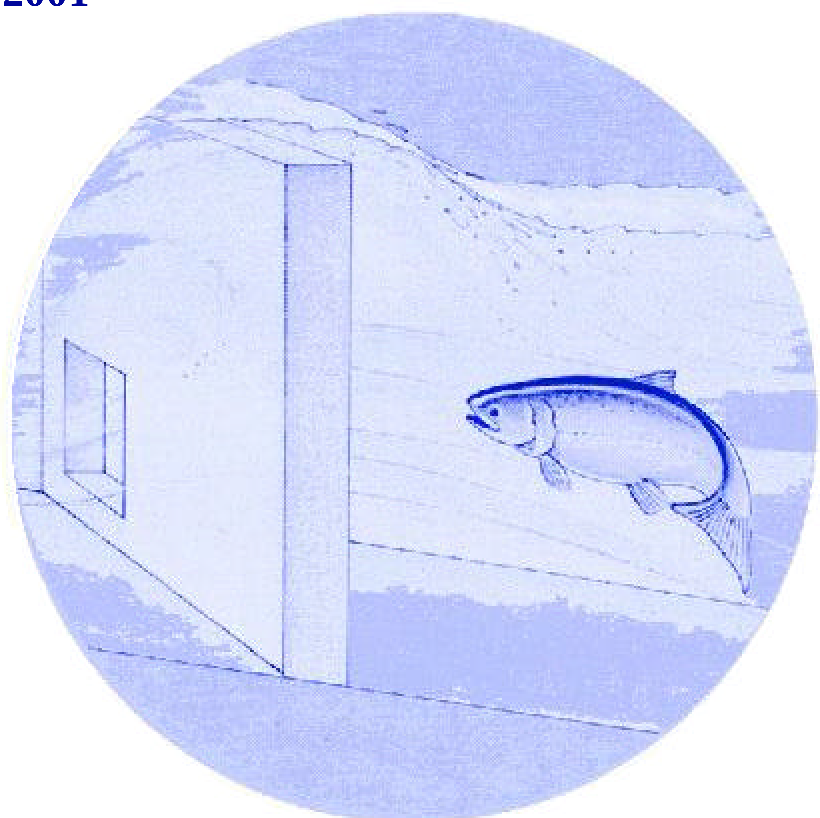
Development of an Index to Bird Predation of Juvenile Salmonids within the Yakima River

Annual Report
2001



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Development of an Index to Bird Predation of Juvenile Salmonids within the Yakima River

Annual Report 2001

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ABSTRACT

Avian predation of fish is suspected to contribute to the loss of out-migrating juvenile salmonids in the Yakima Basin, potentially constraining natural and artificial production. In 1997 and 1998, the Yakima/Klickitat Fisheries Project (YKFP)—whose goal is increasing natural production within the Yakima River—initiated investigations to assess the feasibility of developing an index to avian predation of juvenile salmon within the river. This research—conducted by Dr. Steve Mathews and David Phinney of the University of Washington and the Wasington Department of Fish and Wildlife (WDFW)—confirmed that Ring-billed Gulls and Common Mergansers were the primary avian predators of juvenile salmon (Phinney et al. 1998), and that under certain conditions could significantly impact migrating smolt populations.

Beginning in 1999, the Washington Cooperative Fish and Wildlife Research Unit (WACFWRU) was asked by the YKFP to continue development of avian consumption indices. Monitoring methods developed by Phinney et al. (1998) were adopted (with modifications) and monitoring of impacts to juvenile salmon along river reaches and at areas of high predator/prey concentrations (colloquially referred to as “hotspots”) has continued each year through 2001.

In 2001, piscivorous birds were counted from river banks at hotspots and from a raft or drift boat along river reaches. Consumption by gulls at hotspots was based on direct observations of foraging success and modeled abundance; consumption by all other piscivorous birds was estimated using published dietary requirements and modeled abundance. Seasonal patterns of avian piscivore abundance were identified, diurnal patterns of gull abundance at hotspots were identified, and predation indices were calculated for hotspots and river reaches (for both spring and summer). Changes in survey methods in 2001 included the addition of surveys in the 'Canyon' reach during spring and altering the method of directly measuring gull feeding rates at hotspots.

Primary avian predators in 2001 were ‘gulls’ (California and Ring-billed) at hotspots and Common Mergansers within upper river reaches. Consumption on the lower reaches was distributed among a number of species, with slightly more then half of all fish consumption being attributed to American White Pelicans. Estimated consumption by gulls at both hotspots combined (8 Apr - 30 Jun) was 169,883 fish. Assuming a worst case scenario (all fish taken were smolts) this represented approximately 4.9% of all smolts estimated passing or being released from the Prosser Dam area during the 2001 smolt migration season. Total gull abundances and estimates of consumption between the two hotspot sites were opposite that seen in 2000. Foraging gulls at Horn Rapids Dam were regressed against flow for the 3 years and found to be significant (alpha=0.1, P=0.081, r^2=.2589). A similar 3-year regression vs fish passage through the Chandler Juvenile Fish Facility, however, did not show a significant relationship (alpha=0.1, P=0.396, r^2=.3708) .

Total estimated take by Common Mergansers across all strata surveyed was 14,777 kg between 8 Apr and 31 Aug, 2001. Approximately 66 percent of that consumption was within the upper river reaches (Stratum 1) where there is a known breeding population of mergansers. Graphical comparisons of merganser abundances over the three years (1999-2001) in the upper reaches of the Yakima River suggest an increase in 2001 from the previous 2 years in both the spring and summer survey periods, but overlapping confidence intervals prevent assumptions regarding upward or downward trends in abundance.

INTRODUCTION

Note: For the purposes of this document the phrase "juvenile salmonids" refers to juveniles of the following stocks: spring chinook, (*Oncorhynchus tshawytscha*), fall chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*), and summer steelhead (*Oncorhynchus mykiss*). Although the mountain whitefish (*Prosopium williamsoni*) is of the family *salmonidae*, it was not included in this study.

Avian Predation of Juvenile Salmon

Avian predation is suspected to be a significant constraint to salmonid production and has been shown to impact the survival of juvenile salmonids within river habitats and fish culture facilities (White 1936, 1939; Mills 1967; Sealy 1973; Alexander 1979; Packhurst et al. 1987; Wood 1987a,b; Pitt et al. 1998; Derby and Lovvorn 1997). The magnitude of impact to migrating smolts by avian predators is highly variable within and across river systems. Estimations of avian consumption of juvenile salmonids within specific river systems and specific years range between 1-66% of particular runs or releases (Alexander 1979; Mace 1983; Ruggerone 1986; Wood 1987b; Kennedy and Greer 1988; Roby et al. 1998; Phinney et al. 1998). As shown repeatedly by investigations throughout North America and Europe, avian predators can consume large number of juvenile salmonids when appropriate conditions for bird/fish interactions occur (Elson 1962; Feltham 1995a; Modde and Wasowicz 1996).

Bird predation of juvenile salmonids is particularly common throughout the Columbia River Basin (CRB) which supports some of the largest populations of piscivorous birds throughout North America and Europe (Ruggerone 1986; Roby et al. 1998). Most piscivorous birds within the CRB are colonial nesting birds (Ring-billed, Mew, California and Glaucous-winged Gulls, Caspian Terns, Double-crested Cormorants, Great Blue Herons) which are particularly suited to the exploitation of fluctuating prey fish densities (Alcock 1968; Ward and Zahavi 1996). Such prey fish fluctuations can result from—but are not limited to—large migratory accumulations, hatchery releases, physical obstructions that concentrate or disorient, and other natural features and events which occur in complex river habitats.

The advantage held by colonial birds under such conditions is hypothesized to result from unsuccessful foragers within a colony receiving cues from successful foragers as to prey type and location (Forbes 1986; Greene 1987). Such cues can lead to a rapid response by large numbers of avian predators to available concentrations of prey fishes. These behaviors, in combination with large nesting populations, can lead to high levels of consumption of migrating salmon smolts by avian predators. For example, in 1997, consumption of juvenile salmonids by a single species of avian piscivore—the Caspian Tern—from a single nesting colony within the Columbia River estuary--Rice Island-- was estimated to be 6-25% of the 100 million out-migrating smolts that reached the estuary (Roby et al. 1998).

Salmon Supplementation in the Yakima and Klickitat Rivers

The Yakima/Klickitat Fisheries Project (YKFP) seeks to "test the hypothesis that new supplementation techniques can be used in the Yakima River Basin to increase natural production and to improve harvest opportunities, while maintaining the long-term genetic fitness of the wild and native salmonid populations and keeping adverse ecological interactions within acceptable limits" (Sampson and Fast 2000) This goal will be accomplished by a combination of salmon supplementation, hatchery rearing adjustments and habitat improvements targeting four principal species of salmonids: spring chinook, fall chinook, coho, and summer steelhead. At this time, stock specific supplementation programs are at different operational levels.

Intensive monitoring has been implemented in conjunction with the YKFP salmon supplementation efforts. This monitoring seeks to identify impacts of salmon supplementation on natural production, impacts on harvest, on genetic interactions between natural and supplemented stocks, and on ecological interactions among target and non-target species. Impacts of salmon supplementation on non-target species are being assessed by comparisons of non-target species population parameters (abundance, size-structure and distribution) and interaction indices before and after supplementation. Impacts of predators upon supplemented and naturally spawning salmonid stocks will be assessed by indices of predation.

It is anticipated that interaction between supplemented salmonid stocks and key fish-eating species (biotic interactions) may impact the ultimate success of the YKFP supplementation efforts (Busack et al. 1997; Pearsons 1998). Understanding such interactions has been identified as a high priority by the YKFP Monitoring Implementation Planning Team (MIPT), leading to the funding of the research detailed within this document -- the development of an index to bird predation of juvenile salmonids within the Yakima River.

Initial Assessment of Consumption of Juvenile Salmon by Avian Piscivores—1997-1998

In 1997, Dr Steve Matthews and Dave Phinney (Phinney et al. 1998), in collaboration with the YKFP, began investigations to assess the potential of avian piscivores to impact juvenile spring chinook populations within the Yakima River. This effort was focused upon broad scale assessments of piscivorous bird abundance within rearing areas preferred by juvenile chinook, as well as abundance and feeding behavior of piscivorous birds at localized areas of intense predation referred to as "hotspots". In 1997 and 1998, Mathews and Phinney developed field methods, surveyed river reaches and hotspots, estimated piscivorous bird abundance along river reaches and hotspots, estimated piscivorous bird consumption of juvenile salmonids at the most significant hotspots, and investigated the relationship between water flow and avian predation at hotspots. Mathews and Phinney found gulls were the most abundant avian predator at the hotspots and that Horn Rapids Dam and the Chandler Canal Bypass Pipe were the hotspots with the most intense avian predation (Phinney et al. 1998). Common Mergansers were found to be the most abundant avian predator along river reaches and the Zillah reach contained the greatest number of avian predators. In 1998, gull abundance at hotspots was negatively correlated (-0.426, P<0.001 at Chandler and -0.385, P = 0.001 at Horn Rapids) with river discharge (Phinney et al. 1998).

Phinney et al. (1998) estimated total consumption of salmonids by birds congregating at Horn Rapids Dam and the Chandler Canal bypass to be 1.7% and 1.1%, respectively, of total salmon/trout passage. Based upon the assumption that all fish consumed by avian piscivores were salmon, and that salmon were consumed in proportion to the relative number passing, 0.52% of all spring chinook passing Horn Rapids Dam and 0.20% of all spring chinook passing Chandler Canal bypass were consumed (Phinney et al. 1998). The authors also suggested that the relatively high flows in spring of 1998 were responsible for holding avian consumption of salmon and trout at hotspots to low levels. They suggested that unusually low water levels during spring smolt migrations may facilitate a much higher level of avian predation of migrating salmon and trout. During 1999, spring flows were again higher than average and combined take by avian predators at the hotspots was 2.7% of all salmonids passing over Chandler Dam (Grassley and Grue 1999) (assuming all species taken were salmonid); very similar to the percentage taken the year before (Phinney et al. 1998).

Determination of species composition of fishes consumed by avian piscivores has proven problematic. Consumption estimates have relied principally upon observations of predation by gulls at hotspots, and daily energy requirements of avian piscivores enumerated on river reaches. Phinney et al. 1998 attempted a direct assessment of consumption for a single species of avian piscivores along river reaches—the Common Merganser—resulting in the collection of the contents of 20 bird stomachs. Prey species composition and percent of stomachs containing identified prey items only (percent by species) were obtained, but no length/mass estimates of prey items identified were reported.

Consumption of Juvenile Salmon by Avian Piscivores—1999

Beginning in 1999, the YKFP asked the Washington Cooperative Fish and Wildlife Research Unit (WACFWRU) to continue research efforts begun by Mathews and Phinney toward the development of an index to bird predation of juvenile salmonids. Monitoring methods developed by Mathews and Phinney for river reaches and hotspots were largely adopted; the frequency of surveys was increased and some methodological alterations were implemented (Grassley and Grue 2001).

Continued were the abundance and consumption surveys of avian predation at two principal hotspots (Horn Rapids Dam and Chandler Canal bypass) and abundance surveys along five river reaches (Easton, Cle Elum, Zillah, Benton, Vangie). New efforts implemented in 1999 included monitoring of hatchery acclimation sites by YN personnel at the Easton and Clark Flats facilities, monitoring of the North Fork Teanaway River associated with the Jack Creek acclimation facility, and the addition of aerial surveys along low and middle river reaches.

Hotspot Surveys—Spring

Hotspot surveys were conducted from 15 Mar to 30 May to assess the impact of localized areas of intense avian predation on the migrating spring chinook smolt population (and other spring migrant juvenile salmon/trout). The abundance of avian piscivores was determined and behavioral based consumption of fish was estimated. These estimates were expanded across larger time frames in order to estimate seasonal impacts to migrating salmon smolts.

Hotspots were defined as any sustained and localized area of intense avian predation of fish. Hotspots can be caused by natural circumstances (such as a pool of fish at extreme low water events), a by-product of hatchery operations (such as open fish holding ponds), or the result of fish interacting with physical objects within the river channel (dams, irrigation and fish bypass structures). Although the hotspot surveys were designed to address the impact of smolt concentration and disorientation caused by dams and fish bypass structures, the definition was intentionally generalized to encompass any natural circumstance that may produce the same outcome. It was intended that this survey would be applicable to any hotspot which may emerge, especially as the physical parameters of the river change over time (e.g., increased/decreased flows, new construction).

Within the Yakima River in normal flow years, hotspots are most commonly the result of interactions between water flow and man-made structures, which lead to local areas of intensely disrupted water. Movement through such areas by fish (such as migrating juvenile chinook) can lead to a temporary suspension of normal predatory avoidance behaviors due to disorientation, injury or shock. Under such circumstances, predation by avian predators may be highly efficient and intense.

River Reach Surveys—Spring and Summer

Spring river reach surveys were conducted from 15 Mar to 30 May on the Benton, Vangie, Zillah and Cle Elum reaches and focused on avian impacts to migrating spring chinook. Summer river reach surveys were conducted from 1 Jun to 30 Aug and consisted of the Cle Elum and Easton reaches. These reaches are in the upper Yakima and focused on impacts to coho and spring chinook parr and/or residualized coho and spring chinook. Selection of river reaches was based on a combination of factors including historical precedence (reaches utilized by Phinney et al. 1998), degree of representation of typical habitats within the Yakima River, and the logistical constraints imposed by intermittent river access points and impassable obstructions (dams, log-jams). River reach surveys were designed to estimate bird abundance and not directly measure consumption. Objectives related to estimating consumption by avian piscivores along river reaches were accomplished through a combination of bird abundance estimates and published daily caloric requirements for individual species.

Acclimation Site Survey—Spring

YKFP supplementation efforts utilize acclimation facilities to hold and imprint salmon smolts to different waters within the Yakima River system. Acclimation sites incorporate traditional and semi-natural raceways, artificial outer channels, and volitional release regimes to facilitate introduction of salmon smolts into waters targeted for natural production by returning adults. Acclimation site surveys were initiated in 1999 to assess the potential for avian piscivores to be attracted to acclimation sites. These surveys were designed by the WACFWRU and implemented in 1999 by Yakam Nation hatchery (YN) personnel.

Aerial Surveys—Spring and Summer

Aerial bird surveys of the middle and lower Yakima River have been conducted regularly by the YN to provide broad scale census data for target species. Beginning in 1999, these surveys included all piscivorous bird species that could be dependably identified. These surveys provided abundance data and confirmation that hotspots chosen for intensive monitoring were the most active sites. Aerial surveys are being considered as a potential alternative to more expensive river drift surveys.

North Fork Teanaway River Surveys—Spring and Summer

The Teanaway River is a major tributary to the upper Yakima River, entering at river kilometer 284. Approximately 26 kilometers up the Teanaway, along the North Fork Teanaway River, the Jack Creek acclimation facility was established in 1999 as part of the YKFP supplementation effort with the release of 240,000 coho. Anticipating the potential for newly established acclimation facilities to attract avian piscivores, surveys were begun in 1999 to monitor any changes in piscivorous bird abundance and estimate consumption of salmonids along a refererence reach of the North Fork Teanaway.

Summation

In 1999, piscivorous birds were counted from river banks at hotspots and from a raft or drift boat along river reaches. Consumption by gulls was based on direct observations of foraging success and modeled abundance; consumption by Common Mergansers (which forage underwater) was estimated using published dietary requirements and modeled abundance. A second-order polynomial equation was used to interpolate gull and Common Merganser abundance on days when surveys were not conducted. Seasonal patterns of avian piscivore abundance were identified, diurnal patterns of gull abundance at hotspots were identified, predation indices were calculated for hotspots and summer river reaches, and the efficacy of aerial surveys for estimating bird abundance within river reaches was evaluated (Grassley and Grue 2001).

Primary avian predators were California and Ring-billed Gulls at hotspots and Common Mergansers within upper river reaches. Estimated take (presumed to be salmonids) by gulls at hotspots (22 Apr - 30 May) was 4,084 fish at the Chandler Bypass Outfall and 12,636 fish at Horn Rapids Dam. Combined take was 2.7% of the salmonids passing over Chandler Dam or 0.9 % of all smolts estimated passing or being released from the Chandler Dam area during the 1999 smolt migration season. Estimated take by Common Mergansers in the upper reaches of the Yakima River was 2,068 kg between 1 Jul and 30 Aug.

Consumption of Juvenile Salmon by Avian Piscivores—2000

In 2000, the YKFP asked the Washington Cooperative Fish and Wildlife Research Unit to continue its research efforts begun in 1999 (Grassley et al. 2002).

This effort was again organized into two specific time frames within which impacts of bird predation on juvenile salmon were assessed. The first, 8 Apr to 30 Jun addressed impacts of avian predators on juvenile salmon during the spring migration of smolts out of the Yakima River. The second, 1 Jul to 31 Aug, addressed impacts to coho and spring chinook parr and/or residualized coho and spring chinook in the upper reaches of the Yakima River. These two time frames followed the basis of organization and methodological design set forward in the 1999 annual report (Grassley and Grue 2001) and are informally referred to within this document as “spring” and “summer”. This report and subsequent analysis is organized into these generalized time frames in an effort to focus on impacts to particular salmonid life histories considered important by fisheries researchers and management personnel. Compared to 1999, spring river surveys were begun approximately 1 month later and continued approximately 3 weeks longer. Hotspot surveys were also begun approximately 1 month later and lasted 1 month longer. The adjustments in survey dates was the result of trying to more effectively match survey efforts with seasonal bird abundances. We feel the dates utilized in 2000 better capture bird impacts to resident and migrating salmonid populations.

Hotspot Surveys—Spring

With the exception of the date shifts mentioned above, abundance and consumption surveys of avian predation at two principal hotspots (Horn Rapids Dam and Chandler Canal Bypass) were continued in the same manner as 1999.

River Reach Surveys—–Spring and Summer

With the exception of the date shifts, abundance surveys along five river reaches (Easton, Cle Elum, Zillah, Benton, Vangie) were continued in the same manner as 1999.

Acclimation Site Surveys—Spring

Acclimation site surveys were continued in 2000 in the same manner as 1999 to assess the potential for avian piscivores to be attracted to acclimation sites. These surveys were designed by the WACFWRU and implemented by the Yakama Nation (YN) hatchery personnel.

Aerial Surveys—Spring

These surveys provided abundance data and confirmation that hotspots chosen for intensive monitoring were the most active sites. In 2000, aerial surveys were paired on 4 days with river drifts on the Benton reach in an effort to compare the two survey methods.

North Fork Teanaway River Surveys--Spring and Summer

As anticipated, spring chinook smolt production and acclimation were begun at the Jack Creek facility in 2000 with a release of smolts in spring (31 Mar to 2 Jun). Surveys were continued along the reference reach of the North Fork Teanaway below the acclimation facility in the same manner as 1999. The only modification was the shortening (in river miles) of the survey.

Summation

In 2000, piscivorous birds were counted from river banks at hotspots and from a raft or drift boat along river reaches. Consumption by gulls was based on direct observations of foraging success and modeled abundance; consumption by Common Mergansers was estimated using published dietary requirements and modeled abundance. Seasonal patterns of avian piscivore abundance were identified, diurnal patterns of gull abundance at hotspots were identified, predation indices were calculated for hotspots and summer river reaches, and the efficacy of aerial surveys for estimating bird abundance within river reaches was evaluated (Grassley, et al. 2002).

Primary avian predators were California and Ring-billed Gulls at hotspots and Common Mergansers within upper river reaches. Estimated take (presumed to be salmonids) by gulls at hotspots (8 Apr - 30 Jun) was 30,340 fish at the Chandler Bypass Outfall and 133,135 fish at Horn Rapids Dam. Combined take was approximately 6% of the salmonids passing over or being released from the Chandler Dam area during the 2000 smolt migration season. Estimated take by Common Mergansers in Stratum 1 was 4,866 kg between 1 Jul and 31 Aug.

Consumption of Juvenile Salmon by Avian Piscivores—2001

In 2001, the YKFP again asked the Washington Cooperative Fish and Wildlife Research Unit to continue the research efforts begun in 1999

This effort was again organized into two specific time frames within which impacts of bird predation on juvenile salmon were assessed. The first, 8 Apr to 30 Jun addressed impacts of avian predators on juvenile salmon (principally spring chinook) during the spring migration of smolts out of the Yakima River. The second, 1 Jul to 31 Aug, addressed impacts to coho and spring chinook parr and/or residualized coho and spring chinook in the upper reaches of the Yakima River. These dates allow for all future sampling efforts to be accomplished on even numbers of 2-week blocks to best fit the consumption model. These dates still follow the basic organization and methodological design established in 1999 and are informally referred to within this document as “spring” and “summer”.

Hotspot Surveys—Spring

Hotspot survey methods were altered for the 2001 season in order to better estimate capture rates and consumption of smolts by gulls and to better deal with potential statistical bias. The new method involves acquiring time intervals between successful takes by gulls to determine consumption.

River Reach Surveys—Spring and Summer

With the exception of adding the Canyon reach to the spring survey schedule, all river reach surveys were continued in the same manner as previous years.

Acclimation Site Surveys—Spring

Acclimation site surveys were continued in 2001 in the same manner as 2000 to assess the potential for avian piscivores to be attracted to acclimation sites. These surveys were designed by the WACFWRU and implemented by (YN) hatchery personnel.

North Fork Teanaway River Surveys—Spring and Summer

Smolt production and acclimation were begun at the Jack Creek facility in 1999 with the release of approximately 240,000 coho. Since that time, the facility has been used as the release site for spring chinook. Surveys for avian piscivores were continued in 2001 along the reference reach of the North Fork Teanaway below the acclimation facility in the same manner as previous years.

Summation

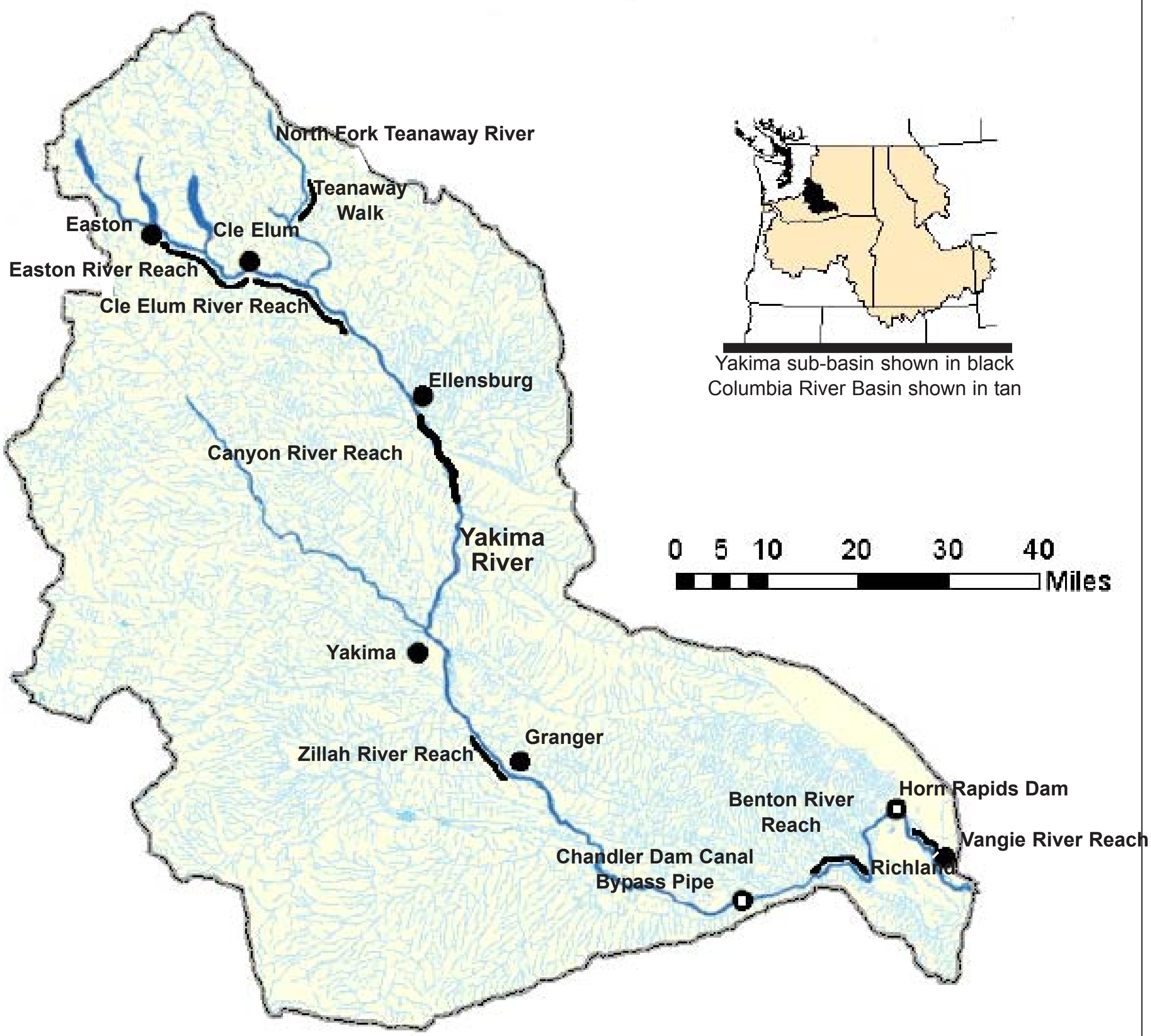
This report summarizes data collection activities, methods, results, and topics of discussion for the three field seasons (1999-2001) conducted by the Washington Cooperative Fish and Wildlife Research with comparisons to initial findings reported by Phinney et al. 1998. Except where noted, methodology and experimental design are consistent throughout the 3 years. Results in this report are divided into two parts: (1) findings from the 2001 field season and (2) results of multi-year comparisons. This report is intended to satisfy the contractual requirement for annual reporting of activities by the Washington Cooperative Fish and Wildlife Research Unit toward the development of an index to bird predation of juvenile salmonids within the Yakima River for the Washington Department of Fish and Wildlife.

METHODS

Study Locations

The Yakima River Basin encompasses a total of 15,900 square kilometers in south central Washington State along the eastern slopes of the Cascade mountain range, running a total length of approximately 330 kilometers (Figure 1). Terrain and habitat varies greatly along it's length, beginning at 2,440 meters elevation at the headwaters and ending at 104 meters elevation at the mouth, prior to entering the Columbia River near the City of Richland, WA. The upper reaches of the Yakima River (Cle Elum, WA and above) are high elevation loss areas predominated by mixed hardwood/conifer forests in association with a high degree of river braiding, log jams and woody debris. Reaches from Cle Elum to Selah, WA are intermediate elevation loss areas with less braiding and more varied terrain, including mixed conifer and hardwoods proximate to the river channel, frequent canyon type geography, and increasingly frequent arid steppe, sagebrush and irrigated

Figure 1. Map of the Yakima River Basin, Washington with approximate locations of the six river drift reaches (Easton, Cle Elum, Canyon, Zillah, Benton and Vangie) and the two hotspot locations (Horn Rapids Dam and Chandler Canal Bypass outfall).



Map date: February 2001. Data sources: Washington Dept. of Fish and Wildlife and Yakama Nation agricultural lands. Middle and lower reaches (Selah to the Columbia River) exhibit low elevation loss, an infrequently braided river channel dominated principally by hardwoods proximate to the river channel with arid steppe and irrigated agricultural lands abutting the shoreline.

Data Collection Methods

Hotspot Survey—Spring

In 2001, hotspot surveys were conducted systematically on a 2-week cycle of five surveys at each site, totaling 33 surveys at each site for the 2001 field season; 8 Apr to 30 Jun (Table 1). In 2001, sites were surveyed simultaneously (on the same day by different personnel) twice every 2-week period with the remaining observation days alternating between the two locations. Observations on simultaneous survey days began on the nearest 15-minute interval after sunrise and ended on the nearest 15-minute interval before sunset. Other observation days either began at a similar time after sunrise and ran until midday or began at midday and ran until the same time before sunset as defined previously for the simultaneous days. This allowed for observations during all periods of the day to account for the diurnal patterns of avian piscivores. Regionally calibrated tables obtained from the National Oceanic and Atmospheric Administration were used to determine the time of sunrise and sunset. Depending upon the length of day and start time, seven or eight, 2-hour periods existed within a single day.

The survey area for Horn Rapids Dam included 50 meters of river above the dam and 150 meters below the dam. The buoy located above the dam was not included within the survey area; birds resting upon the buoy were not included in abundance counts. The survey area for the Chandler Canal Bypass outfall included 50 meters of river above the outfall pipe and 150 meters of river below the outfall pipe. All birds resting upon the shoreline lateral to the specified 50 meters of river above and 150 of river meters below both hotspots were included in abundance counts. Observations were made from shore stations in either an automobile (Horn Rapids Dam) or bird blind

Table 1. Hotspot survey dates for Chandler Canal Bypass Pipe and Horn Rapids Dam in 2001.

Date	Chandler Pipe	Horn Rapids
11-Apr		*
13-Apr	*	
14-Apr		*
15-Apr	*	
16-Apr		*
18-Apr	*	*
20-Apr	*	
21-Apr		*
22-Apr	*	
23-Apr		*
25-Apr	*	*
27-Apr		*
28-Apr	*	
29-Apr		*
30-Apr	*	
2-May	*	*
4-May		*
5-May	*	
6-May		*
7-May	*	
9-May	*	*
11-May		*
12-May	*	
13-May		*
14-May	*	
16-May	*	*
18-May		*
19-May	*	
20-May		*
21-May	*	
22-May	*	
23-May		*
25-May	*	
26-May		*
27-May	*	
28-May		*
30-May	*	*
1-Jun	*	
2-Jun		*
3-Jun	*	
4-Jun		*
6-Jun	*	*
8-Jun	*	
9-Jun		*
10-Jun	*	
11-Jun		*
13-Jun	*	*
15-Jun		*
16-Jun	*	
17-Jun		*
18-Jun	*	
19-Jun	*	*
21-Jun	*	
23-Jun		*
24-Jun	*	
25-Jun		*
27-Jun	*	

(Chandler Canal Bypass) to avoid disrupting normal bird activity. Binoculars (Leica, 10x42) were used to aid identification. At Horn Rapids Dam, survey personnel stationed themselves on the windward bank of the river such that the preferred orientation of feeding birds (primarily gulls) was towards the observer. At the Chandler Canal Bypass outfall, altering the side of the river from which observations were made was not feasible. However, the distance from one side of the river to the other was considerably less than at Horn Rapids Dam, which improved the observers ability to accurately monitor bird behavior.

Each day was divided into 2-hour survey 'windows', consisting of three, 15-minute abundance/feeding 'blocks'. Each of these blocks was divided by a 15-minute period of no observation. This 75-minute cycle of 'blocks' was followed by a 45-minute rest period before beginning a new 2-hour 'window'. Within the 15-minute survey 'blocks', abundance of all piscivorous birds, foraging ratios (number feeding to total number present) and foraging rates (fish consumed/min) of gulls were determined (Table 2). Gulls flying within the study area were considered foraging. Gulls within the study area foraging on terrestrial prey items—such as insects, seeds, plants—were not considered feeding, but were included in total abundance counts.

Gulls sitting or standing on rocks emerging from the river or along the river edge were not counted as part of the foraging fraction. Although gulls sometimes utilized such rocks as fishing platforms, more frequently such platforms were used for loafing and other non-foraging activities. In addition, it was not feasible to distinguish foraging gulls standing on rocks from those loafing.

The gull chosen to be observed for foraging rate was

Table 2. Hotspot survey period design

Window	Block	Activity
1	1 Observation (15-minute)	Abundance of all piscivorous birds and ratio of gulls present to gulls foraging determined at beginning of block. First gull observed successfully capturing a fish followed continually until second successful capture. Time of foraging interval recorded. Abundance of all piscivorous birds and ratio of gulls present to gulls foraging determined at end of block
1	Rest (15-minute)	Any ongoing foraging interval was continued into this period until a second successful capture or the end of the 15-minute rest period. If there was no interval ongoing then no data were collected.
1	2 (15-minute)	Same activities as block 1.
1	Rest (15-minute)	Same as previous rest period.
1	3 (15-minute)	Same as blocks 1 and 2.
1	Rest (45-minute)	Any ongoing foraging interval was continued into the first 15-minutes of this period and ended according to the above criteria. The observer then rested for 30 minutes with no data collection activity.
2	1 (15-minute)	Repeat as Window 1.

the first individual observed consuming a fish within the study area. Once a gull was chosen it was followed continuously until a second successful capture occurred or a maximum of 30 minutes had passed. Initial successful feeding attempts were those in which a foraging bird captured a fish by plunging from the air into the water. Second takes were counted regardless of the means of capture. This accounted for the rare instance in which the second successful take by a gull was accomplished by stealing from another bird or jumping from an exposed rock or log into the water to catch a fish.

River Reach Surveys—Spring and Summer
Spring river surveys included four river reaches, each surveyed approximately every 2 weeks from 8 Apr to 30 Jun (Table 3). These reaches included Canyon, Zillah, Benton and Vangie. The Cle Elum reach was surveyed approximately every week from 8 Apr to Aug 31 and the Easton reach was surveyed weekly from 17 May until 31 Aug. All reaches surveyed in both spring and summer were identical in length and location as those in 1999 and 2000.

All river reach surveys were conducted by a two-person survey team from a 5.2 m aluminum drift boat or a two-person raft (depending upon water conditions). All surveys began between 0800 and 0900 and lasted between 2.5 to 5.5 hours, depending upon length of reach, water flow and wind speed. All surveys were preformed while actively rowing the drift boat/raft down stream to decrease the interval of time required to traverse the reach.

Of the two-person survey team, one was responsible for navigation while the other was responsible for identifying and recording birds (team members alternated rowing and bird identification duties approximately every hour). All piscivorous birds detected visually or aurally were recorded, including time of observation, species, sex, and age if distinguishable. Binoculars (Leica, 10x42) were used to aid identification. All birds positively identified by the navigator were included, although the team member responsible for bird identification at the time of the encounter made final decisions for uncertain or potential repeat identifications (double counting).

All piscivorous birds encountered on the river by survey personnel were recorded at the point of initial observation. Most birds observed were only slightly disturbed by the presence of the survey boat and were quickly passed. Navigation of the survey boat to the opposite side of the river away from encountered birds minimized escape behaviors. If subsequent to the encounter the bird attempted to escape from the survey boat by moving down river a note was made that the bird was being pushed. Birds being pushed were usually kept in sight until passed by the survey boat. Passage usually occurred when the river widened sufficiently to let the pushed bird pass to the side of the survey boat.

If the bird being pushed down river moved out of sight of the survey personnel, a note was made, and the next bird of the same species/age/sex to be encountered within the next 1000 meters of river was assumed to be the pushed bird. If a bird of the same species/age/sex was not encountered in the subsequent 1000 meters, the bird was assumed to have departed the river or passed the survey boat without detection, and the next identification of a bird of the same species/age/sex was recorded as a new observation.

Acclimation Site Surveys—Spring
Beginning on 11 Apr and continuing to 30 May, YN hatchery technicians at the Clark Flats, Jack Creek and Easton acclimation sites conducted piscivorous bird surveys. Surveys were conducted at various times throughout the day All piscivorous birds within the acclimation facility, along the length of the artificial acclimation stream, and 50 meters above and 150 meters below the acclimation stream outlet (into the main stem of the Yakima River or N. Fork Teanaway) were identified and recorded within their respective zones. Surveys were conducted on foot by hatchery technicians.

North Fork Teanaway River Surveys—Spring and Summer
The Teanaway River is a major tributary to the upper

Table 3. River reach survey dates for spring and summer, 2001. Dashed line demarcates spring and summer survey periods.

DATE	BENTON	CANYON	CLE ELUM	EASTON	TEANAWAY	VANGIE	ZILLAH
10-Apr							X
12-Apr	X					X	
17-Apr			X				
20-Apr		X					
24-Apr			X				X
26-Apr	X					X	
1-May			X				
3-May		X					
8-May							X
9-May			X				
10-May	X					X	
15-May			X				
16-May			X				
17-May		X		X			
22-May							X
23-May			X				
24-May					X		
29-May			X				
30-May				X			
31-May		X					
5-Jun							X
6-Jun			X		X		
7-Jun	X			X		X	
12-Jun			X				
13-Jun				X			
14-Jun		X					
20-Jun			X		X		X
21-Jun				X			
22-Jun	X					X	
26-Jun				X			
27-Jun			X				
28-Jun		X					
4-Jul				X			
5-Jul			X		X		
11-Jul				X			
12-Jul			X				
18-Jul				X			
19-Jul			X		X		
25-Jul			X				
26-Jul				X			
1-Aug			X		X		
2-Aug				X			
8-Aug			X				
9-Aug				X			
15-Aug			X		X		
16-Aug				X			
5-Sep				X			
6-Sep			X				

Table 4. River reach start point, end point and total length (km) surveyed for piscivorous birds.

Name	Start	End	Length	Strata
Vangie	1.6 km above Twin Bridges	Van Giesen St Hwy Bridge	9.3	3
Benton	Chandler Canal Power Plant	Benton City Bridge	9.6	3
Zillah	US Hwy 97/St. Hwy 8 Bridge	Granger Bridge Ave Hwy Bridge	16.0	3
Canyon	Ringer Road	Lmuma Recreation Site	20.8	2
Cle Elum	South Cle Elum Bridge	Thorp Hwy Bridge	28.3	1
Easton	Easton Acclimation Site	South Cle Elum Bridge	29.3	1
North Fork Teanaway	Jungle Creek	300 m above the Dickey Creek Bridge	5.5	N/A

Yakima River, entering at river kilometer 284. Approximately 26 kilometers up the Teanaway, along the North Fork Teanaway River, is the Jack Creek acclimation facility.

The survey reach included the river and it's banks from the Jungle Creek/North Fork Teanaway confluence down river past the Jack Creek acclimation site to the Dickey Creek bridge (5.79 km). One surveyor moved down from Jungle Creek, noting the presence of piscivorous birds. If navigation of the river-bank was not possible, the river was crossed and surveys continued on the opposite bank. If it was not possible to cross the river, detours were taken away from the river-bank (down stream) and paths through the underbrush were located to enable periodic return to the river-bank. Once there, a visual search up and down the stream was conducted. All piscivorous birds detected visually were recorded including time of observation, species of bird, sex and age if distinguishable. A pair of Leica 10x42 binoculars was utilized to aid in identification. This river reach was surveyed seven times between 24 May and 15 Aug 2001.

Statistical Modeling Methods

Estimates of smolt predation from the survey data were calculated by dividing the river into three spatial strata and two hotspot locations. Each stratum reflected differences in species abundance, distribution and geography. Hotspot surveys differ from river reach surveys in both the type of survey data collected, and the survey effort. The three strata were 1) the upper Yakima River (84 km), 2) the canyon (40 km), and 3) the river below the canyon to the mouth (198 km). The two hotspot locations were Horn Rapids Dam and the Chandler Canal Bypass Pipe. In addition, seven foot surveys along the North Fork Teanaway River were included. Estimates of biomass consumed were calculated for the three strata, however, a lack of data on fish community composition and size prevented calculations of the number of fish taken. Numbers of fish taken were calculated for the hotspots. The equations used to estimate bird abundance, biomass consumed and eventually calculate the number of smolts taken (when more precise fish population data become available), are slightly different for each area. A stratified approach to the estimation allows data taken with varying degrees of effort to be combined.

The primary data used to calculate smolt predation were abundance estimates of piscivorous bird species on the river as observed by boat. River reach surveys encompassed approximately 35% of the Yakima River. In addition, feeding rates and bird abundance data were collected at the two hotspots on the river. Assumptions common to both strata and hotspots were: 1) that all birds observed were correctly counted and identified to species, 2) that observing the birds did not effect their behavior, 3) that the behavior and abundance of birds during the time of observation was representative of birds at all times, and 4) that predation only occurred between the hours of dawn and dusk.

The total number of smolts taken from the river during the outmigration season *M*, was estimated by summing the estimates across strata. An estimate of *M*, is given by:

$$\hat{M} = \sum_{i=1}^{4} \hat{M}_i$$

Where,

$\hat{M}$ = the estimated total number of smolts consumed,

$\hat{M}_i$ = the estimated number of smolts consumed in the ith stratum (i = 1,...,4).*

*for summation purposes, hotspots are defined as the 4th strata.

River Reaches

Surveys in Stratum 1 were conducted by river drifts at regular intervals throughout the survey period on two reaches, Easton (29.3 km) and Cle Elum (28.3 km). The Cle Elum reach was surveyed throughout the season, from April to August and the Easton reach was surveyed from May to August. Each was surveyed on a different day. The Cle Elum section was surveyed more than the Easton section for each survey period (spring and summer). The reach surveyed was assumed to be representative of the entire stratum. Smolt consumption was estimated by the following:

$$\hat{M}_1 = \sum_{j=1}^{B_i} \sum_{k=1}^{t_1} \frac{W_j P_j}{\left(\sum_{h=1}^{H} s_{1kh} p_{1kh} \right)^I} \left[\frac{T_1}{\sum_{s=1}^{n} t_{1ks}} \cdot \frac{Km_1}{\sum_{s=1}^{n} km_{1ks}} \cdot \sum_{s=1}^{n} b_{1jks} \right]$$

where

T_1= number of possible days in survey for Stratum 1

t_{1ks} = number of float trips during of s^{th} river section (s = 1,2) in the kth block, in the 1st stratum,

Km_1 = the total length of river in the 1st stratum (84 km stratum)

km_{1ks} = the number of river miles drifted on the s^{th} river section, in the kth block, in the 1st stratum (28.3 km for Cle Elum and 29.3 for Easton),

b_{1jks} = the number of birds observed on the s^{th} river section of the kth trip, of the jth species in the 1st stratum,

B_1 = the number of bird species in the 1st stratum,

W_j = daily dietary food consumption rate for the jth (j = 1,2,…,B) bird species in terms of grams per day,

P_j = the proportion of the jth (j = 1,2,…,B) bird species diet comprised of the hth salmonid species (h = 1,2,…,H),

s_h = the size of the hth salmonid species in grams,

p_h = the proportion of the hth salmonid species available for feeding.

$$I = \begin{cases} 1 & \text{indicator when calculations of } \hat{M}_i \text{ in terms of the number of smolts eaten} \\ 0 & \text{when } \hat{M}_i \text{ expressed in terms of grams of salmonid smolts eaten} \end{cases}$$

The survey season was divided into blocks of approximately 2 weeks, centered on a river reach drift. Blocks were constructed to account for changes in species composition of juvenile salmonids during the outmigration season. Bird abundance during the river drift survey was considered representative of the entire block. Either one or two river reaches were surveyed in each block, and bird abundance was expanded by the appropriate temporal and spatial sampling fraction. The temporal sampling fraction was calculated by the following:

$$\frac{T_{1k}}{\sum_{s=1}^{n} t_{1ks}}$$

and the spatial sampling fraction was,

$$\frac{Km_1}{\sum_{s=1}^{n} km_{1ks}}$$

When the reaches were floated on consecutive days, they were treated as one survey, and sampling fractions were calculated accordingly, i.e., t_{1ks} for each block, however the number of days in each block, T_{1ks} varied.

Bird abundance for each block was estimated by:

$$\frac{T_{1k}}{\sum_{s=1}^{n} t_{1ks}} \cdot \frac{Km_1}{\sum_{s=1}^{n} km_{1ks}} \cdot \sum_{s=1}^{n} b_{1jks}$$

where $\sum_{s=1}^{n} b_{1jks}$

is the sum of the number of birds of each species counted in the river drifts, *s*, expanded by the sampling fractions for the k^{th} survey block.

In cases where river reaches were floated twice in a 2-week period, it was possible to evaluate the variability within the period

Consumption rates for birds are usually given in terms of the number of grams consumed per day. The number of grams per day can be converted into the number of fish per day consumed using information on the average size of different fish species, and their occurrence in the river over the survey season. The proportion of each species available for consumption (species composition) can be calculated from the number of smolts released from hatcheries in Stratum 1, and from the abundance of resident salmonids estimated by river surveys done in the fall by WDFW. The Salmonid species consisted of two outmigrating species, spring chinook, coho salmon and one resident species, rainbow trout. Although estimates of rainbow trout are calculated from fall survey data, they can serve as an index of resident salmonid abundance. The composition of salmonid species can be calculated by the following:

$$p_{1hk} = \frac{n_{hk}}{\sum_{h=1}^{H} n_{hk}}$$

where n_{hk} = the abundance of the h^{th} salmonid species (size) in the k^{th} block.

The abundance of both spring chinook and coho can be calculated using the number of each species released from the hatcheries and rearing ponds during the survey block. It can be assumed that all migrating juvenile fish exit the stratum in each block, so that the species composition estimated from the release data is representative of the species composition in the survey block. Further, not all fish size preferences are available for all bird species. Therefore, different size classes of the resident fish were taken into account.

Finally,

$$\sum_{k=1}^{t_1} \frac{W_j P_j}{\left(\sum_{h=1}^{H} s_{1kh} p_{1kh}\right)^I} \left[\frac{T_1}{\sum_{s=1}^{n} t_{1ks}} \cdot \frac{Km_1}{\sum_{s=1}^{n} km_{1ks}} \cdot \sum_{s=1}^{n} b_{1jks} \right]$$

is an estimate of the total number of fish consumed by the j^{th} bird species in Stratum 1 based on the consumption estimate W_j. Both estimates of biomass and numbers of fish consumed were calculated for each species in each survey block. Equation 2 then sums over all bird species to obtain an estimate of total fish consumption in the first stratum.

The estimator includes the following assumptions:

1. Birds are detected with probability 1
2. Birds are stationary targets throughout the day over the course of the survey,
3. All birds predating on fish are observable from the river,
4. The fraction of the river surveyed is a random sample of the reach (stratum),
5. Consumption rates, grams per day, are the same across all days regardless of the number of hours of daylight.
6. All outmigrating fish released into the river during an survey block exit before the start of the next survey block.
7. The abundance of resident salmonids observed in the fall are an index of residents available to birds in the spring.

Calculations for Strata 2 and 3 are similar to Stratum 1. The Benton reach was floated with the Vangie (West Richland) reach, so these two reaches were treated as one. The Zillah reach was always floated alone and 1-week separated the Zillah and Benton/ Vangie reach. Therefore, blocks were generally 1-week in length, centered on a survey of either the

Zillah or Benton/Vangie reach. There was one 2-week block where only the Zillah reach was surveyed due to logistical constraints and was therefore treated as its own spatial and temporal expansion factor representing that one drift.

Hotspots

Horn Rapids Dam and the Chandler Canal Bypass Outfall were defined as hotspot locations due to high levels of avian predation, primarily by gulls. To estimate predation we used two pieces of information collected during the survey, the number of birds actively foraging, and the average time between successful feeding attempts by a bird. Surveys were conducted in 2-hour windows consisting of three 15-minute blocks in which foraging intervals (time between successful takes by a gull) and six instantaneous counts of the number of foraging gulls were recorded.

The time between each successful take was recorded by the surveyors, and the data used in the calculations were the interval lengths, or t_{ijklm}. The average number of fish per bird-minutes per survey block was calculated by,

$$\overline{t}_{ijkl} = \frac{\sum_{m=1}^{M} t_{ijklm}}{M} = \frac{\text{bird} \times \text{min}}{\text{fish}}$$

where, t_{ijklms} = the number of minutes between successful fish takes for the sth (s = 1, 2,…,S) bird, for the mth forage block (m = 1,2,3) for the lth survey window (2-hour period) (l = 1,2,…,L) of the kth (k = 1,2,…,K) survey for the jth (j = 1,2,…,J) bird species on the ith (i = 1,2) hotspot.

The number of birds actively foraging was defined as in previous years. The number of bird-minutes for the survey block was calculated by,

$$\overline{y}_{ijklm} = \left(\frac{y_{ijklm1} + y_{ijklm2}}{2} \right) \cdot 15$$

where, y_{ijklmr} = the number of bird-minutes in the s^{th} (s = 1, 2) count, the m^{th} survey blockl (m = 1,2,3), for the l^{th} survey window (2-hour period) (l = 1,2,…,L), of the k^{th} (k = 1,2,…,K) survey, for the j^{th} (j = 1,2,…,J) bird species, on the i^{th} (i = 1,2) hotspot.

The number of fish taken in the m^{th} survey blockl of the l^{th} survey window, f_{ijklm}, was,

$$f_{ijklm} = \frac{\overline{y}_{ijklm}}{\overline{t}_{ijklm}} = \frac{\text{bird} \times \text{min}}{\text{bird} \times \text{min} / \text{fish}} = \text{fish}$$

where f_{ijkl} = the number of fish taken in the m^{th} survey block (m = 1,2,3), for the l^{th} survey window (2-hour period) (l = 1,2,…,L), of the k^{th} (k = 1,2,…,K) survey, for the j^{th} (j = 1,2,…,J) bird species, on the i^{th} (i = 1,2) hotspot.

The total number of fish taken for the year, f, is calculated by expanding fish counts by sampling fractions and summing across survey days, bird species and hotspots,

$$f = \sum_{i=1}^{2} \sum_{j=1}^{J} \frac{K}{k} \sum_{k=1}^{K} \frac{L}{l} \sum_{l=1}^{L} \frac{8}{3} \sum_{m=1}^{3} f_{ijklm}$$

Variances for f_{ijkl} were calculated using the delta method, and the overall variance was calculated using the variance for a multi-stage sampling design (Cochran 1977).

North Fork Teanaway River Surveys

Bird abundance data were also collected during seven foot surveys along a reference reach of the North Fork Teanaway River. These were done every other week from 24 May to 15 Aug. This area included the Jack Creek Acclimation Site. No data on the length of the river were included in the survey, so the estimate of biomass consumption for this stratum is for the survey reach only, between the time of the first and second survey. Biomass (M_5) of fish consumed was calculated by,

$$M_5 = W_j P_j \left[\frac{T_5}{t_5} \sum_{s=1}^{n} b_{5jk} \right]$$

where

T_5 = the length of the survey season in days for stratum five,

t_5 = the number of survey days for stratum five

b_{1jk} = the number of birds observed on the k^{th} survey, of the j^{th} species in stratum five,

B_1 = the number of bird species in the third stratum,

W_j = daily dietary food consumption rate for the j^{th} (j = 1,2,…,B) bird species in terms of grams per day,

P_j = the proportion of the diet consisting of the j^{th} (j = 1,2,…,B) comprised of the h^{th} salmonid species (h = 1,2,…,H).

RESULTS & DISCUSSION

2001 Survey Season

River Reach Surveys

Avian Piscivore Abundance—Spring
After combining gull species into a single group (gulls), 13 species of avian piscivores were identified, including, Black-crowned Night Herons, Belted Kingfishers, Common Mergansers, Double-crested Cormorants, Great Blue Herons, gulls, Hooded Mergansers, Great Egrets, Forster's Terns, Green Herons, American White Pelicans, American Bittern (single siting) and Osprey.

Inclusive of gulls, avian piscivore abundance during spring surveys ranged from 1.3 birds/km on the Canyon reach to 6.5 birds/km on the Vangie reach (Figure 2). The peak abundance of all piscivorous birds for any single survey day was 11.0 birds/km on 22 Jun within the Vangie reach. If gulls are excluded, mean bird abundances drop significantly on the Benton and Vangie reaches to 0.8 and 1.6 birds/km, respectively. Because gulls were not sighted on the Zillah, Canyon or Cle Elum drifts, total avian piscivore abundance does not decline when gulls are excluded from those calculations. Of the 13 species encountered, only the Great Blue Heron and Common Merganser occurred on all five reaches during the spring. The Belted Kingfisher was identified on four of the five survey reaches, absent only in the Vangie reach.

Common Mergansers, which are of particular importance because of their known utilization of salmon smolts as forage (White 1957; Wood 1985) and their relatively high abundance within the upper reaches of the Yakima River, were encountered most frequently in the Cle Elum reach (1.7 birds/km; Figure 3). They represented approximately 85% of all piscivorous birds within the Cle Elum reach during spring. In the lower three reaches, Common Mergansers accounted for 0.1% (Benton) to 18% (Zillah) of all avian piscivores observed (gulls included). In the Canyon reach, Common Mergansers accounted for nearly half (48%) of all piscivorous birds observed.

The distribution of bird species over all five reaches during spring was highly variable (Figures 4 to 8). Lower sections of the river had a greater diversity of species (all 13 occurring) and two species (Great Blue Heron and American White Pelican) had densities approaching that of the Common Mergansers on the Cle Elum reach. Excluding gulls, the Vangie reach had the greatest diversity of any reach with 9 of the 13 species occurring at some point during the spring survey season.

Avian Piscivore Abundance—Summer
Due to increasing water temperatures in the lower sections of the Yakima River and a shift in priority of monitoring efforts to summer parr (and resident

Figure 2. Spring abundance of all avian piscivores by reach—including gull sightings, 8 Apr to 30 Jun. Error bars represent standard deviation.

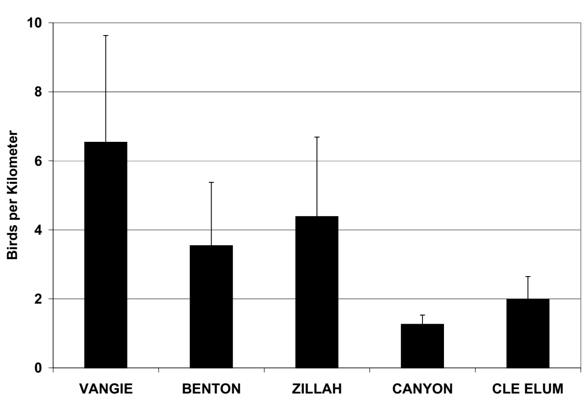


Figure 3. Spring abundance of Common Mergansers by reach, 8 Apr to 30 Jun. Error bars represent standard deviation.

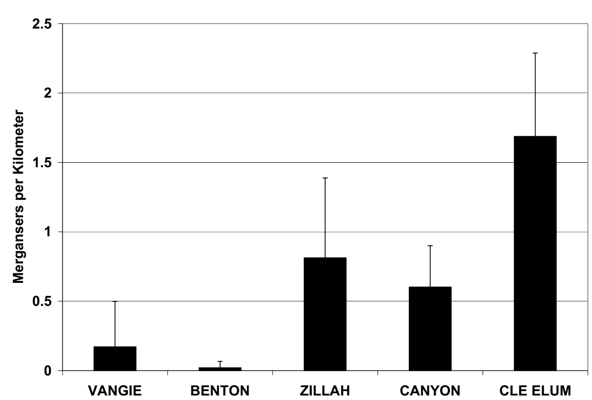


Figure 7. Average spring avian piscivore abundance per kilometer on the Vangie river reach, 8 Apr to 30 Jun. Error bars represent standard deviations. Bars without errors represent a single observation.

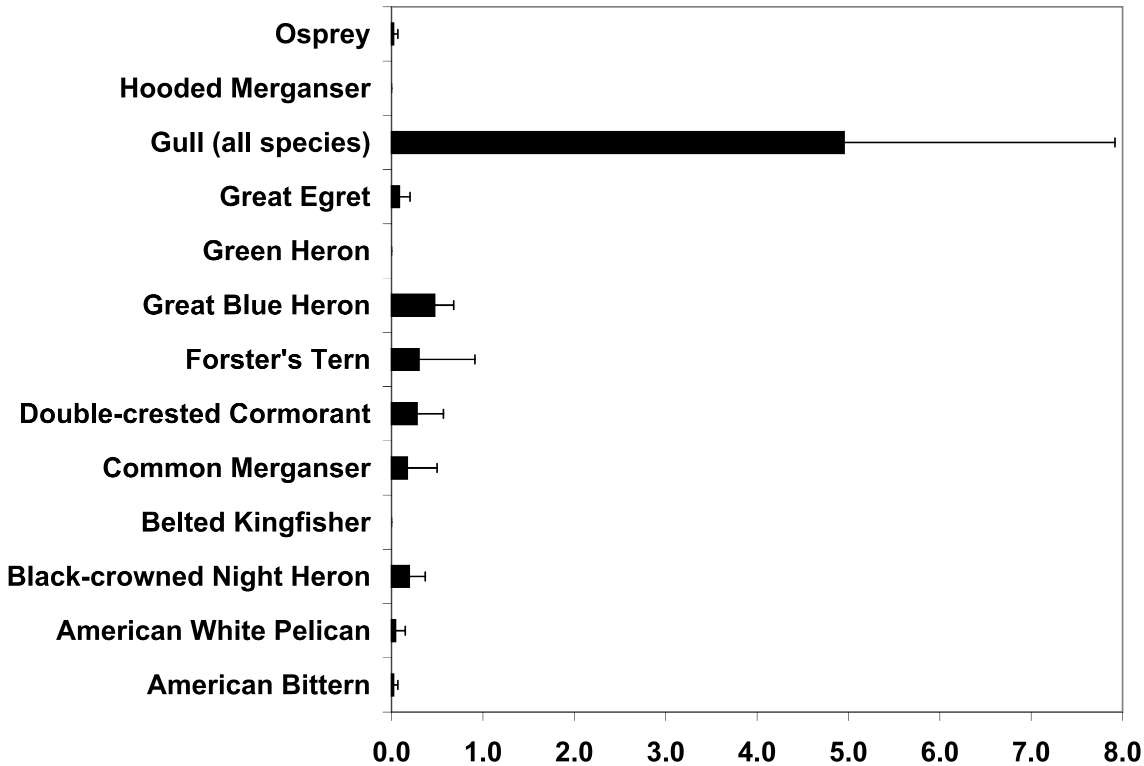


Figure 6. Average spring avian piscivore abundance per kilometer on the Benton river reach, 8 Apr to 30 Jun. Error bars represent standard deviations. Bars without errors represent a single observation.

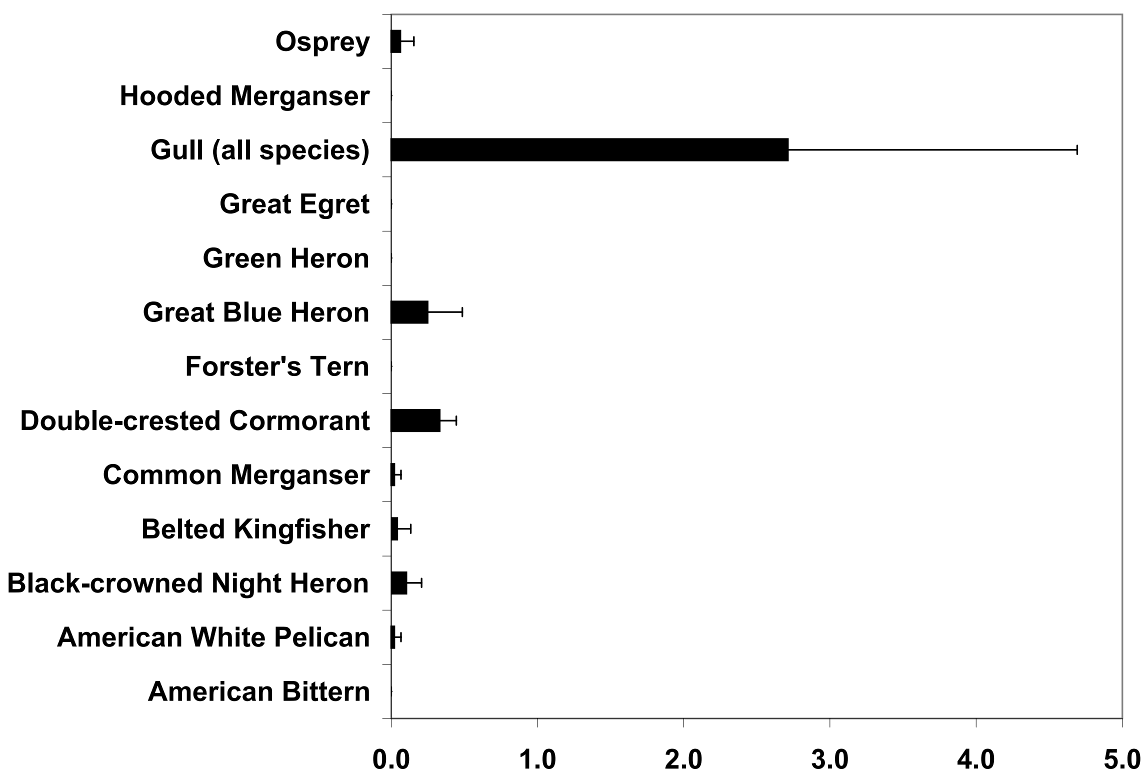


Figure 5. Average spring avian piscivore abundance per kilometer on the Zillah river reach, 8 Apr to 30 Jun. Error bars represent standard deviations. Bars without errors represent a single observation.

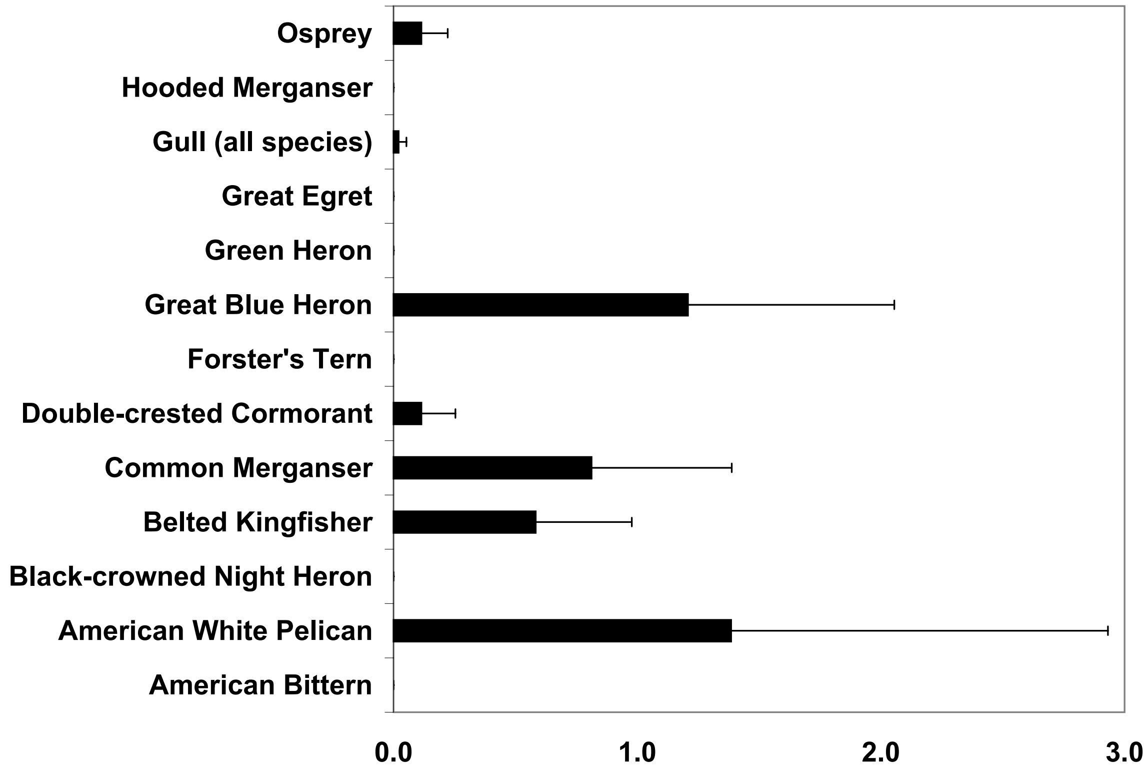


Figure 8. Average spring avian piscivore abundance per kilometer on the Canyon river reach, 8 Apr to 30 Jun. Error bars represent standard deviations. Bars without errors represent a single observation.

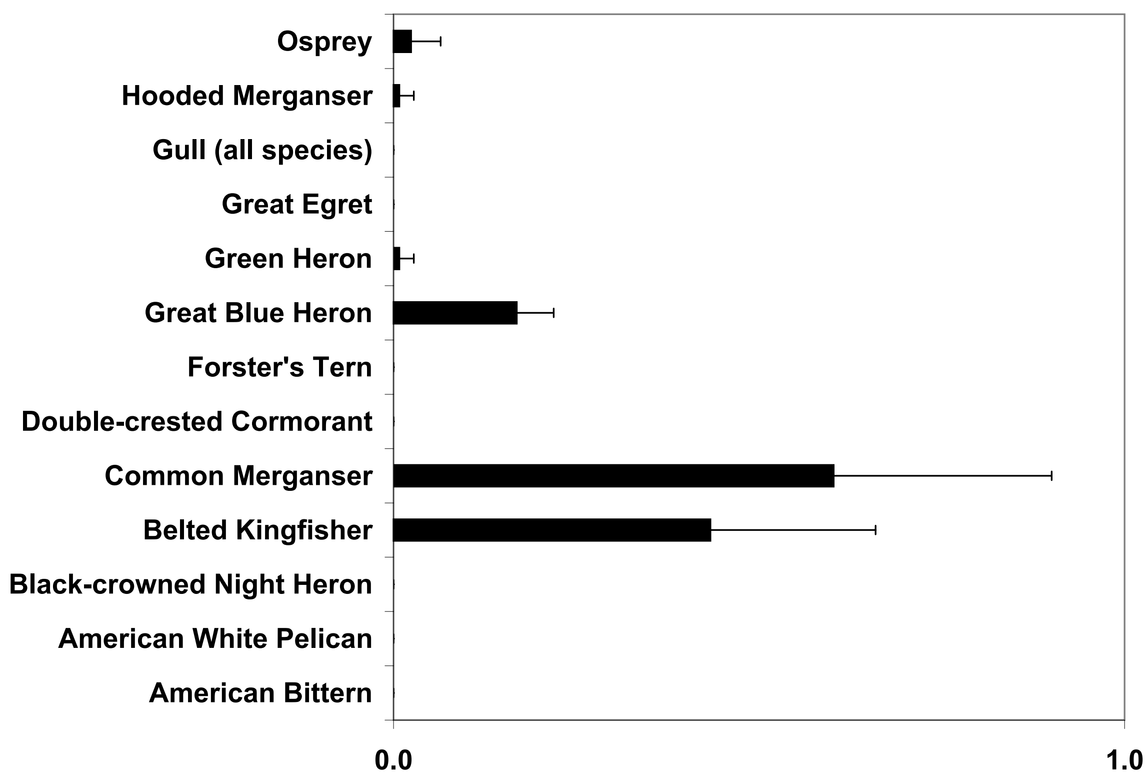
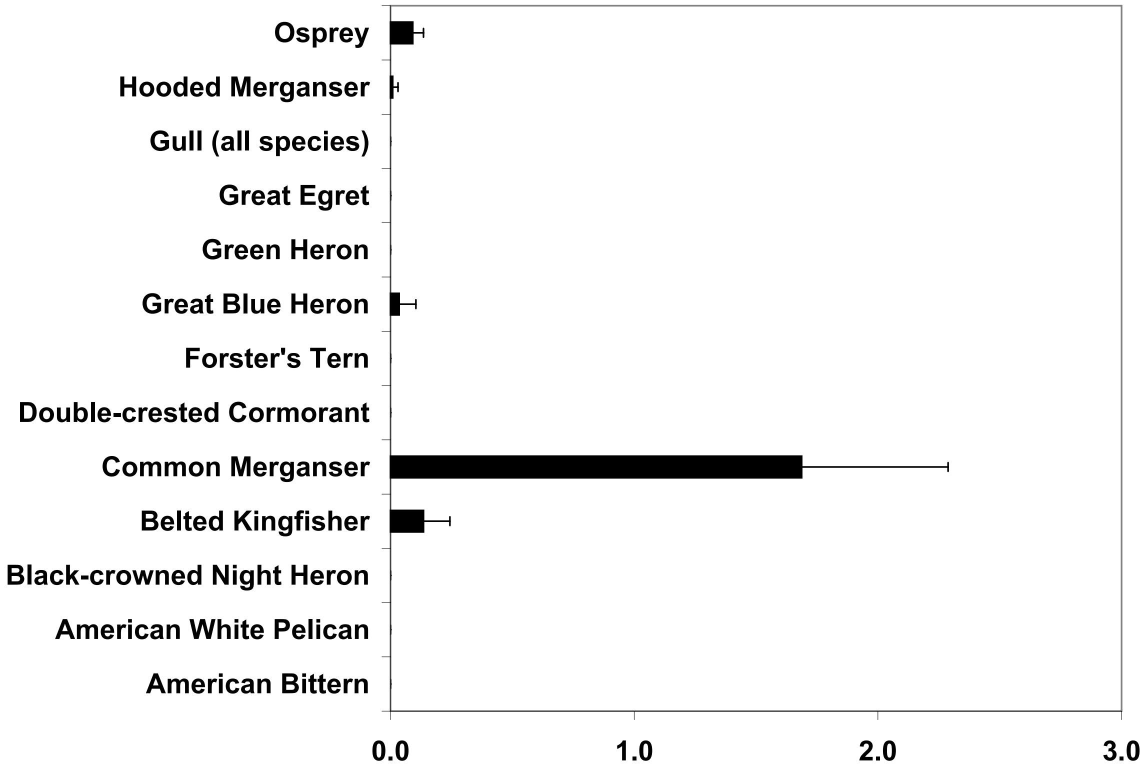


Figure 4. Average spring avian piscivore abundance per kilometer on the Cle Elum river reach, 8 Apr to 30 Jun. Error bars represent standard deviations. Bars without errors represent a single observation.



salmonid smolts), drifts during the summer survey period were limited to the Easton and Cle Elum reaches. After combining Ring-billed and California Gulls into a single group (gulls), eight species of avian piscivores were identified across both reaches. These included: Belted Kingfishers, Common Mergansers, Great Blue Herons, gulls, Osprey, Green Herons and Hooded Mergansers (Figures 9 and 10). Inclusive of gulls, avian piscivore abundance during the summer surveys was 2.2 birds/km on the Cle Elum reach and 2.4 birds/km on the Easton reach (Figure 11). The peak abundance of all piscivorous birds for any single survey day was 4.4 birds/km on 11 Jul on the Easton reach. Because gulls were extremely rare on these two reaches of the upper Yakima (0.01 birds/km), excluding them from the counts creates a negligible difference in mean or peak numbers of birds observed. Six of the eight species were encountered on both reaches. Hooded Mergansers and Black-crowned Night Herons were only observed on the Easton reach. Mergansers were the predominant species on the two reaches, averaging 1.9 and 1.8 birds/km on the Easton and Cle Elum reaches, respectively (Figure 12). This represented 79% and 81% of all piscivorous birds counted on the Easton and Cle Elum reaches, respectively. Mergansers breed extensively in the upper Yakima and many of the birds recorded during the summer survey period were young of the year. Belted Kingfishers, Great Blue Herons and Osprey all occurred consistently throughout the survey period, but never averaged greater than 0.5 birds/km for any individual drift and much less than that for the summer survey period.

Avian Piscivore Consumption—Spring

In previous years, Bald Eagles were included in biomass estimates of consumption on river reaches. Reviewing the literature more closely regarding this species' food habits, however, has led us to conclude they have little impact on migrating smolts or summer parr. While Bald Eagles do utilize fish for a certain proportion of their diet, it is primarily larger carcasses or warmer, shallow-water fishes. The remainder of their diet (up to 85%) consists of waterfowl and other bird species (Fielder 1982; Lang, et al. 1999; Mabie,

Figure 10. Average summer abundance of all avian piscivores per river kilometer by drift on the Cle Elum river reach, 1 Jul to 31 Aug. Error bars represent standard deviations. Bars without errors represent a single observation.

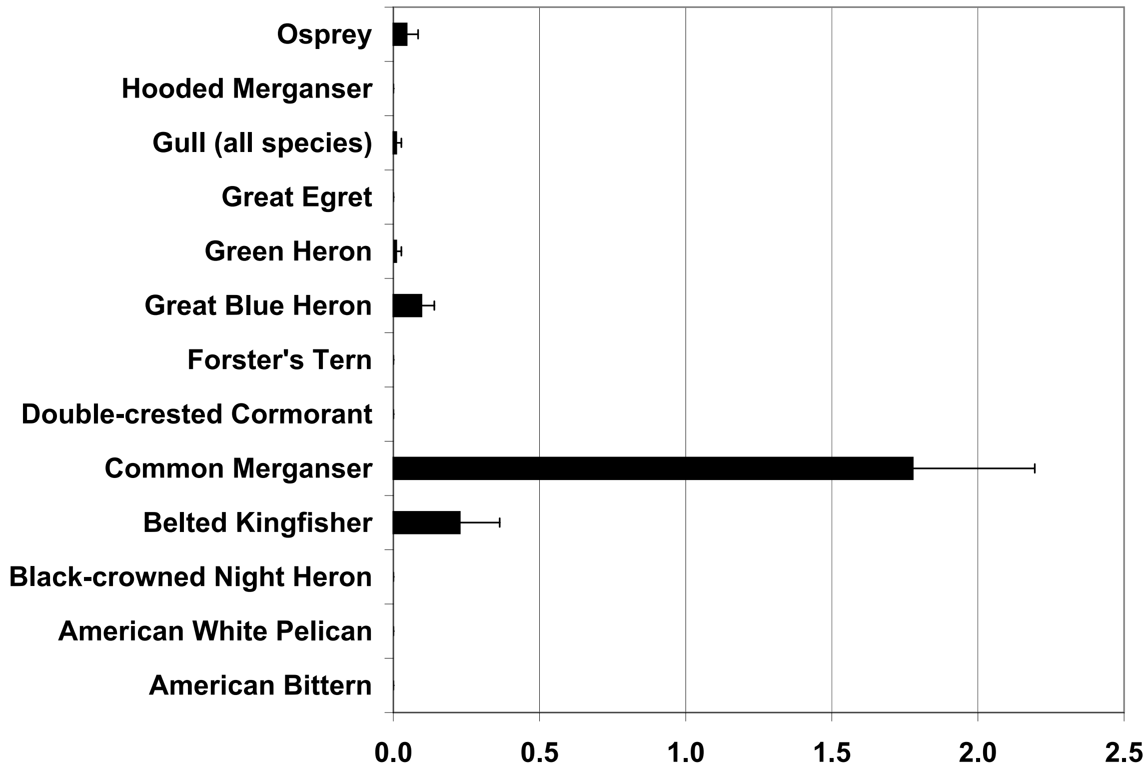


Figure 9. Average summer abundance of all avian piscivores per river kilometer by drift on the Easton river reach, 1 Jul to 31 Aug. Error bars represent standard deviations. Bars without errors represent a single observation.

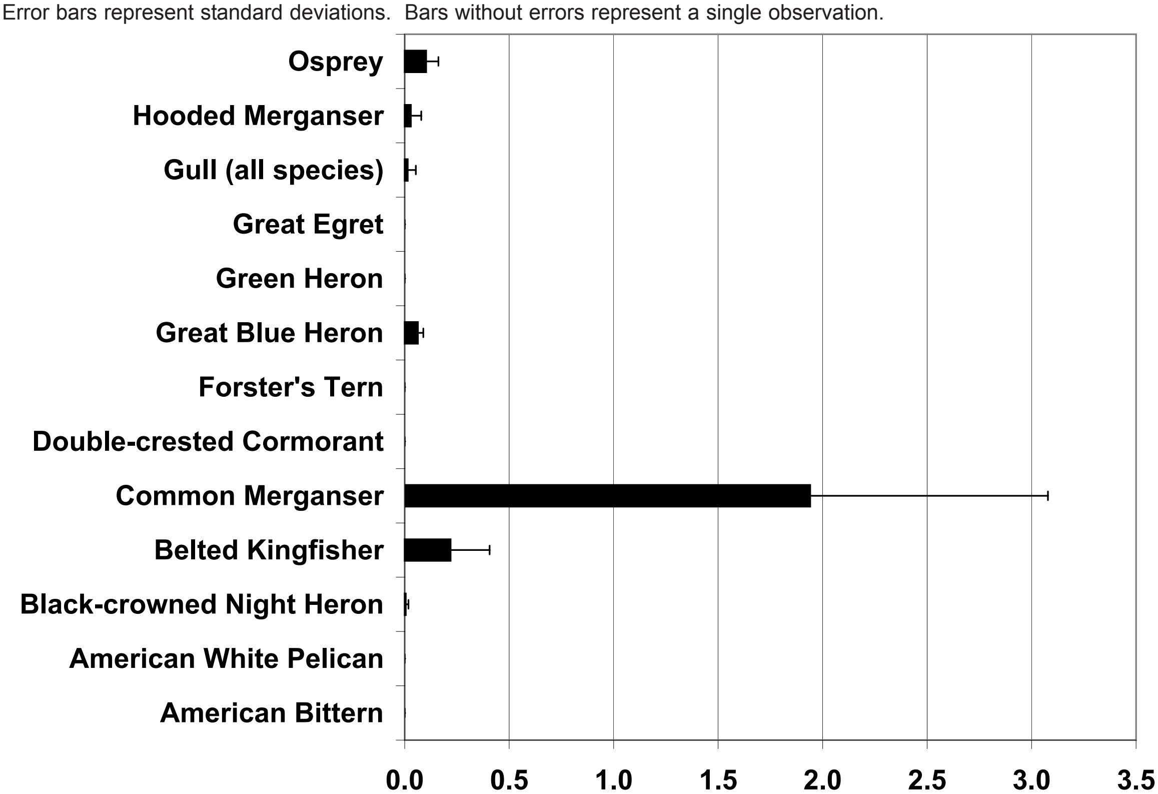


Figure 11. Average summer avian piscivore abundance per km on the Easton and Cle Elum reaches and the Teanaway foot survey, 1 Jul to 31 Aug. Error bars represent standard deviation.

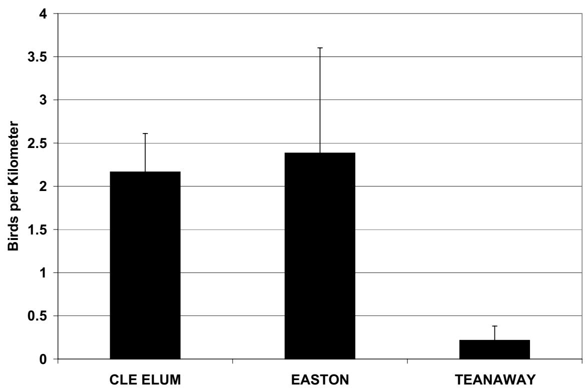
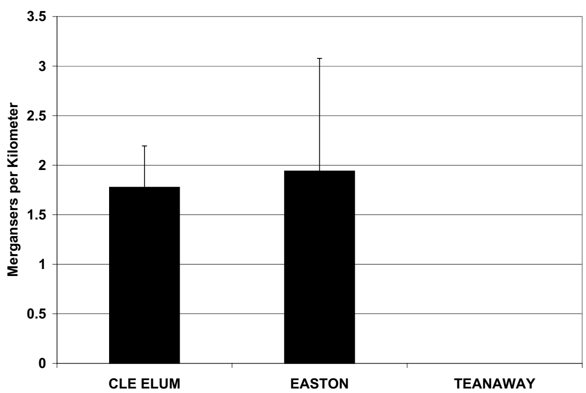


Figure 12. Average summer Common Merganser abundance per km on the Easton and Cle Elum reaches and the Teanaway foot survey, 1 Jul to 31 Aug. Error bars represent standard deviation.



et al. 1995). Osprey remain in the biomass estimates because it is widely accepted that their diet is comprised almost entirely of live fish and prey size selection by Osprey could include parr, steelhead, or rainbow trout populations of interest. However, it should be noted that Osprey primarily feed on fish weighing between 150-300 g (Cramp and Simmons 1977;) or 25-35 cm (Green 1976; Swenson 1978). Van Daele and Van Daele (1982) found this size class to constitute nearly 90% of the Osprey diet in Idaho. Therefore, impacts to fishes outside these length and weight ranges by Osprey could be adjusted accordingly if the length distribution of the fish community were known.

Mean biomass consumption for the spring survey season was greater within Stratum 3 (162.9 kg/km) than within Stratum 1 (75.7 kg/km) or Stratum 2 (33.6 kg/km). The primary consumer within Stratum 1 was the Common Merganser, accounting for 93.3% of total biomass consumed. The next species of significance within Stratum 1 during spring were the Great-blue Heron and Osprey which together accounted for 5.4% of the total biomass consumed. Though present in substantial numbers in Stratum 1 during the spring, Belted Kingfishers consumed less than 1% of the total biomass taken.

Stratum 2 contained bird species similar to that of Stratum 1 and Common Mergansers accounted for the greatest consumption (72.1%). Great Blue Herons and Belted Kingfishers accounted for 18.4% and 6.2% of fish biomass consumed in Stratum 2, respectively.

Stratum 3 had the greatest diversity of avian piscivores. Included were: American White Pelicans, Double-crested Cormorants, Great-blue Herons, and Common Mergansers. Of this group, American White Pelicans were estimated to have consumed the largest percentage of fish biomass (54.0%), while Great Blue Herons, Common Mergansers and Double-crested Cormorants consumed 16.8%, 12.5% and 4.7%, respectively. Although present in greater numbers in Stratum 3 than any other stratum during the spring, Belted Kingfishers consumed less than 1% of the total biomass taken.

Avian Piscivore Consumption—Summer

Because water temperatures in the lower river were too high for salmon smolts to survive, summer surveys were conducted only within Stratum 1 (upper reaches of the Yakima). During this time of year, salmonids are represented by residualized spring chinook, summer parr, steelhead and rainbow trout in the upper river and are still vulnerable to avian predation. Mean biomass consumed within Stratum 1 in summer was 50.0 kg/km. This represented approximately half (40%) of all the estimated biomass consumed within Stratum 1 for the entire season. Common Mergansers accounted for the greatest proportion of the take (91.5%) during the summer period. During this time period, Common Mergansers are in their highest numbers because broods have moved onto the river to feed. Although Great Blue Herons are not known to breed within the upper reaches, they were observed more frequently during the summer within Stratum 1 than during the spring. Their estimated consumption was approximately 3.5% of total estimated biomass consumed (second to that of Common Mergansers) . Belted Kingfishers nearly tripled in abundance from the spring survey period, yet still accounted for just less than 1% of the total estimated take.

Hotspot Surveys

Avian Piscivore Abundance

In 2001, hotspot surveys were conducted on 33 days at both Chandler Canal Bypass (Chandler) and Horn Rapids Dam (Horn Rapids). Surveys occurred between 8 Apr and 30 Jun. Although other piscivorous birds were identified, gulls (California and Ring-billed) were by far the most numerous. Mean gull abundance was consistently low (< 5/day) until late April at Chandler and mid-May at Horn Rapids. Numbers peaked quickly at Horn Rapids by the third week of May and then dropped to less than 5 gulls/day again until the end of surveys. At Chandler, numbers peaked quickly in early May and maintained an average of > 20 birds/day until late June.

Species other than gulls identified at the Chandler hotspot included: Black-crowned Night Herons, Great Blue Herons, Common Mergansers, American White Pelicans, Great Egrets, Belted Kingfishers and Double-crested Cormorants. Species identified at Horn Rapids included all those sighted at Chandler plus Caspian Terns, Forster's Terns and Osprey.

Within the time period surveyed, the maximum number of gulls at Chandler occurred on 7 May with an average of 125.3 gulls (Figure 13) and at Horn Rapids the maximum occurred on 23 May with 49.4 gulls (Figure 14). This represented a shift in gull abundance between the two sites from the previous year.

Figure 13. Average gull abundance at Chandler Canal Bypass Pipe 8 Apr to 30 Jun. Error bars represent standard deviation

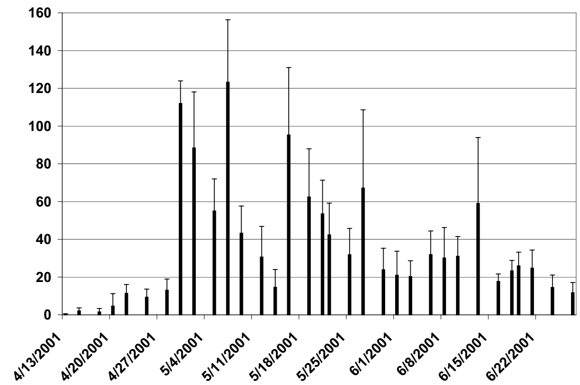
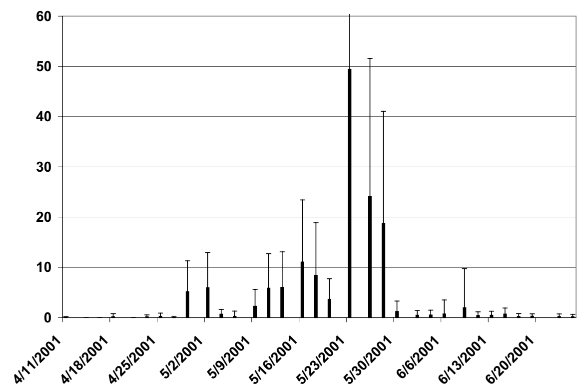


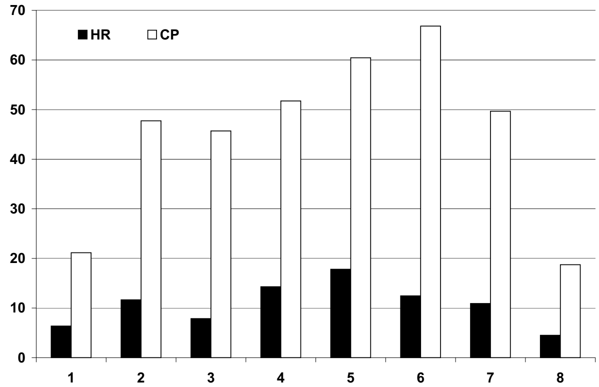
Figure 14. Average gull abundance at Horn Rapids Dam 8 Apr to 30 Jun. Error bars represent standard deviation.



Diurnal patterns of gull abundance were difficult to discern when gull numbers were low early in the season. As gull numbers increased, patterns of diurnal abundance became more apparent. To resolve these patterns, survey periods which were numbered sequentially 1 to 8 (each 2 hours long with seven or eight occurring per day depending upon survey start time and length of day) were averaged across the survey season—8 Apr to 30 Jun. All survey Period 1 gull observations (first and second hour after sunrise) were averaged across all days, all survey Period 2 gull observations (third and fourth hour after sunrise) and so on for all survey periods.

Mean daily abundance patterns at Chandler showed a general, steady increase in gulls from sunrise to a mean daily peak 66.8 gulls in Period 6 (Figure 15).

Figure 15. Diurnal patterns of gull abundance at Horn Rapids Dam and Chandler Canal Bypass. Numbers 1 through 8 represent 2-hour survey periods beginning at sunrise.



This is approximately the 8th or 9th hour after sunrise. The pattern of gull abundance after the peak is a consistent decline over the last two periods. By Period 8, the last of the surveys, gull numbers were still averaging greater than 10 birds, but observations after sunset were not possible. It is assumed that there was insufficient light for effective foraging after this point and most remaining gulls were loafing or sleeping on rocks. Quite often, the last count of the 2-hour window was near zero, though higher counts early in the window produced a mean abundance of approximately 10 birds.

A similar analysis at Horn Rapids shows a pattern somewhat consistent with that at Chandler, although with a proportionately smaller number of birds. Gull numbers at Horn Rapids also showed an increase over the day, though peak numbers occurred in period 5 (17.8 birds). This is approximately the 7th or 8th hour after sunrise. Like Chandler, gulls showed a steady decline over the last 3 periods. By the last period, mean gull abundance had decreased to less than 5 birds.

Unlike survey results from 1999 and 2000, neither site showed a daily peak in the 3rd period. Nor was the pattern of increase to the peak or subsequent decline consistent across the 3 years. This brings into question utilizing the daily peak or other parameter associated with diurnal abundance as an index for determining mean daily gull abundance with less intensive monitoring as was suggested in our 1999 and 2000 annual report (Grassley and Grue 2001; Grassley et al. 2002).

Consumption by Gulls

Modeled average rates of successful fish capture by gulls at both hotspots resulted in consumption estimates for these sites of 37,035 (SE=8,398) fish at Horn Rapids and 132,848 (SE=22,313) fish at Chandler. If the release of 2.001 million fall chinook smolts from below Chandler Dam are taken into account (148,000 smolts on 10 Apr and 1,853,037 smolts on 25 May), then our combined consumption estimate of 169,883 fish represents 4.9% of all smolts estimated passing or being released from the Chandler Dam area during the 2001 smolt migration season. These figures do not include consumption by gulls at hotspots before surveys began (8 Apr) or after surveys ended (30 Jun) and assume that all fish taken were smolts.

Acclimation Site Surveys

Piscivorous bird surveys were conducted from late March until early June at the Cle Elum acclimation facility; from late March to late April at the Clark Flats site; and from early April until mid May at the Easton site. Surveys were generally done on a daily basis during the time periods mentioned. However, daily survey times and frequencies varied greatly. Piscivorous birds observed included: Great Blue Herons, Belted Kingfishers, Osprey and three species of mergansers (Hooded, Common and Red-breasted). Of the three acclimation sites, Cle Elum and Easton had the greatest diversity of piscivorous species (five of the six), whereas Clark Flats only had four of six. Red-breasted Mergansers were only seen at Clark Flats and Great Blue Herons were never seen there. Because of the differing survey time periods and irregularities of the daily survey schedule it is difficult to compare bird abundances among the sites or make other than qualitative statements about individual sites. Common Mergansers were the most frequently occurring species at the Easton and Cle Elum sites where counts greater than 10 occurred on 9 of 22 days at Easton and 19 of 58 days at Cle Elum. There were only 2 days during the survey period in which no Common Mergansers were seen at these two sites. Clark Flats had much less piscivorous bird use than the other two sites and Belted Kingfishers were the most consistent species recorded. However, all three merganser species were observed at the Clark Flats site in small numbers (5 or less).

North Fork Teanaway River Surveys

Surveys along the North Fork Teanaway resulted in low bird abundance (0.2 birds/km) and consumption (36.3 kg) for the entire season 24 May to 31 Aug. The only birds encountered on the North Fork Teanaway were Great Blue Herons, Common Mergansers and Belted Kingfishers (Figure 16). If consumption is assumed to be 100 percent salmonids this would represent less than 0.5 percent of the Spring Chinook released from the Jack Creek acclimation facility in the spring.

Figure 16. Average spring avian piscivore abundance per kilometer on the North Fork Teanaway foot survey, 24 May to 30 Jun. Error bars represent standard deviations.

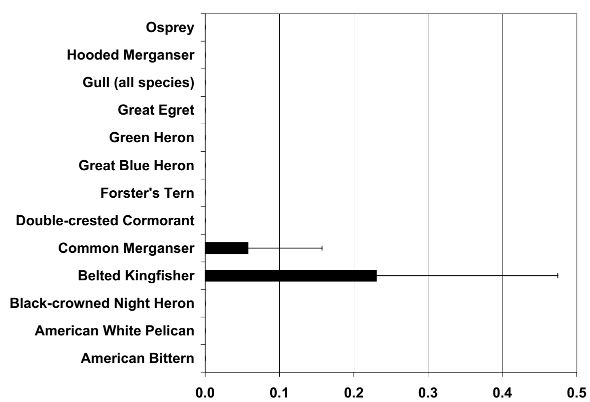
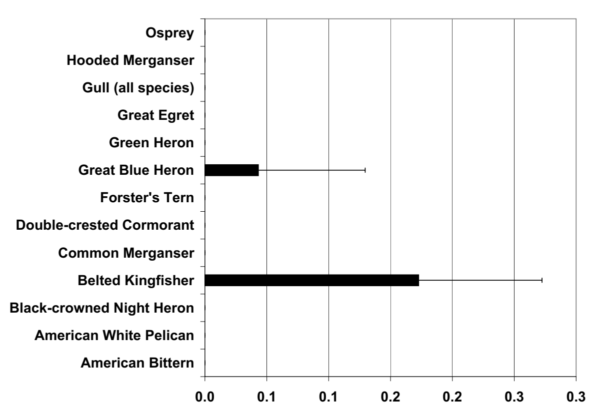


Figure 17. Average summer avian piscivore abundance per kilometer on the North Fork Teanaway foot survey, 1 Jul to 31 Aug. Error bars represent standard deviations.



Comparisons Among Years, 1999-2001

Hotspot Surveys

Mean daily gull abundances varied from year to year and at the individual sites (Figures 18 and 19). Because of the different survey period in 1999, seasonal comparisons to 2000 and 2001 are problematic. 1999 did not include surveys after 31 May, which was found to be a time of high gull abundance in later years. Surveys were also started earlier in 1999 before gulls may have arrived in the area. Thus, the 1999 data contain an approximately equal survey effort as 2000 and 2001, but the time is shifted to earlier in the season which resulted in much lower overall gull numbers recorded. Mean gull abundances in 2000 and 2001, however, are directly comparable and result in an interesting swap between years and sites of greatest total gull abundance. In 2000, total gull abundances at Horn Rapids Dam and the Chandler Outfall Pipe averaged 21.8 gulls/day (SE = 4.9) and 11.1 gulls/day (SE = 2.7), respectively. In 2001, total gull abundance was greater at Chandler (36.5 gulls/day, SE = 5.5) than at Horn Rapids Dam (8.9 gulls/day, SE = 3.3). Estimates of consumption at hotspots were determined utilizing counts of foraging (not total) gulls and the feeding rate as measured by successful captures. Numbers of fish consumed by gulls (Table 5) showed a similar relationship (swap) between sites and years for 2000 and 2001.

Table 5. Total seasonal consumption (numbers of fish) by gulls at hotspots for three years, 1999-2001.

	Chandler Pipe	Horn Rapids Dam	Survey Dates
1999*	2,157	19,406	3/15-5/31
2000	30,340	133,135	4/8-6/30
2001	132,848	37,035	4/8-6/30

*survey dates shifted

At Horn Rapids we saw decreases in both foraging gull and total gull numbers from 2000 to 2001. Total gull numbers at Chandler, however, increased dramatically from 2000 to 2001 (as previously discussed) while the mean number of foraging gulls for the two years remained approximately constant. Therefore, the swap in consumption estimates between 2000 and 2001 consistent with that of total gull abundances was the result of a much higher rate of feeding at Chandler in 2001.

Phinney et al. (1998) estimated a predation threshold of 8,000 cfs (measured at Kiona) for Horn Rapids Dam and 4,000 cfs for the Chandler Outfall Pipe. In 1998, the year of their study, flows frequently attained and surpassed these limits and it was found that beyond these flows, predation approached zero. Because of these observations, the authors hypothesized that a low-flow year would result in the exact opposite of that seen beyond their predation thresholds, i.e. a significant increase in predation at both hotspots. In 2001, we found that their hypothesis did not hold true at Horn Rapids Dam, but was supported at Chandler where predation rates and total gull numbers increased dramatically.

Because of low water levels in 2001, it was possible to more closely investigate the relationship of gull abundance and foraging behavior at hotspots in relation to river flow. Using data from all 3 years (1999-2001), we regressed numbers of foraging gulls at Horn Rapids against flow and year effects (Figure 20). Results suggest that across years, flow is positively (r^2 =.2589, alpha = 0.1, P=0.08) correlated to the number of foraging gulls.

Because the chronology of the spring smolt migra-

Figure 18. Mean daily gull abundance at Horn Rapids Dam for 1999, 2000 and 2001

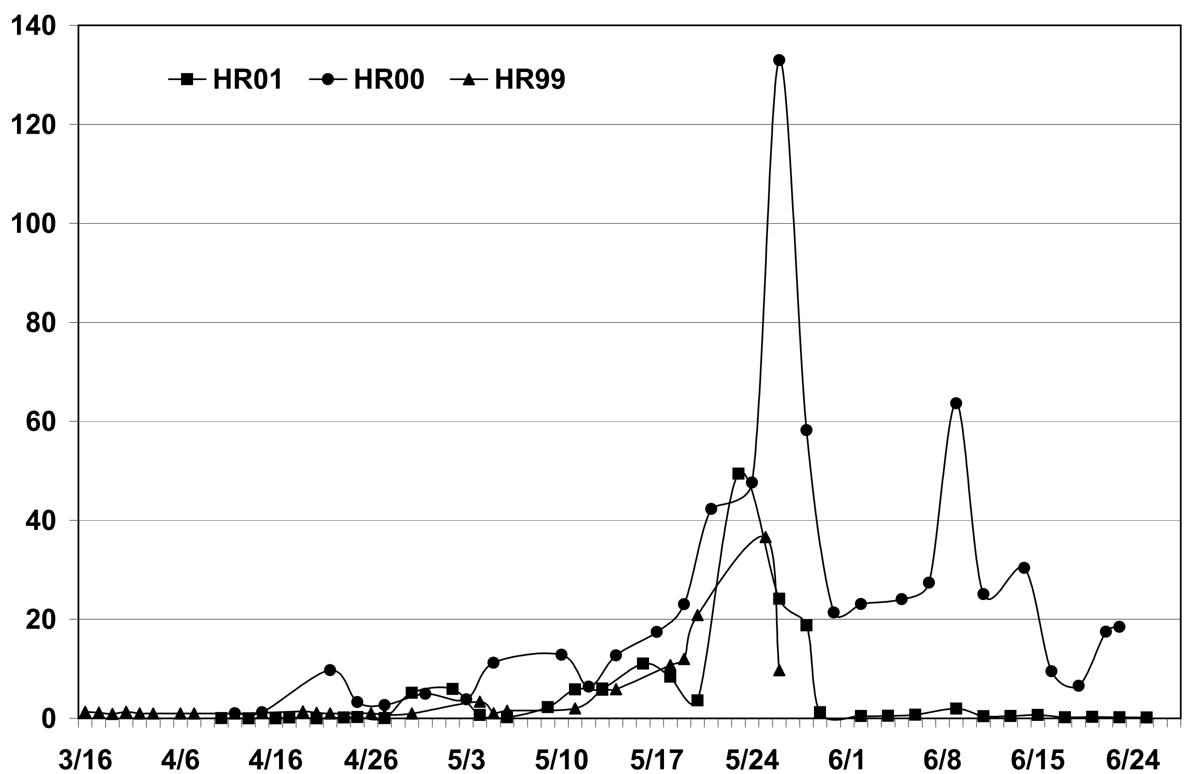
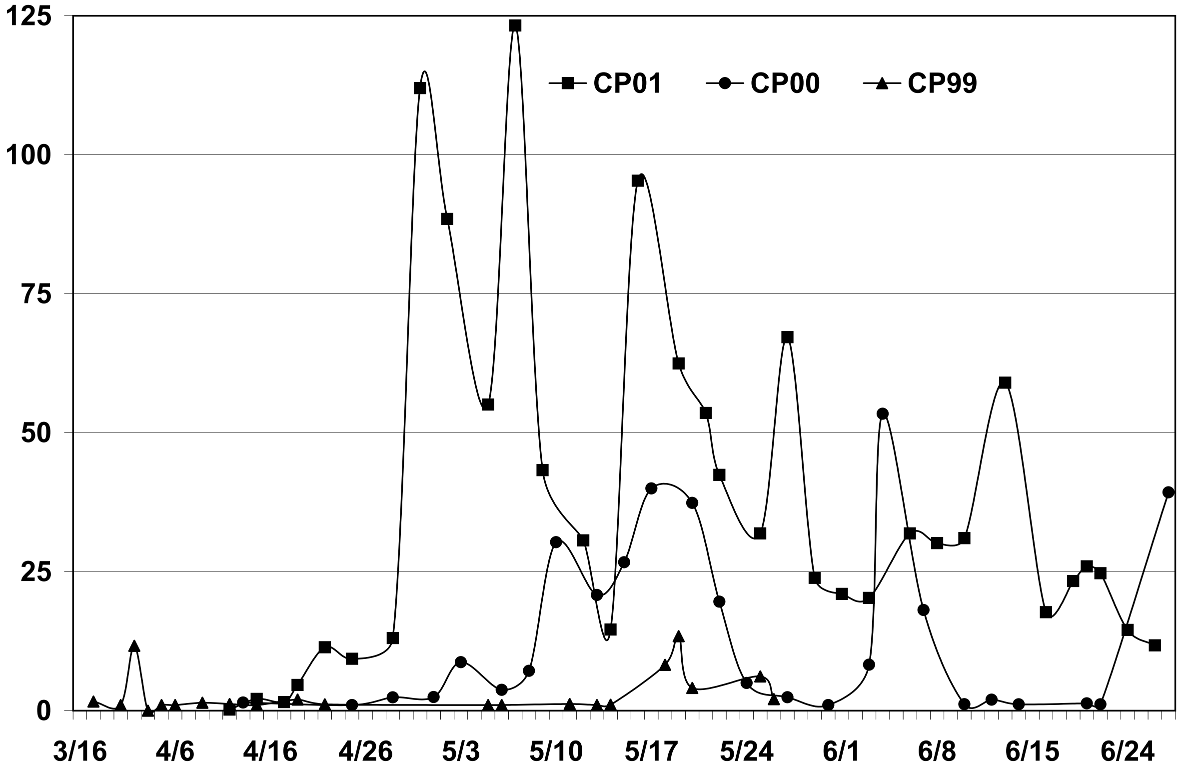


Figure 19. Mean daily gull abundance at Chandler Canal Bypass for 1999, 2000 and 2001



tion varies somewhat (between April and July) from year to year, it was important to test for a correlation between gull numbers and fish passage in addition to river flow. The estimated number of foraging gulls at Horn Rapids Dam on a single survey day was regressed against the number of juvenile smolts passing through Chandler 2-days prior to the date of each survey. The relationship between the numbers of foraging gulls and the number of smolts observed at Chandler 2-days prior to the survey day changes from year to year, as indicated by a significant interaction (P=0.001) between year and fish numbers (Figure 21). Because of this interaction, numbers of foraging gulls appear not to be significantly correlated to fish passage. Usually, significant interactions make the main effects (fish passage and year) difficult to interpret. In the current evaluation, much of the interaction is derived from 2000, whose slope is quite different than 1999 and 2001. When analyzed separately, there was a statistically significant relationship between the fish passage and the number of foraging gulls for 2000 and 2001. In 2000, the estimated coefficient for the slope of the regression line of fish versus foraging birds was 0.2697 (P=0.017), In biological terms, this slope value translates into an increase of about 270 foraging bird-use-days for each increase in 1000 smolts passing through Chandler 2 days prior to a bird survey day. For 2001, the slope of the regression line was 0.0079 (P=0.068), which translates into an increase of only 8 bird-use-days for each increase of 1000 fish. Although the slope of 2001 is statistically significant, it may not be biologically meaningful.

Using a 2-day lag in fish passage time was based upon a limited knowledge of true migration travel times. Similar results and patterns of regression occurred when the analysis was done using a 1-day lag and same day passage. It was also found that the number of smolts passing through Chandler on one day is correlated with the number passing through the next. Using time series techniques, it was found that fish passage on any day in 1999 and 2001 was correlated with passage on any other day up to 18 days earlier. In 2000, this effect occurred up to 4 days prior. Thus, the patterns of regression seen in the analysis are most likely an artifact of a larger scale gull response to an overall increase in smolt availability. Another possibility is that gull abundance is the result of the reproductive phenology of the local gull population. Gulls could be arriving and beginning to breed in the area for a number of reasons and simply utilize the foraging opportunities at Horn Rapids when they arise. A better understanding of this phenology could be vital in predicting the relationships between foraging gull numbers, river flow and fish passage. Our current analyses are making the assumption that low gull numbers are a response to one of the main effects (fish passage, flow, year), when in fact there may not be any gulls in the area. A similar analysis, but using trimmed dates to better reflect gull presence in the area may be done in 2002.

In this and previous reports, understanding the diurnal pattern of gull abundance at hotspots has been discussed as a means of accomplishing equally accurate surveys under a less intensive sampling regime. In 1999 and 2000, the peak period of daily bird abundance was in the 3rd period for both sites, although the pattern of increasing and decreasing bird numbers was not consistent across years or sites. In 2001 the peak time of bird abundance was during period 5 and 6 for Horn Rapids and Chandler, respectively. The low flows in 2001 may be responsible for this shift in time of peak bird numbers, although the mechanism causing this shift is unknown. It is possible that fish movement is being impacted by flow rates which in turn affects gull presence throughout the day. It is anticipated that flows in 2002 will be similar to that of 2000, giving us the opportunity to see if gull diurnal patterns return to those seen in 2000.

River Reach Surveys

Sixteen piscivorous bird species have been recorded during the 3 years of surveys (Table 6), with the greatest diversity of species occurring in the lower sections of the Yakima River (Stratum 3). Patterns of bird abundance in this portion of the river over the 3 years lack consistency within and/or across years (Figure 22). The increase in overall abundance in 2001 is distributed across most of the occurring species, but is heavily weighted by the immigration of American White Pelicans into the area. There were no pelicans counted in either 1999 or 2000. A total of 136 were counted across six separate drifts in 2001 (all but three on the Zillah reach). Low flows could have contributed to the increase in numbers and diversity of avian piscivores in 2001, although it is difficult to determine if these flow conditions would have increased salmonid availability disproportionately to other fish species. Therefore, it becomes problematic to assume that the increased bird abundance also resulted in an increased consumption of smolts. More likely, low flows created a host of other problems (lethal water temperatures, heavier concentrations of pollutants/ parasites/pathogens and more favorable habitat for competing species) of more serious concern to salmon health than avian predators.

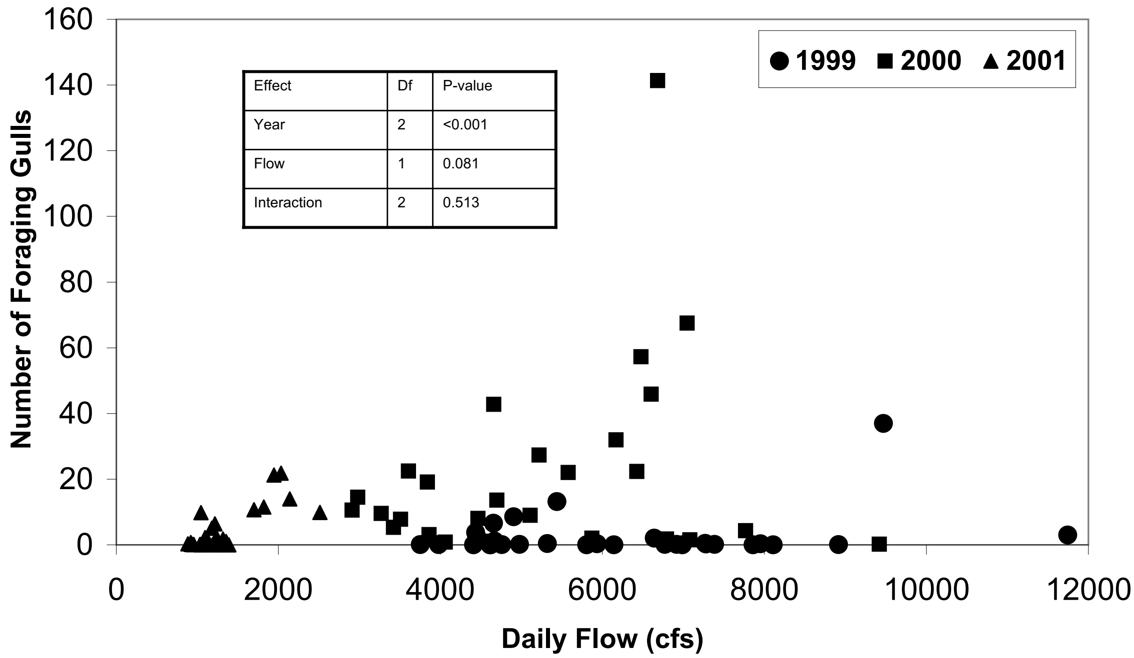
Bird abundances in the upper portion of the Yakima (Stratum 1) were again dominated by Common Mergansers in 2001. This species breeds extensively in the upper reaches and is the avian piscivore of greatest concern to out-migrating salmonids. Patterns of abundance for mergansers show a seasonal trend within each of the years and across the 3 years (Figure 23). Numbers slowly increase to a peak throughout most of June when clutches begin to hatch and broods move out onto the river. By late July, numbers start to drop as breeding adults and some early-hatched birds depart and spring mortality has accrued . In 2000, there was a short upward spike in abundance the last week of July and the second week of August.

Trends in the abundance of mergansers during the spring and summer survey periods for 1999-2001 were assessed both graphically and using weighted regression across the 3 years. Three years of data are not enough to detect a trend, especially if variances of the abundance indices are high. A plot of the abundance data and associated 95% confidence limits are shown in Figures 24 and 25. There is no apparent trend in the spring abundance indices, and although abundance during the summer does appear to increase over time, the confidence intervals of the three estimates overlap. As with total bird abundances in the lower Yakima (Stratum 3), Common Merganser numbers in Stratum 1 were greater in 2001 for both the spring and summer survey period than either 1999 or 2000.

Table 6. Piscivorous bird species encountered during 3 years of surveys on the Yakima River, 1999-2001

- American Bittern *(Botaurus lentiginosus)*
- American White Pelican *(Pelecanus erythrorhynchos)*
- Belted Kingfisher *(Ceryle alcyon)*
- Black-crowned Night Heron *(Nicticorax nicticorax)*
- California Gull *(Larus californicus)*
- Caspian Tern *(Sterna caspia)*
- Common Merganser *(Mergus merganser)*
- Double-crested Cormorant *(Phalacrocorax auritus)*
- Forster's Tern *(Sterna forsteri)*
- Great Blue Heron*(Ardea herodias)*
- Green Heron*(Butorides virescens)*
- Great Egret *(Ardea alba)*
- Hooded Merganser *(Lophodytes cucullatus)*
- Osprey *(Pandion haliaetus)*
- Ring-billed Gull *(Larus delawarensis)*
- Red-breasted Merganser *(Mergus serrator)*

Figure 20. Flow vs number of foraging gulls at Horn Rapids Dam, 1999-2001.



Effect	Df	P-value
Year	2	<0.001
Flow	1	0.081
Interaction	2	0.513

Figure 21. Total smolt passage at Chandler Juvenile Fish Processing Center (as measured 2 days prior to gull surveys at Horn Rapids Dam) vs number of foraging gulls at Horn Rapids Dam, 1999-2001.

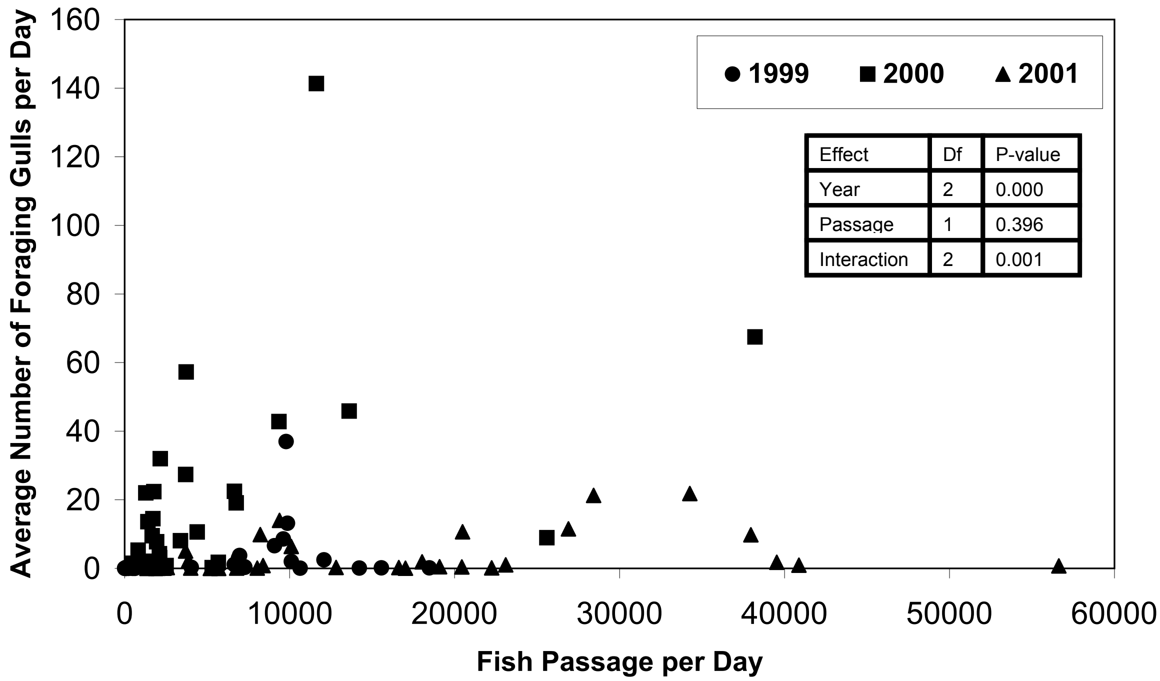


Figure 22. Abundance per kilometer of all piscivorous bird species combined for the lower Yakima River (Stratum 3), 1999-2001.

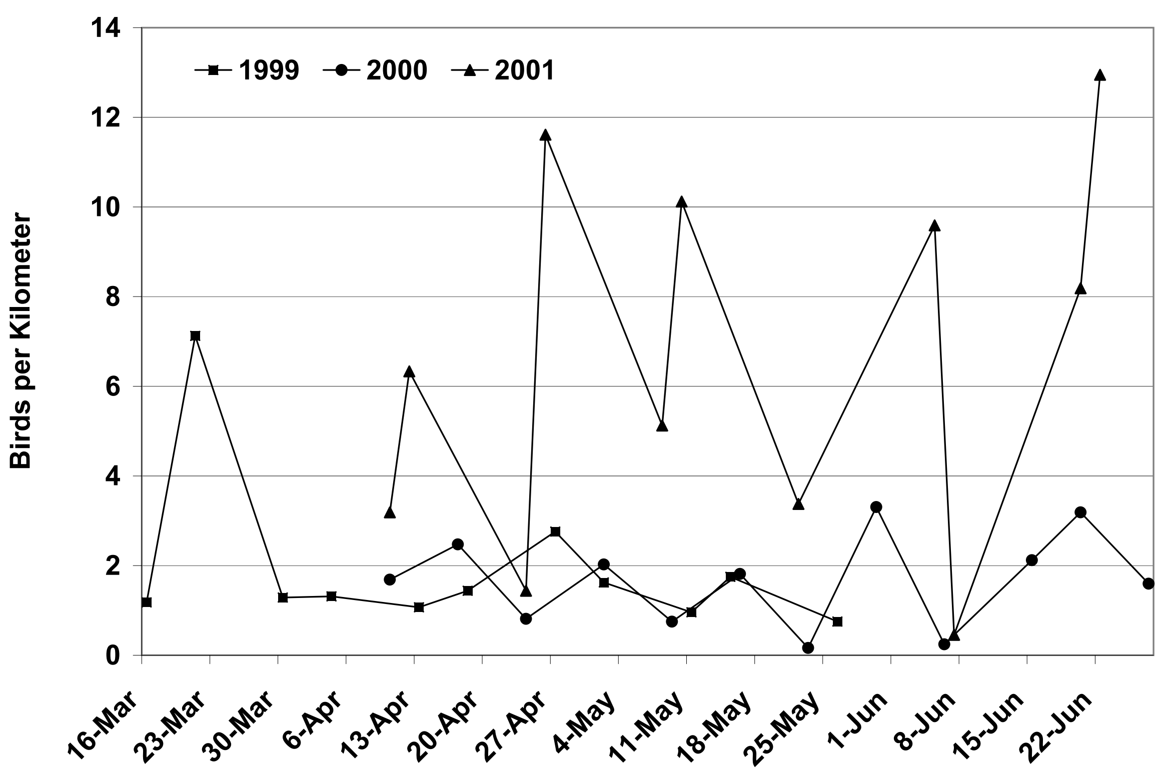


Figure 23. Merganser abundance per kilometer on the Yakima River (Stratum 1) for the 3 years, 1999-2001.

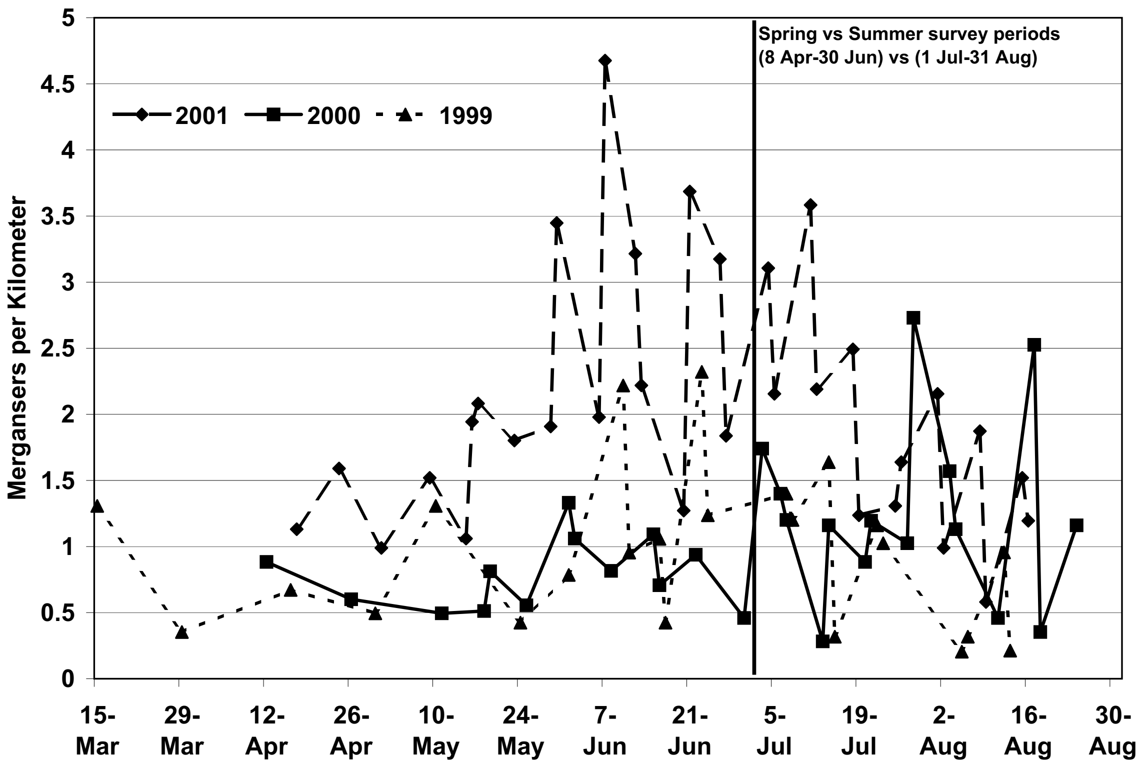


Figure 24. Mean spring merganser bird-use days and 95% CIs on the Yakima River (Stratum 1) for the 3 years, 1999-2001

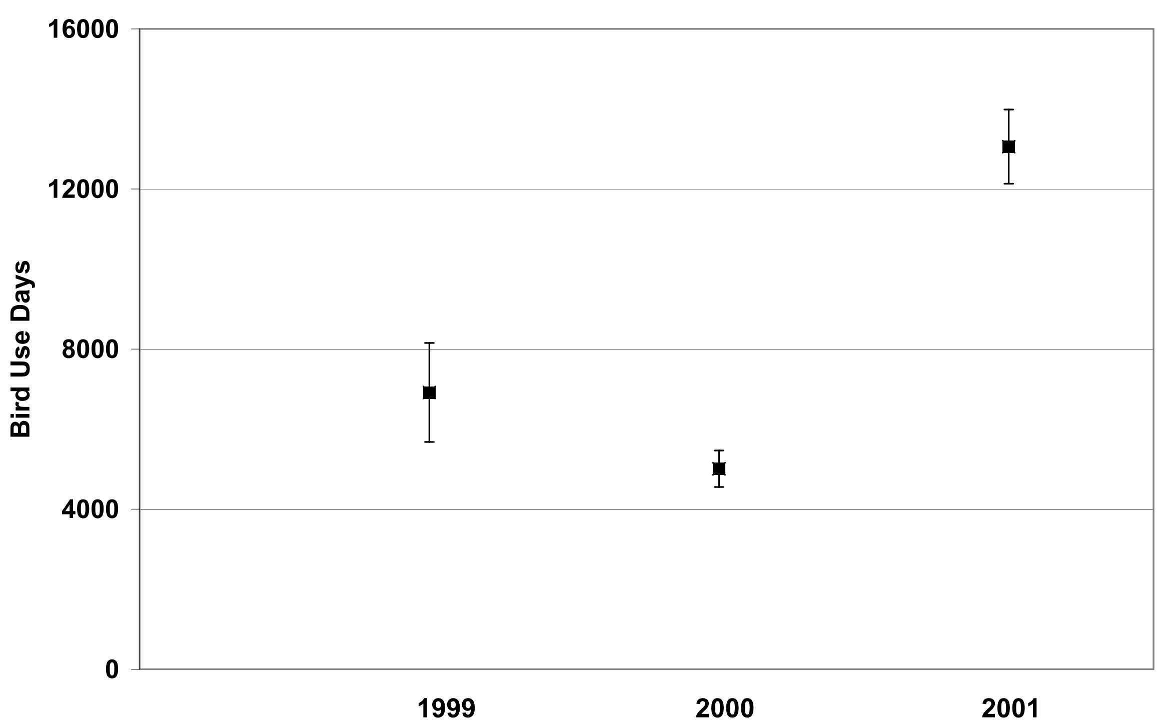
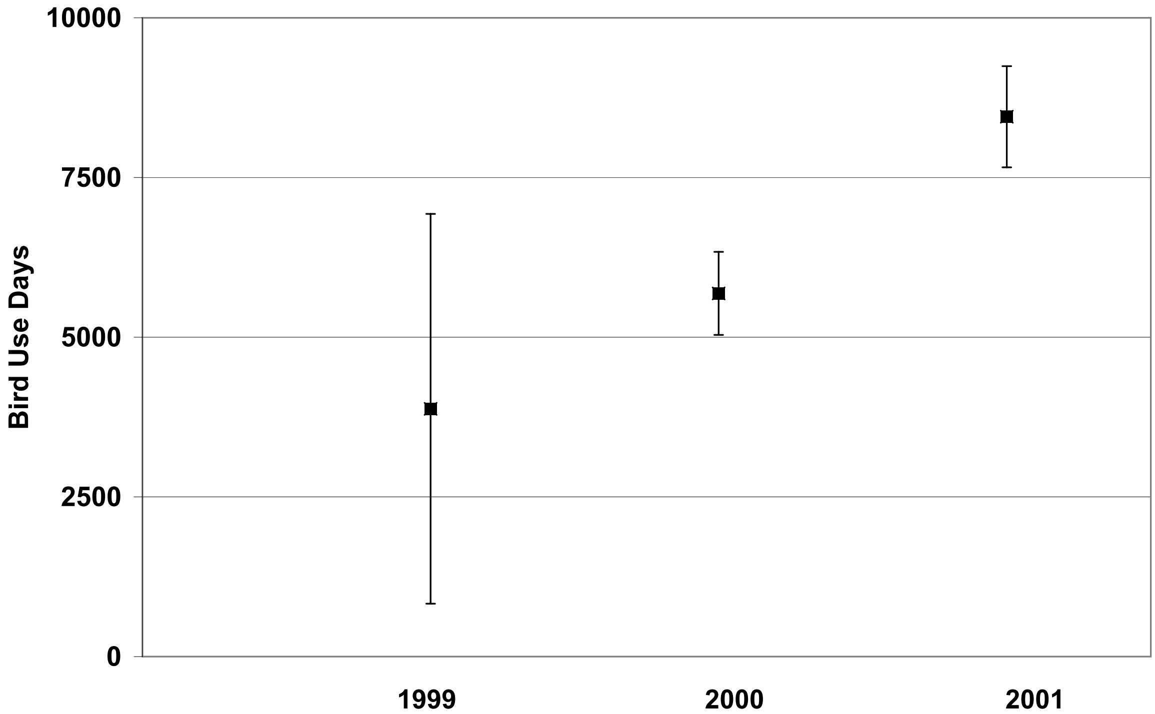


Figure 25. Mean summer merganser bird-use days and 95% CIs on the Yakima River (Stratum 1) for the 3 years, 1999-2001.



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