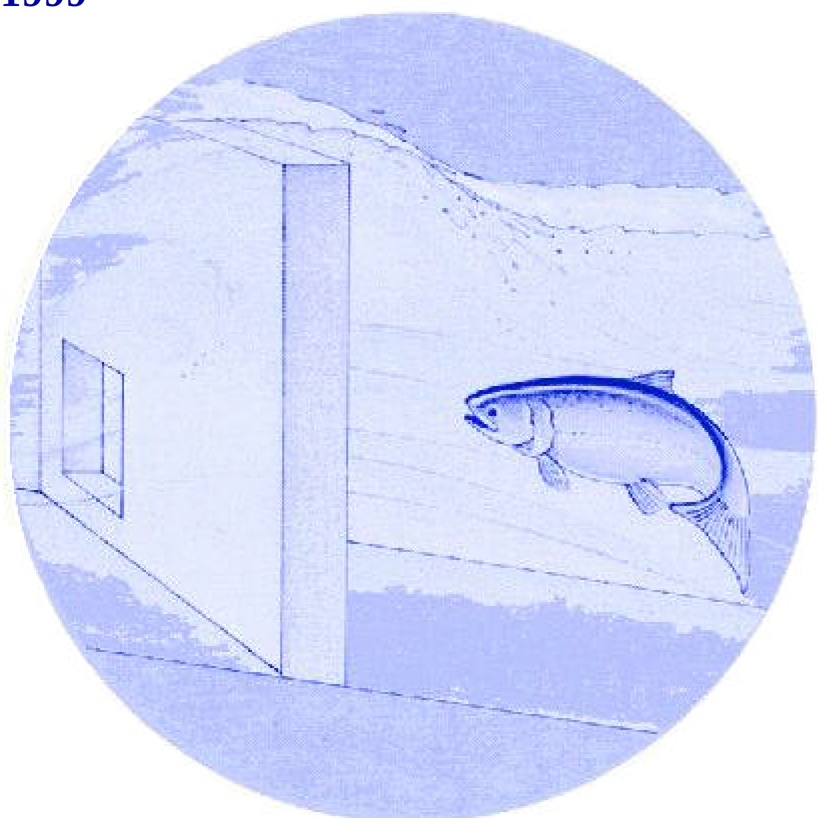
Development of an Index to Bird Predation of Juvenile Salmonids within the Yakima River

Annual Report
1999



DOE/BP-00004666-4 October 2001

This Document should be cited as follows:

Grassley, James, Christian Grue, "Development of an Index to Bird Predation of Juvenile Salmonids within the Yakima River", Project No. 1995-06424, 40 electronic pages, (BPA Report DOE/BP-00004666-4)

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

This report covers one of many topics under the Yakima/Klickitat Fisheries Project's Monitoring and Evaluation Program (YKFPME). The YKFPME is funded under many BPA contracts to the Yakama Nation and the Washington Department of Fish and Wildlife. The current report (Project Number 1995-064-08) was completed by the Washington Cooperative Fish and Wildlife Research Unit under a sub-contract from the Washington Department of Fish and Wildlife.

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

Annual Report 1999

Prepared by:

James M. Grassley
Christian E. Grue

Washington Cooperative Fish and Wildlife Research Unit
University of Washington, School of Aquatic and Fishery Sciences
Box 355020, Seattle, WA 98195

Prepared for:

Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501-0191

October 2001

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES 4

ABSTRACT 6

INTRODUCTION

Avian Predation of Juvenile Salmon
Supplementation in the Yakima and Klickitat Rivers 7

Assessment of Consumption of Juvenile Salmon by Avian Piscivores
1997-1998 8

Assessment of Consumption of Juvenile Salmon by Avian Piscivores
1999 9

Hotspot Survey—Spring 9
River Reach Survey—Spring and Summer 10
Acclimation Site Survey—Spring 10
Aerial Survey—Spring and Summer 10

METHODS

Study Locations 11

Spring Smolt Migration--Methods for Assessment of Consumption
of Juvenile Salmon by Avian Piscivores 12

Hotspot Survey—Spring 12
River Reach Survey—Spring 14
Acclimation Site Survey—Spring 16
Aerial Survey—Spring 16
Miscellaneous Survey—Spring 16

Summer Parr Rearing--Methods for Assessment of Consumption
of Juvenile Salmon by Avian Piscivores 18

River Reach Survey—Summer 18
North Fork Teanaway River Survey—Summer 18

RESULTS

Hotspot Survey—Spring 20

Avian Piscivore Abundance 20
Diurnal Pattern of Abundance 22
Consumption of Juvenile Salmonids by Gulls 23

RESULTS (continued)

River Reach Survey—Spring ... 25

Avian Piscivore Abundance ... 25
Consumption of Juvenile Salmonids ... 29

Acclimation Site Survey—Spring ... 29

Aerial Survey—Spring ... 29

River Reach Survey—Summer ... 30

Avian Piscivore Abundance ... 30
Consumption of Juvenile Salmonids by ... 30
Common Mergansers ... 30

North Fork Teanaway River Survey—Summer ... 33

DISCUSSION

Hotspot Survey—Spring ... 34

Avian Piscivore Abundance ... 34
Diurnal Pattern of Abundance ... 34
Consumption of Juvenile Salmonids by Gulls ... 34

River Reach Survey—Spring ... 35

Double Counting Birds—River Drifts ... 35

Aerial Survey—Spring ... 36

River Reach Survey—Summer ... 36

Avian Piscivore Abundance ... 37
Consumption of Juvenile Salmonids by ... 37
Common Mergansers ... 37

North Fork Teanaway River Survey—Summer ... 37

CITATIONS ... 38

LIST of TABLES and FIGURES

TABLES

Table 1. 1999 hotspot survey dates for Horn Rapids Dam and Chandler Canal Bypass Pipe with number of 2-hour survey periods completed per day. Table 2 details activities within each 2-hour survey period.. 12

Table 2. Abundance, foraging ratio and individual feeding success data collection pattern...................... 13

Table 3. Spring river reach survey dates.. 15

Table 4. River reach start point, end point and total length (km) surveyed for piscivorous birds................ 15

Table 5. Aerial piscivorous bird survey dates and reaches surveyed in 1999.. 17

Table 6. Start location, end location and length of aerial bird surveys.................................... 17

Table 7. Summer river reach survey dates in 1999...19

Table 8. Summer river reach, start point, end point and total length (km)... 19

Table 9. Frequency of occurrence by species and month of avian piscivores identified at Chandler Dam Canal Bypass Pipe and Horn Rapids Dam during hotspot surveys between 15 Mar and 30 May, 1999.. 20

Table 10. Abundances of piscivorous birds counted during aerial flight surveys of the Yakima River during spring and summer of 1999. NC denotes those reaches which were not flown due to hazardous conditions..30

FIGURES

Figure 1. Duration of smolt passage and average number of passage days by stock. Passage duration bars begin at 10% and end at 90% cumulative passage. The number of passage years compromising the passage history varies among stocks.. 18

Figure 2. Average gull abundance at Chandler Canal Bypass Pipe 23 Apr to 30 May. Error bars represent standard error.. 21

Figure 3. Average gull abundance at Horn Rapids Dam 23 Apr to 30 May. Error bars represent standard error.. 21

Figure 4. Pattern of diurnal gull abundance at Chandler Canal Bypass Pipe for all survey days combined, 23 Apr to 30 May. Time period 1 represents the first and second hours after sunrise, period 2 represents the third and fourth hours after sunrise, and so on to the final and 8th period which includes sunset. Error bars represent standard error.. 22

Figure 5. Pattern of diurnal gull abundance at Horn Rapids Dam for all survey days combined, 23 Apr to 30 May. Time period 1 represents the first and second hours after sunrise, period 2 represents the third and fourth hours after sunrise, and so on to the final and 8th period which includes sunset. Error bars represent the standard error..23

Figure 6. Pattern of diurnal gull abundance at Horn Rapids Dam by intra-day survey period for a single day only—25 May, 1999. Error bars represent standard deviation.. 24

Figure 7. Pattern of diurnal gull abundance at Horn Rapids Dam by intra-day survey period. All survey days (23 Apr to 30 May) combined except 25 May. Error bars represent standard error................................... 24

Figure 8. Second order polynomial regression model of average gull abundance for Chandler Canal Bypass Pipe.. 25

Figure 9. Second order polynomial regression model of average gull abundance for Horn Rapids Dam.. 25

FIGURES (continued)

Figure 10. Fish passage, gull abundance and cumulative fish consumption at Chandler Dam Bypass Pipe 23 Apr to 30 May.......... 25

Figure 11. Fish passage, gull abundance and cumulative fish consumption at Horn Rapids Dam 23 Apr to 30 May. Fish passage at Horn Rapids assumed identical to Chandler Dam..........26

Figure 12. Spring avian piscivore abundance by reach—including gull sightings, 23 Apr to 30 May. Error bars represent standard deviation (sd). Zillah sd=2.72..........26

Figure 13. Spring avian piscivore abundance by reach—excluding gull sightings, 23 Apr to 30 May. Error bars represent standard deviation (sd). Zillah sd=2.72..........26

Figure 14. Average spring Common Merganser abundance per kilometer by reach, 23 Apr to 30 May. Error bars represent standard deviation (sd) Zillah sd=1.18. Observations without error bars were derived from a single river reach survey..........27

Figure 15. Average spring avian piscivore abundance per kilometer within the Zillah river reach, 16 Mar to 30 May. Error bars represent standard deviation (sd). Great Blue Heron sd=1.14, Common Merganser sd=1.18. Observations without error bars were derived from a single river reach survey..........27

Figure 16. Average spring avian piscivore abundance per kilometer within the Cle Elum river reach, 16 Mar to 30 May. Error bars represent standard deviation. Observations without error bars were derived from a single river reach survey..........28

Figure 17. Average spring avian piscivore abundance per kilometer within the Benton river reach, 16 Mar to 30 May. Error bars represent standard deviation (sd). Gull sd=2.34. Obervations without error bars were derived from a single river reach survey..........28

Figure 18. Average spring avian piscivore abundance per kilometer within the Vangie river reach, 16 Mar to 30 May. Error bars represent standard deviation (sd). Gull sd=1.23. Observations without error bars were derived from a single river reach survey..........29

Figure 19. Average summer avian piscivore abundance within the Easton and Cle Elum reaches, 30 May to 15 Aug. Error bars represent standard deviation..........31

Figure 20. Average abundance of all avian piscivores per river kilometer by drift along the Easton river reach..........31

Figure 21. Average abundance of all avian piscivores per river kilometer by drift along the Cle Elum river reach..........31

Figure 22. Average summer avian piscivore abundance per kilometer within the Easton river reach, 30 May to 15 Aug. Error bars represent standard deviation (sd). Common Merganser sd=0.73. Observations without error bars were derived from a single river reach survey..........32

Figure 23. Average summer avian piscivore abundance per kilometer within the Cle Elum river reach, 30 May to 15 Aug. Error bars represent standard deviation. Observations without error bars were derived from a single river reach survey..........32

Figure 24. Abundance of Common Mergansers per river kilometer by drift along the Easton river reach..........33

Figure 25. Abundance of Common Mergansers per river kilometer by drift along the Cle Elum river reach..........33

Figure 26. Second order polynomial regression of seasonal Common Merganser abundance within the Easton river reach..........33

Figure 27. Second order polynomial regression of seasonal Common Merganser abundance within the Cle Elum river reach..........33

ABSTRACT

Development of an Index to Piscivorous Bird Predation on Juvenile Salmonids in the Yakima River

Avian predation of fish is suspected to contribute to the loss of juvenile spring chinook salmon in the Yakima Basin, potentially constraining natural production. In 1997 and 1998, the Yakama/Klickitat Fisheries Project (YKFP) and the Washington Department of Fish and Wildlife (WDFW)--whose goal is to increase natural production historically present 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--confirmed that Ring-billed Gulls and Common Mergansers were the primary avian predators of juvenile salmon, and that under certain conditions could significantly impact migrating smolt populations.

Beginning in 1999, the Washington Cooperative Fish and Wildlife Research Unit was asked by the YKFP and the WDFW to continue development of avian consumption indices. Monitoring methods developed by Mathews and Phinney 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") continued. New efforts initiated in 1999 included piscivorous bird surveys at smolt acclimation sites operated by the Yakama Nation, monitoring of the North Fork Teanaway River for changes in avian piscivore abundance associated with the installation of the Jack Creek acclimation facility, and aerial surveys seeking to identify avian piscivores along the length of the Yakima River.

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.

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 April - 30 May) was 4,084 fish at the Chandler Bypass Outfall and 12,636 fish at Horn Rapids Dam. Combined take was 2.65% of the salmonids passing over Chandler Dam or 0.89 % of all smolts estimated passing or being released from the Chandler Dam area during the 1999 smolt migration season. Estimated take by Common Mergansers within upper river reaches in summer was 4,092 kg between 7 May and 18 August 1999.

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 is not generally given the same level of consideration as those salmonids within the genus *Oncorhynchus*.

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 and Conover 1996; Derby and Lovvorn 1997). The magnitude of impact to migrating smolts by avian predators is highly variable within and across river systems. Investigations estimating impacts 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 1999). As shown repeatedly by investigations throughout North America and Europe, avian predators can consume large number of juvenile salmonids when appropriate factors 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 Glaucus-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 (Forbs 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 Kilckitat Rivers

The Yakima/Klickitat Fisheries Project (YKFP) seeks to increase natural production of salmon and steelhead historically present within two eastern Washington State river basins, the Yakima and the Klickitat Rivers (both of which are tributaries to the CRB). This goal will be accomplished by a combination of salmon supplementation 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. Currently the most intense supplementation effort organized under the YKFP focuses on upper Yakima River spring chinook.

Intensive monitoring efforts have been implemented in conjunction with the YKFP salmon supplementation. These efforts seek to identifty impacts of salmon supplementation on natural production, impacts of (and opportunities for) harvest, genetic interactions between natural and supplemented stocks, and impacts of ecological interactions between 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, competition, pathogens and changes in key predator population parameters.

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.

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

In 1997, Dr. Steve Mathews and David Phinney (University of Washington, School Aquatic and Fishery Sciences), 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, Phinney et al. (1998) developed field methods, surveyed river reaches and hotspots, estimated piscivorous bird abundance along river reaches and hotspot's, estimated piscivorous bird consumption of juvenile salmonids at the most significant hotspots, and investigated the relationship between water flow and avian predation at hotspots.

Phinney et al. (1998) 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 predators (Phinney et al. 1998). At hotspots, both abundance and consumption was strongly associated with river discharge. At low to moderate flows, abundance and consumption was high. The spring flows of 1998 were unusually high and therefore the predation index was hypothesized to be low relative to average years (Phinney et al. 1998).

Consumption of salmonids by birds congregating at Horn Rapids Dam and the Chandler Canal bypass (the most active of hotspots studied in 1997 – 1998) was estimated to be 1.7% and 1.1%, respectively, of total salmon/trout passage for each site (Phinney et al. 1998). Based upon the assumption that all fish consumed by avian piscivores were salmon, and that these 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) 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. These findings suggested that unusually low water levels during spring smolt migrations may facilitate a much higher level of avian predation of migrating salmon and trout.

The greatest uncertainty encountered by Phinney et al. (1998) to develop predation indices was determination of species composition of fishes consumed by avian piscivores along river reaches and at hotspots and estimating accurate consumption at high bird abundances. Consumption work conducted in 1998 relied principally upon behavioral observations of predation by gulls at hotspots, through which one can enumerate the number of fish captured. It was found, however, that measuring the number of successful takes at high bird densities is extremely difficult and inherently leads to an underestimate of consumption. Direct assessment of consumption was attempted for a single species of avian piscivores along river reaches—the Common Merganser—resulting in the collection of gut 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.

Assessment of 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 Phinney et al. (1998) toward the development of an index to bird predation of juvenile salmonids. Monitoring methods developed by Phinney et al. (1998) for river reaches and hotspots were largely adopted; the frequency of surveys was increased and some methodological alterations were implemented.

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 Fort Teanaway River associated with the Jack Creek acclimation facility, and the addition of aerial surveys along low and middle river reaches to more fully monitor piscivorous bird abundance.

This study was organized into two specific time frames within which impacts of bird predation on juvenile salmon were assessed. The first, 15 Mar to 30 May, 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 Jun to 15 Aug, addressed impacts of avian predators on coho parr and residual spring chinook within the upper reaches of the Yakima River. These two time frames form the basis of organization and methodological design for this study, and are informally referred to within this document as “spring” and “summer”.

Within the Yakima River, avian predation of juvenile salmon can be segregated into two principal components: predation along the entire length of the river by a diverse assembly of avian predators, and predation at point locations of concentrations of avian predators (referred to as “hotspots”). To estimate consumption along the length of the river, surveys of avian piscivore abundance were conducted along river reaches by drift boat and raft during both spring and summer. To estimate consumption at hotspots, point surveys were conducted at locations historically with high levels of attention by avian piscivores. Hotspot surveys occurred only in the spring, whereas river reach surveys occurred in both the spring and summer. Other survey activities included assessments of abundance of piscivorous birds at hatchery acclimation sites, aerial surveys along the low and middle river reaches, and a walking survey along a tributary river reach associated with an acclimation facility.

Hotspot Survey—Spring

Hotspot surveys were conducted to assess the impact of localized areas of intense avian predation on the spring chinook smolt population (and other spring migrant juvenile salmon/trout). The abundance of avian piscivores were 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 is 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 and shock. Under such circumstances, predation by avian predators can be highly efficient and intense.

River Reach Survey—Spring and Summer
Spring river reach surveys were conducted to estimate the abundance and distribution of piscivorous birds foraging along the length of river reaches during the spring smolt migration. 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, logjams). 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 experimental raceways, artificial acclimation streams, 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 YN hatchery personnel.

Aerial Survey—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 also considered a potential alternative to more expensive river drift surveys and results from the two methods were compared.

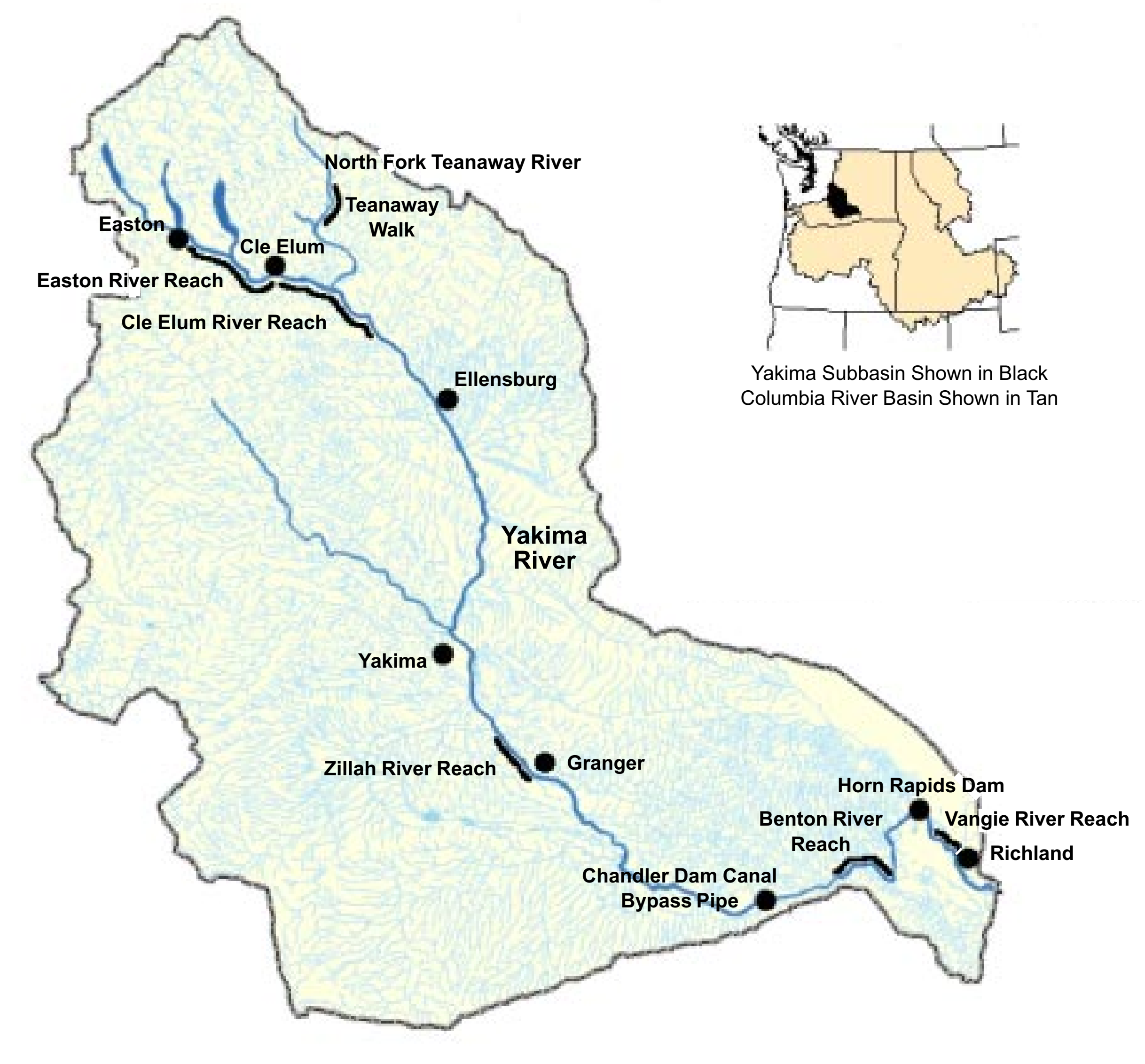
Summation
This report summarizes data collection activities, methods, results, and topics of discussion for the 1999 field season—15 Mar to 15 Aug—by the Washington Cooperative Fish and Wildlife Research Unit. This report is intended to satisfy the contractual requirement for annual report of activities 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. All findings in this report should be considered preliminary and subject to revision until presented as a final report.

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 (map below). 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 agricultural lands. Middle and lower river reaches (Selah to the Columbia River) exhibit low elevation loss, an infrequently braided river channel



Map Date: February 2001. Data Sources: Washington Dept of Fish and Wildlife and Yakama Nation and shoreline habitat dominated principally by hardwoods, arid steppe brush and irrigated agricultural lands.

Spring Smolt Migration--
Methods for Assessment of Consumption of Juvenile Salmon by Avian Piscivores

Hotspot Survey—Spring

In 1999, hotspot surveys conducted at Horn Rapids Dam and the Chandler Canal bypass outfall were more intensive (greater number of surveys within survey days), and more frequent (more survey days within the season) than in 1998. The increase in survey intensity and frequency allowed for improved estimates of daily consumption as well as resolution of daily use patterns. Surveys were conducted systematically on a 2-week cycle which included a total of five day-long surveys within each 2-week period, totaling approximately 30 surveys at each site for the 1999 field season; 15 Mar to 30 May (Table 1). On days in which hotspot surveys occurred, both sites were surveyed simultaneously. This required two survey personnel (one at each site for the day) which alternated between the sites every other survey day to reduce observer bias.

The survey area for Horn Rapids Dam included the width of the river channel, 50 meters above 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 the width of the river channel, 50 meters above and 150 meters of river below the outfall pipe. All birds flying above or resting upon the banks/shoreline lateral to the specified 50 meters of river above and 150 of river meters below both hotspots were included in abundance/foraging counts.

Observations were made from shore stations in either an automobile (Horn Rapids Dam) or bird blind (Chandler Canal bypass outfall) 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 behaviors.

Each hotspot-survey day was divided into 2-hour survey periods, the first began 1-hour before sunrise, the last ending 1-hour after sunset (to the nearest fifteen-minute interval). 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 first abundance count of the day began at dawn—no

Table 1. 1999 hotspot survey dates for Horn Rapids Dam and Chandler Canal Bypass Pipe with number of 2-hour survey periods completed per day. Table 2 details activities within each survey period.

Date	Periods	Date	Periods
3/17	7	4/23	8
3/19	7	4/27	8
3/24	8	4/28	7
3/25	7	4/30	7
3/26	7	5/5	8
3/31	7	5/6	7
4/2	7	5/7	8
4/3	7	5/12	8
4/7	7	5/14	8
4/8	8	5/15	4*
4/9	7	5/19	8
4/14	8	5/20	8
4/16	8	5/21	7
4/21	8	5/25	8
4/22	8	5/26	8

* Early departure

longer too dark to see, yet prior to the actual sunrise. The last abundance count of the day usually occurred just before, during, or just after sunset.

Each 2-hour period consisted of a 45 minute abundance/feeding survey cycle, followed by a 75 minute period without data collection. Within the 45 minute abundance/feeding survey cycle, data on bird abundance, foraging ratios and foraging success of individuals were collected (Table 2). For abundance counts, all piscivorous birds within the 200 meter study area were counted, including those on the bank. The proportion of gulls foraging were those birds flying within the study area. Birds within the study area foraging on terrestrial prey items—such as insects, seeds, plants—were not considered feed-

Table 2. Abundance, foraging ratio and individual feeding success data collection pattern.

Minutes	Activity	Conditional Factor
1-5	One abundance count per minute (total 5) for each species present, including sex and age if possible.	None
6-10	Determine abundance and foraging ratio of all birds. Count unsuccessful and successful feeding attempts of a single bird for 5 minutes.	First bird of the most abundant piscivorous bird species present which makes an aggressive attempt to capture a fish
11-15	Determine abundance and foraging ratio of all birds. Count unsuccessful and successful feeding attempts of a single bird for 5 minutes.	First bird of the most abundant piscivorous bird species present which makes an aggressive attempt to capture a fish
16-20	Determine abundance and foraging ratio of all birds. Count unsuccessful and successful feeding attempts of a single bird for 5 minutes	First bird of the most abundant piscivorous bird species present which makes an aggressive attempt to capture a fish
21-25	One abundance count per minute (total 5) for each species present, including sex and age if possible.	None
26-30	Determine abundance and foraging ratio of all birds. Count unsuccessful and successful feeding attempts of a single bird for 5 minutes	First bird of the most abundant piscivorous bird species present which makes an aggressive attempt to capture a fish
31-35	DDetermine abundance and foraging ratio of all birds. Count unsuccessful and successful feeding attempts of a single bird for 5 minutes	First bird of the most abundant piscivorous bird species present which makes an aggressive attempt to capture a fish
36-	Determine abundance and foraging ratio of all birds. Count unsuccessful and successful feeding attempts of a single bird for 5 minutes	First bird of the most abundant piscivorous bird species present which makes an aggressive attempt to capture a fish
41-45	One abundance count per minute (total 5) for each species present, including sex and age if possible.	None
46-120	No survey activity.	

ing, 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 fishing gulls standing on rocks from loafing gulls standing on rocks.

The bird chosen to be observed for the 5-minute observation interval was the first individual of the most abundant species of avian piscivore present to make an aggressive attempt to capture a fish in the study area. Because of the inability to truly select foraging birds at random in the context of our hotspots, the "first attempt" method was chosen. This differs from the method utilized by Phinney et al. (1998) where an attempt to enumerate all takes within the observation period was made. As mentioned previously, this method likely underestimates consumption, especially at high bird abundances.

Once a bird was chosen, the number of attempts and successful attempts at fish capture were recorded. Successful feeding attempts were those in which the bird being observed consumed a fish, regardless of the means of acquisition. For gulls, aggressive (but unsuccessful) feeding attempts were defined as any clear and sudden movement towards the water resulting in contact with the water, but not resulting in a fish being consumed. Some examples of unsuccessful attempts include:

1. The observed gull dives towards and touches the water with wing, bill, or foot and does not capture and consume a fish.

2. The observed gull captures a fish but drops the fish prior to consuming it.

3. The observed gull captures a fish, but the fish is stolen away by another gull who consumes it.

4. The observed gull steals a fish from another gull, looses control of the fish, and does not consume it.

Although all birds within the survey area were counted and recorded, foraging and feeding behavior assessments were focused upon gulls due to their overwhelming presence. If identification of particular gulls to species was feasible, such data were collected. If gull density was high or viewing conditions poor, foraging and feeding behavior of gulls was attributed to the general category of “gull”, rather than to a specific species.

Daily average numbers of gulls were calculated by expanding the 15 abundance counts recorded during any 45 minute data collection cycle across the 2-hour survey period in which it was collected. Average gull abundance per 2-hour survey period was averaged across all periods occurring within a full day--most days consisted of 7 or 8 survey periods--to derive the average daily gull abundance. The resulting "daily average number of gulls" represents the number of gulls predicted to be present at any time during daylight hours. Diurnal abundance patterns for gulls are presented as the average gull abundance for all observations within the season for the same survey period (numbered 1 to 8; 7 or 8 occurring within most days depending upon survey start time and length of day).

Average daily gull abundance was modeled using a second order polynomial regression of average daily gull abundance values from all days surveyed. This regression model was used to predict the average number of gulls for all days within the season. Daily consumption of salmonids by gulls is expressed as the predicted average number of gulls multiplied by the number of minutes per day multiplied by the seasonal average number of successful fish captures by gulls per minute.

River Reach Survey—Spring

Spring river surveys included four river reaches, each surveyed every 2 weeks from 15 March to 30 May (Table 3). These reaches included Cle Elum, Zillah,

Table 3. Spring river reach survey dates.

Date	Vangie	Benton	Zillah	Cle Elum
16-Mar-99	—	—	—	X
18-Mar-99	X	X	—	—
23-Mar-99	—	—	X	—
30-Mar-99	—	—	—	X
01-Apr-99	X	X	—	—
06-Apr-99	—	—	X	—
15-Apr-99	X	X	—	—
17-Apr-99	—	—	—	X
20-Apr-99	—	—	X	—
29-Apr-99	X	X	—	—
01-May-99	—	—	—	X
04-May-99	—	—	X	—
11-May-99	—	—	—	X
13-May-99	X	X	—	—
17-May-99	—	—	X	—
25-May-99	—	—	—	X
28-May-99	X	—	—	—

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

Name	Start	End	Length
Vangie	1.6 km above Twin Bridges*	Van Giesen St. Hwy. Bridge	9.3
Benton	Chandler Canal Power Plant	Benton City Bridge	9.6
Zillah	US Hwy. 97/St. Hwy. 8 Bridge	Granger Bridge Ave. Hwy. Bridge	16.0
Cle Elum	South Cle Elum Bridge	Thorp Hwy. Bridge	28.3

* Informal public boat launch on east bank.

Benton and Vangie (Table 4 details start/stop points and total length). The Vangie and Benton reaches were identical to the surveys performed by Phinney et al. in 1998 (start/stop position). The Zillah reach approximately corresponds to the Granger reach of Phinney et al. (1998), and the Cle Elum reach encompasses their Cle Elum reach.

All river reach surveys were conducted by a two-person survey team from a 17-foot 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 (face forward position) to decrease the interval of time required to traverse the reach. Where the river divided into more than one channel, the larger of the two was chosen for safer navigation. This created the potential for underestimating bird abundances, as the missed channel was not surveyed. Because this occurred only on the upper reaches (Strata 1) and primarily on the Easton reach, we believe any resulting underestimation is minimal and does not significantly impact river-wide estimates of consumption.

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 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 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 passage 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 by survey personnel 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 Survey—Spring

Beginning on 15 Mar and continuing to 30 May, YN hatchery technicians at the Clark Flats and Easton acclimation sites conducted piscivorous bird surveys. Surveys were conducted every 2-hours begining one hour before sunrise on even numbered days and at sunrise on odd number days. At the beginning of each 2-hour period 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) were identified and recorded within their respective zones. Surveys were conducted on foot by hatchery technicians who utilized a pair of 8x binoculars to aid species identification.

Aerial Survey—Spring

Five aerial surveys were conducted by the YN between 24 Mar and 18 Jun (Table 5). Surveys began at the mouth of the Yakima River and progressed up river as far as weather conditions permitted. All piscivorous birds visually detectable were recorded within reaches defined by physical objects and structures detectable from the plane. Start point, end point and length of aerial survey sections are detailed in Table 6.

Miscellaneous Surveys—Spring

In order to minimize the possibility that unexpectedly intense predation of fish by avian piscivores was occurring in areas outside the geographic range of scheduled hotspots, river drifts and acclimation surveys, periodic surveys were conducted at locations previously identified by others (Phinney 1999; Pearsons, pers. com.) as potentially attractive to piscivorous birds. These areas included Chandler Dam (Prosser), Parker Dam, Roza Dam, Sunnyside Dam, Union Gap Dam, Thorp Diversion and the Cle Elum Hatchery acclimation slough. These sites were surveyed periodically (one 45-minute observation survey) as described in Table 2. Each of the previously listed sites was visited two or three times between 15 Mar and 30 May. In some instances, YN

Table 5. Aerial piscivorous bird survey dates and reaches surveyed in 1999.

Reach	24 Mar	8 Apr	7 May	4 Jun	18 Jun
Mouth of Yakima River to Horn Rapids Dam	X	X	X	X	X
Horn Rapids Dam to Benton City Bridge	X	X	X	X	X
Benton City to Prosser Dam	X	X	X	X	X
Prosser Dam to Mabton Bridge	X	X	X	X	X
Mabton Bridge to Union Gap	X	X	X	X	X
Union Gap to Selah Gap	X	X	X	X	X
Selah Gap to South end of Ellensburg Canyon	X	X	X	X	X
Ellensburg Canyon	*	*	*	*	*
North End of Ellensburg Canyon to Clark Flat	X	X	X	X	X
Clark Flat to Indian John Hill (Power Lines)	*	*	X	X	X
Indian John Hill to Cle Elum Hatchery	X	X	*	*	*
Cle Elum Hatchery to Easton	X	X	X	*	*

* No data due to high winds – section not flown.

Table 6. Start location, end location and length of aerial surveys.

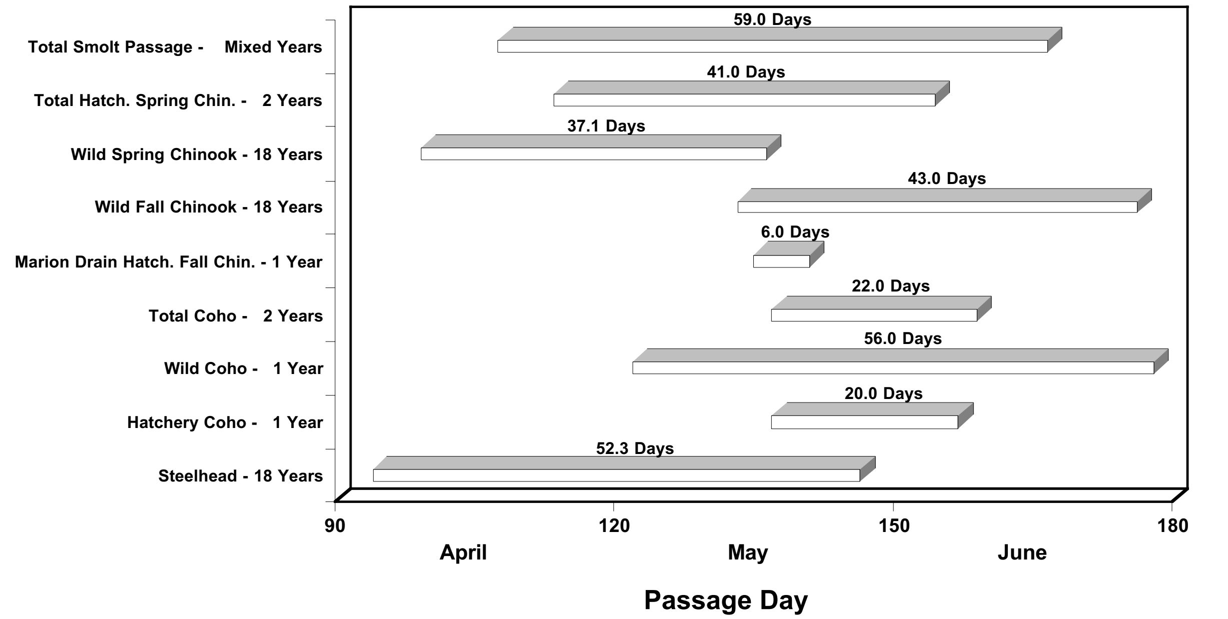
River Reach Name	Start River km	End River km	Total km
Mouth of Yakima River to Horn Rapids Dam	0.0	28.8	28.8
Horn Rapids Dam to Benton City Bridge	28.8	47.6	18.8
Benton City to Prosser Dam	47.6	75.3	27.6
Prosser Dam to Mabton Bridge	75.3	95.6	20.3
Mabton Bridge to Union Gap	95.6	171.3	75.6
Union Gap to Selah Gap	171.3	187.3	16.0
Selah Gap to South end of Ellensburg Canyon	187.3	197.9	10.5
Ellensburg Canyon	197.9	238.2	40.3
North End of Ellensburg Canyon to Clark Flat	238.2	267.8	29.6
Clark Flat to Indian John Hill (Power Lines)	267.8	279.0	11.2
Indian John Hill to Cle Elum Hatchery	279.0	292.9	13.9
Cle Elum Hatchery to Easton	292.9	322.2	29.2

hatchery personnel conducted more regular abundance counts.

Summer Parr Rearing--
Methods for Assessment of Consumption of Juvenile Salmon by Avian Piscivores

Beginning early April and ending late June (Figure 1) migrating smolts move down the Yakima River and enter the Columbia River on their way to marine waters. Within this time frame, water flows within the Yakima River begin to stabilize, air temperatures increase and the river begins to warm. Typically before the end of June, water temperatures within the mid and lower sections of the Yakima River exceed 21 degrees Centigrade, a level considered too warm for most salmonids. These higher water temperatures force smolts out of the lower reaches, or they succumb to heat related stresses and die.

Figure 1. Duration of smolt passage and average number of passage days by stock. Passage duration bars begin at 10% and end at 90% cumulative passage. The number of passage years compromising the passage history varies among stocks.



Those salmonids which escape the warm waters either depart the Yakima River system (enter the Columbia River), or retreat back to the cooler waters of the upper reaches.

Because of this effect, the second time frame of this research--Summer Parr Rearing--did not include surveys within the mid and lower reaches of the Yakima River wherein salmonid presence/survival is low. Rather, summer surveys were focused within the higher elevation reaches where biotic and abiotic factors (primarily lower water temperatures) allow the summertime residence of naturally produced spring chinook, rearing parr, residualized hatchery released spring chinook and many other species.

River Reach Survey—Summer

Two river reaches within the upper Yakima River were chosen which could be systematically surveyed every 7 days, resulting in eight surveys along the Easton reach and nine surveys along the Cle Elum reach between 1 Jun and 15 Aug 1999 (Table 7). Start and stop positions for the Easton and Cle Elum reaches are detailed in Table 8. The Cle Elum reach encompassed the Cle Elum reach of Phinney et al. (1998), and was the same as that used in our spring river surveys. The Easton reach was not surveyed by Phinney et al. in 1998. All summer river reach surveys were conducted exactly as those described for the spring.

Average abundance of common Mergansers per river drift were calculated. A second order polynomial regression model was used to predict average daily Common Merganser abundance for days not surveyed along each river reach. Daily consumption of salmonids was expressed as the predicted number of Common Mergansers along a given reach multiplied by literature derived daily consumption of prey items in grams.

North Fork Teanaway River Survey—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 as part of the YKFP supplementation effort, beginning in 1999 with the release of 240,000 coho smolts on 10 May. Anticipating the potential for newly established acclima-

Table 7. Summer river reach survey dates in 1999.

Date	Easton	Cle Elum
01-Jun	X	—
02-Jun		*
10-Jun	X	—
11-Jun	—	X
16-Jun	X	—
17-Jun	—	X
23-Jun	X	—
24-Jun	—	X
07-Jul	X	—
08-Jul	—	X
14-Jul	X	—
15-Jul	—	X
22-Jul	X	—
23-Jul	—	X
05-Aug	X	—
06-Aug	—	X
12-Aug	X	—
13-Aug	—	X

* Lost data sheet

tion facilities to attract avian piscivores, surveys were begun in 1999 along a reference river reach of the North Fork Teanaway River below the acclimation release site.

The survey area included the river and it's banks from the Jungle Creek/North Fork Teanaway confluence down river past the Jack Creek acclimation site and the Dickey Creek Bridge, ending at the Teanaway Highway bridge--approximately 11 kilometers. Two survey personnel conducted surveys on foot, one starting at Jungle Creek (surveying down to the Dicky Creek Bridge) and the other starting at the Dickey Creek bridge (surveying down to the Teanaway Highway bridge).

Both surveyors moved down river from their respective start points, noting piscivorous bird activity. 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 or if neither bank was navigable, 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 was conducted. All piscivorous birds detected visually or aurally were recorded, including time of observation, species of bird, sex and age if distinguishable. A pair of Leica 10x42 binoculars was utilized to aid identification. This river reach was surveyed four times between 1 Jun to 15 Aug, 1999.

Table 8. Summer river reach, start point, end point and total length (km).

Name	Start	End	Length
Cle Elum	South Cle Elum Bridge	Thorp Hwy. Bridge	28.3
Easton	Easton Acclimation Site	South Cle Elum Bridge	29.3
Teanaway	Jungle Creek	Teanaway Hwy. Bridge	10.8

RESULTS

Hotspot Survey—Spring

Avian Piscivore Abundance

In 1999, hotspot surveys were conducted on 30 days at both Chandler Canal Bypass (Chandler) and Horn Rapids Dam (Horn Rapids). Surveys began on 17 Mar and ended on 26 May. Although other piscivorous birds were identified, gulls were by far the most numerous . Gull abundance was low (near zero on many days) in March and April, and began to climb in early May. Peak numbers occurred in late May, although the last survey conducted at either site occurred on 26 May. It is presumed that gull predation occurred at these sites in June, but was not monitored.

Species identified at the Chandler hotspot included the Black-crowned Night-heron, Great Blue Heron, Gulls (California, Mew, and Ring-bill), Common Merganser, and Double-crested Cormorant (Table 9). Gulls were the most frequently observed species at Chandler; Ring-bill Gulls were the most frequently observed species of gull. Other species identified at Horn Rapids included Double-crested Cormorant, California and Mew gulls, Caspian Tern, Common Merganser, Great Blue Heron, Hooded Merganser, Osprey, and Western Grebe. Gulls were also the most frequently observed avian piscivore at Horn Rapids and Ring-bill Gulls were the most frequently observed species of gull.

Within the time period surveyed, the maximum number of gulls at Chandler occurred on 20 May with an average of 11.1 gulls (Figure 2) and at Horn Rapids the maximum occurred on 25 May with 25.2 gulls (Figure 3). While the average number of gulls present at hotspots on any given day ranged from 5 to 25 birds, gull abundance within any single day commonly ranged from zero (at early dawn and late dusk), to as many as 150 gulls (mid-morning).

Table 9. Frequency of occurrence by species and month of avian piscivores identified at Chandler Dam Canal Bypass Pipe and Horn Rapids Dam during hotspot surveys between 15 Mar and 30 May, 1999.

Chandler **Frequency**	**Species**	**Month**	**Diurnal Presence**
Common	Black-crowned Night-heron	Apr/May	All Day
Common	Great Blue Heron	Mar/Apr/May	All Day
Common	Gull (mixed species)	Mar/Apr/May	All Day
Rare	Common Merganser	Mar/Apr	All Day
Rare	Double-crested Cormorant	Mar/Apr/May	Mid-Day
Horn Rapids			
Frequency	**Species**	**Month**	**Diurnal Presence**
Common	Double-crested Cormorant	Mar/Apr/May	All Day
Common	Gull (mixed species)	Mar/Apr/May	All Day
Rare	Caspian Tern	May	Morning
Rare	Common Merganser	Mar/Apr/May	Midday
Rare	Great Blue Heron	Apr/May	Morning
Rare	Hooded Merganser	Apr	Midday
Rare	Osprey	Apr	Midday
Rare	Western Grebe	Apr	All Day

Figure 2. Average gull abundance at Chandler Canal Bypass Pipe 23 Apr to 30 May. Error bars represent standard error.

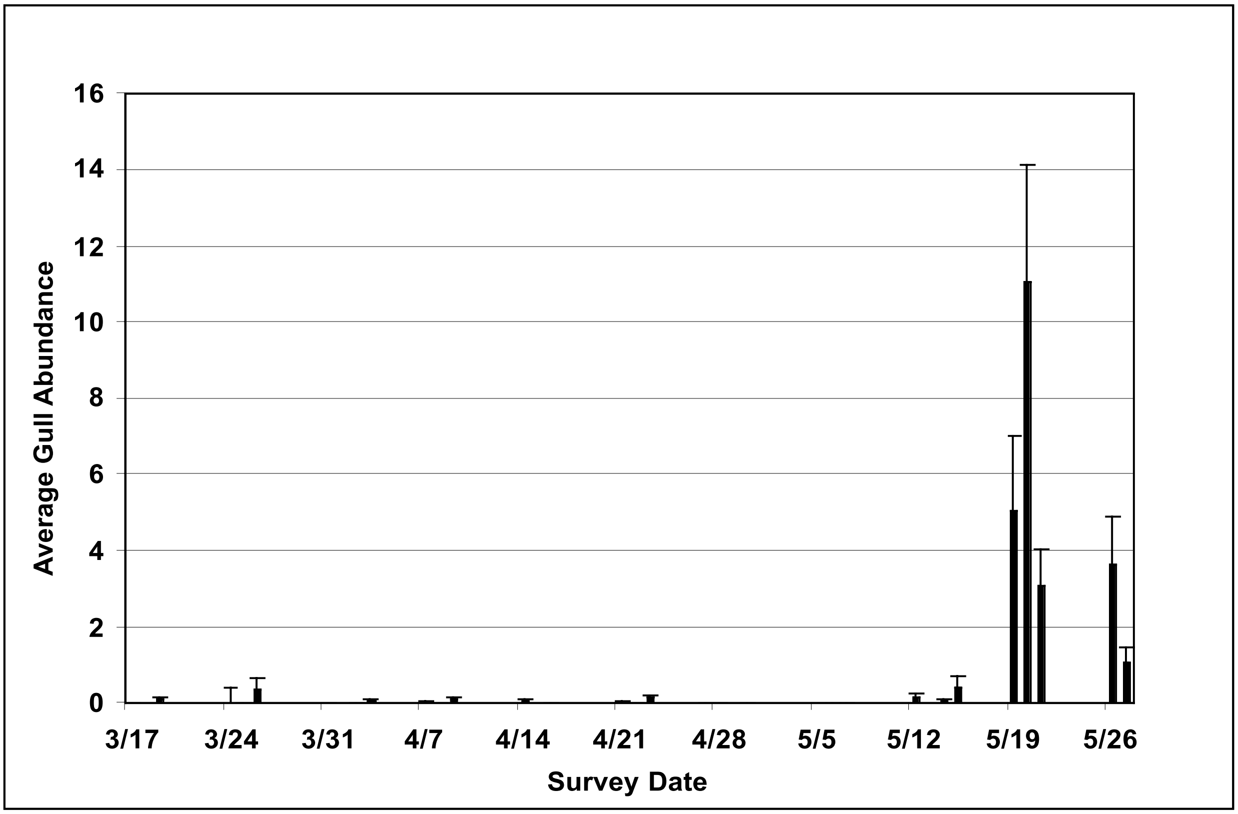
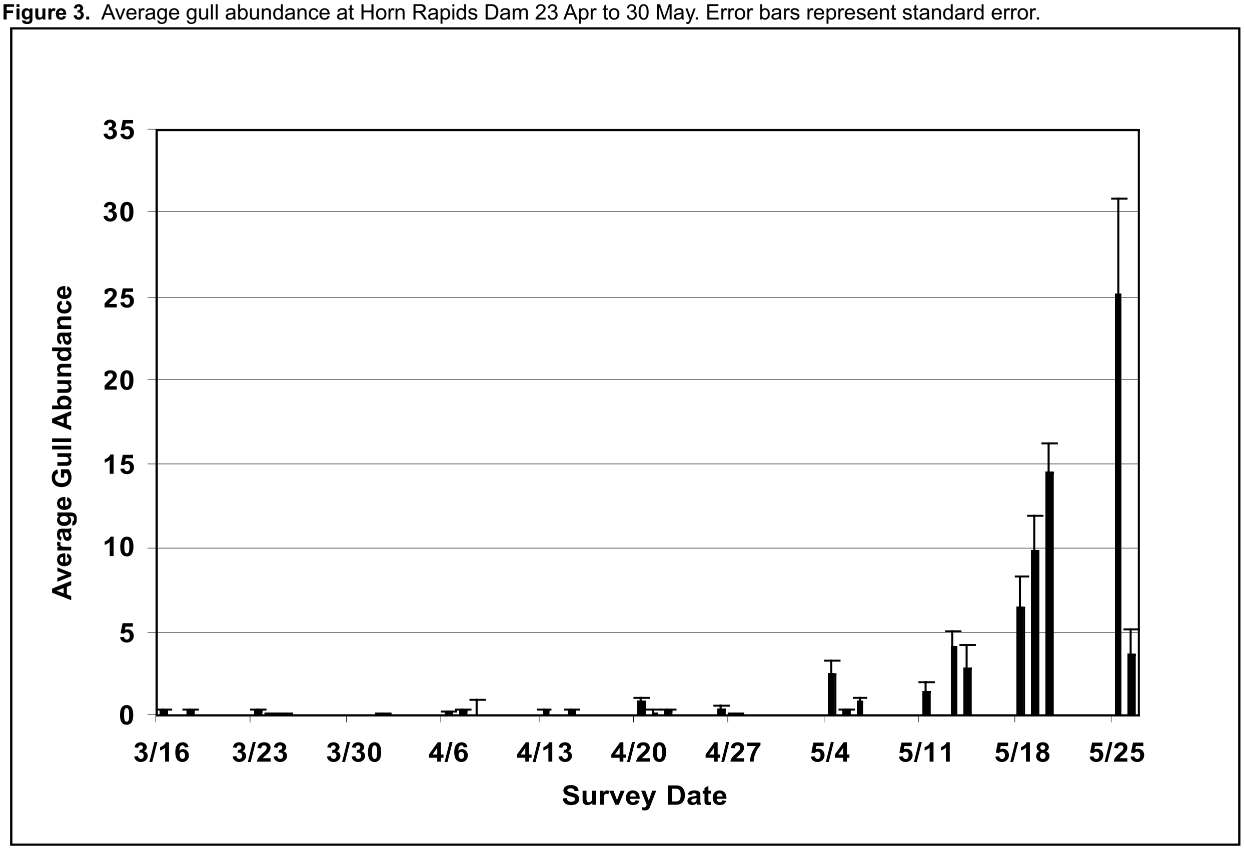


Figure 3. Average gull abundance at Horn Rapids Dam 23 Apr to 30 May. Error bars represent standard error.



When gull numbers reached their peak levels (100 and above), accurate counts became problematic due to the difficulty in separating counted from uncounted gulls. At Horn Rapids in particular, where survey personnel were often at considerable distance from feeding gulls (upwards of 50 meters), gulls would often fly in and out of dense groups near to feeding areas, making counting difficult. Although gull numbers rarely reached such high numbers, when they did occur, surveyors estimated the total number of gulls present.

Diurnal Pattern of Abundance

Diurnal patterns of gull abundance were difficult to discern when gull numbers were low, as occurred the first 6 weeks of the survey period. As gull numbers increased in mid May (Figure 2), patterns of diurnal abundance became apparent. To resolve these patterns survey periods which were numbered sequentially 1 to 8 (each two hours long with seven or eight occurring per day depending upon survey start time and length of day) were averaged across the survey season--15 Mar to 30 May. 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 forth hour after sunrise) were averaged across all days, and so on for all survey periods.

Daily abundance patterns at Chandler (Figure 4) show a quickly building gull presence from sunrise to a daily peak abundance in the 5th and 6th hour after sunrise, usually around 10:00. Subsequently, gull abundance steadily fell throughout the day, with the last gulls departing after sunset when there was insufficient light to forage.

A similar analysis at Horn Rapids shows a pattern quite unlike that seen at Chandler (Figure 5). Here, gull numbers increased throughout the day. However, when gull abundances are plotted individually (day by day), most show patterns (peaks within pe-

Figure 4. Pattern of diurnal gull abundance at Chandler Canal Bypass Pipe for all survey days combined, 23 Apr to 30 May. Time period 1 represents the first and second hours after sunrise, period 2 represents the third and fourth hours after sunrise, and so on to the final and 8th period which includes sunset. Error bars represent standard error.

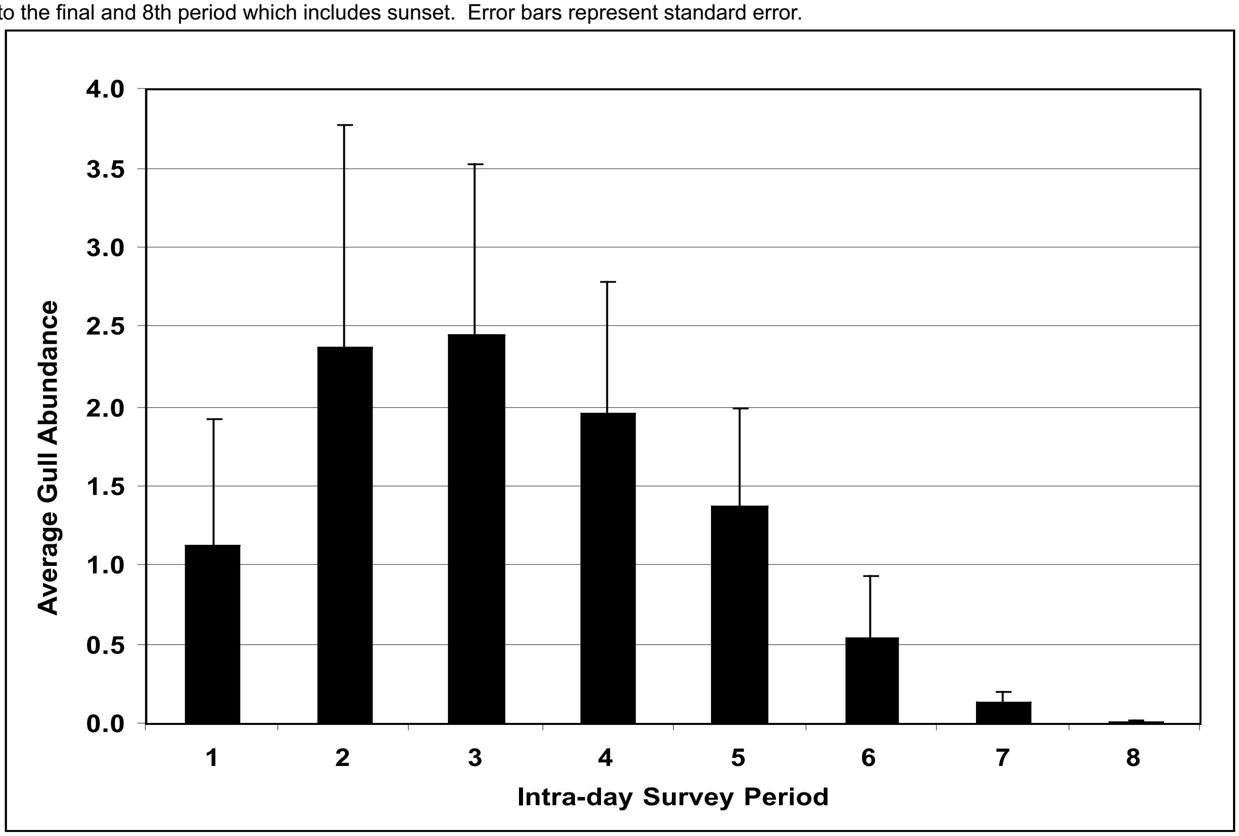
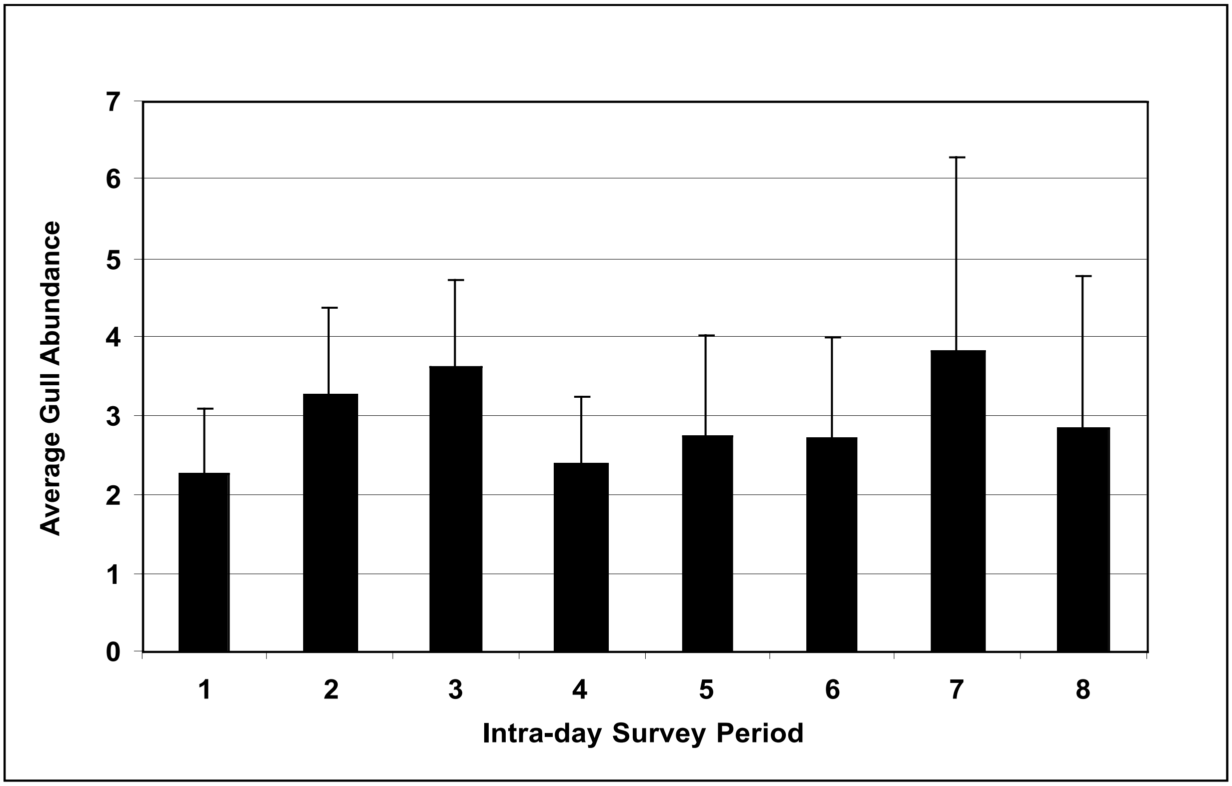


Figure 5. Pattern of diurnal gull abundance at Horn Rapids Dam for all survey days combined, 23 Apr to 30 May. Survey period 1 represents the first and second hours after sunrise, period 2 represents the third and fourth hours after sunrise, and so on to the final and 8th period which includes sunset. Error bars represent the standard error.



riod 3 followed by steady declines through the remainder of the day) similar to that seen at Chandler, with the exception of 25 May. On 25 May the pattern is reversed: lower abundance in the morning and a peak in survey period 7, which is approximately 17:00-19:00 (Figure 6). When this single day is removed from the data set, the diurnal pattern of gull abundance at Horn Rapids (Figure 7) is more consistent with that seen at Chandler--peak gull abundances in survey period 3 followed by steady declines through the day.

This pattern is likely related to typical foraging strategies of gulls, which will be discussed further in subsequent reports. It should be noted that the single day of Horn Rapids survey data identified as upsetting the diurnal pattern at Horn Rapids--25 May--was also the day with the highest average gull abundance for the entire survey period at both sites.

Consumption of Juvenile Salmonids by Gulls

Second order polynomial regression models were developed for gull abundance at both Chandler and Horn Rapids (Figures 8 and 9, respectively). Regression models were used to calculate average number of gulls for all days within the study period (15 Mar to 30 May). Due to low gull abundance in March and early April, the regression models do not derive positive gull abundance numbers for either site until 23 Apr. The seasonal average number of successful fish captures by gulls per minute for Chandler and Horn Rapids Dam combined was 0.055.

Modeled average gull abundance values and average rates of successful fish capture by gulls at both hotspots resulted in consumption estimates for these sites of 4,084 fish at Chandler and 12,636 fish at Horn Rapids (Figures 10 and 11, respectively). If the release of 1.882 million fall chinook smolts from below Chandler Dam are taken into account (113,000 smolts on 26 Apr, 1,690,000 smolts on 24 May, 79,000 smolts on 25 May), then our combined estimate of 16,720 fish represents 0.89% of all smolts

Figure 6. Pattern of diurnal gull abundance at Horn Rapids Dam by intra-day survey period for a single day only—25 May, 1999. Error bars represent standard deviation.

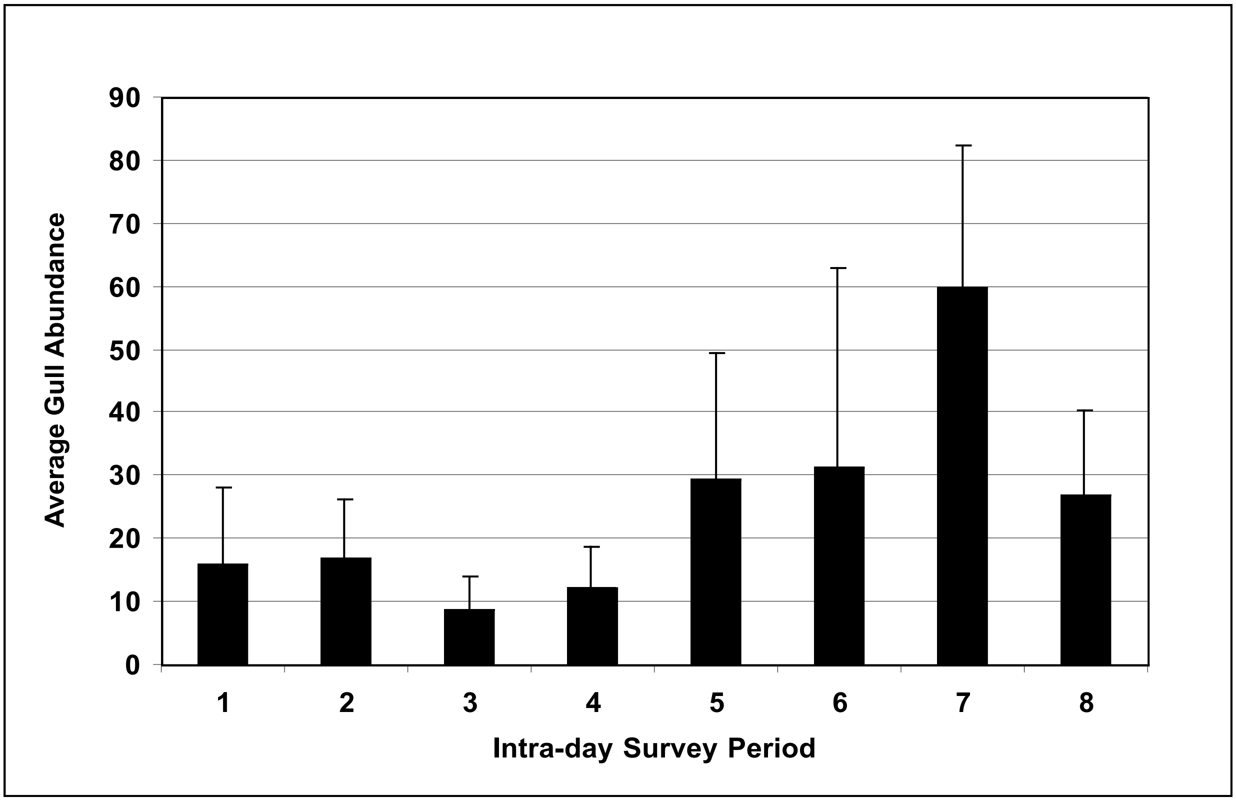


Figure 7. Pattern of diurnal gull abundance at Horn Rapids Dam by intra-day survey period. All survey days (23 Apr to 30 May) combined except 25 May. Error bars represent standard error.

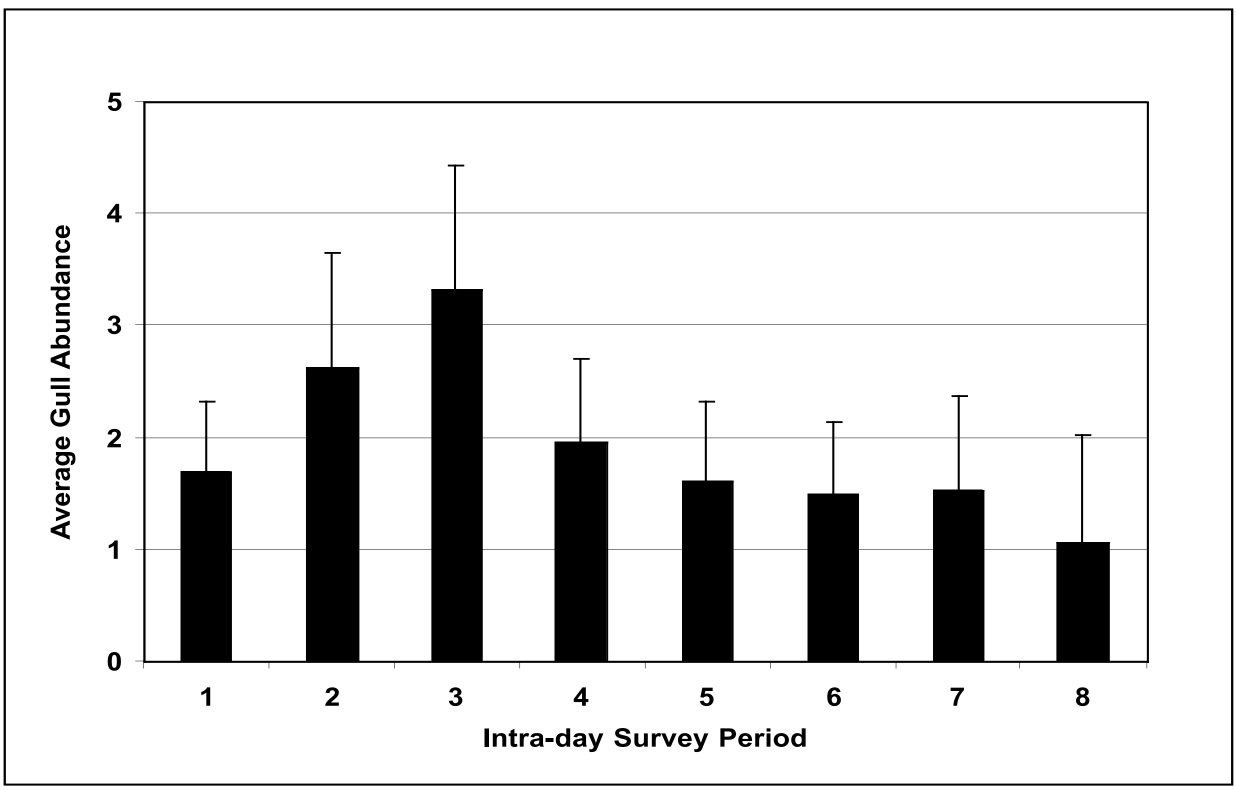


Figure 8. Second order polynomial regression model of average gull abundance for Chandler Canal Bypass Pipe.

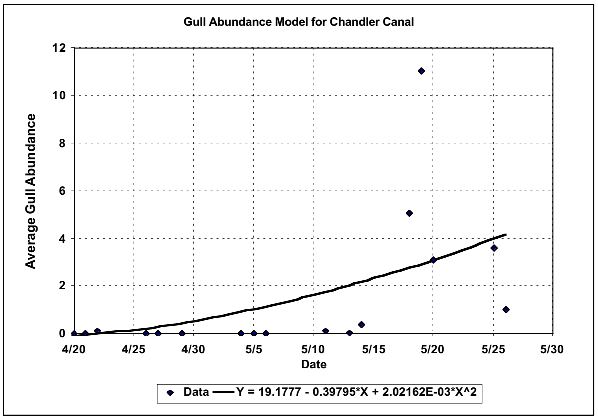


Figure 9. Second order polynomial regression model of average gull abundance for Horn Rapids Dam.

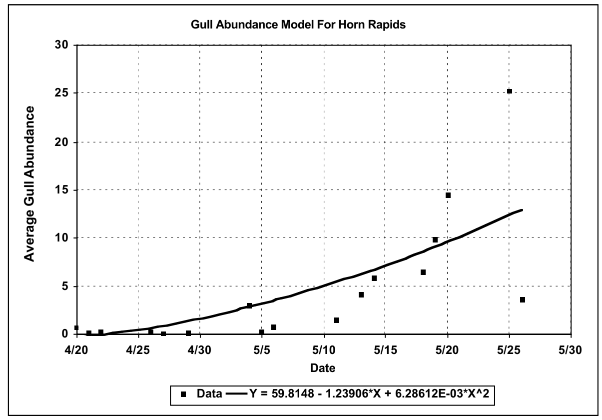
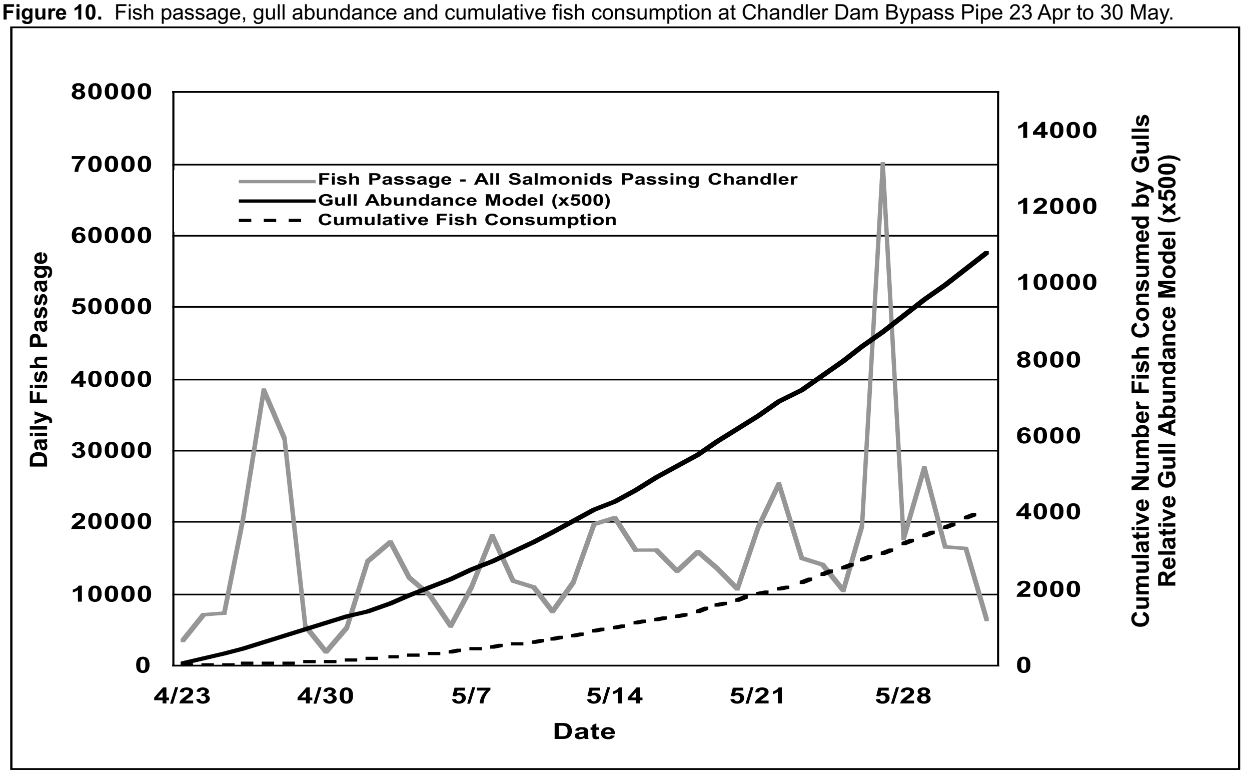


Figure 10. Fish passage, gull abundance and cumulative fish consumption at Chandler Dam Bypass Pipe 23 Apr to 30 May.



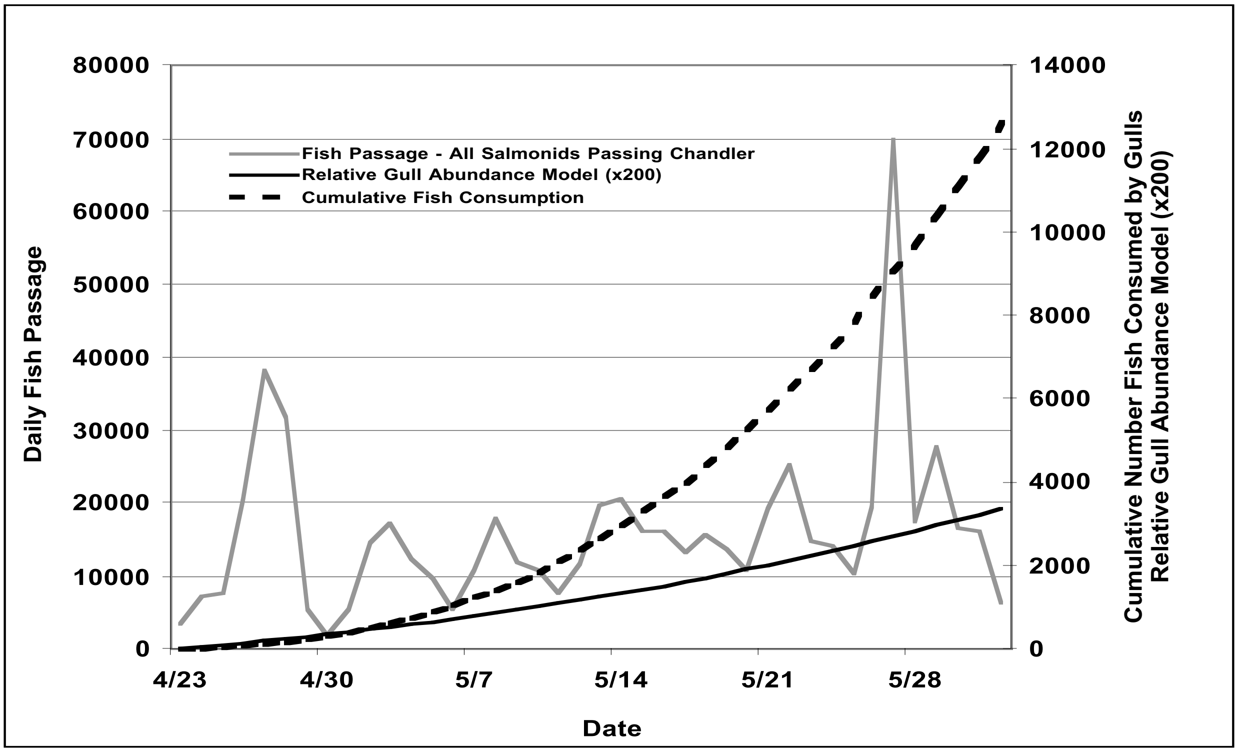
estimated passing or being released from the Chandler Dam area during the 1999 smolt migration season. These figures do not include consumption by gulls at hotspots before surveys began (15 Mar) or after surveys ended (30 May).

River Reach Survey—Spring

Avian Piscivore Abundance

Thirteen species of piscivores were identified, including Bald Eagle, Barrow's Goldeneye, Black-crowned Night-heron, Belted Kingfisher, Common Merganser, Double-crested Cormorant, Great Blue Heron, California, Mew, and Ring-billed Gulls, Horned Grebe, Hooded Merganser, and Osprey. Inclusive of gulls, Zillah was the reach with the highest abundance of avian piscivores per kilometer, followed by Vangie, Cle Elum and Benton (Figure 12). The peak abundance for any single day within the survey period was along the Zillah reach with 7.6 birds per kilometer on 23 Mar. Exclusive of gulls, Zillah remained the reach of highest avian piscivore abun-

Figure 11. Fish passage, gull abundance and cumulative fish consumption at Horn Rapids Dam 23 Apr to 30 May. Fish passage at Horn Rapids assumed identical to Chandler Dam.



dance, followed by Cle Elum, Vangie and Benton (Figure 13). Due to the infrequent sighting of gulls within the Zillah and Cle Elum reaches, these reaches' seasonal average abundance values do not noticeably decline when gull sightings are excluded. However, with the exclusion of gulls, the seasonal average avian piscivore abundance drops by approximately 60% at Vangie and 66% at Benton.

Common Mergansers, which are of particular importance due to their known utilization of salmon smolts as forage and their relative high abundance within certain reaches of the Yakima River, were most abundant along the Zillah reach within the spring survey period (Figure 14). Although Common Mergansers accounted for 46% of all avian piscivores within the Zillah reach (inclusive of gulls; Figure 15), the Cle Elum reach had the greatest proportion of all avian piscivores represented by Common Mergansers (60%; Figure 16), wherein they are known

Figure 12. Spring avian piscivore abundance by reach--including gull sightings, 23 Apr to 30 May. Error bars represent standard deviation (sd). Zillah sd=2.72.

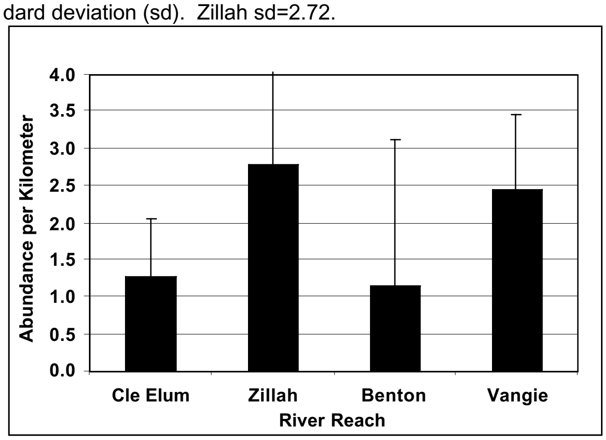


Figure 13. Spring avian piscivore abundance by reach--excluding gull sightings, 23 Apr to 30 May. Error bars represent standard deviation (sd). Zillah sd=2.72

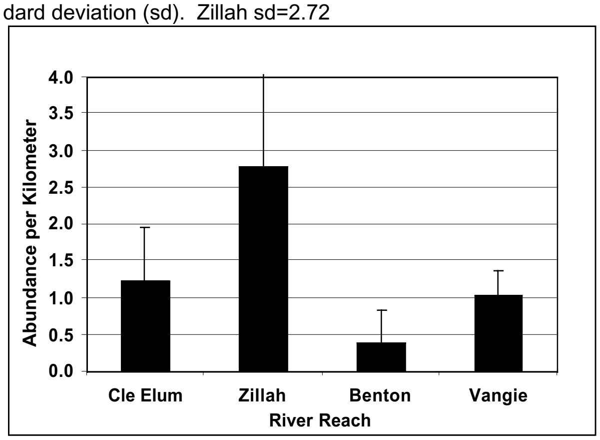
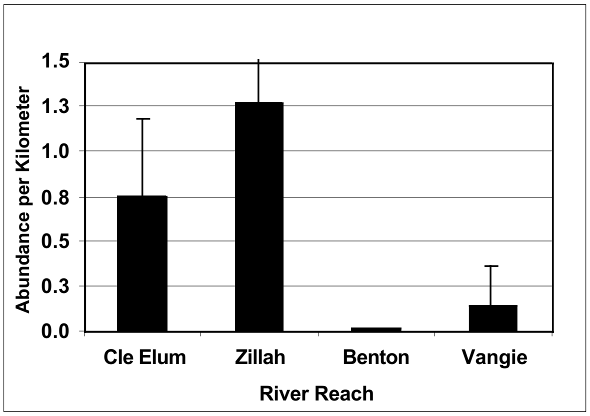


Figure 14. Average spring Common Merganser abundance per kilometer by reach, 23 Apr to 30 May. Error bars represent standard deviation (sd). Zillah sd=1.18. Observations without error bars were derived from a single river reach survey.



to breed in significant numbers. Common Mergansers represented only 2% and 6% of total avian piscivore abundance within the Benton and Vangie reaches (Figure 17, 18).

The second most abundant bird within the Zillah reach was the Great Blue Heron. This species has a large rookery along the banks of this reach, whereas other river reaches surveyed (which show a lesser abundance of Great Blue Herons) are not known to contain rookeries.

Within all reaches, Barrow's and Common Goldeneye were commonly sighted, yet few appear to breed within the regions surveyed. Sightings were most common within the early spring and male and females are in approximately equal ratios. For these reasons it is believed that most individuals of this species are migrants moving further north to the Canadian Interior. Common Goldeneyes do not appear in Figures 15-18 as sufficient evidence exists that this species is not likely to consume salmon smolts. Specific information of a similar sort has not yet been identified for Barrow's Goldeneye, although, it is expected to exist. The availability of information supporting the hypothesis that goldeneyes do not consume salmon smolts will result in the removal of this species from classification as piscivorous.

The Great Blue Heron and the Common Merganser are the only species of avian piscivore identified

Figure 15. Average spring avian piscivore abundance per kilometer within the Zillah river reach, 16 Mar to 30 May. Error bars represent standard deviation (sd). Great Blue Heron sd=1.14, Common Merganser sd=1.18. Observations without error bars were derived from a single river reach survey.

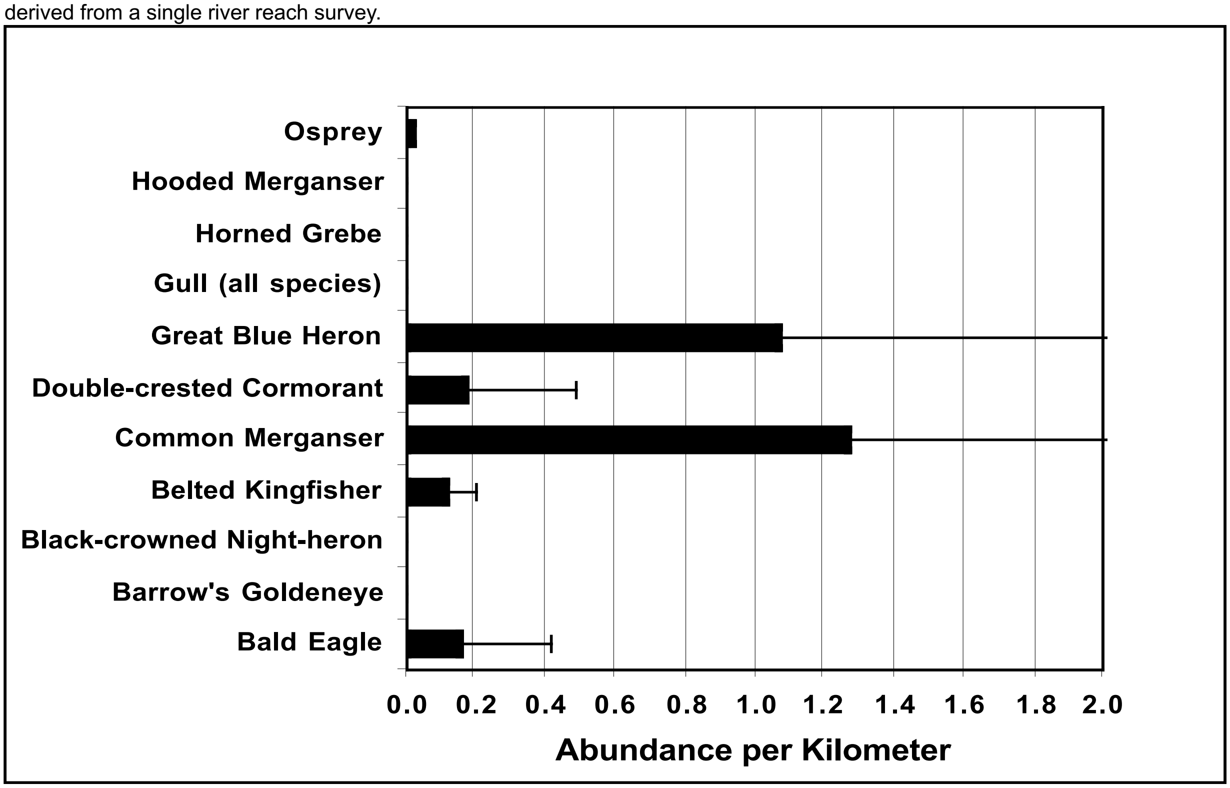


Figure 16. Average spring avian piscivore abundance per kilometer within the Cle Elum river reach, 16 Mar to 30 May. Error bars represent standard deviation. Observations without error bars were derived from a single river reach survey.

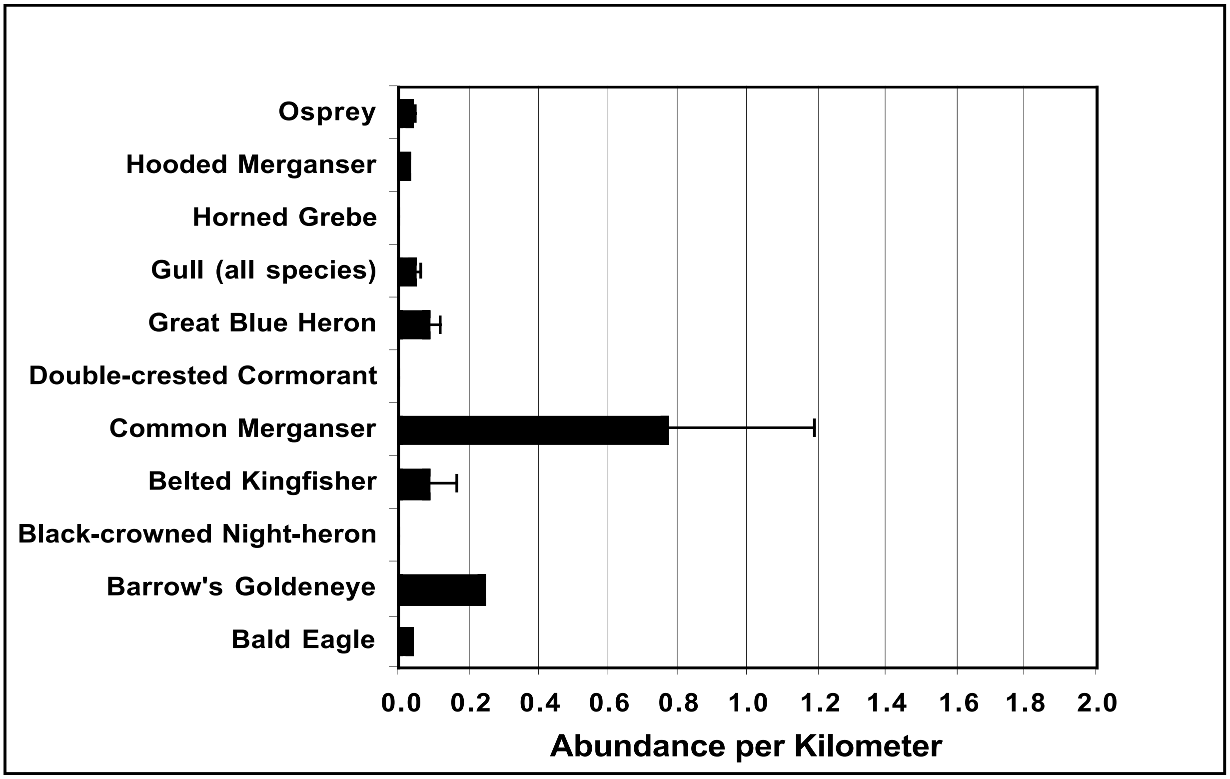


Figure 17. Average spring avian piscivore abundance per kilometer within the Benton river reach, 16 Mar to 30 May. Error bars represent standard deviation (sd). Gull sd=2.34. Observations without error bars were derived from a single river reach survey.

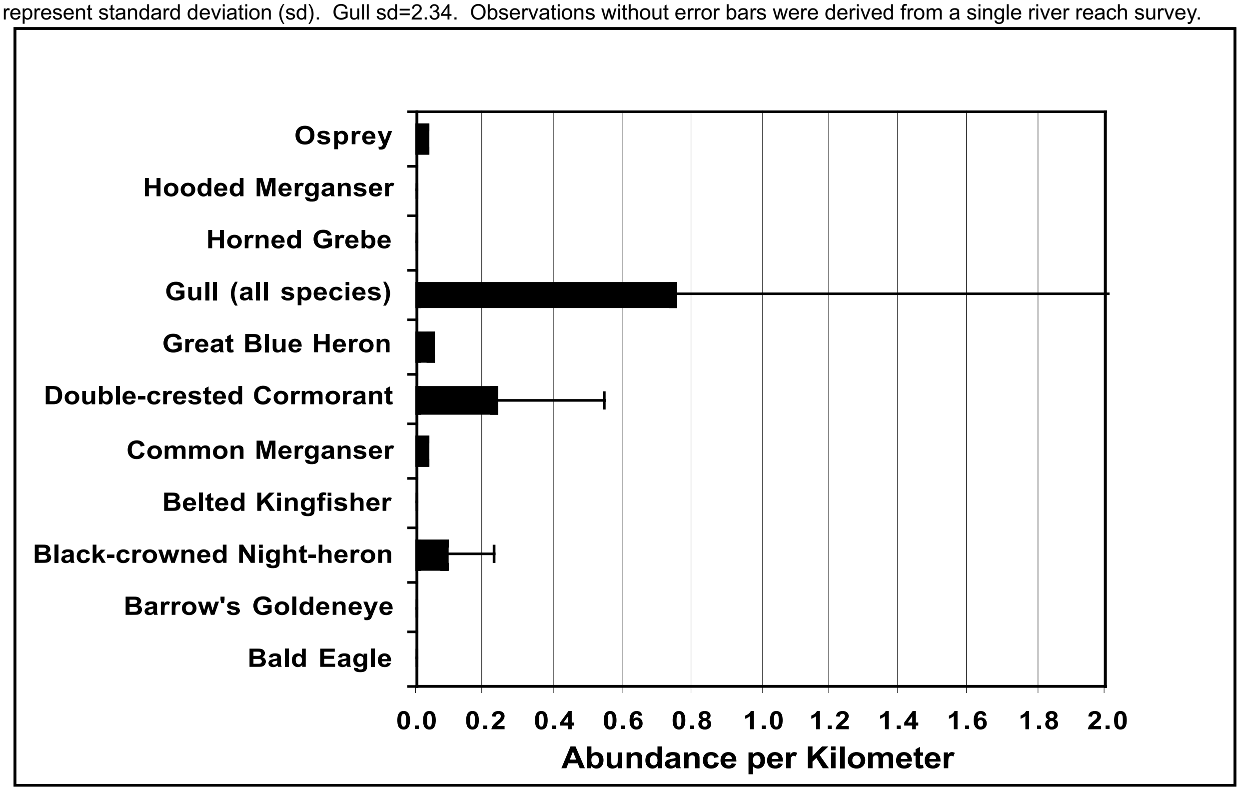
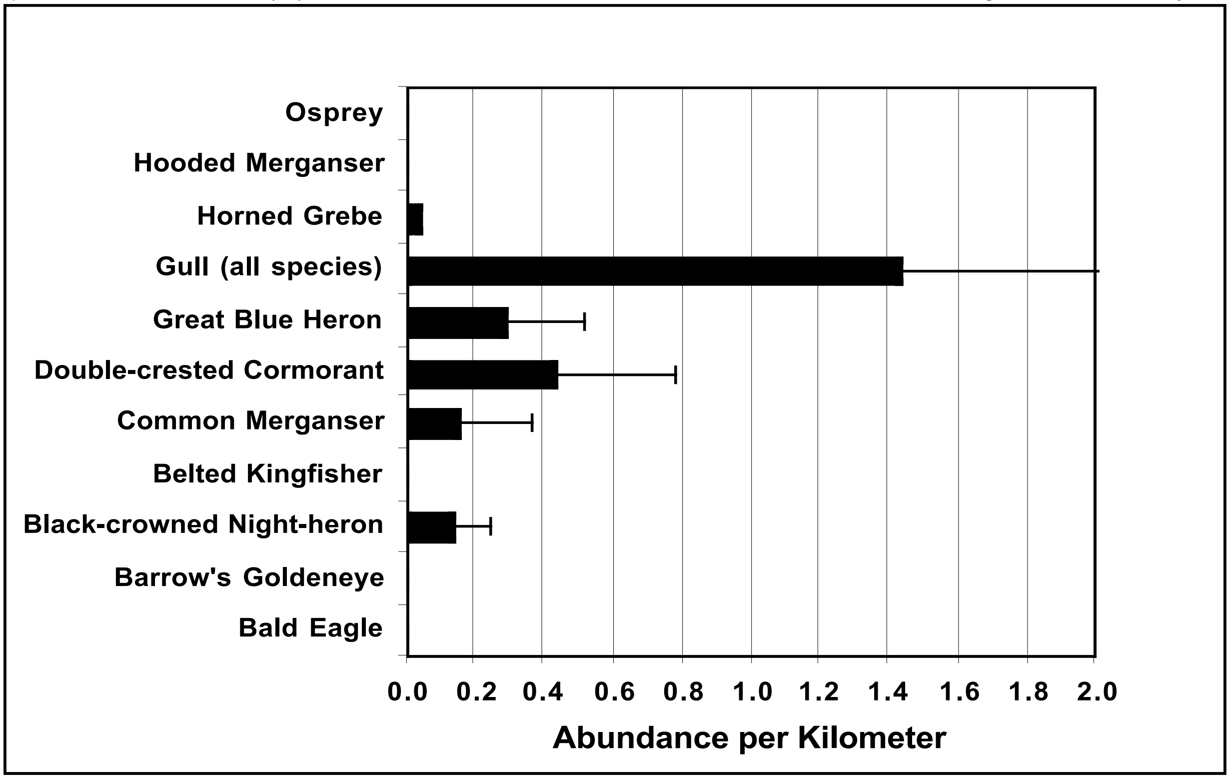


Figure 18. Average spring avian piscivore abundance per kilometer within the Vangie river reach, 16 Mar to 30 May. Error bars represent standard deviation (sd). Gull sd=1.23. Observations without error bars were derived from a single river reach survey.



within all four reaches surveyed. The Hooded Merganser is the only species identified only within the upper most reach (Easton). Species which favor the upper reaches include Bald Eagle, Barrow's Goldeneye, Belted Kingfisher, and Hooded Merganser. Species favoring lower reaches include Black-crowned Night-heron, Double-crested Cormorant, and gulls. The Horned Grebe is the only species identified only within the lowest reach (Vangie), although this species was observed on only two occasions.

Consumption of Juvenile Salmonids
Consumption of juvenile salmon and trout along river reaches in spring by avian piscivores will not be calculated until completion of the second year of surveys--spring 2000.

Acclimation Site Survey—Spring

Those surveys completed do not suggest that abnormally large numbers of piscivorous birds congregate within or near the Easton and Clark Flats spring chinook acclimation facilities. However, not all surveys originally scheduled were completed by site personnel. Further detail regarding the results of these surveys will be provided at a later date (final report).

Aerial Survey—Spring

Five aerial surveys were conducted by the YN between 24 Mar and 18 Jun. Due to scheduling difficulties few aerial flights coincided (same day) with river drifts, resulting in a lack of paired surveys. Due to difficult flying conditions, all five surveys were only partially completed. Those reaches impacted by incomplete flights include the Clark Flat to Indian John Hill, Indian John Hill to Cle Elum, and Cle Elum to Easton (Table 5). The Yakima River canyon reach (Ellensburg Canyon) was never flown due to hazards of flying low within the gorge.

After combining all gull species into a single category (gulls), seven species of avian piscivores were identified by aerial flights within the reaches surveyed

Table 10. Abundances of piscivorous birds counted during aerial flight surveys of the Yakima River during spring and summer of 1999. NC denotes those reaches which were not flown due to hazardous conditions.

Date	REACH	Common Merganser	Gull	Common Goldeneye	Double-crested Cormorant	American White Pelican	Caspian Tern	Bald Eagle
24-Mar	Benton City to Prosser Dam	6	0	6	1	0	0	0
	Clark Flat to Indian John Hill	0	0	0	0	0	0	0
	Cle Elum Hatchery to Easton	89	0	0	0	0	0	0
	Ellensburg Canyon	0	0	0	0	0	0	0
	Horn Rapids Dam to Bend in River at Benton City	8	12	3	0	0	0	0
	Indian John Hill to Cle Elum Hatchery	10	0	27	0	0	0	0
	Mabton Bridge to Union Gap	42	0	0	50	11	0	2
	Mouth of Yakima River to Horn Rapids Dam	3	2	0	0	0	0	1
	North End of Ellensburg Canyon to Clark Flat	7	0	0	0	0	0	0
	Prosser Dam to Mabton Bridge	10	2	0	0	0	0	0
	Selah Gap to South end of Ellensburg Canyon	NC	NC	NC	NC	NC	NC	NC
	Union Gap to Selah Gap	6	0	0	0	0	0	0
8-Apr	Benton City to Prosser Dam	0	0	25	2	0	0	0
	Clark Flat to Indian John Hill	0	0	0	0	0	0	0
	Cle Elum Hatchery to Easton	11	0	1	0	0	0	0
	Ellensburg Canyon	0	0	0	0	0	0	0
	Horn Rapids Dam to Bend in River at Benton City	0	3	25	2	0	0	0
	Indian John Hill to Cle Elum Hatchery	30	0	12	0	0	0	0
	Mabton Bridge to Union Gap	13	0	0	7	22	0	0
	Mouth of Yakima River to Horn Rapids Dam	3	3	1	0	0	0	0
	North End of Ellensburg Canyon to Clark Flat	13	0	0	0	0	0	0
	Prosser Dam to Mabton Bridge	0	0	60	0	0	0	0
	Selah Gap to South end of Ellensburg Canyon	2	0	0	0	0	0	0
	Union Gap to Selah Gap	4	0	0	0	0	0	0
7-May	Benton City to Prosser Dam	0	8	4	0	0	0	0
	Clark Flat to Indian John Hill	1	0	0	0	0	0	0
	Cle Elum Hatchery to Easton	27	0	0	0	0	0	0
	Ellensburg Canyon	0	0	0	0	0	0	0
	Horn Rapids Dam to Bend in River at Benton City	0	4	0	2	0	0	0
	Indian John Hill to Cle Elum Hatchery	3	0	0	0	0	0	0
	Mabton Bridge to Union Gap	7	0	0	50	95	0	0
	Mouth of Yakima River to Horn Rapids Dam	0	49	0	2	0	0	0
	North End of Ellensburg Canyon to Clark Flat	2	0	0	0	0	0	0
	Prosser Dam to Mabton Bridge	0	14	0	1	0	0	0
	Selah Gap to South end of Ellensburg Canyon	0	0	0	1	0	0	0
	Union Gap to Selah Gap	0	1	0	0	0	0	0
4-Jun	Benton City to Prosser Dam	0	8	0	1	0	0	0
	Clark Flat to Indian John Hill	NC	NC	NC	NC	NC	NC	NC
	Cle Elum Hatchery to Easton	0	0	0	0	0	0	0
	Ellensburg Canyon	0	0	0	0	0	0	0
	Horn Rapids Dam to Bend in River at Benton City	0	11	0	1	0	0	0
	Indian John Hill to Cle Elum Hatchery	NC	NC	NC	NC	NC	NC	NC
	Mabton Bridge to Union Gap	0	7	0	50	25	0	0
	Mouth of Yakima River to Horn Rapids Dam	0	98	0	9	0	6	0
	North End of Ellensburg Canyon to Clark Flat	3	1	0	0	0	0	0
	Prosser Dam to Mabton Bridge	0	5	0	5	50	0	0
	Selah Gap to South end of Ellensburg Canyon	NC	NC	NC	NC	NC	NC	NC
	Union Gap to Selah Gap	NC	NC	NC	NC	NC	NC	NC
18-Jun	Benton City to Prosser Dam	0	15	0	1	0	2	0
	Clark Flat to Indian John Hill	NC	NC	NC	NC	NC	NC	NC
	Cle Elum Hatchery to Easton	0	0	0	0	0	0	0
	Ellensburg Canyon	0	0	0	0	0	0	0
	Horn Rapids Dam to Bend in River at Benton City	0	0	0	0	0	3	0
	Indian John Hill to Cle Elum Hatchery	0	0	0	0	0	0	0
	Mabton Bridge to Union Gap	0	4	0	50	54	0	0
	Mouth of Yakima River to Horn Rapids Dam	1	52	0	8	3	5	0
	North End of Ellensburg Canyon to Clark Flat	NC	NC	NC	NC	NC	NC	NC
	Prosser Dam to Mabton Bridge	0	67	0	2	0	0	0
	Selah Gap to South end of Ellensburg Canyon	NC	NC	NC	NC	NC	NC	NC
	Union Gap to Selah Gap	NC	NC	NC	NC	NC	NC	NC

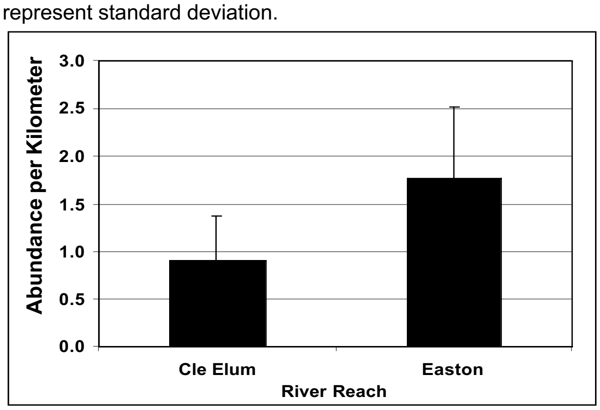
(Table 10); within the same approximate time period (May, June, July) and locations, a total of ten species were identified by river drift techniques. Aerial flights were unique in the detection of American White Pelicans and Caspian Terns while river drift surveys were unique in the detection of Black-crowned Night Herons, Belted Kingfishers, Great Blue Herons, Horned Grebes, Hooded Mergansers, and Ospreys. Those species consistently identified by both survey techniques include Bald Eagles, Common Mergansers, Double-crested Cormorants, and gulls.

River Reach Survey—Summer

Avian Piscivore Abundance

In 1999, six species of avian piscivores were identified: Bald Eagle, Belted Kingfisher, Common Merganser, Double-crested Cormorant, Great Blue Heron, Hooded Merganser, and Osprey. Seasonal average abundance for all species combined was twice as high within the Easton reach as in the Cle Elum, 1.77 and 0.91 birds per kilometer, respectively (Figure 19). The peak abundance for all species per kilometer for a single drift within the Easton reach was 2.85 on 10 Jun (Figure 20), and 1.40 piscivores within the Cle Elum Reach on 23 Jul (Figure 21).

Figure 19. Average summer avian piscivore abundance within the Easton and Cle Elum reaches, 30 May to 15 Aug. Error bars represent standard deviation.



Mergansers were by far the most numerous species within the Easton reach with 1.40 birds per kilometer, followed by Belted Kingfisher (0.16 birds), Great Blue Heron (0.09 birds), Osprey (0.07 birds), Hooded Merganser (0.02 birds), and Bald Eagle (0.01 birds) on a seasonal average basis (Figure 22). Mergansers were also the most numerous species within the Cle Elum reach with 0.71 birds/km, followed by Belted Kingfisher (0.08 birds), Osprey (0.07 birds), Great Blue Heron (0.04 birds), Bald Eagle (0.01 birds) and Double-crested Cormorant (0.004 birds; Figure 23). Peak numbers of Common Mergansers were observed within both river reaches in late June (Figures 24 and 25).

Consumption of Juvenile Salmonids by Common Mergansers

The regression models for 1999 first derive positive Common Merganser numbers for Easton on 7 May (day 127) and for Cle Elum on 28 May (day 147) and predict a return to zero for Easton on 18 Aug (day 230) and for Cle Elum on 13 Aug (day 225; Figures 26 and 27, respectively). Estimates of daily consumption per Common Merganser were based upon data published by Feltham (1995b) which attribute an average of 501 grams of fish consumed per adult Common Merganser per day. No adjust-

Figure 20. Average abundance of all avian piscivores per river kilometer by drift along the Easton river reach.

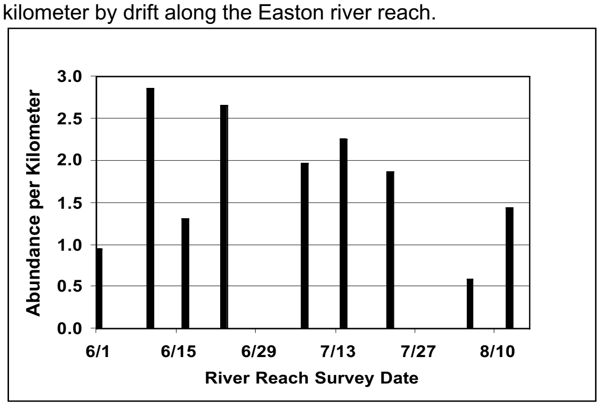


Figure 21. Average abundance of all avian piscivores per river kilometer by drift along the Cle Elum river reach.

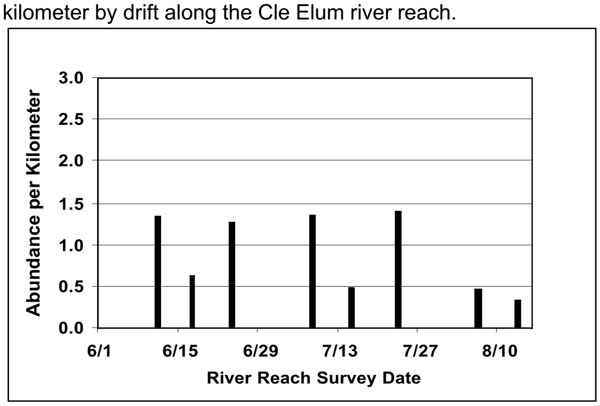


Figure 22. Average summer avian piscivore abundance per kilometer within the Easton river reach, 30 May to 15 Aug. Error bars represent standard deviation (sd). Common Merganser sd=0.73. Observations without error bars were derived from a single river reach survey.

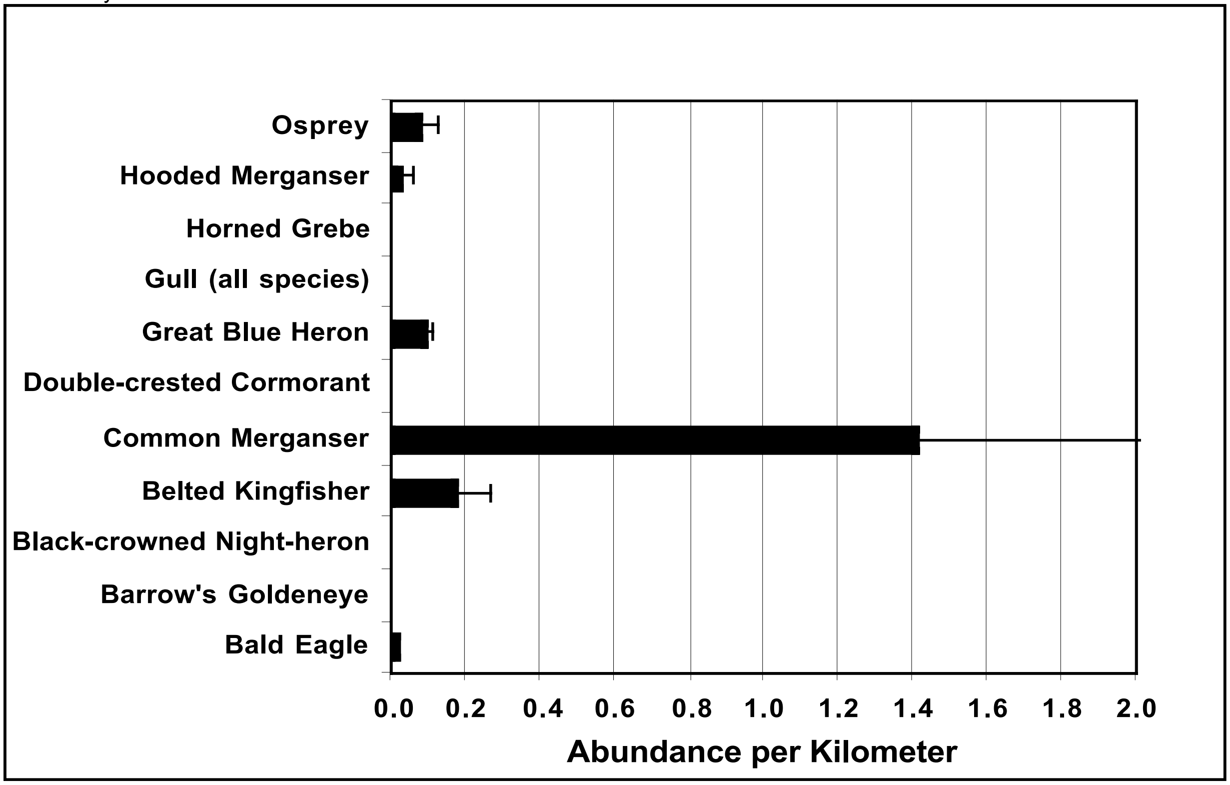


Figure 23. Average summer avian piscivore abundance per kilometer within the Cle Elum river reach, 30 May to 15 Aug. Error bars represent standard deviation. Observations without error bars were derived from a single river reach survey.

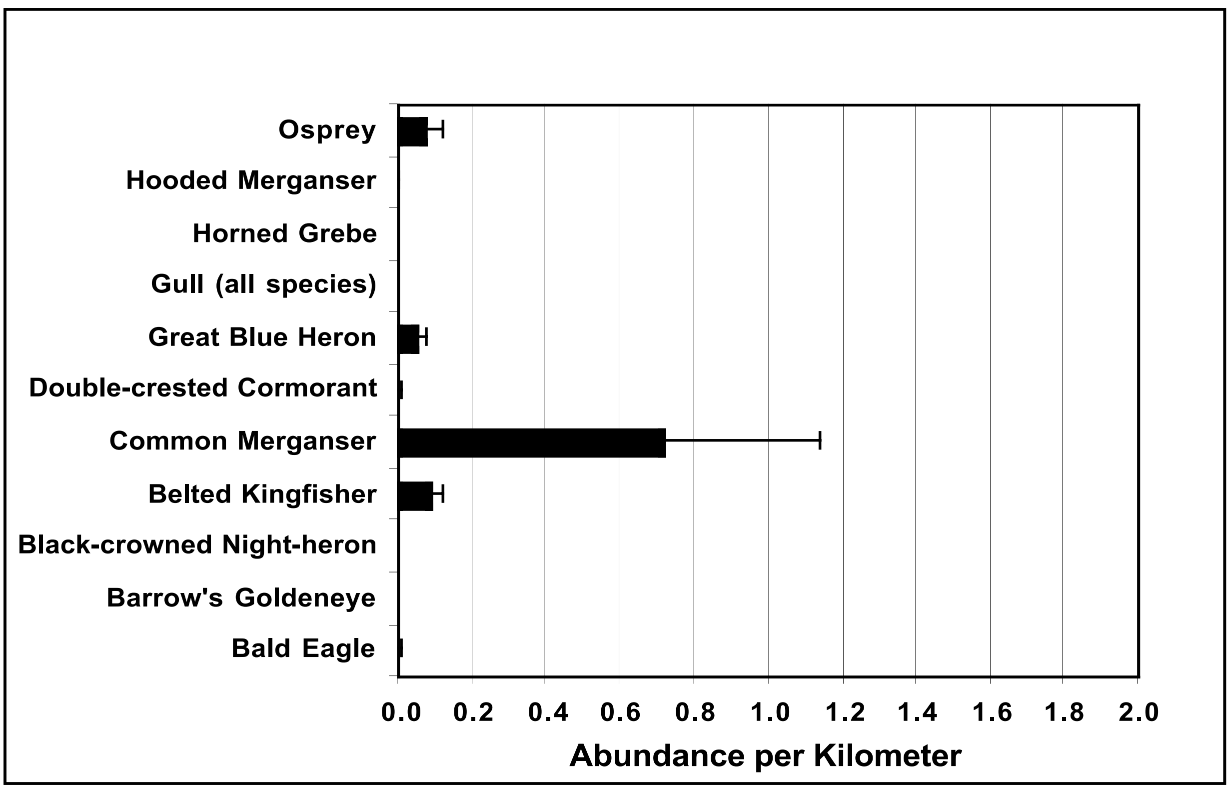


Figure 24. Abundance of Common Mergansers per river kilometer by drift along the Easton river reach.

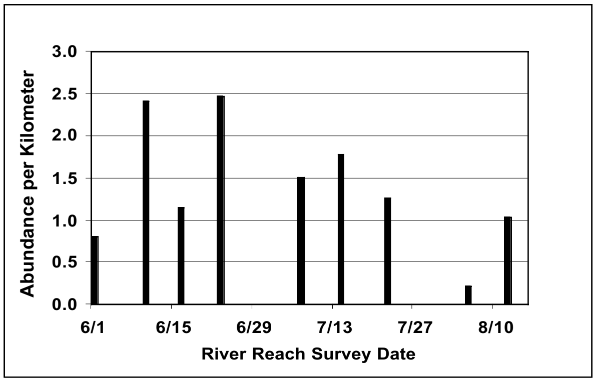


Figure 25. Abundance of Common Mergansers per river kilometer by drift along the Cle Elum river reach.

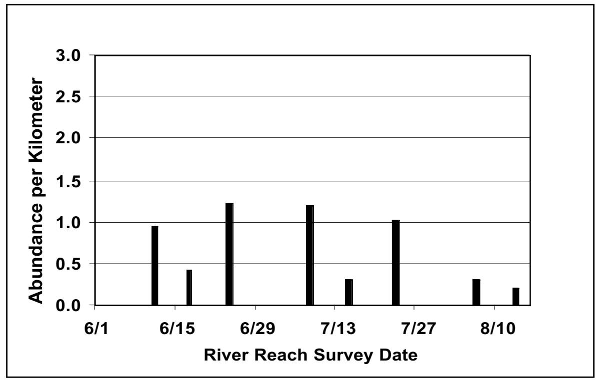


Figure 26. Second order polynomial regression of seasonal Common Merganser abundance within the Easton river reach.

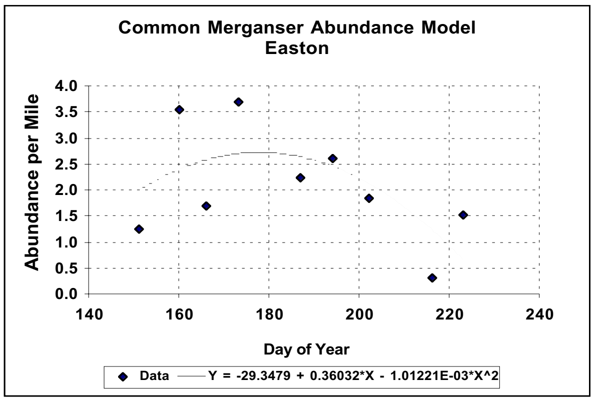
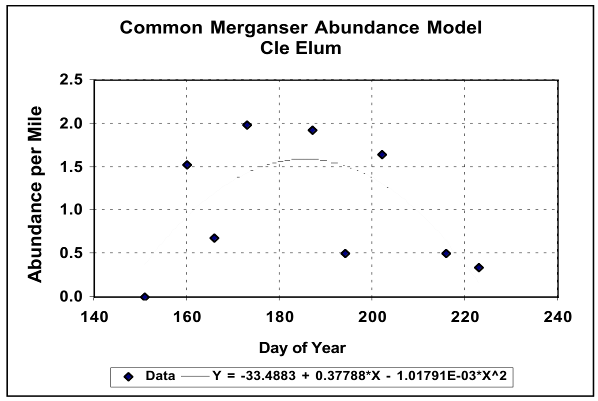


Figure 27. Second order polynomial regression of seasonal Common Merganser abundance within the Cle Elum river reach.



ments were made for differential body mass of Mergansers, nor energy density (kCal/gram) of various prey items consumed by Mergansers. Consumption estimates are given for all days wherein the regression model predicted positive Common Merganser abundance.

Between 7 May and 18 Aug, an estimated 2,789 kilograms of fish (and/or other prey items) were consumed by Common Mergansers along the Easton river reach, and 1,303 kilograms of prey along the Cle Elum river reach. Total kilograms of prey consumed along the Easton and Cle Elum river reaches combined was 4,092. These consumption estimates are given specifically as "prey", and are of unknown species composition.

North Fork Teanaway River Survey—Summer

Surveys were conducted along the Teanaway reach on 17 Jun, 24 Jun, 8 Jul, 22 Jul, and 13 Aug, for a total of five surveys during the summer of 1999. Only one species of avian piscivore was identified within survey areas, the Belted Kingfisher. A single sighting of a Common Merganser and an Osprey occurred outside the formal survey area, but within the North Fort Teanaway on 17 Jun. The Belted Kingfisher was observed during three of five surveys, always above the Dickey Creek Bridge in approximately the same location.

DISCUSSION

Hotspot Survey—Spring

Avian Piscivore Abundance

In 1999, hotspot surveys were conducted on 30 days at both Chandler Canal Bypass (Chandler) and Horn Rapids Dam (Horn Rapids). Although this intensity of observation was necessary to collect sufficiently detailed data required for consumption modeling and basic understanding of fish/bird interactions, it is not practical for long term monitoring efforts. We anticipate the continuation of this higher level of observation to be required in 2000 and 2001. Thereafter, less intensive monitoring methods at hotspots will likely be recommended.

In 1999, hotspot surveys were initially scheduled to begin on March 15 and end on 30 May. These dates proved earlier than optimum. Avian piscivore abundance at Chandler Canal Bypass Pipe (Chandler) and Horn Rapids Dams (Horn Rapids) remained at or near zero until late April, and salmon smolt passage and high gull abundances continued beyond 30 May, resulting in incomplete seasonal abundance data.

Historically, steelhead smolts are the earliest migrants to pass Chandler Dam (Prosser, WA), followed closely by wild spring chinook (Figure 1), both beginning in early April. We would not anticipate increased gull abundance until sometime after the onset of smolt passage. Fall chinook and wild coho are historically the last smolt populations to pass Chandler Dam, extending as late as the third and fourth week of June. For these reasons, hotspot surveys in 2000 will begin on 15 Apr and continue until 30 Jun.

Diurnal Pattern of Abundance

Daily abundance patterns at Chandler and Horn Rapids (less 25 May) both indicated a daily peak in gull abundance during the third 2-hour survey period--approximately 10:00 or 11:00--followed by slowly falling abundance throughout the remainder of the day. Preliminary linear regression modeling (results not presented in this report), suggest the correlation between the daily peak abundance (survey period 3 abundance) and the average number of gulls/day to be high. If such patterns continue in subsequent survey seasons, we may be able to utilize this relationship in future monitoring protocols, significantly reducing gull abundance survey efforts at hotspots.

Related to this issue is the fact that prior to the removal of survey data derived at Horn Rapids on 25 May (Figure 6), diurnal gull abundance was not similar to that seen at Chandler (Figure 5 vs. Figure 4). We feel that segregation of gull abundance data derived on 25 May from the data set characterizing typical diurnal abundance patterns for gulls is appropriate due to the unusually high gull numbers, which were likely stimulated by the release of 1.69 million fall chinook just below Chandler Dam on 24 May. This pattern will be further examined in 2000 and 2001.

Consumption of Juvenile Salmonids by Gulls

Due to the early cessation of abundance surveys, estimated consumption values, 4,084 fish at Chandler and 12,636, must be considered to be only a portion of the total that occurred at Chandler and Horn Rapids in 1999. These estimates represent "fish" consumed by gulls and are of unknown species composition. While on some occasions fish being consumed by gulls could be identified with some assurance to family or genus, identifications to species was at best questionable. Even the identification of prey taken by gulls in close proximity of survey personnel was at times difficult, especially if the angle of observation was poor, the handling of fish by gulls was quick, or when lighting conditions were poor.

Assuming that all fish consumed by gulls were migrating salmon/trout smolts--we calculate that the consumption in 1999 at both hotspots combined represented 2.87% of the 582,368 smolts passing Chandler Dam. If the release of 1.882 million fall chinook smolts from below Chandler Dam are included, then the combined estimate of 16,720 fish represents

0.89% of all smolts estimated passing or being released from the Chandler Dam area during the 1999 smolt migration season. This figure does not include consumption by gulls at hotspots before surveys began (15 Mar) or after surveys ended (30 May) or consumption of naturally produced fall chinook below Chandler Dam. As noted previously, consumption estimates likely overestimate actual take at the hotspots.

Bird response to hatchery inputs is evidenced by the peak in gull abundance observed at Horn Rapids on 25 May, one day after the release of 1.69 million fall chinook (24 May). We believe this release stimulated both a large numerical response in gull abundance (Figure 3) and a shift in typical diurnal attendance pattern for a single day at Horn Rapids (Figure 6). Gull abundance at Chandler and Horn Rapids on 26 May--two days after the release of the fall chinook--do not appear elevated. These events suggest that smolt travel time between Chandler Dam and Horn Rapids Dam can, at least for some fraction of the fish released, be as little as 24 hours (total distance traveled = 46 kilometers). Similar increases in gull abundance were not observed at Chandler Dam Canal Bypass Pipe on 25 May (approximately 50 meters below the fall chinook release site), suggesting that these smolts quickly departed the initial release area.

While it remains unknown what fraction of fall chinook smolts released on 24 May reached Horn Rapids Dam by the afternoon of 25 May, the resulting single day spike in gull abundance followed by normal (or even low) numbers of gulls on 26 May, suggests that these smolts are passing as one large cohort rather than spreading out within the river and passing over multiple days or even weeks. Likely contributing to this quicker than expected passage was a 24% increase in river flow (cfs) on 25 May, occurring within an already higher than normal flow spring season. It is possible that similar events occurring under low flow conditions may not produce similarly short travel times between Chandler and Horn Rapids, nor similar response from gull populations. We anticipate the opportunity to investigate these events further in 2000 and 2001.

River Reach Survey—Spring

In 1999, consumption modeling occurred only at hotspots and summer reference river reaches. No estimates of consumption along river reaches in spring will be produced until consumption models are more fully developed.

Double Counting Birds-River Drifts

Methodologically, the aspect of river reach surveys which produced the greatest uncertainty was the potential to count the same bird more than once. This problem (over-counting) occurred under two specific scenarios in 1999. The first scenario occurred when a bird encountered on a river drift was pushed down river out of sight of observers, creating uncertainty as to whether the next bird identified of the same species/age/sex was the same bird or a new bird. This behavior is referred to as "running". The second scenario occurred when a bird from up river (from behind the survey boat), flew down into view of the survey personnel, creating confusion as to whether the bird was already counted. This behavior is referred to as "tailing".

Running was by far the most frequent and simplest to remedy. When birds run, the initial encounter is recorded. If a bird of the same species/sex/age is passed by the survey boat within the next 1,000 meters of river, it was not recorded (i.e., assumed to be the same bird). If a bird of the same species/age/sex as that which was running was not again identified within 1,000 meters of the initial sighting, it was assumed to have departed the river or passed unnoticed by survey personnel, the observation was retained, and the next bird of the same species/sex/age was recorded as a new bird. Some latitude on the 1,000 meters was given to Osprey which can cover great distances in a short time.

This method can result in a double count of the same bird if the running bird avoids a second detection within the next 1000 meters, and is then again encountered and enumerated a second time some-where further down river. While the frequency of such events is ultimately unknown—and certain to occur—we believe the occurrence of such events is very low. The great majority of encounters resulting in running by the identified bird were reconciled within several hundred meters of river. Navigation of the survey boat to the opposite side of the river away from encountered birds minimized running by birds.

This method also has the advantage of not being biased due to the differential escape methods (escape from the survey boat) utilized by different species of birds. Common Mergansers, which rarely depart the river while running, will eventually be passed even if the point of passage is 1,000 meters beyond the initial encounter. On the other hand, many birds--such as Great Blue Herons, Belted Kingishers, Green Herons, Black-crowned Night Herons--escape into tree cover adjacent to the river, creating a higher probability that the bird will not be observed a second time within the 1,000 meter limit. Because enumeration occurs at the point of initial sighting, both the Common Merganser and the Great Blue Heron (each with different escape behaviors) were recorded.

The alternative to this method is to enumerate a bird only upon passage by the survey boat. While this method addresses over-counting, it introduces the alternate probability of under-counting. Such under-counting would occur when a bird runs, and then departs the viewable area of the river once out of sight of the survey personnel, resulting in no record of the initial sighting. Given the different escape methods utilized by bird species, this method would be biased towards birds which remained upon the river, and against those birds which escaped from view.

The potential to under count during a run also exists if the running bird, once it has left the view of the survey personnel, departs the river, and by coincidence there exists another bird of the same species/sex/age around the corner. Under such circumstances the running birds departure from the river would go undetected, and the identical bird will be assumed to be the running bird. No method has been developed to prevent this event, and is presumed to be exceedingly rare.

The second event which can result in double counting occurs when a bird flies from up river, is noticed by the survey crew, then moves out of sight again in either an up river or down river direction. Under such conditions it is unknown whether the bird was previously counted. In order to minimize overestimation of bird abundance due to double counting, we assumed that the bird had been previously counted.

Aerial Survey—Spring

Due to the lack of a sufficient number of paired samples, a formal analysis of the feasibility of substituting river drift surveys with aerial surveys could not be conducted. Additionally, we anticipate future difficulties in conducting paired surveys within the upper reaches of the Yakima River (above the Ellensburg Canyon) due to the regularity of poor flying conditions. In order to eliminate some of these difficulties, paired surveys will be conducted repeatedly along a single drift within the lower reaches of the river in spring 2000.

Even with the accomplishment of five or more paired aerial/drift surveys, we anticipate that certain species of avian piscivores will be differentially detected by the two survey methods. Based upon results of surveys conducted in 1999, we speculate that aerial surveys are biased against small birds, dark colored birds, and cover loving birds (Kingfishers, Hooded Mergansers and Night Herons), and biased towards large birds, white birds, and birds which prefer open spaces (Bald Eagles, Common Mergansers, gulls).

Although the substitution of river drifts by aerial flights may not ultimately be feasible, the latter are still valuable. To accurately assess avian predation of salmon smolts within the Yakima River, hotspot surveys should be conducted where and when large concentrations of avian piscivores occur. Although information regarding the occurrence of consistently intense feeding activity within areas not formally under observation by survey personnel is derived by communication with other YKFP participants and other informal observations, the existence of aerial flights helps to ensure that newly developing hotspots do not go undetected.

River Reach Survey—Summer

Avian Piscivore Abundance

Breeding activity was observed within both river reaches for Belted Kingfishers (adults carrying fish), Common Mergansers (presence of juveniles), and Osprey (nesting activity); breeding activity for Hooded Merganser was observed (presence of juveniles) only within the Easton reach. Great Blue Herons were suspected of breeding within both river reaches due to the presence of juveniles, but no rookeries or nesting sites were identified within either reach. No signs of breeding within either river reach were observed for Bald Eagles or Double-crested Cormorants.

Peak numbers of Common Mergansers were observed within both river reaches in late June (Figures 24 and 25). By this time males have departed the river and juveniles began attending adult females on the river. Beyond this point in time, male Common Mergansers were rarely observed within these reaches.

Throughout the summer season, first-year male and female Common Mergansers are indistinguishable, appearing in color as adult females. By middle to late August, first-year birds attain approximately 80 to 90 percent of adult female size, at which point identification between adult females and mature young of the year becomes difficult. As juvenile birds mature, females become less attentive to their young and appeared to decline in number throughout both river reaches. At this time, large groups of juveniles form along the river reaches, sometimes reaching as many as 20-25 individuals. By late August, Common Merganser abundance had decreased dramatically compared to spring and early summer.

Consumption of Juvenile Salmonids by Common Mergansers

Published estimates of the daily food requirement (DFR) of Common Mergansers range from 370 (Wood and Hand 1985) to 501 (Feltham 1995b) grams per day. These estimates have been derived from a variety of methods, including assessments of stomach contents, observation of feeding behaviors, consumption by captive adults, energy demand modeling, and doubly-labelled water analysis (DLW). The latter, DLW analysis, has been argued to be the most accurate method of DFR estimation due to the avoidance of specific methodological problems inherent in the other methods, which usually result in under-estimation of true consumption (Feltham and Davies 1996). For the purposes of this research, DFR values attributed to Common Mergansers (501 grams per day; Feltham 1995b) were derived by DLW studies.

North Fork Teanaway River Survey—Summer

What is believed to be a single Belted Kingfisher was repeatedly observed in early summer--the only avian piscivore observed along this reference river reach. Two other species were observed near the confluence of the North Fork and the main stem of the Teanaway River, a Common Merganser and an Osprey, but these were incidental observations outside the formal survey areas.

Surveys occurring below the Dickey Creek bridge were often difficult due to geography and private property considerations. In 2000, it is anticipated that this survey reach will be shortened to include those areas of the North Fork Teanaway from Jungle Creek to the Dickey Creek Bridge.

CITATIONS

Alcock, J. 1968. Observational learning in three species of birds. Ibis 111:308-321.

Alexander, G.R. 1979. Predators of fish in coldwater streams. Pages 153-170 *in* R. H. Stroud and H. Clepper (eds), Predator-prey Systems in Fisheries Management. Sport Fishing Institute, Washington, D. C.

Busack, C., B. Watson, T. Pearsons, C. Knudsen, S. Phelps, M. Johnston. 1997. Yakima Fisheries Project Spring chinook Supplementation Monitoring Plan. Report DOE/BP-64878-1. Bonneville Power Administration, Portland, OR.

Derby, C.E., and J. R. Lovvorn. 1997. Predation on fish by cormorants and pelicans in a cold-water river: a field and modeling study. Canadian Journal of Fisheries and Aquatic Sciences 54:1480-1493.

Elson, P.F. 1962. Predator-prey relationships between fish-eating birds and Atlantic salmon (with a supplement on fundamentals of merganser control). Bulletin of the Fisheries Research Board of Canada 133. 87pp.

Feltham, M.J. 1995a. Predation of Atlantic salmon, smolts and parr by red-breasted mergansers on two Scottish rivers. Fisheries Management and Ecology 2:289-298.

Feltham, M.J. 1995b. Consumption of Atlantic salmon smolts and parr by goosanders: Estimates from doubly-labelled water measurements of captive birds released on two Scottish rivers. Journal of Fish Biology 46: 273-281.

Feltham, M.J. and J.M. Davies. 1996. The daily food requirements of fish-eating birds: getting the sums right. pages 53-57 *in* Simon P., R. Greenstreet and M.L. Tasker (eds) Aquatic predators and their prey. Fishing News Books, Blackwell Science Ltd., Cambridge, MA and Oxford, England.

Forbes, L.S. 1986. The timing and direction of food flights from an inland great blue heronry. Canadian Journal of Zoology 64:667-669.

Greene, E. 1987. Individuals in an osprey colony discriminate between high and low quality information. Nature 329:239-241.

Kennedy, G.J.A. and J.E. Greer. 1988. Predation by cormorants. *Phalacrocorax carbo* L., on the salmonid populations of an Irish river. Aquaculture and Fisheries Management 19:159-170.

Mills, D.H. 1967. Predation on fish by other animals. Pages 377-397 *in* S.D Gerking, (ed), The Biological Basis of Freshwater Fish Production. Wiley, New York.

Modde, T. and A.F. Wasowicz. 1996. Cormorant and grebe predation on rainbow trout stocked in a southern Utah reservoir. North American Journal of Fisheries Management 16:388-394.

Packhurst J.A., R.P Brooks, and D.E. Arnold. 1987. A survey of wildlife depredation and control techniques at fish-rearing facilities. Wildlife Society Bulletin 15:386-394.

Pearsons, T.N. 1998. Draft objectives for non-target taxa of concern relative to supplementation of upper Yakima spring chinook salmon. Chapter 1 in Pearsons et al. Yakima Species Interactions Studies progress report for 1995-1997. Submitted to Bonneville Power Administration, Portland, OR.

Phinney, D.D., S.B. Matthews and T.N. Pearsons 1998. Development of a Bird Predation Index, Annual Report 1998. Report to Bonneville Power Administration, Contract No. 1998AT02689, Project No. 199506408, 133 electronic pages (BPA Report DOE/BP-64878-3)

Pitt, W.C., D.A. Beauchamp, and M.R. Conover. 1998. Evaluation of bioenergetics models for predicting great blue heron consumption of rainbow trout at hatcheries. North American Journal of Fisheries

Management 18:52-65.

Roby, D.D., D.P. Craig, K. Collis, and S.L. Adamany. 1998. Avian predation on juvenile salmonids in the lower Columbia River. Annual Report for 1997. Bonneville Power Administration, Portland, Oregon.

Ruggerone, G.T. 1986. Consumption of migrating juvenile salmonids by gulls foraging below a Columbia River Dam. Transactions of the American Fisheries Society 115:736-742.

Sealy, S.G. 1973. Interspecific feeding assemblages of marine birds off British Columbia. Auk 90:796-802.

Ward, P. and A. Zahavi. 1973. The importance of certain assemblages of birds as “information centers” for food finding. Ibis 115:517-534.

White, H.C. 1936. The food of kingfishers and mergansers on the Margaree River, Nova Scotia. Journal of the Biological Board of Canada 2:299-309.

White, H.C. 1939. Bird control to increase the Margaree River salmon. Bulletin of the Fisheries Research Board of Canada 58:1-30.

Wood, C.C. 1987a. Predation of juvenile Pacific salmon by the common merganser (*Mergus merganser*) on eastern Vancouver Island. I: Predation during the seaward migration. Canadian Journal of Fisheries and Aquatic Sciences 44:941-949.

Wood, C.C. 1987b. Predation of juvenile Pacific salmon by the common merganser (*Mergus merganser*) on eastern Vancouver Island. II: Predation of stream-resident juvenile salmon by merganser broods. Canadian Journal of Fisheries and Aquatic Sciences 44:950-959.

Wood, C.C. and C.M. Hand. 1985. Food-searching behaviour of the common merganser (*Mergus merganser*) I: Functional responses to prey and predator density. Canadian Journal of Zoology. 63: 1260-1270.