vs. stream flow at the Chandler Canal bypass outfall. Gull-hours is natural log (+1) transformed and stream flow at Chandler is square root transformed. Trendline is a loess smoothed curve.

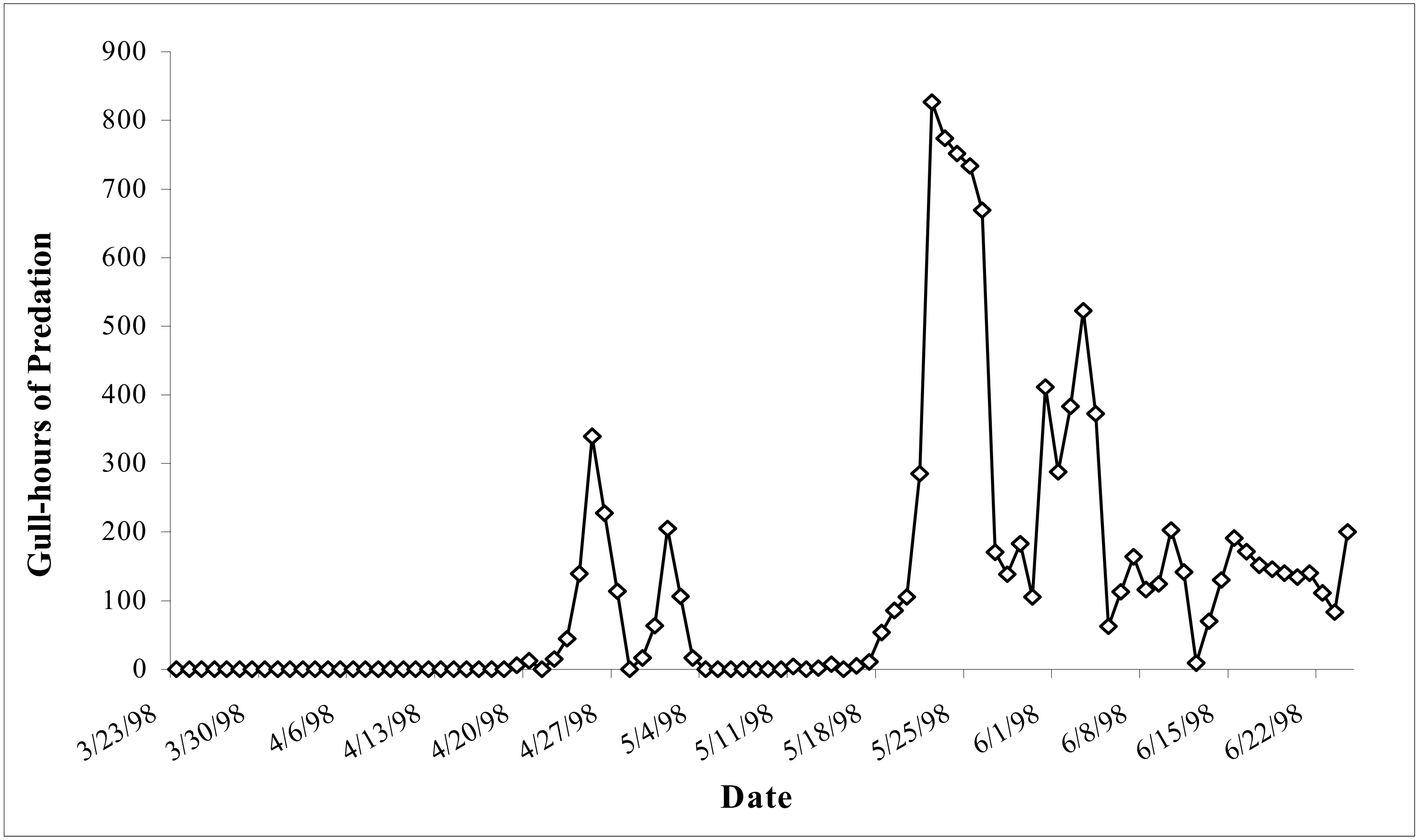


Figure 20. Daily gull-hours of predation at Horn Rapids Dam over the study period

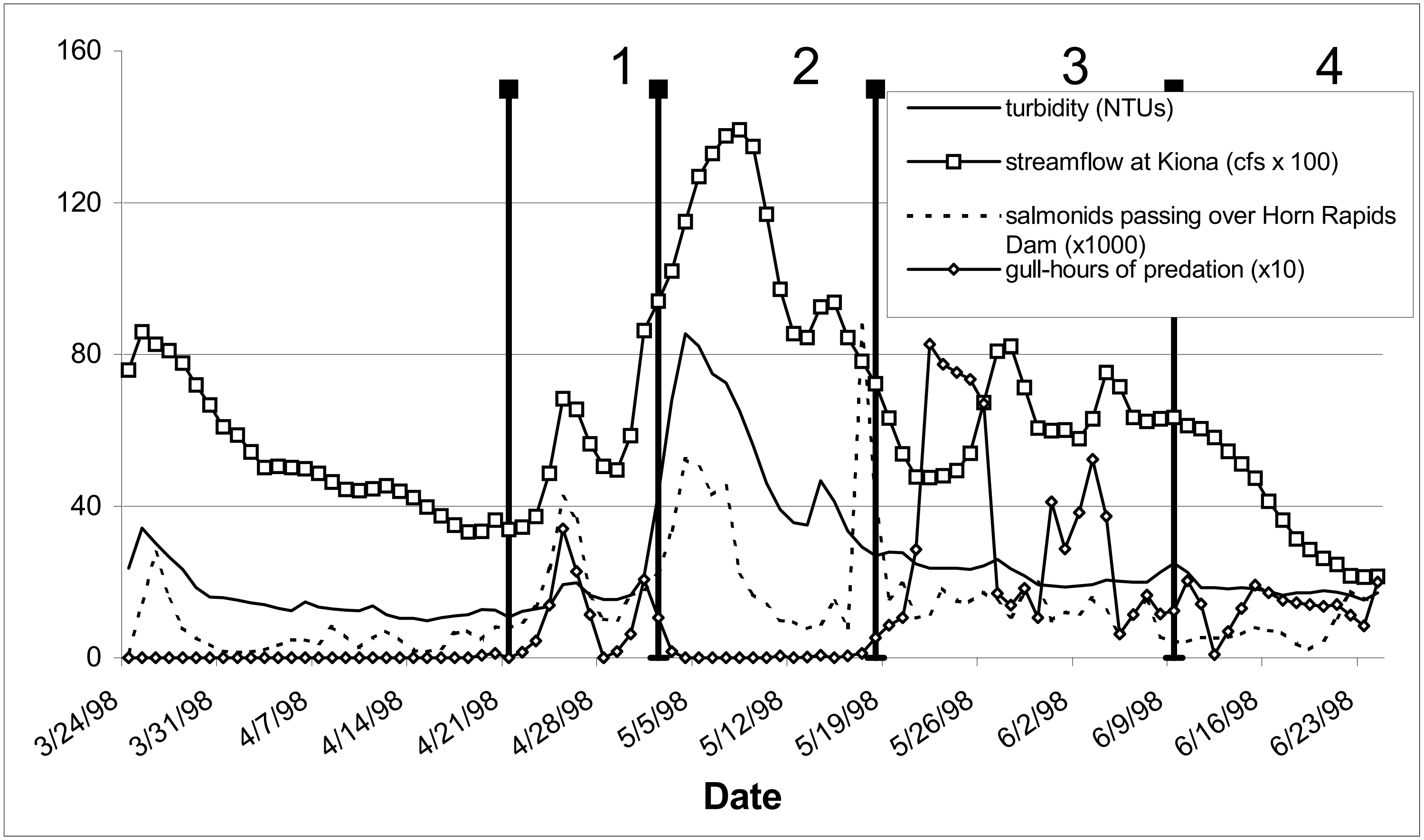


Figure 21. Daily gull-hours of predation, turbidity, streamflow, and fish passage at Horn Rapids Dam. Vertical bars represent four time-period delineations used to illustrate the relationship between the four variables (see text for explanation).

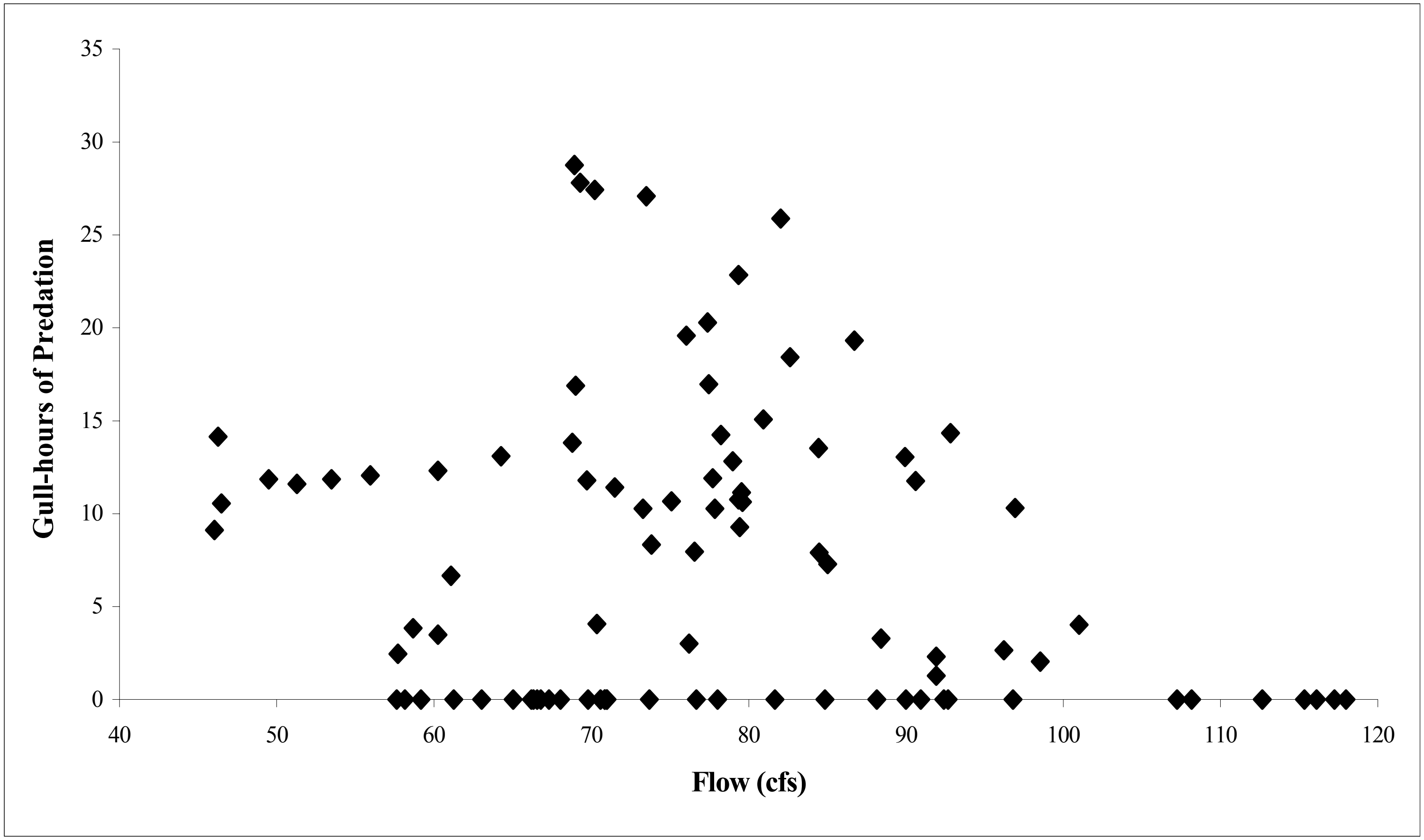


Figure 22. Daily gull-hours of predation at Horn Rapids Dam vs. stream flow at Kiona. Both variables are square root transformed. The square root of 8000 is 89.4 which represents the apparent predation threshold at Horn Rapids Dam on this figure. Trendline is a loess smoothed curve.

DISCUSSION

This report provided a broad overview of avian predation throughout the Yakima River Basin. It examined localized predation at "hot spots" in spring, during juvenile salmonid outmigration, and in long river reaches during rearing and outmigration. Finally, it looked at predation at acclimation sites used for rearing large numbers of hatchery-raised coho and fall chinook. This study also provides a basis for future, more detailed studies of specific piscivorous birds, river reaches, and hot spots. Predation was monitored in free-flowing index areas during juvenile spring chinook rearing and migration, providing insight into the potential impacts of avian predation throughout the Basin and to the seasonal and spatial patterns of abundance of the various piscivorous bird species. In addition, the observations at hot spots helped identify which irrigation diversion dams and smolt bypass outfalls may cause significant avian predation on juvenile salmonids during their outmigration. Finally, the acclimation site observations indicated that different avian predators will respond to large concentrations of fish in different areas of the river. The three parts of this study were designed to focus on predation on juvenile spring chinook since spring chinook are the subject of and intensive restoration effort called the Yakima Fisheries Project; however, the locations and timing are such that predation on other salmonid species can also be assessed.

AVIAN PREDATORS

MERGANSERS

Common mergansers were not observed foraging at any of the hot spots; however, they were observed at least once in each of the index areas (Figure 23). Of the three sections evaluated in the fall and winter, the Canyon index appeared to have had the highest abundance, although it was highly variable, followed by Selah and Granger. This pattern is not surprising since juvenile spring chinook rear throughout the Canyon section in fall/winter and a healthy population of rainbow trout exists in the river in that area as well. Casual observations suggest that, during very cold weather when many local surface waters freeze over, mergansers congregate on the Yakima River. Some of the variability in the Canyon index area could be the result of such cold weather. In spring, the Canyon index area generally supported the highest abundance of mergansers; however, all three of the areas had distinct peaks in spring abundance. These peaks were likely the result of mergansers migrating through the Basin on their way to breeding grounds in the upper Yakima River and elsewhere (T. Hames, YIN, pers. comm.). The three index areas in the lower river always had the lowest merganser abundance, possibly a result of the poor water quality and impaired fish communities that characterize the lower river (Cuffney et al. 1997, Joy and Patterson 1997). In addition, the lower Yakima River is slow moving and often turbid and mergansers prefer to feed in faster moving, clear water (White 1937, 1957; Lindroth 1955).

Mergansers breed in the upper Yakima River and its tributaries during the spring and fledge young during the summer. Most of this breeding appears to occur upstream from Ellensburg, although one female with a brood of six young was observed in the Canyon index section on 7 June. In the Cle Elum index, the highest abundance of juvenile mergansers was 2.4 per km on 17 July, the last float in the area. The largest brood observed with a single female was 16 on 17 July. Female mergansers did not appear to move far when they had broods. Several females with broods (likely the same ones because of brood size) were seen on repeat surveys in the same general areas on two or all three of the spring Cle Elum floats. This site loyalty could result in significant impacts on local fish communities if mergansers that are attracted to the upper Yakima River by releases of juvenile spring chinook from the supplementation hatchery subsequently remain in the area to breed (Wood 1986). Naturally produced spring chinook smolts are generally most abundant below the Granger area in spring, but the hatchery will release smolts in the upper river each spring, expanding the food supply in the area. This new, ample food supply could draw more mergansers to the upper river.

Unfortunately, this food supply will be gone in summer by the time that merganser chicks emerge from nests. Without the buffering of the natural food supply by hatchery fish, these birds could induce high predation on other fish species, two of which are naturally produced spring chinook fry and trout fry and fingerlings. Both of these species are abundant in the upper Yakima River during summer. My observations at Lost Creek Ponds coho acclimation site in the upper Naches River and observations of more than 90 mergansers feeding at a coho acclimation site in the upper Yakima River in spring 1999 (T. Pearsons, WDFW, pers. comm.) suggest that mergansers are the avian predators most likely to prey on spring chinook in upper Yakima River acclimation sites.

Mergansers also keyed in on the coho acclimation site of Roza Wasteway #3. The most observed at any one time was a flock of 18 flying out of the wasteway. I believe it likely that many more than 18 different birds fed in the wasteway. On 6 May a flock of more than 27 mergansers was observed on the Yakima River just downriver from the confluence of Roza Wasteway #3. The attraction of this acclimation site may have influenced merganser counts in the Granger index area since it is located near the river, within the index area.

The stomach content data for fall/winter in the Canyon and Selah areas suggest that mergansers may consume a large number of salmonids, both chinook salmon and rainbow trout. Salmonids were found in 41% of the stomachs, making up 42% of the prey items by number. In the Canyon index section in fall 1993 and 1994, mountain whitefish (30-39%), suckers (15-25%), sculpin (2-15%), and spring chinook (10-26%) were the most abundant species while rainbow trout comprised only 4-9% of the fish assemblage (Pearsons et al. 1996). None of the samples I examined contained remains from mountain whitefish, but I did find two with remains from suckers, making up 10.5% of the prey items by number. Some studies have concluded that on productive salmonid-rearing waters, mergansers tend to select juvenile salmonids over other fish species (Salyer and Lagler 1940, Lindroth 1955, Elson 1962, Alexander 1972), while other studies indicate that mergansers eat whatever fish are abundant (White 1936, 1937, 1957, Munro and Clemens 1937, Lindroth 1955, Mills 1962, Timken and Anderson 1969, Wood 1987*a*).

In the spring, salmonid consumption was lower, with sculpin and dace as the major prey items. Typically, by spring most of the spring chinook have moved through the Canyon and Selah areas and are found further downriver. In the Granger section in spring, only one salmonid was found in a merganser stomach. This is somewhat surprising since coho were being acclimated in the vicinity of the Granger section in Roza Wasteway #3 and mergansers were observed flying in and out of the acclimation site. Also, spring chinook would have been moving through the area, as well as coho released from upriver acclimation sites.

Mergansers consumed rainbow trout in a higher proportion than their abundance in the fall/winter in the Canyon/Selah index areas, assuming that species assemblages in 1997 were similar to those in 1993-1994. Researchers have pointed out that prey abundance does not necessarily equate to prey availability (Kelly 1996). Wood and Hand (1985) found that mergansers were less successful at capturing coho smolts and fry in stream enclosures with cover from undercut banks than they were in enclosures lacking such cover. The preference of a predator is influenced by its attack capability, the prey's escape mechanisms, and protective cover (Rapport and Turner 1970). Sjöberg (1988) found that when different species of fish were presented to hungry mergansers in a small trough where the prey was easily and equally available, the mergansers showed no preference in prey selections. However, when the same fish species were presented to satiated birds, they showed definite preferences; the most preferred species were baltic salmon (*S. salar*) and brown trout (*S. trutta*) followed in decreasing order by minnows (*Phoxinus phoxinus*), whitefish (*Coregonus lavaretus*), sculpin (*C. gobio*), burbot (*Lota lota*), and river lamprey (*Lampetra fluviatilis*). Under semi-natural conditions in a stream tank, the number of each species caught was related to their escape behavior, not to the previously determined predator preferences. Mergansers were found to search randomly for prey in substrate cavities. This searching allowed the birds to capture hidden prey or force them to leave their shelter, making them more vulnerable to attack. Trout were caught less often than salmon because they reacted to predator disturbance by quickly switching to a new hiding place. In contrast, salmon tried more often to escape by swimming through open water where they were usually caught; however, open water oriented species, such as grayling (*Thymallus thymallus*), were caught in greater numbers when available. My finding that rainbow trout were caught by mergansers in a higher proportion than their abundance suggests that mergansers were feeding preferentially on rainbow trout, although the sample size is small.

GULLS

Unlike mergansers, California and ring-billed gulls were not observed feeding during any of the index area floats. They were, however, common predators at the hot spots of Chandler Canal bypass outfall and Horn Rapids Dam, consuming approximately 2,607 (± 982, 95% CI) and 20,987 (± 4479, 95% CI) juvenile salmonids, respectively. I believe that the gulls feeding at both locations originated from the nearby breeding colonies. The arrival of the gulls coincided with the onset of the nesting season in mid-April (Roby et al. 1998). No gulls were seen during late winter observations or during early spring observations, although the streamflow was relatively low and many fish were already outmigrating (Figure 24). It seems likely that there would have been gulls feeding during this time if local, resident gulls were the predators at Horn Rapids Dam and Chandler Canal bypass outfall.

The peak 1998 count was 90 gulls at Horn Rapids Dam, a small fraction of the total breeding population of nearly 80,000 gulls on the three nearby Columbia River colonies. This suggests that the majority of the gulls were feeding elsewhere. Predation abatement measures at nearby dams have been somewhat successful in eliminating gull consumption of outmigrating salmonids (Steuber et al. 1993). Roby et al. (1998) studied diet composition of gulls breeding at the three nearby colonies. He found no fish in ring-billed gull diets at Crescent Island, Island 18, and Richland Island and only a small proportion by mass in California gull diets at the same colonies (2%, 3%, and 0%, respectively). None of the fish were salmonids. The diets of both species were mainly composed of mollusks, insects, vertebrates (non-fish), plant matter, and refuse. These results coincide with casual observations during the study period of large numbers of gulls in agricultural fields and at Horn Rapids Dam eating insects along the gravel access road.

The question then arises as to why gulls did not prey more heavily on fish at both Horn Rapids Dam and Chandler Canal bypass outfall. The simplest reason was that foraging must have been more productive at locations other than Horn Rapids Dam and Chandler Canal bypass outfall. However, at times, gulls did forage at both locations; therefore, at times, Horn Rapids Dam and Chandler Canal bypass outfall must have been equal to, or more productive than, other foraging locations for gulls. What limited foraging at these hot spots? One possibility was the number of gulls that were foraging at a given time. The Horn Rapids Dam data showed a significant, negative correlation between observational success rate and the number of gulls feeding. In addition, the number of feeding attempts per gull decreased as the number of gulls increased. Therefore, not only did the success rate decrease as gull numbers increased, but fewer feeding attempts were also made per bird. The combination of these factors may have decreased the productivity of Horn Rapids Dam to the point where the birds were better off foraging elsewhere, thereby serving to limit the number of foraging gulls at Horn Rapids Dam. Optimal foraging theory suggests that birds should concentrate their foraging efforts where there is abundant, easily obtained, and high quality food (Schoener 1971, Krebs et al. 1981). As the number of gulls increased at Horn Rapids Dam, the availability of fish might not have been high enough to support the increased level of predation. In this situation, gulls would be expected to depart for more productive feeding areas.

Decreased feeding success with increased bird numbers is opposite that found by other researchers for seabirds. Götmark et al. (1986) found that individual success of feeding black-headed gulls (*L. ridibundus*) increased with flock-size up to at least eight gulls. Also, seabirds are known to form large mixed species feeding flocks, sometimes with more than 50,000 birds, to exploit concentrations of food (Sealy 1973, Hoffman et al. 1981). Sealy (1973) recorded 70-100% success rates for Glaucus-winged gulls (*L. glaucescens*) feeding in such flocks in marine waters off Alaska and Washington. This success rate is much higher than I observed for gulls at both Horn Rapids Dam (daily average range from 9.1% to 36.2%, mean 22.7%) and Chandler Canal bypass outfall (daily average range from 23.2% to 37.8%, mean 29.8%). In addition, the Horn Rapids Dam and Chandler Canal bypass outfall success rates were lower than other researchers have found for gulls foraging below mainstem Columbia River dams. Ruggerone (1986) recorded an average success rate of 65% during bright light conditions and 51% during low-light conditions for gulls foraging below Wanapum Dam. The success rate for gulls foraging below Bonneville Dam in spring 1995-1997 ranged from 35.4% to 47.6 (Jones et al. 1998). The rate for gulls foraging below John Day Dam during the same time-period ranged from 34.9% to 65.9% (Jones et al. 1998).

Gull numbers at both hot spots appear to have been limited by flow and turbidity. Nearly all of the gulls at Chandler Canal bypass outfall foraged from the air, taking advantage of the design of the submerged pipe that returns fish to the river. This pipe extends from the left bank out into the river about 8 m with a 90° bend upward near its terminus. This effectively pushed the juvenile fish toward the surface of the river. At low flows, the outlet looked like a small geyser with water bubbling as high as a meter. Gulls circled this “geyser”, plunging into the water when they saw fish. In addition, the area immediately below Chandler Canal bypass outfall had numerous exposed rocks at low flows. Gulls were occasionally observed resting on these rocks and then jumping into the water to grab fish. This predation was not factored into the calculated gull-hours of predation; however, flows during spring 1998 were rarely low enough for these rocks to be sufficiently exposed for birds to perch on them. Therefore, this predation would have made only a slight contribution to the calculated seasonal gull-hours of predation.

The apparent predation threshold of approximately 4,000 cfs at Chandler Canal bypass outfall is logical when the structure of the pipe is considered. Gulls relied on fish being forced to the surface of the river where they were able to capture them. When flow increased, the water was deeper over the pipe and likely flowing more rapidly. At this point, the force of the water exiting the pipe was not strong enough to push fish to the surface of the deeper, faster flowing river. Thus, predation by the surface feeding gulls was thwarted. In addition, since turbidity was significantly correlated with flow, gulls were also unable to see the fish that come out of the pipe. As flow and turbidity decreased, gulls were again able to forage.

At Horn Rapids Dam, there was a predation threshold at approximately 8,000 cfs. At certain flow levels, water flowing over a low-head dam, such as Horn Rapids Dam, plunges downward, creating a void or depression. Water downstream from the dam flows upriver to fill this depression, creating a backwash at the base of the dam. This recirculating motion is apparent when one watches a log stuck in a low-head dam; the upriver current can be quite strong and the log surfaces slightly downstream from the dam only to be drawn upriver again. Undoubtedly, fish passing over the dam were also affected by this recirculation. They were caught in the backwash and recirculated up to the surface where gulls took advantage of their vulnerability. The apparent predation threshold of 8,000 cfs could be the result of a breakdown in the recirculating motion of the water at the base of the dam. As the flow rose, the current patterns that favored gull predation broke down. Also, turbidity was highly correlated with flow ($r = 0.839$, $p<0.001$) so visibility declined dramatically at high flows. The combination of these two factors would make it difficult for gulls to spot fish.

In addition, the average daily fish consumption per gull-hour of predation decreased significantly with increased turbidity and flow at Horn Rapids Dam. This appeared to be the result of decreased daily average feeding attempts per gull since the daily average feeding success rate was not significantly correlated with either flow or turbidity. Interestingly, this implies that gulls do not become less successful at foraging when flow and turbidity increase. They simply do not make as many feeding attempts.

Daily gull-hours of predation, daily average success rate, daily average attempts per gull, and daily average fish consumed per gull-hour of predation were not correlated with the number of fish passing over Horn Rapids Dam. However, Figure 21 suggests that a relationship existed between daily gull-hours of predation and fish abundance.

This was supported by a significant positive correlation between gull-hours of predation per day and fish abundance on the days that I made feeding observations ($r = 0.364$, $p<0.001$). Thus, the confounding effects of bird absence during high flow events, turbidity, and bird absence at the beginning of the season have been removed. Therefore, the productivity of Horn Rapids Dam for gulls was not only affected by flow and turbidity, but also fish abundance.

The relationship between predation at Horn Rapids Dam and turbidity and flow becomes important when the 1998 Yakima River hydrograph is compared to long-term mean daily flow and to 1992, an unusually low flow-year (Figure 25). The graph shows that 1998 was an above average flow-year as compared to the long-term daily mean, yet gulls at Horn Rapids Dam consumed 20,987, or 1.2%, of the fish that outmigrated during the study period (25 March to 23 June). With elimination of fish that outmigrated on days before gulls arrived at Horn Rapids Dam and on days that gulls did not forage due to high flows (above the threshold of about 8,000 cfs), that consumption rose to 3.1% of the fish that were available to foraging gulls. This gives some indication of the level gull predation that may occur at Horn Rapids Dam during a year when flow does not limit foraging. This percentage was slightly higher than the estimated gull consumption below Wanapum Dam of 2% of the spring migration in 1982 (Ruggerone 1986)

Still, on many of the days that gulls did forage, flows were high and gull abundance was low. In addition, gulls that did forage on high flow days caught fewer fish per gull-hour of predation. I believe that gull consumption as a proportion of outmigrating fish would be much higher in low-flow years, such as 1992. The peak flow that year was only about 4,000 cfs, half of the Horn Rapids Dam predation threshold of about 8,000 cfs. However, given that spring chinook outmigration peaked before gulls arrived at Horn Rapids Dam in 1998 (Figure 24), gulls still may not consume large numbers of these fish in low-flow years. It is likely that similar relationships between gull abundance, feeding, flow, and turbidity would hold for Chandler Canal bypass outfall, although they were not evaluated in 1998 due to lack of data.

The percentage of outmigrating salmonids consumed by gulls at Horn Rapids Dam may be an overestimate. A significant proportion of the Yakima River fall chinook population spawns between Prosser Dam and Benton City. The fish passage numbers obtained at CJMF cannot enumerate the fall chinook fry that originate from spawning below Prosser Dam. These fry will pass over Horn Rapids Dam and be available for consumption by foraging gulls. The fish passage data generated at CJMF also does not include any non-salmonids moving downriver. During feeding observations at Horn Rapids Dam I assumed that all silvery fish were salmonids, but this may not be the case. Other fish such as chiselmouth (*Achrocheilus alutaceous*), northern pikeminnow (*Ptychocheilus oregonensis*), and peamouth (*Mylocheilus caurinus*) can also appear silvery and all are found in the Yakima River (Wydoski and Whitney 1979). These would be difficult to distinguish from salmonids over the distance between the observer and the foraging gulls; therefore, it is likely that some captured non-salmonids were classified as salmonids. In calculating the percentages I did not adjust for mortality of salmonids between CJMF and Horn Rapids Dam. This mortality would decrease the number of fish passing over the dam, thereby increasing the true percentage of outmigrants consumed by gulls. However, without conducting a study of gull stomach contents, fall chinook fry production below Prosser Dam, and fish mortality between CJMF and Horn Rapids Dam, this was the best estimate of consumption available.

There is no doubt that gulls respond quickly to high concentrations of prey. The morning after the start of the volitional release at Chandler Hatchery there were gulls feeding on the fall chinook fry. These numbers quickly built to over 100 gulls with the birds consuming fish at a high rate. This numerical response and consumption rate is not unlike that observed by researchers for other species of gulls. Mace (1983) documented up to 1,700 Bonaparte's gulls (*L. philadelphia*) responding to releases of hatchery chinook and Götmark et al. (1986) found that each black-headed gull was able to consume ten to thirty - 6.5cm bleak (*Alburnus alburnus*) in 3 min.

TERNS

Both Forster's and Caspian terns were observed in the Yakima River, but infrequently and not until the end of May. I did not see any terns at acclimation sites and I only saw terns on two occasions while floating index stretches, both in the second week of June. Surprisingly, one observation was in the Granger section, quite far from the tern nesting colonies. The other sighting was in the Vangie section. In addition, the only hot spots with tern observations were Chandler Canal bypass outfall and Horn Rapids Dam. The first tern was seen at Chandler Canal bypass outfall in mid-July, while terns first appeared at Horn Rapids Dam in the third week of May. Both times a tern captured a fish at Horn Rapids Dam it was harassed by gulls trying to steal the fish and both times the tern left the area. Gulls are known to be kleptoparasitic so their behavior was not surprising (Hoffman et al. 1981). Hoffman et al. (1981) defines kleptoparasitism as the pirating of fish or other food from other birds.

In addition, casual observations in the stretch of river between the Columbia River confluence and the Van Giesen Street Bridge indicated that terns did not necessarily become more abundant closer to the Columbia River. Based on these low abundances it is apparent that tern predation in the Yakima River was likely miniscule in 1998. However, the nearby tern colony on Crescent Island increased by 200% from 1996 to 1997 to about 2,000 birds (Roby et al. 1998) and the sighting of a Forster's tern may indicate that this species still nests in the area. If this rate of colony growth continues and terns begin to feed on the Yakima River, tern predation could quickly become a factor in juvenile salmonid survival in the river.

CORMORANTS

Predation by double-crested cormorants occurred in the lower four index areas; no cormorants were observed feeding in the Cle Elum, Canyon, or Selah index areas. The first cormorant sighting was in the Granger index stretch on 2 April at a density of 0.08 per km (Figure 26). Although cormorants are thought to inhabit the Granger area year-round (T. Hames, YIN, pers. comm.), none were seen in that section in the fall or winter.

In the lower river, the Vangie section generally had the highest cormorant density, followed by Benton, and then Horn.

The only hot spot with consistent cormorant predation was Horn Rapids Dam; cormorants were not seen at any acclimation sites. The limited feeding observations indicated that salmonids made up a very small proportion of the cormorant diet. They appeared to prefer larger non-salmonids on the order of 25 cm in length. Assuming that diet preferences were similar in free-flowing stretches of the river, cormorants probably had little impact on outmigrating salmonids. While the three cormorant stomachs I examined did not contain prey that large, they did not contain any salmonids either, although salmonids were probably present in their foraging areas. However, I do not believe the diet observations were sufficient to dismiss cormorant predation. A detailed diet study will be necessary, especially in light of the colonies near the lower Yakima River and the newly established colony near Granger. If these colonies develop population trajectories like that of Rice Island in the Columbia River estuary, cormorant numbers would rapidly increase. From 1996 to 1997, the Rice Island cormorants increased by 92% to approximately 1,200 pairs (Roby et al. 1998).

HERONS

Black-crowned night herons were occasionally seen during this study. Night-heron numbers were low and they were confined to the lower river, specifically the lower two index areas. In addition, several were commonly observed flying to the Chandler Canal fish screens at dusk where they likely took advantage of the lighting, slow-moving water, and screens delaying the fish. Based on their abundance, I do not believe that night herons caused significant mortality of juvenile salmonids in 1998.

Great blue herons were more abundant and widespread than night herons. They were present in each index area, four hot spots, and three acclimation sites. In the fall, heron abundance was highest in the Canyon section, while in the spring, the Granger section had the most herons, although the counts were highly variable (Figure 27). It was surprising that the heron index was low in the Selah section in May and June given that there is a heron colony visible from the river in the index area. I counted 21-23 nests, most of which were occupied on 16 April. I was not surprised that heron abundance was highest in the Granger section. At last count, there were 600 nests between Mabton and Union Gap, encompassing the Granger index area (T. Hames, YIN, pers. comm.). The significant difference in abundance between fall/winter and spring was likely the result of birds congregating for the breeding season. In addition, the acclimation site Roza Wasteway #3 was located near the river within the index section. Thus, herons that fed at the acclimation site at night might rest on the river during the day. This is supported by observations of nearly all herons flying from Roza Wasteway #3 toward the river. Black and Collopy (1982) found no significant difference in either the percentage of time herons were present or in the percentage of time they spent foraging during diurnal and nocturnal surveys in the tidal flats surrounding Cedar Key, Florida.

Herons foraged at the hot spots of Sunnyside Dam, Prosser Dam, Chandler Canal bypass outfall, and Horn Rapids Dam, but not in large numbers. Presence at Sunnyside Dam was the most consistent of the four hot spots with herons foraging on 60% of the observation days. Generally, only one heron was present at a time.

A single heron was observed one day at Lost Creek Ponds, but YIN personnel indicated that they often saw a heron when they arrived to feed the coho. Although I did not have an index area in the upper Naches River, the upper Yakima River index area at Cle Elum had only a single heron observed on each of two different floats. The situation at Roza Wasteway #3, however, was much different. As mentioned above, this acclimation site was in the vicinity of the heron nesting colonies. The herons responded quickly to this concentration of fish with 15 herons observed slightly more than 1 week after the fish were placed into the wasteway. The peak heron count was 29. Herons also preyed on fish at Chandler Hatchery on release day. A single great blue heron was at the confluence of the outlet creek and the river. Although the hatchery ponds were protected with bird netting, on at least one occasion I saw a heron inside the netted enclosure that contained the ponds.

I did not conduct diet studies or feeding observations of great blue herons and, therefore, cannot directly assess their impact on juvenile salmonids in the Yakima River. However, I believe that they did not consume a large number of salmonids unless those salmonids were concentrated in a confined area. While on floats and traveling between areas, I frequently observed herons in fields and marshes. Herons are known to consume a wide variety fishes, amphibians, reptiles, crustaceans, insects, birds, and small mammals (White 1939, Kirkpatrick 1940, Urhahn 1968) and may have fulfilled much of their daily food requirements away from the river. In addition, when I saw herons in the river they were generally in backwater sloughs and in very slow moving water, such as that on the inside of a river bend. Other researchers have observed a preference for these same kinds of foraging areas (White 1939) which are generally not areas preferred by juvenile salmonids. A possible exception is coho, which may overwinter in sloughs; however, naturally produced coho abundance is low and hatchery coho quickly migrate out of the river when released from acclimation sites. One study found that voles accounted for 62-67% of all food items taken by herons nesting at Heyburn State Park, ID (Collazo 1985). Of the fish consumed, only 1% were game fish and the author concluded that “herons are not believed detrimental to game fish populations at Heyburn State Park and nearby tributaries. In fact, herons probably have a beneficial effect in preying chiefly on what many fishermen and fisheries biologists consider nuisance species in Idaho”. I suspect that this may also be the case in the Yakima River.

However, the situation was different for fish concentrated in a confined area such as an acclimation site. Herons are considered significant predators of fish at hatcheries (Schaeffer 1992, Pitt and Conover 1996) and probably consumed a large number of the coho at Roza Wasteway #3.

KINGFISHERS

Belted kingfishers were observed in all of the free-flowing index areas. Abundances were highly variable throughout the year, although numbers were generally higher in the middle and upper river (Figure 28). Much of the variation could be due to the small size of kingfishers which made them easy to overlook, especially if they remained perched in a tree. In the Canyon index, I saw an average of 0.45 birds per km during the fall/winter, but no kingfishers in spring. In the Selah section the fall/winter and spring averages were equal at approximately 0.25 per km. Likewise, the fall/winter and spring average abundances in the Granger stretch were estimated to be equal. The peak abundance in the lower river was 0.16 kingfishers per km in the Vangie section; however, the section was short and this corresponded to only two birds. The smaller numbers in the lower river could be the result of the character of the river: slow flow and poor water quality. While kingfishers often feed in slow moving water, they have difficulty catching prey in turbid water (Salyer and Lagler 1946, White 1953).

The only acclimation site that had kingfisher sightings was Roza Wasteway #3 where one or two were seen on several occasions. The low abundance was not surprising given that fish longer that 12.7 cm are thought to be difficult for kingfishers to swallow (Salyer and Lagler 1946) and most of the hatchery coho at the acclimation sites were larger than this. The fall chinook fry at Chandler Hatchery would have been more suitable prey for kingfishers had they not been protected by bird netting. I do not believe that kingfisher abundance was high enough for them to pose a significant threat to Yakima River salmonids.

MANAGEMENT IMPLICATIONS

WATER FLOWS

Avian observations at both Chandler Canal bypass outfall and Horn Rapids Dam indicated that stream flow was critical to alleviating predation of salmonids at hot spots. When flow at Chandler reached a threshold of about 4,000 cfs predation began to decrease at Chandler Canal bypass outfall. For Horn Rapids Dam, the threshold flow at Kiona was about 8,000 cfs. At high flows, predation was non-existent at both locations. Figure 25 shows flow at Kiona, illustrating that 1998 was an unusually high flow year and that in most years the threshold at Horn Rapids Dam would not have been reached.

Higher instream flow should be a priority for recovery of Yakima River salmonids because it will also serve to "flush" outmigrating salmonids from the river. This will reduce their time of exposure to predators in free-flowing sections of the river, such as common mergansers in the Granger area; however, the predation level on rearing and resident salmonids in the Cle Elum, Canyon, and Selah areas would probably not be affected.

A project is already underway to improve flows. In 1979, following a series of years of below average runoff, when proratable water rights holders received only a fraction of their entitlements, Congress enacted Public Law 96-162, the Yakima River Basin Water Enhancement Project (YRBWEP) (SOAC 1998). Public Law 103-434 was passed in 1994, authorizing implementation of Phase 2 of YRBWEP. Title XII (Section 1201) states the following purposes: "(1) to protect, mitigate, and enhance fish and wildlife through improved water management; improved instream flows; improved water quality; protection, creation and enhancement of wetlands; by other appropriate means of habitat improvement; (2) to improve the reliability of water supply for irrigation" (SOAC 1998). The primary component of Title XII is the voluntary Yakima River Basin Water Conservation Program. It provides financial incentives to Basin interests to plan and implement water conservation measures designed to "improve the availability of water supplies for irrigation and the protection and enhancement of fish and wildlife resources, including wetlands, while improving the quality of water in the Yakima Basin" (Section 1203(a)(1)). Title XII also established new targets for instream flows at two locations in the lower Basin (Table 8). Water conservation by irrigation entities will improve system efficiencies and result in reduced water diversion with two-thirds of the conserved water being dedicated to instream flow needs for fish and wildlife protection, enhancement, and recovery. Water may also be acquired for instream flows by purchase or lease of land and/or water (SOAC 1998). The goal of this program is to "realize sufficient water savings … so that not less than 40,000 acre-feet of water savings per year are achieved by the end of the fourth year … and not less than 110,000 acre-feet of water savings per year are achieved by the end of the eighth year of the program to protect and enhance fish and wildlife resources" (Section 1201).

PREDATION ABATEMENT

Given that the process of improving streamflow is a long-term, weather-dependent venture and that the needs of fish, wildlife and irrigators must be balanced, other ways of reducing predation must be examined. Draulans (1987) reviewed the effectiveness of different types of attempts to control predation by fish eating birds at fish farms. He concluded that there is, so far, no scientific basis to claim that removal of predators through relocation or killing reduces bird abundance or increases fish yields. On the other hand, most bird deterrents, such as visual (scarecrows, flags, glass or metal reflectors, pyrotechnics, lights and flashing lights, model airplanes, and helicopters), acoustic (gun shots, firecrackers, and gas cannons), and biological (recorded distress and warning calls, dead birds, model predators, and running dogs), have only a very short-lived effect, if any. Ecological measures have not yet been tested. These are attempts to lessen the predation pressure on a particular fish population by reducing the encounter rate between predator and vulnerable fish. Draulans (1987) concluded that "the only reasonable solution to prevent fish from being eaten by piscivorous birds is to make sites inaccessible through wiring and netting".

Ecological measures, as defined by Draulans (1987), show promise in the Yakima River. The design of the outfall pipe at Chandler Canal bypass outfall contributes to gull predation. The 90° bend upward at the terminus forces fish to the surface where they are vulnerable to gulls. If this pipe was redesigned such that it opened in a downstream direction, bird predation could be reduced. In addition, removal of the large boulders immediately downstream of the pipe would eliminate a prime resting spot for gulls and prevent foraging from the rocks as the fish swim between them. Redesigning Horn Rapids Dam to eliminate the perfect rolling motion at the base of dam would serve to reduce predation at that hot spot; however, that solution would be very costly.

Another likely way to reduce predation at both hot spots, and the most practical for Horn Rapids Dam, is to make the sites inaccessible to avian predators by using arrays of overhead lines. This method has been employed with success at numerous Columbia and Snake River dams (Steuber et al. 1993). On the basis of average daily numbers of gulls present, a line array at The Dalles Dam appeared to deter over 95% of gulls from feeding and a line array over the upstream portion of John Day Dam virtually eliminated gull feeding from that part of the spillway channel (Jones et al. 1997). Presumably, line arrays over the pipe outlet at Chandler Canal bypass outfall and over the backwash at Horn Rapids Dam would have a similar impact on gull predation.

A third way to reduce predation by gulls on the Yakima River is to limit the size of the breeding colonies, assuming that foraging gulls are commuting from the three nearby Columbia River colonies. Both California and ring-billed gulls prefer to nest where vegetation is low and sparse. They avoid dense herbaceous or shrub cover (Vermeer 1970). Planting of vegetation on the islands could make them unsuitable for gull nesting.

Predation could also be used to discourage gull nesting. Southern et al. (1985) found that ring-billed and herring gulls (*L. argentatus*) nesting on South Manitou Island in Lake Michigan experienced total or nearly total reproductive failure during all but one of nine years as a result of predation by red foxes. Sekora et al. (1979) found that glaucous-winged gulls abandoned nest sites on the Aleutian Islands once foxes were successfully established. Predation by great horned owls (*Bubo virginianus*) on breeding California gulls in California and Colorado disrupted nesting, causing some gulls to leave the area entirely. While loss of adult gulls to owls was negligible, loss of chicks was sometimes great. Chick losses were the result of direct predation and indirect loss from hypothermia and predation by other gulls when adults left the nest site during attacks. golden eagles (*Aquila chrysaetos*) and common ravens (*Corvus corax*) also preyed on the nesting gulls (Jehl and Chase 1987). Unfortunately, in the case of the nearby Columbia River colonies, predation by terrestrial mammals is problematic because the gulls nest on islands. This probably precludes regular visitation by terrestrial predators, and the islands are likely too small to provide alternate food supplies for predators while gulls are seasonally absent. However, erecting perches around the island could encourage predation by raptors. Increased predation should encourage gulls to nest elsewhere, ideally in locations where they pose less of a threat to Yakima River salmonids.

Table 8. Yakima River target flows as specified by Congress in Section 1205 (a)(1), Title XII, Public Law 103-434.

Water Supply Estimate for Period (million acre-feet):				Target Flow From Date of Estimate Thru October Downstream of (cubic feet per second):	
April thru September	May thru September	June thru September	July thru September	Sunnyside Diversion Dam	Prosser Diversion Dam
3.2	2.9	2.4	1.9	600	600
2.9	2.65	2.2	1.7	500	500
2.65	2.4	2.0	1.5	400	400
Less than line 3 water supply				300	300

Source: Soac 1998

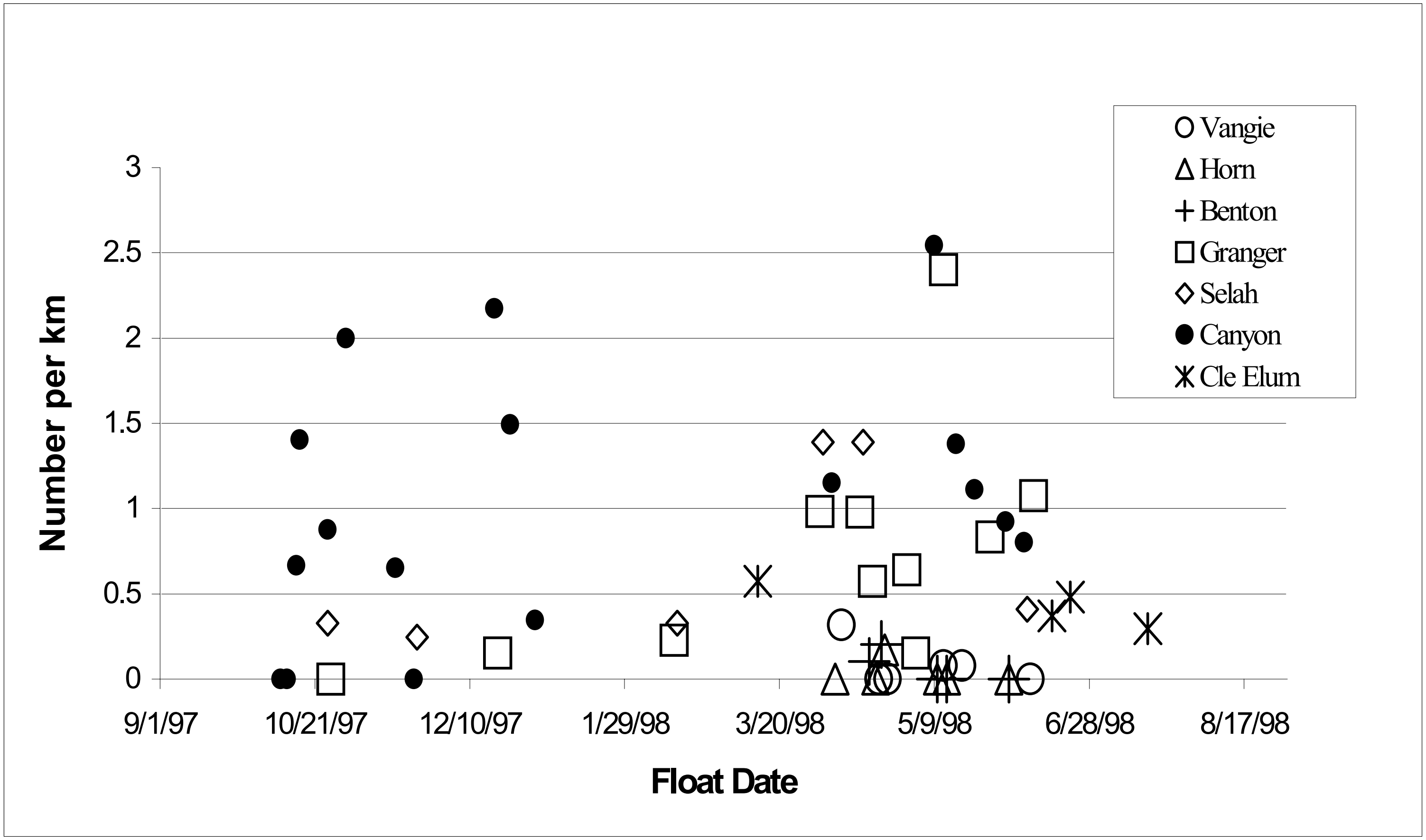


Figure 23. Common merganser abundance by index area.

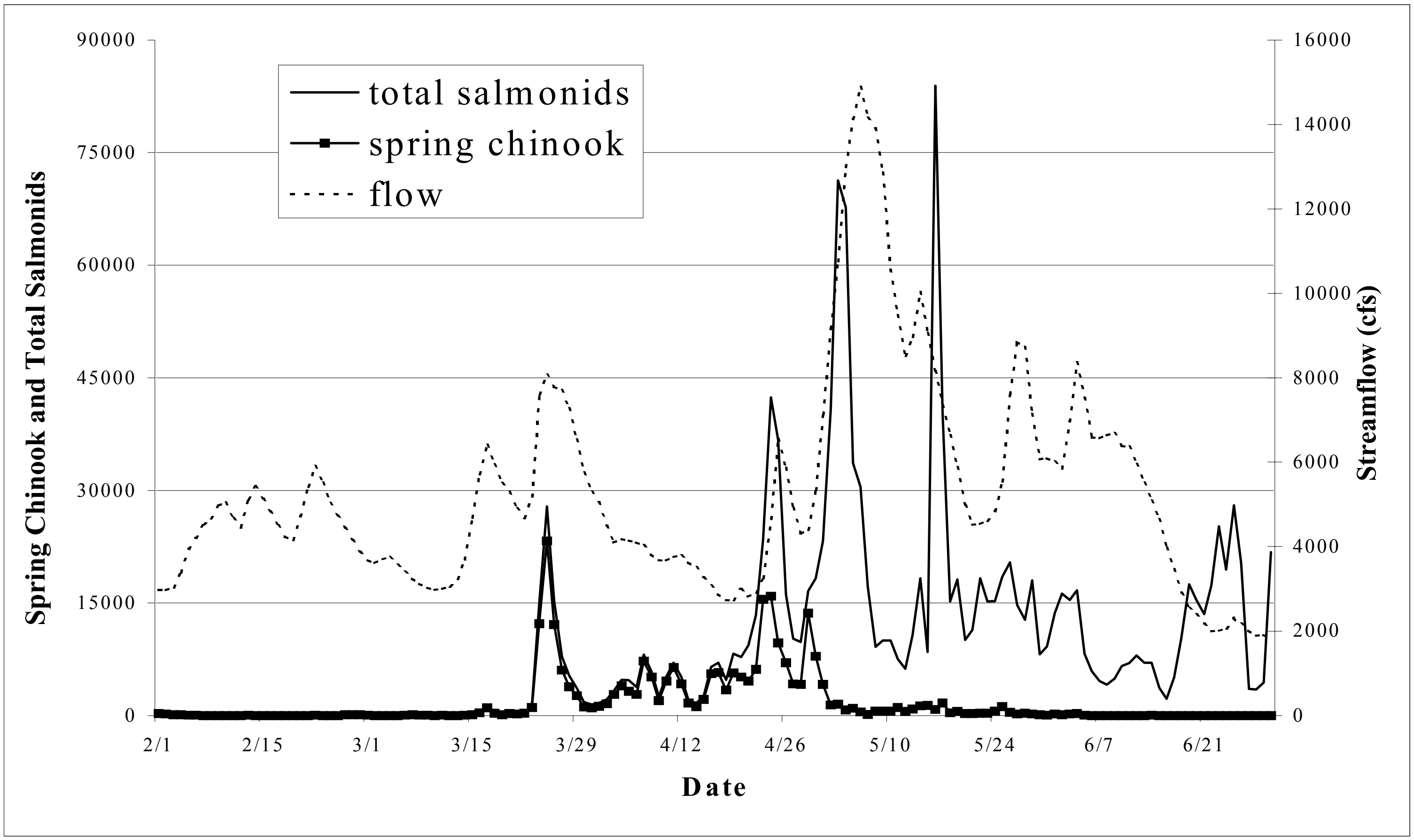


Figure 24. Fish outmigration past Prosser Dam (spring chinook and total salmonids) and streamflow at Prosser Dam from 1 February to 30 June 1998.

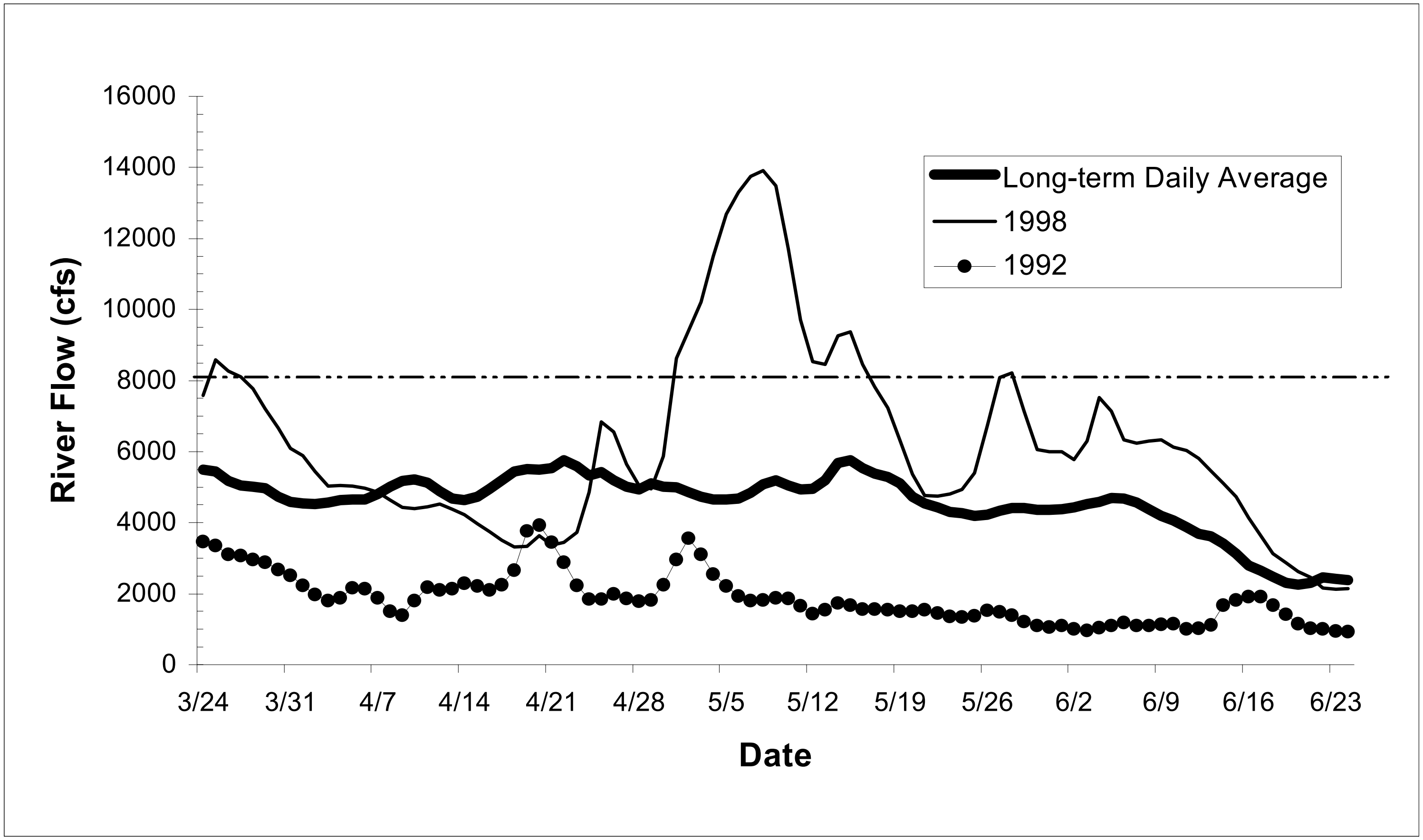


Figure 25. Spring streamflow for the Yakima River at Kiona with the long-term daily average, 1992, and 1998 flows. Horizontal line represents the predation threshold of 8,000 cfs observed for gulls foraging at Horn Rapids Dam in 1998.

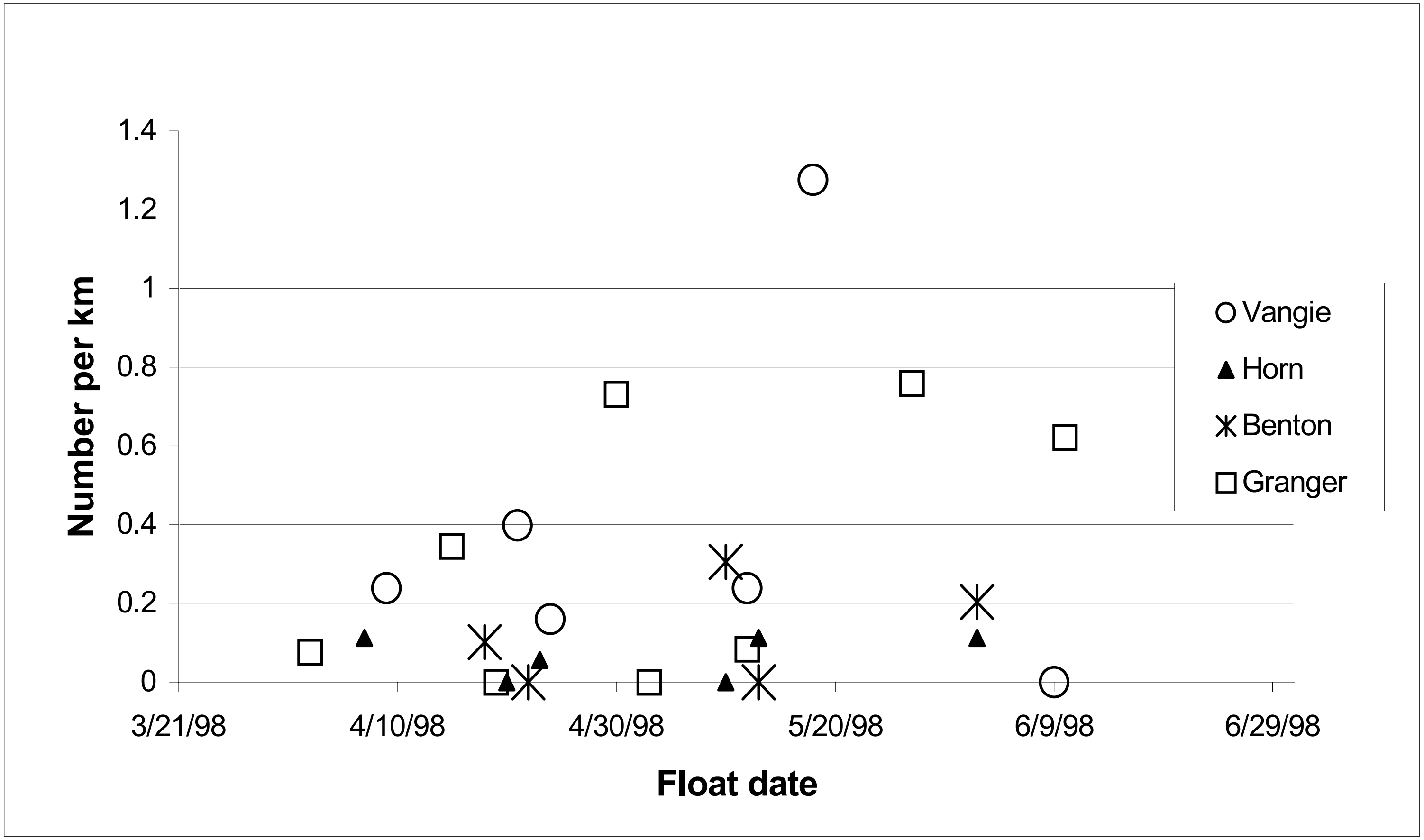


Figure 26. Double-crested cormorant abundance by index area for spring floats.

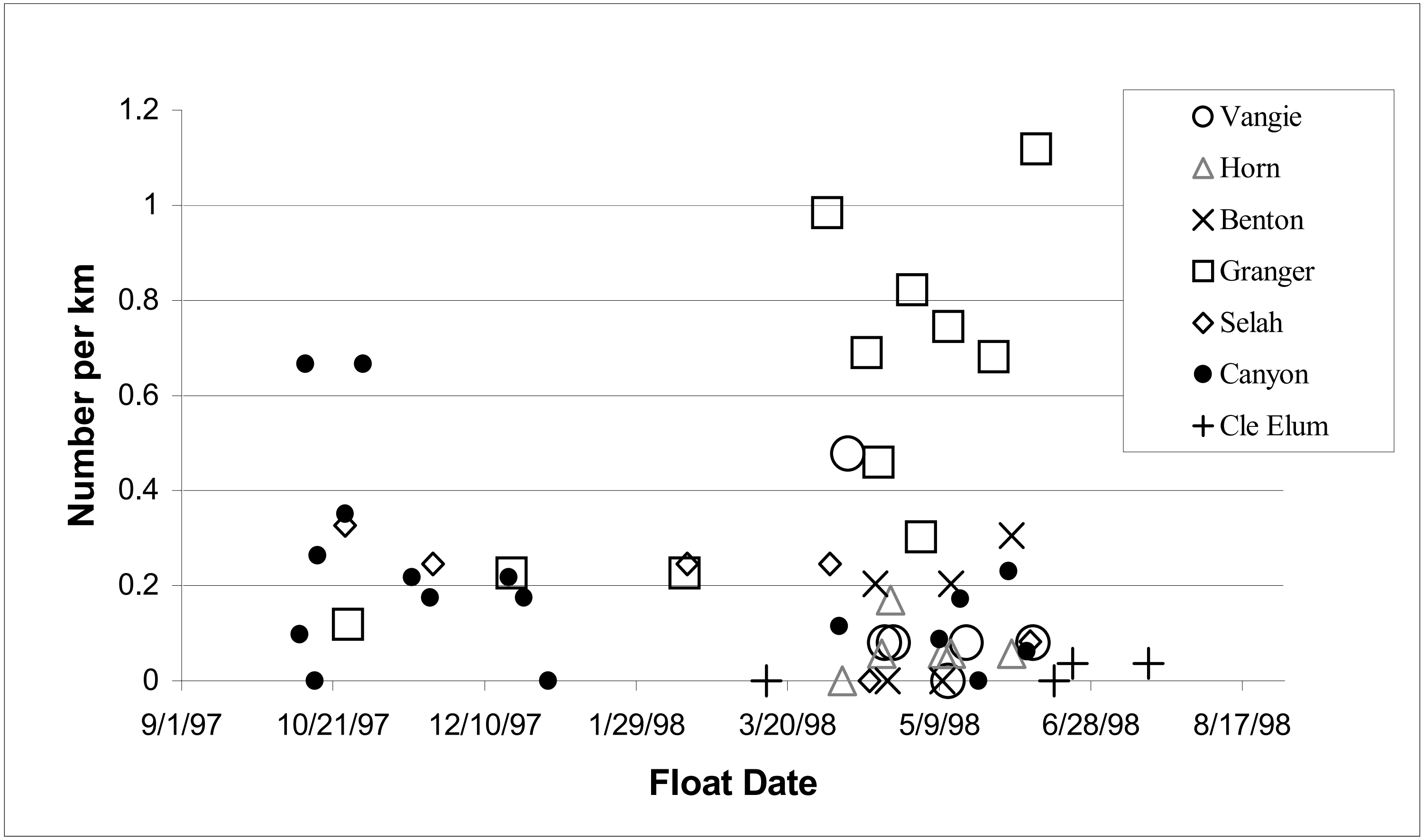


Figure 27. Great blue heron abundance by index area.

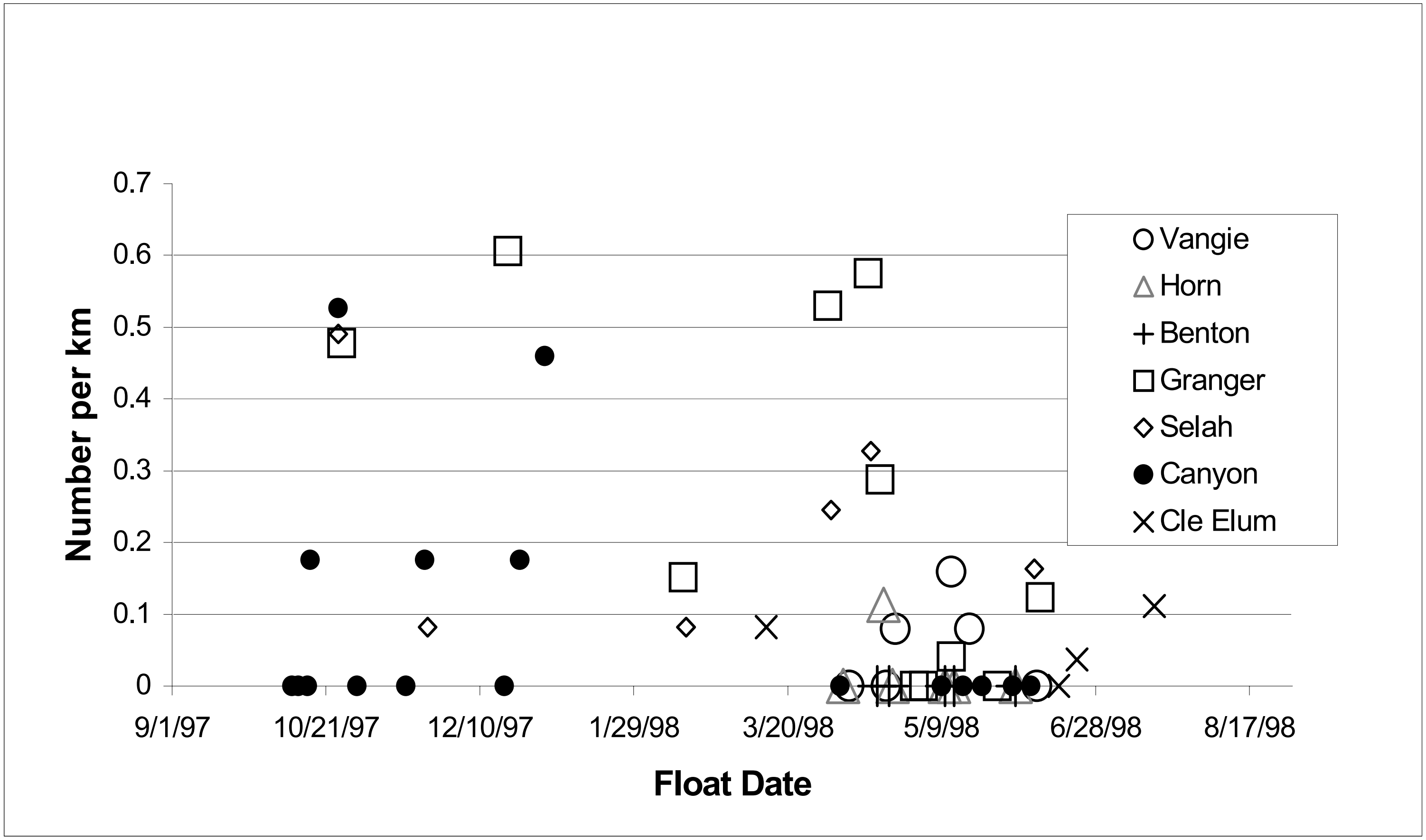


Figure 28. Belted kingfisher abundance by index area.

CONCLUSION

Humans have greatly altered the nature of the Columbia River Basin and "it should be appreciated that if avian predation is a major source of mortality for juvenile salmonids it is certainly a reflection of anthropogenic change" (Roby et al. 1998). Historically, predation by gulls probably would not have occurred. There were no dams on the Yakima River to provide foraging locations and their Columbia River nest sites would have been inundated by spring runoff. Thus, in a historical context, gull predation could be considered significant; however, in a biological context, I do not believe that the 1998 predation level was significant or that the success of the spring chinook YFP will be influenced by a loss of fewer than 2% of the smolts to gull predation. Predation by mergansers could be high during times when the birds are abundant on the river, both during winter cold spells and during migration to breeding grounds, but additional study will be necessary to evaluate the biological significance of this predation. We cannot blame piscivorous birds for preying on salmonids and set about eliminating the birds; however, there may be times when bird predation locally depresses salmon stocks (Mossman 1959). For recovery of the depleted Yakima River salmonids, a comprehensive management plan must focus, in part, on avian predators if they are consuming significant numbers of fish relative to other mortality sources. This can be accomplished by limiting access of the predators to their prey, not by eliminating the predators. The birds should not be used as scapegoats and a program of lethal control should not be instituted.

HOT SPOTS

Observations indicated that predation at many of the hot spots was low in 1998. Predation at Roza Dam, Roza Canal bypass outfall, Wapato Dam, Wapato Canal bypass outfall, Sunnyside Dam, Sunnyside Canal bypass outfall, Prosser Dam, and Columbia

Canal bypass outfall was either non-existent or very low, while predation at Chandler Canal bypass outfall and Horn Rapids Dam was higher. Gulls foraged at both Horn Rapids Dam and Chandler Canal bypass outfall throughout the spring, consuming an estimated 1.7% and 1.1%, respectively, of the fish that outmigrated through the hot spot during the period of study. These proportions increased to 2.6% and 3.1% of the fish that outmigrated on the days that gulls foraged at the sites. The proportion of spring chinook consumed is likely smaller since their outmigration peaked before the gull predation began. In 1998, hot spot predation on juvenile spring chinook was low, but 1998 was a relatively high-flow year where the apparent predation threshold flows were exceeded for many days. In normal flow-years, gull predation at both Chandler Canal bypass outfall and Horn Rapids Dam would not be affected by river conditions.

FREE-FLOWING INDEX AREAS

Floats in free-flowing index areas throughout the river at times when spring chinook were abundant indicated that predation was low in the lower river. Summer observations in the Cle Elum index section suggested that common mergansers and their broods may consume large numbers of spring chinook fry; however, no stomachs were taken in the summer to evaluate this possibility. Throughout the year, these fry slowly move downriver. Fall/winter observations in the Canyon, Selah, and Granger index areas suggested that common mergansers were the most significant predator, based on bird abundance. The fall/winter stomachs I examined contained one chinook and several rainbow trout. Spring observations, during outmigration, in the Benton, Horn, and Vangie sections did not reveal large numbers of piscivorous birds. Cormorants were most abundant; however, feeding observations and stomach contents suggest that they preyed mainly on larger non-salmonids, not on outmigrating salmonid smolts. Therefore, I believe that mergansers were the most significant avian predators of spring chinook before they entered the lower river on their way to the ocean. In the lower river, the gulls at Chandler Canal bypass outfall and Horn Rapids Dam were the most significant avian predators of outmigrating chinook.

ACCLIMATION AND RELEASE SITES

Observations at acclimation sites in 1998 provided insight into the predators that will be of concern when hatchery produced spring chinook are placed into acclimation ponds. These ponds are located in the upper Yakima River so the predation I observed by gulls at Chandler Hatchery and the predation by mergansers and herons at Roza Wasteway #3 will likely not be of concern. However, I believe that predation at Lost Creek Ponds in the upper Naches River is representative of the predation that will occur at acclimation sites in the upper Yakima River. Common mergansers were the most abundant predator at the Naches River acclimation site and summer observations in the Cle Elum index area showed common mergansers to be the most abundant predator in the upper Yakima River. Therefore, I believe that if spring chinook acclimation sites are affected by avian predation, the major predator will be common mergansers. In fact, this was the situation at a newly established hatchery coho acclimation site in spring 1999 in the upper Yakima River where more than 90 mergansers at one time were observed feeding on the coho (T. Pearsons, WDFW, pers. comm.).

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