Monitoring and Evaluation of Avian Predation on Juvenile Salmonids on the Yakima River, Washington

Annual Report 2005

Appendix I in Yakima/Klickitat Monitoring and Evaluation Project (199506325) 2005-2006 Annual Report to Bonneville Power Administration DOE/BP 00022449-1

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EXECUTIVE SUMMARY

The monitoring of avian predation on juvenile salmonids in the Yakima River as part of the Yakima Klickitat Fisheries Project has been on-going since 1997. In 2005, as in the previous 6 years, piscivorous birds were monitored along river reaches, at salmon smolt predation hotspots (Chandler Fish Bypass and Horn Rapids Dam) and at 7 smolt acclimation sites. Smolt consumption estimates of Ring-billed and California Gulls at hotspots were based on direct observations of foraging success and modeled abundance, while consumption estimates of American White Pelicans were based on abundance estimates, daily food requirements and smolt runs estimates. Consumption by all piscivorous birds on river reaches sites were estimated based on dietary requirements and modeled abundances. Consumption by birds at smolt acclimation ponds were estimated from daily counts and dietary requirements. Besides Common Mergansers in the upper river, and American White Pelicans and gulls in the lower river, no other bird species appears to be significant in consuming salmon smolts in the Yakima Basin at the present time.

As in all the previous years, Common Mergansers were the most significant fish predator in the upper and middle river, consuming the great majority of the fish biomass consumed by birds in these reaches, potentially consuming 46% of the hatchery and wild spring chinook and hatchery smolts present. However, an earlier dietary analysis of Yakima River Common Mergansers suggests that breeding mergansers eat a broad range of small fish, ranging from sculpin to chiselmouth, with juvenile trout and other salmonids predominating in their fall/winter diet.

As in the previous three years, American White Pelicans were the dominant bird consumer of fish in the lower river, consuming over 82% of the fish consumed by birds in the lower river and over 72% of the fish biomass consumed by birds on the entire river. Pelicans inhabiting the lower river could potentially consume the entire hatchery production of fall chinook and coho smolts released in the lower river (2.3 million smolts) and yet only supply 22% of their dietary requirements, indicating they must be eating other fish (ie. sucker and carp) in addition to any salmonids consumed. Knowledge of the actual fish consumption of both Common Mergansers and American White Pelicans along river reaches is limited by incomplete fish biomass estimates and the general lack of direct observation of birds feeding on smolts or other fish.

Pelicans are the dominant avian predator at Chandler Fish Bypass, while gulls dominate at Horn Rapids Dam. Pelicans averaged 57 birds per day at Chandler, down from 73 birds per day in 2004. Based on the assumptions that Chandler pelicans are fulfilling their entire daily dietary requirements at the site, are consuming only salmon smolts, and consume smolts in proportion to their availability, Chandler pelicans potentially consumed an estimated 826,000 smolts (94% fall chinook) in 2005, down from an estimated 1.5 million smolts in 2004. However a number of lines of evidence including correlation analysis and anecdotal observations clearly call these assumptions into question, making these huge smolt consumption estimates for pelicans highly doubtful.

Correlation analysis suggests pelicans are not primarily tracking fall chinook at Chandler, but instead may be tracking coho smolts. Pelican numbers at Chandler showed the highest, moderate correlations with the coho smolt runs in 2004-2005, and the weakest correlations with fall chinook, spring chinook and steelhead smolt runs. The size of smolts may be an important factor in the bioenergetics of pelican consumption. Coho smolts averaged 33 g, while fall chinook smolts averaged about 6 g. The fall chinook smolts may be far too small to be an efficient food source for pelicans. Anecdotal observations at Chandler bypass pipe suggest pelicans are also consuming significant numbers of other fish species of size classes larger than salmon smolts, including sucker, chiselmouth and northern pikeminnow.
Gulls numbers declined at Horn Rapids in 2005, from about 11 birds per day in 2004 to about 6 birds per day with concomitant declines in fish consumption observed. Gulls were estimated to have consumed only 19,108 fish this past year at the hotspots, nearly all at Horn Rapids, a decline of 82% from the totals in 2004. This decrease continues the declining trend in gull consumption at the hotspots since 2002. The total gull consumption in 2005 represents only 0.62% of the more than 3 million smolts that passed Chandler and Horn Rapids. In a pattern similar to the pelicans at Chandler, gull numbers at Horn Rapids in 2004-2005 showed the highest correlation with the coho smolt run and the total salmon smolt run (counted at Chandler), with lowest correlations for the spring chinook, fall chinook and steelhead runs. However, the highest correlations for 2005 were only moderate, while the highest correlations for 2004 were strong, indicating a greater level of significance. Twenty-nine gulls collected at Horn Rapids in late May, 2005 contained land-based food items and no fish remains indicating the birds had not been feeding on site.

Predation by Common Merganser, Belted Kingfisher and Great Blue Heron at seven spring chinook and coho smolt acclimation ponds appeared to be relatively minor in 2005, as it was in 2004. Only at Boone Pond, a coho site, did Common Merganser appear to have a major impact, possibly taking 64% of the 38,000 smolts present. In 2004, Common Mergansers consumed an estimate 9% of the 234,000 coho smolts released at Boone. Except for Boone, no smolt acclimation sites have proven to be vulnerable to avian predators.

Plans for the 2006 field season include continued monitoring of birds along river reaches and hotspots with a greater emphasis on pelican consumption. Pelicans will be color-marked and radio-collared at hotspots and other locations to gather information on their diet, movements and nesting.

INTRODUCTION

Note:

For the purposes of this document the phrase “juvenile salmonids” refers to immature fish of the following stocks: spring chinook and fall chinook (Oncorhynchus tshawytscha), coho (O. kisutch), and summer steelhead (O. mykiss). For a more detailed description of previous years’ results and the statistical methods involved in this monitoring effort please refer to this project’s previous annual reports located on the Yakima Klickitat Fisheries Project’s website, www.ykfp.org or the Bonneville Power Administration’s fish and wildlife technical publications and draft reports website, www.efw.bpa.gov/reports.aspx.

Avian Predation of Juvenile Salmon

Avian predation on juvenile salmonids potentially constrains salmon production within both river habitats and fish culture facilities (White 1936, 1939; Mills 1967; Sealy 1973; Alexander 1979; Packhurst et al. 1987; Wood 1987a, b; Pitt et al. 1998; Derby and Lovvorn 1997). The magnitude of the impact on migrating smolts by avian predators is highly variable within and across river systems. Estimations of avian consumption of juvenile salmonids within specific river systems and specific years range between 1-66% of particular runs or releases (Alexander 1979; Mace 1983; Ruggerone 1986; Wood 1987b; Kennedy and Greer 1988; Roby et al. 1998; Phinney et al. 1998; Major et al. 2005). As shown repeatedly by studies throughout North America and Europe, avian predators can consume large number of juvenile salmonids when appropriate conditions occur (Elson 1962; Feltham 1995a; Modde and Wasowicz 1996, Roby et al. 1998).

Bird predation of juvenile salmonids is common throughout the Columbia River Basin, which supports some of the highest populations of piscivorous birds in North America and Europe (Ruggerone 1986; Roby et al. 1998). Many piscivorous birds within this basin are colonial nesters, including Ring-billed and California Gulls, Caspian and Forster’s Terns, Double-crested Cormorants, Great Blue Herons, Black-
crowned Night-herons, Great Egrets and American White Pelicans (See table 1 for Latin names). Colonial nesters are particularly suited to the exploitation of prey fish with fluctuating densities (Alcock 1968; Ward and Zahavi

| Common Merganser (Mergus merganser) COME |
| American White Pelican (Pelecanus erythrorhynchos) AWPE |
| California Gull (Larus californicus) GULL |
| Ring-billed Gull (Larus delawarensis) GULL |
| Belted Kingfisher (Ceryle alcyon) BEKI |
| Great Blue Heron (Ardea herodias) GBHE |
| Double-crested Cormorant (Phalacrocorax auritus) DCCO |
| Black-crowned Night-Heron (Nycticorax nycticorax) BCNH |
| Bald Eagle (Haliaeetus leucocephalus) BAEA |
| Osprey (Pandion haliaetus) OSPR |
| Caspian Tern (Sterna caspia) CATE |
| Forster's Tern (Sterna forsteri) FOTE |
| Great Egret (Ardea alba) GREG |
| Hooded Merganser (Laphodytes cucullatus) HOME |
| Green Heron (Butorides virescens) GNBH |

Table 1. Piscivorous birds observed along the Yakama River (note codes)

1996). Prey fish density fluctuations can result from large migratory accumulations, releases from hatcheries, physical obstructions that concentrate or disorient fish, and other features and events which occur in complex river systems.

The advantage held by colonial birds under such conditions appears to result from many birds within a colony receiving cues from successful foragers as to prey type and location (Forbes 1986; Greene 1987). Such cues can lead to a rapid response by large numbers of avian predators to available concentrations of prey fishes. These behaviors, in combination with large nesting bird populations, can lead to high levels of consumption of migrating salmon smolts. For example, in 1997, Caspian Terns from a single nesting colony within the Columbia River estuary, consumed an estimated 6-25% of the 100 million out-migrating smolts (Roby et al. 1998).

Salmon Supplementation in the Yakima and Klickitat Rivers: The Yakima Klickitat Fisheries Project (YKFP)

The YKFP uses supplementation techniques to increase natural production of wild, native salmonid populations and to improve harvest opportunities, while maintaining long-term genetic fitness and keeping adverse ecological interactions within acceptable limits (Sampson and Fast 2000). Supplementation, hatchery rearing adjustments and habitat improvements within the project target four principal salmon stocks: spring chinook, fall chinook, coho, and summer steelhead.

In conjunction with the supplementation activities, intensive monitoring has been ongoing since 1997. It was anticipated that the interactions between supplemented salmonid stocks and key fish-eating species could impact the ultimate success of the YKFP supplementation efforts (Busack et al. 1997; Pearsons 1998). The impacts of avian predators on juvenile salmonids within the Yakima River have been assessed by using index-based methods from 1997-2005.
In 1997, Steve Mathews of the University of Washington and Dave Phinney of the Washington State Department of Fish and Wildlife (WDFW), in collaboration with the YKFP, began investigations to assess the impact of avian piscivores on juvenile spring chinook populations within the Yakima River. This effort was focused on 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 predation referred to as “hotspots”.

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 during extreme low water events, as 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 such as dams, irrigation and fish bypass structures. In normal flow years, hotspots are the result of interactions between water flow and man-made structures which lead to local areas of intensely turbulent water. The movement through such areas by migrating juvenile salmonids can lead to a temporary suspension of normal predatory avoidance behaviors due to disorientation, shock or injury. Under such circumstances, predation by avian predators may be highly efficient and intense. Although the hotspot surveys were designed to address the impact of smolt concentration and disorientation caused by dams and fish bypass structures, the definition could be 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, such as changes in flow or new construction.

The initial study found that California and Ring-billed Gulls (gulls) were the most abundant avian predators at the hotspots, with Horn Rapids Dam and the Chandler Canal Bypass having the most intense avian predation (Phinney et al. 1998). Common Mergansers were found to be the most abundant avian predator along the upper river reaches. The Zillah reach in the lower river contained the highest number of species of avian predator. Gull abundance at hotspots was negatively correlated with river discharge. When flows at Chandler reached a threshold of 4000 cfs and flows at Horn Rapids reached 8,000 cfs predation began to decrease. Gulls apparently could not forage at high flows (Phinney et al. 1998).

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

Determining the composition of fish species consumed by piscivorous birds on the Yakima River was (and continues to be) problematic. Consumption estimates relied upon direct observations of predation on fish by gulls at hotspots, and estimated abundances and daily energy requirements of all species of avian piscivores enumerated on river reaches and acclimation ponds.
Common Mergansers appeared to be the dominant avian fish consumer in the upper and middle river reaches in both spring and summer periods. Mathews and Phinney attempted a direct assessment of consumption for the Common Merganser along Yakima River reaches in the fall, winter and spring, 1997-98, collecting 20 Mergansers for stomach analysis. Of the 9 birds collected in the fall/winter in the Canyon and Selah reaches, 42.2% of the prey items were salmonids (15.8% Chinook, 21.1% rainbow trout (O. mykiss) and 5.3% unidentified salmonid), along with sculpin (Cottus spp), smallmouth bass (Micropterus dolomieui), northern pikeminnow (Ptychocheilus oregonensis), redside shiner (Richardsonius balteatus), sucker (Castostomus spp) and crayfish. Rainbow trout and unidentified salmonids made up 6.2% of the stomach items in the 7 birds collected in the spring in the Canyon and Selah reaches, along with sculpin spp. (alone making up 71.9%), dace (Rhinichthys spp) and crayfish. Of 4 birds collected in the spring in the Granger reach, unidentified salmonids made up 16.7% of the items, which included chiselmouth (Acrocheilus alutaceus) (alone making up 50%), dace spp. and northern pikeminnow.

A conclusion that could be drawn from this diet analysis is that Common Mergansers breeding and wintering along the Yakima River were eating small fish of a diversity of species in direct proportion to their local and seasonal availability. They did not appear to target juvenile salmonids, that is, to select them in a greater proportion than their availability in the entire fish community assemblage.

Re-colonization of the American White Pelican in the Mid-Columbia Region

Historically, American White Pelicans (pelicans) bred in low numbers in Washington. Pelicans ceased breeding in the state in 1926, with their last nesting island submerged by dam construction at Moses Lake. Up until the mid-1990s non-breeding birds continued to be observed in Washington in low numbers. In the Yakima River Basin, pelicans disappeared for nearly 60 years. The first reoccurrence of pelicans in the Yakima River was apparently in the mid to late 1980s, and they have been increasing in areas upstream of Prosser since 1994 (Tracy Hames, Yakama Nation Wildlife Resources Program, personal communication).

Pelicans re-appeared as a Washington breeder in 1994, when 50 birds nested on Crescent Island in the Columbia River, near Burbank, WA. They are currently listed as a State endangered species. At present, the only breeding site in Washington is on Badger Island on the Columbia River, downstream from the mouth of the Yakima River. The Badger Island colony consists of about 500 breeding pairs. These colonial nesters are known to travel 50-80 km in search of food, so some of the birds observed on the Yakima River could be coming from this colony (Motschenbacher 1984). However, the behavior of the birds at Chandler and other Yakima River sites suggests those individuals are non-breeders. Leg bands that were recovered from three pelicans found dead on the lower Yakima Basin in recent years indicated the birds came from British Columbia, eastern Montana, and the Klamath National Wildlife Refuge near the California – Oregon border (Tracy Hames, YNWRP, personal communication). Those findings suggest that Yakima River pelicans are birds dispersing from much of the western breeding range of the species.

In the YKFP study, pelicans were first recorded during hotspot surveys at Chandler in 2000 and during river reach surveys along the lower Yakima River in 2001. Based on the avian consumption model, pelicans in the lower Yakima River, below the Yakima Canyon to its mouth on the Columbia River, accounted for about half of the total fish biomass depredated by piscivorous birds in the entire Yakima River in 2001-2002.

There was a dramatic increase in the number of pelicans found at Chandler between 2002 and 2004. In these three seasons, spring and summer water levels were low and abundant rocks were exposed giving gulls and pelicans numerous sites to rest and launch foraging attempts at disoriented fish exiting from the bypass pipe. In 2004, pelicans returned earlier in the year then in 2003. As the numbers of pelicans increased, they began to displace gulls at foraging and resting sites at Chandler. Instances of pelicans stealing fish from gulls were observed. Although two water sprinklers were installed at Chandler near the
fish outfall pipe in 2004 – 2005 to deter pelicans, they have had no significant effect, as birds became either habituated to the weak spray or could easily avoid it.

**Fish Biomass Estimates in the Yakima River**

To understand the potential impact of gulls, pelicans and other piscivorous birds, salmonid biomass estimates for the Yakima River are essential. In 2005, Yakima Nation salmon hatcheries alone contributed nearly 3.8 million salmon smolts (between 4-35 g) to the Yakima Basin, including fall chinook, spring chinook and coho. This represents an estimated 124.4 kg/km of fish biomass in the form of spring chinook and coho smolts introduced into the upper and middle sections of the river and 104.7 kg/km in the form of fall chinook and coho smolts introduced to the lower river. In 2004, salmon hatcheries contributed over 4.1 million salmon smolts (between 5-36 g) representing 141.7 kg/km of fish biomass introduced into the upper and middle sections of the river and 128.9 kg/km of biomass into the lower river.

Estimates of the wild salmon biomass produced in the Yakima River can be partially measured by using production estimates of wild spring chinook, the most abundant salmon species spawning in the river. In 2003, 1,825 spring chinook redds were located in the entire Yakima Basin, including the Upper Yakima River and Naches Basin. If each redd is assumed to represent the successful spawning of one female and it is also assumed that the fecundity of each Upper Yakima female was 3,976 and each Naches Basin female was 5,232, (fecundity estimated from the average productivity 1980-96) than together these fish spawned 8.4 million eggs. Those eggs have a 59.6% chance of surviving to become 0.3 gram fry the next year, representing 5 million fish.

In the upper Yakima River alone, an estimated 3 million spring chinook eggs were deposited in 890 redds in 2003, leading to the production of an estimated 1.8 million fry above Roza Dam. However when the outgoing smolts from the upper Yakima and Naches Basin were counted at Chandler Bypass in 2005, only 157,057 remained, a fry to smolt survivorship rate of only 3.1%. That is, nearly 97% of the fry or smolts had either died from various environmental causes or were consumed by predators. This is an egg to smolt survival rate (calculated to Chandler) of 1.9%. Egg to smolt survival ranged from 0.8 to 10.8 in the years 1981-97, averaging 4.3%. There is a density dependent relationship between egg deposition in the Yakima Basin and smolt survival to Chandler, with the highest egg deposition years correlating with the lowest smolt survival. Either factors important in setting carrying capacity, such as food supply or cover, are limited at high fry or smolt densities or predators key in on juvenile fish under high densities. It is not clear what habitat conditions or predator species are the primary factors in fish mortality or when fry or smolts die.

Spring chinook fry weighing 0.3 grams are far too small to be food items of the most important piscivorous birds on the Yakima River: the Common Merganser, both gull species, and American White Pelican. Smolts of spring chinook, coho, and steelhead are of the appropriate size (>20g) to be consumed by them. Fall chinook smolts at 4-7 g, may be near the lower limit of prey size for these piscivores.

Of the 157,057 wild spring chinook smolts enumerated at Chandler in 2005, 139,680 were counted between April 1 and July 1, 2005. Beckman et al. (2000) calculated growth curves for wild Yakima River spring chinook in 1993-94. Spring chinook grew from an average of under 1 gram in May of their first year after hatching to about 27 grams the following May. Thus in spring of any year, 1 year old fry weighing between 1-14.5 g. intermingle with 2 year old smolts weighing between 20-27 g. Using 2005 smolt counts from Chandler; a linear survival curve that was based on redd counts; egg to smolt survivorship estimates; and growth curve weights from the Beckman study, wild juvenile spring chinook biomass in the upper and middle Yakima River in spring and summer 2005 was calculated. In 2005, 1 year old wild spring chinook fry contributed an estimated 66.3 kg/km of fish biomass and 2 year old fry, 21.8 kg/km, for a total wild spring chinook biomass of 88.1 kg/km.
If biomass estimates of hatchery spring chinook and coho smolts are combined with the wild spring chinook estimates, the upper and middle Yakima River has a minimum of 212.5 kg/km of juvenile salmonid biomass. It is important to note that this figure does not include smolt biomass estimates of wild coho, steelhead or fall chinook and other wild or hatchery juvenile salmonid fish of similar size, such as rainbow, cutthroat (Salmo clarki), brown (S. trutta) or bull trout (Salvelinus malma) and kokanee (O. nerka).

Another line of fish biomass evidence comes from a 5-year Washington Department of Fish and Wildlife study (1997-2001, Gabriel Temple, personal communication), which has important limitations as the investigators consider the number of salmon smolts to be underestimated. That data indicates that juvenile salmonids potentially suitable as prey for avian predators (defined here as between 5-75 g) made up an estimated 3.6% of the total fish biomass in the upper river in spring and summer, with 5-75 g fish of all other taxa making up another 9.0% of the fish biomass in the upper river. In the middle river, juvenile salmonids made up 2.5% of the fish biomass spring and summer, with 5-75 g fish of all other taxa making up another 6.8%. In the lower river – upper section, from Roza Dam to Prosser Dam, juvenile salmonids made up an estimated 1.7% of the total fish biomass in spring with 5-75 g fish of all other taxa making up another 21.0% of the fish biomass. In the lowest section of the river in the spring from Prosser Dam to the Yakima River mouth on the Columbia River, juvenile salmonids made up 10.2% of the fish biomass with all other taxa of 5-75 g making up another 15.7%. In total, small fish suitable as prey for even the smallest avian predator made up an average estimated 21.0% of the fish biomass in the entire Yakima River in spring (2.3% salmonids and 18.7% other taxa).

METHODS

Study Area

The Yakima River Basin encompasses a total of 15,900 square kilometers in south-central Washington State. The Yakima River runs along the eastern slopes of the Cascade mountain range for a total length of approximately 330 kilometers (Figures 1 & 2). The terrain and habitat varies greatly along its length, which begins at 2,440 meters in elevation at the headwaters and ends at 104 meters elevation at its mouth on the Columbia River near the City of Richland, WA.

The upper reaches of the Yakima River, above the town of Cle Elum, are high gradient areas dominated 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 are areas of intermediate gradient 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 shrub-steppe and irrigated agricultural lands. The middle and lower reaches of the river, from Selah to the Columbia River, exhibit a low gradient, infrequently braided river channel, and are dominated by hardwoods proximate to the river channel with some arid steppe and irrigated agricultural lands abutting the shoreline.
Figure 1. Yakima River Basin with locations of surveyed reaches.
Figure 2. Yakima River Basin with locations of hotspots (Chandler & Horn Rapids) and acclimation sites.
Survey Seasonality

This effort was organized into two specific time frames within which the impacts of bird predation on juvenile salmon were assessed. The first time frame, from early April to June 30, “spring”, addressed the impacts of avian predators on juvenile salmon during the spring migration of smolts out of the Yakima River. The second time frame, from July 1 to August 31, “summer”, addressed impacts to coho and spring chinook parr and/or residualized coho and spring chinook in the upper reaches of the Yakima River. Dividing the survey dates into these time periods allowed for all future sampling efforts to be accomplished on even numbers of 2-week blocks which best fits the consumption model. These two time frames followed the methodological design set forward in the 1999 annual report (Grassley and Grue 2001) and are referred to within this document as “spring” and “summer”. This report and subsequent analysis is organized into these two generalized time frames in an effort to focus on impacts to particular salmonid life histories.

Data Collection Methods

Hotspot Surveys

At Chandler Bypass and Horn Rapids Dam the abundance of gulls, pelicans and other predatory birds was estimated. Seasonal and diurnal patterns of gull and pelican abundance at hotspots were identified. For heuristic purposes, all fish consumed by gulls and pelicans were assumed to be salmonids. Estimated consumption of smolts by gulls was based on direct observation. Gull abundance and consumption estimates were expanded across larger time frames to create an index of smolt consumption by gulls. A smolt predation index for pelicans was based on average daily abundance estimates, dietary requirements extrapolated over the entire 3 month pelican residency period, and estimates of salmonid smolt runs.

In 2005, hotspot surveys were conducted on Mondays, Wednesdays, and Fridays at Chandler Bypass and Horn Rapids Dam. Thirty-four surveys were conducted at Chandler between April 6 and July 1. Thirty surveys were conducted at Horn Rapids between April 6 and June 20. Both sites were generally surveyed on the same day at the same time period by different individuals. Leica 10x42 binoculars were used to help monitor bird behavior. The survey area for Horn Rapids included the area 50 meters of river above the dam and 150 meters below the dam. The buoy located above the dam was not included within the survey area; therefore any birds resting upon the buoy were not included in abundance counts. The survey area for Chandler included 50 meters of river above the outfall pipe and 150 meters of river below the outfall pipe. All birds resting upon the shoreline lateral to the specified area at both hotspots were included in the abundance counts. Observations at both sites were made from the shore. At Horn Rapids observations were made from the south bank of the river, either inside or outside an automobile. At Chandler observations were made from a blind just downstream of the outlet pipe from the juvenile fish facility.

The hotspot survey design for 2005 was consistent with methods used since 2001 (Table 2). Observations either began on the nearest 15-minute interval after sunrise and ran for eight hours, or began at midday and ended on the nearest 15-minute interval before sunset. This allowed for observations during all periods of the day, to account for the diurnal patterns of avian piscivores. Regionally calibrated tables obtained from the National Oceanic and Atmospheric Administration were used to determine sunrise and sunset times at Richland, WA. Depending upon the length of the day and the start time, between seven and eight 2-hour windows existed for each day.
Each day was divided into 2-hour survey windows, consisting of three 15-minute abundance and feeding blocks. Between each of these three blocks was a 15-minute period of no observation, unless a feeding interval was still being measured, in which case the observation period was extended into the next 15 minutes. This 75-minute cycle of blocks was followed by a 45-minute rest period before a new 2-hour window was begun. Within each 15-minute survey block the abundance of all piscivorous birds was counted.

**Gull Consumption Estimates**

Within the 15 minute survey blocks the foraging ratios of gulls, the number feeding to the total number present, and the number of fish consumed per minute, were determined (Table 2). Any gull flying within the study area was considered foraging. Gulls within the study area foraging on terrestrial prey items, such as insects, seeds, plants, were not considered feeding, but were included in total abundance counts. Gulls sitting or standing on rocks emerging from the river or along the river’s 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. It was not feasible to distinguish foraging gulls standing on rocks from those loafing.

The gull chosen to be observed for foraging rate was the first individual observed consuming a fish within the study area. Once a gull was chosen it was followed continuously until a second successful capture occurred or a maximum of 30 minutes had passed. Initial successful feeding attempts were those in which a foraging bird captured a fish by plunging from the air into the water. Second takes were counted regardless of the means of capture. This accounted for the very rare instance in which the second successful take by a gull was accomplished by stealing from another bird or jumping from an exposed rock or log into the water to catch a fish. Past surveys where a gull was randomly chosen for observation did not provide enough foraging intervals. Foraging data for gulls was placed in the

**Pelican Consumption Estimates**

At Chandler, pelican counts in the 15 minute survey blocks were used to calculate an average number of pelicans per day. This data was combined with daily pelican consumption estimates from the literature and extrapolated over the entire 3 month pelican residency period to calculate an index of salmonid biomass consumption by pelicans at Chandler. Based on smolt runs, consumption of individual salmon species was estimated.
<table>
<thead>
<tr>
<th>Window</th>
<th>Block</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Observation (15-minute)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Abundance of all piscivorous birds and ratio of gulls present to gulls foraging determined at beginning of block. First gull observed successfully capturing a fish followed continually until second successful capture. Time of foraging interval recorded. Abundance of all piscivorous birds and ratio of gulls present to gulls foraging determined at end of block</td>
</tr>
<tr>
<td>1</td>
<td>Rest</td>
<td>Any ongoing foraging interval was continued into this period until a second successful capture or the end of the 15-minute rest period. If there was no interval ongoing then no data were collected.</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>Same activities as block 1. (15-minute)</td>
</tr>
<tr>
<td>1</td>
<td>Rest</td>
<td>Same as previous rest period. (15-minute)</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>Same as blocks 1 and 2. (15-minute)</td>
</tr>
<tr>
<td>1</td>
<td>Rest</td>
<td>Any ongoing foraging interval was continued into the first 15-minutes of this period and ended according to the above criteria. The observer then rested for 30 minutes with no data collection activity. (45-minute)</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Repeat as Window 1. (15-minute)</td>
</tr>
</tbody>
</table>

Table 2. Hotspot Survey Design.
River Reach Surveys

River reach surveys were designed to estimate bird abundance and not directly measure consumption. Total consumption in fish biomass of all birds was estimated through a model which combines bird abundance estimates and published daily caloric requirements for individual bird species. Estimates of consumption of individual fish species have not been calculated, although some conclusions can be drawn from salmonid biomass estimates from hatchery and wild salmon production, and from total fish species biomass estimates collected by the WADFW, 1997-2001.

The spring river surveys included all six river reaches (Figure 1, Table 3). Each reach was surveyed once every 2 weeks, from April 8 through June 28, the spring period. Upper river reaches include Easton and Cle Elum. The single middle river reach is called the Canyon. The lower river reaches include Zillah, Benton, and Vangie. The river reach survey accounts for coverage of approximately 34% of the total length of the Yakima River. During the summer from June 29 through August 28, river surveys included only the upper and middle reaches, which were surveyed every week. All reaches surveyed in both the spring and summers were identical in length and location to those conducted in previous years.

<table>
<thead>
<tr>
<th>Name</th>
<th>Start</th>
<th>End</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vangie</td>
<td>1.6 km above Twin Bridges</td>
<td>Van Giesen St Hwy Bridge</td>
<td>9.3</td>
</tr>
<tr>
<td>Benton</td>
<td>Chandler Canal Power Plant</td>
<td>Benton City Bridge</td>
<td>9.6</td>
</tr>
<tr>
<td>Zillah</td>
<td>US Hwy 97/St. Hwy 8 Bridge</td>
<td>Granger Bridge Ave Hwy Bridge</td>
<td>16.0</td>
</tr>
<tr>
<td>Canyon</td>
<td>Ringer Road</td>
<td>Lmuma Recreation Site</td>
<td>20.8</td>
</tr>
<tr>
<td>Cle Elum</td>
<td>South Cle Elum Bridge</td>
<td>Thorp Hwy Bridge</td>
<td>28.3</td>
</tr>
<tr>
<td>Easton</td>
<td>Easton Acclimation Site</td>
<td>South Cle Elum Bridge</td>
<td>29.3</td>
</tr>
<tr>
<td>North Fork Teanaway</td>
<td>Mouth of Jungle Creek</td>
<td>3.5 km downstream</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Table 3. River reach survey starting and end locations, and total length of reach.

All river reach surveys were conducted by a two-person survey team from a 16 foot drift boat on all reaches except Easton, which was surveyed from a two-person raft. Surveys began between 8:00 am and 9:00 am and lasted between 2 to 6 hours depending upon the length of the reach and the water level. All surveys were conducted while actively rowing the drift boat or raft downstream to decrease the interval of time required to traverse the reach. Usually in the two-person survey team one person rowed the boat while the other person recorded piscivorous birds encountered.

All birds detected visually or aurally were recorded, including time of observation, species, and sex and age if distinguishable. Leica 10x42 binoculars were used to help observe birds. All piscivorous birds encountered on the river were recorded at the point of initial observation. Most birds observed were only mildly 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 the bird attempted to escape from the survey boat by moving down river a note was made that the bird was being pushed. Birds being pushed were usually kept in sight until passed by the survey boat. If the bird being pushed down river moved out of sight of the survey personnel, a note was made, and the next bird of the same species/age/sex to be encountered within the next 1000 meters of river was assumed to be the pushed bird. If a bird of the same species/age/sex was not encountered in the subsequent 1000 meters, the bird was assumed to have departed the river or passed the survey boat without detection, and the next identification of a bird of the same species/age/sex was recorded as a new observation.
Acclimation Site Surveys

Three spring chinook acclimation sites in upper Yakima River (Clark Flat, Jack Creek, & Easton) and four coho acclimation sites (Boone & Holmes in the upper Yakima River Basin, Stiles & Lost Creek on the Naches River, the largest tributary of the Yakima) were surveyed for piscivorous birds in 2005 (Figure 2). Surveys were conducted between January 9 and May 2, though dates varied for each site. Three surveys were conducted at the spring chinook sites each day, at 8:00 am, 12:00 noon, and 4:00 pm. Coho sites were surveyed once or twice on days hatchery personnel were feeding smolts. Surveys were conducted on foot. All piscivorous birds within the acclimation facility, along the length of the artificial acclimation stream, and 50 meters above and 150 meters below the acclimation stream outlet, into the main stem of the Yakima River or North Fork Teanaway, were recorded.

North Fork Teanaway River Surveys

Bird surveys along the North Fork of the Teanaway were conducted from the Jungle Creek/Teanaway River confluence down river past the Jack Creek acclimation site continuing downstream for approximately 3.5 km. One to two surveyors moved down from Jungle Creek, noting the presence of piscivorous birds. If one riverbank was impassible, the river was crossed and surveys were continued on the opposite bank. If it was impossible to cross the river, detours were taken away from the river, downstream, and paths through the underbrush were located to enable periodic returns to the river. Once there, a visual search up and down the river was conducted. All piscivorous birds detected visually or aurally were recorded including time of observation, species of bird, and sex and age if distinguishable. This area was surveyed five times between April 19 and August 31 in 2005. A pair of Leica 10x42 binoculars was used to aid in identification.

Aerial Surveys

Aerial surveys were conducted primarily to identity the abundance and distribution of pelicans along the Yakima River from its mouth on the Columbia River to the city of Yakima. Aerial surveys allow for one hundred percent of the lower Yakima River to be surveyed. Six aerial surveys were conducted over the Yakima River between February 22 and September 25. Typical surveys included the pelican nesting colony of Badger Island, the mouth of the Yakima River in Richland, then upstream to Union Gap in Yakima. Based on aerial surveys conducted on the Yakima River in the past, surveys of the Yakima River were divided into 6 geographic reaches extending from the mouth of the Yakima to Union Gap. Three surveys began at 9:30 AM, one at 12 Noon and two at 2 PM. Surveys lasted approximately three hours.

Secondary Hotspot Surveys

Twenty-five visits were made to Prosser Dam between April 6 and July 1 to determine if there were a significant number of birds feeding below the dam at the head of the canal, where fish are susceptible to predation due to upwelling. No secondary surveys were conducted at the four other dams on the Yakima River in 2005, based on the low number of birds seen at these sites in prior years.
RESULTS & DISCUSSION

River Reach Surveys

In 2005, 15 different piscivorous bird species were observed on the Yakima River (see Table 1 for English and Latin names and alphabetic codes used in figures). These are the same species observed in previous years.

The middle river reach, Canyon, exhibited the lowest diversity of bird species (4) and the Zillah drift in the lower river had the highest (13). Great Blue Heron, Belted Kingfisher and Osprey were the only species found on all six reaches in the spring. Common Mergansers were seen on all reaches except the Vangie reach in the lower river. Common Mergansers were most abundant in the upper reaches of the river as has been the case in all previous years surveyed, followed by Belted Kingfishers (Figure 3 & 4). In the middle reach, Common Mergansers were the most common species in spring and second to the Belted Kingfisher in summer (Figure 5 & 6). The lower reaches were more variable with pelicans the most abundant bird at Zillah, followed by Common Mergansers, and gulls the most abundant birds at Vangie and Benton, followed by pelicans and Double-crested Cormorants, respectively (Figure 7). Great Blue Herons were the third most common species at Zillah and Vangie, and pelicans were the third most common species at Benton. Double-crested Cormorants, a major fish predator on the Lower Columbia River, were found in low to moderate numbers in the lower river, particularly at Benton and Vangie with a few at Zillah. Caspian Terns, another major fish predator on the Lower Columbia River, were only found at Vangie and Benton in low numbers.

![Figure 3](image-url)  
**Figure 3.** Average spring bird abundance on the Upper Yakima River. Bars indicate standard error.
Figure 4. Average summer bird abundance on the Upper Yakima River. Bars indicate standard error.

Figure 5. Average spring bird abundance on the Middle Yakima River. Bars indicate standard error.
Figure 6. Average summer bird abundance on the Middle Yakima River. Bars indicate standard error.
Figure 7. Average spring bird abundance on the Lower Yakima River. Bars indicate standard error.
Common Mergansers are of particular importance because of their known utilization of salmon smolts in Europe and North America (White 1957; Wood 1985) and their relatively high abundance within the upper and middle reaches of the Yakima River. They were also fairly abundant at Zillah in the lower river in spring. As in the previous 7 years, Common Mergansers remained the primary avian predator of the upper and middle river in both the spring and summer periods. Belted Kingfisher and Great Blue Heron, although common in the upper and middle river, are far less important consumers of fish biomass in the Yakima Basin for different reasons. The Belted Kingfisher is too small in size and the Great Blue Heron too thinly distributed to be major factors in the consumption of salmon smolts. Great Blue Herons also prey on a wide variety of aquatic and terrestrial species ranging from frogs to rodents. Pelicans in the lower river are important because of their growing numbers and high daily dietary requirements (Table 3).

Table 4. Daily Dietary Requirements of Avian Piscivores (from Major et al. 2003)

<table>
<thead>
<tr>
<th>Species</th>
<th>Daily Intake (kilograms)</th>
<th>Daily Intake (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>American White Pelican</td>
<td>1.339</td>
<td>2.952</td>
</tr>
<tr>
<td>Black-Crown Night- Heron</td>
<td>0.138</td>
<td>0.304</td>
</tr>
<tr>
<td>Belted Kingfisher</td>
<td>0.059</td>
<td>0.130</td>
</tr>
<tr>
<td>Caspian Tern</td>
<td>0.231</td>
<td>0.509</td>
</tr>
<tr>
<td>Common Merganser</td>
<td>0.455</td>
<td>1.003</td>
</tr>
<tr>
<td>Double-crested Cormorant</td>
<td>0.499</td>
<td>1.100</td>
</tr>
<tr>
<td>Forster’s Tern</td>
<td>0.057</td>
<td>0.126</td>
</tr>
<tr>
<td>Great Blue Heron</td>
<td>0.415</td>
<td>0.915</td>
</tr>
<tr>
<td>Green Heron</td>
<td>0.034</td>
<td>0.075</td>
</tr>
<tr>
<td>Great Egret</td>
<td>0.145</td>
<td>0.320</td>
</tr>
<tr>
<td>All Gull Species</td>
<td>0.094</td>
<td>0.207</td>
</tr>
<tr>
<td>Hooded Merganser</td>
<td>0.24</td>
<td>0.529</td>
</tr>
<tr>
<td>Osprey</td>
<td>0.35</td>
<td>0.772</td>
</tr>
</tbody>
</table>

Common Mergansers along River Reaches

In the upper river in spring, Common Mergansers averaged 2.3 birds/km, while on the middle river they averaged 1.1 birds/km. At Zillah in the lower river, they averaged 1.0 birds/km in the spring. In summer, Mergansers averaged 1.3 birds/km on the upper river, and 0.5 birds/km on the middle river. This is fairly similar to counts in 2004, when Mergansers averaged 2.2 birds/km on the upper river in spring and 1.6 in the summer. In 2004, the middle river averaged 0.7 birds/km in spring and summer. At Zillah they averaged 1.3 birds/km in the spring (Figure 8-13). Common Mergansers have not shown a numeric response to increases in Yakama Nation hatchery releases of spring chinook and coho in the Yakima River.
Figure 8. Average abundance of Common Mergansers on the Yakima River. Bars indicate standard error.
Figure 9. (5 graphs) Average abundance of Common Mergansers per kilometer in Easton, Cle Elum, Canyon, Zillah, & Benton reaches of the Yakima River. Easton is the uppermost and Vangie the lowest reach.
The 2005 estimated consumption of fish biomass by Common Mergansers was 134.3 kg/km in the Upper River and 62.6 kg/km in middle river. This represented 93.3% of the fish biomass consumed by birds in the upper river in spring and 86.6% of the fish consumed by birds in the upper river in summer. In the middle river, Common Mergansers consumed 84.3% of the fish biomass taken by birds in the spring and 55.8% of the fish biomass taken during the summer period.

These consumption estimates are similar to those in 2004, when Mergansers consumed an estimated 133.4 kg/km in the Upper River and 43.3 kg/km in the middle river. In spring 2004, Common Mergansers accounted for 67% of the consumption in the upper river and 69% in the middle river. In the summer 2004, they accounted for 90% of the total consumption in the upper river and 69% in the middle river.

In contrast to the upper and middle sections of the river, Common Mergansers consumption of fish biomass in the lower river during spring 2005 was only 27.9 kg/km, representing only 4.8% of the fish biomass consumed by birds in the lower river during spring. In 2004, merganser spring biomass consumption of 23.4 kg/km represented only 6% of the total fish biomass consumed in the lower river.
Based on our estimates, a minimum of 212.5 kg/km of juvenile wild and hatchery spring chinook and hatchery coho biomass were present in the upper and middle Yakima River in spring and summer 2005. If Common Merganser fed entirely on hatchery and wild spring chinook and hatchery coho smolts in spring and summer, their consumption of an average of 98.5 kg/km in the upper and middle Yakima River, would represent removal of 46.4% of the salmonid smolt biomass present. This worse case scenario represents a likely upper limit for merganser predation on salmon smolts in the Upper and Middle Yakima River. It does not include merganser consumption of salmon at smolt acclimation sites.

The diet analysis of 20 Common Mergansers collected along the Yakima River by Phinney et al. (1998) challenges the assumptions of the worst case scenario above. During that study, only in fall/winter did salmonids make up a significant proportion of the prey, 42.2% (comprised of 15.8% Chinook salmon, 21.1% rainbow trout and 5.3% unidentified salmonids). In spring, middle Yakima River mergansers readily consumed sculpin (alone making up 71.9%), while lower river mergansers readily consumed chiselmouth (alone making up 50%). Yakima River mergansers consumed a wide variety of fish species based on their availability.

Based on our river reach model, Common Mergansers consumed an estimated 11.3% of the fish biomass consumed by birds in the entire Yakima River during the spring period. Based on WDFW data, small fish suitable as prey for small avian predators (5-75 g) make up an estimated average of 21.0% of the fish biomass in the entire Yakima River in spring (2.3% salmonids and 18.7% other taxa), although salmon smolt numbers may be underestimated (WDFW 1997-2001). These two statistics suggest that mergansers consume salmonids and other fish taxa of the appropriate prey size at a proportion that is about half of their availability in the Yakima River, indicating some degree of prey selection, either by species or size.

A conclusion that could be drawn from these varied data sources is that Common Mergansers breeding along the Yakima River eat small fish of a diversity of species based on their local and seasonal availability. It should not be assumed that Common Mergansers eat only juvenile salmonids. Nor can it be assumed that mergansers select salmonids in a greater proportion than their availability out of the entire fish community assemblage.

American White Pelicans along River Reaches

photo by Ann Stephenson
Pelicans were the major avian fish consumer in the lower river in spring 2005, as in 2003-2004, because they were both relatively abundant and have high daily dietary requirements. Pelicans were largely absent from the middle and upper river during both spring and summer. Pelicans averaged 6.9 birds/km in Zillah and 0.5 birds/km at both Benton and Vangie (Figure 10). These are similar figures to those in 2004, when Pelicans averaged 5.9 birds/km at Zillah and 1.2 birds/km and 0.3 birds/km at Benton and Vangie, respectively.

![Figure 10. Average spring abundance of American White Pelicans along the Yakima River. Bars indicate standard error.](image)

Aerial survey counts of pelicans between Union Gap and the Yakima River mouth ranged from a low of about 60 birds on February 22 to a high of about 660 birds on May 17, averaging 247.5 birds. The great majority of the pelicans were observed between Mabton Bridge and Union Gap. Pelicans were often observed in backwater sloughs and oxbows off the mainstem of the river, where it is suspected they fed on carp (*Cyprinus carpio*) and sucker.

![Pelicans adjacent to the Lower Yakima River](image)
Based on the river reach predation model, the total estimated fish consumption by pelicans during the spring 2005 was 482.7 kg/km representing 82.7% of the total estimated fish biomass consumed by birds in the lower river in the spring period, and 72.8% of the total estimated fish biomass consumed by birds in the entire river in the spring. This was a significant increase from 2004, when estimated fish consumption by pelicans was 320.4 kg/km, accounting for 78% of the total consumption in the lower river in the spring and 70.5% of the total fish biomass consumed in the entire river in spring.

If pelicans inhabiting the lower river reaches consumed the entire 2005 hatchery production of fall chinook and coho salmon smolts released in the lower river, representing over 2.2 million chinook and 52,000 coho (a total biomass of 104.7 kg/km), that would equate to less than 22% of the estimated fish biomass consumed by pelicans in the lower river. However, the small size of fall chinook smolts (4-7 g) appears to preclude them from being a major component of the pelican diet. From pelicans observed foraging at hotspots and from the handful of pelican carcasses collected along the lower Yakima River during this study over the last 3 years, it is known that Yakima River pelicans frequently consume other fish species of size classes larger than salmon smolts, including chiselmouth, northern pikeminnow and sucker.

Estimates of salmon and other fish taken by pelicans at Chandler Bypass, which serves a vulnerable bottleneck for smolts, would appear to be a better indicator of smolt consumption by this species than the river reach model, which may be too broad scale to serve as an accurate consumption index.

**Hotspot Surveys**

**Chandler**

In 1999-2002 portion of the YKFP study it was estimated that up to 10% of the out-migrating smolts were consumed by gulls at Chandler and Horn Rapids alone (Major et al. 2005). Over the last 3 years, pelicans have displaced gulls as the dominant predatory bird at Chandler, changing the potential hotspot consumption equation significantly. Estimated consumption of smolts by gulls at Chandler continued to decrease from previous years, declining by 94% from 2004. Bird abundance at the Chandler Juvenile Fish Facility in 2005 was similar to the pattern observed in 2004, with high numbers of pelicans and low numbers of gulls encountered. Pelican numbers dropped to an average of 56.5 bird/day (high of 256) from 72.7 bird/day (high of 291) in 2004. Gull numbers remained relatively stable averaging 1.4 bird/day (high of 6) as compared to 1.3 bird/day (high of 7.5) in 2004. Other piscivorous bird species observed at Chandler included Great Blue Heron, Caspian Tern, Black-crown Night-Heron, Double-crested Cormorant, and Common Merganser. These 7 species as well as Great Egret and Osprey were observed at Horn Rapids. An average of 4.8 gulls and 0.9 Black-crowned Night-herons were seen during each visit to Prosser Dam above Chandler. Due to the close proximity of Prosser Dam and Chandler Bypass, some of these animals may also be included under the Chandler data.

**Pelicans at Chandler**

Pelicans appeared to remain for long periods during daylight hours at Chandler in 2005, a pattern similar to that in 2004 (Figure 15). Pelicans both rest and forage among the exposed rocks at low water at Chandler. A common observation is that although numerous pelicans attempt to forage for fish discharged out of the Chandler fish bypass pipe, many attempts are unsuccessful. Pelicans in the group often jostle each other for discharged fish. Because pelicans typically feed by grabbing and engulfing fish in their pouch, it is usual difficult to identify prey items before they disappear into their gullet. Pelicans have been observed foraging on both salmon molts and non-salmonid fish at Chandler bypass pipe. Non-salmonid observed taken include sucker, chiselmouth, and northern pikeminnow, typically of size classes larger than that of any smolts. Gaylord Mink has observed pelicans unsuccessfully attempting to eat adult salmon at Chandler, the fish being too large and vigorous for them to handle. Pelicans are capable of consuming
their entire food requirements by eating a few large fish in a fairly short time (~1/2 hr) and then remaining inactive for very long periods (up to 14 hrs) (Tommy King, USDA APHIS, personal communication).

If it is assumed pelicans at Chandler are obtaining their entire daily dietary requirements at the site, an estimate of their consumption of fish can be derived from their average daily abundances and dietary requirements extrapolated over the entire survey period. It is important to reiterate that pelican consumption estimates at Chandler are not based on direct foraging observations as the gull consumption estimates have been calculated.

However, based on the above assumptions, pelicans are estimated to have consumed a total of 6,582 kg of fish biomass at Chandler in 2005 down from an estimated 9,637 kg in 2004. If it is further assumed that all fish biomass consumed by pelicans at Chandler consists of salmon smolts predated there, that sets the upper limit of pelican predation on smolts, a worse case scenario. The smolt biomass consumption estimate of 6,582 kg would represent 18.5% of the smolt passage biomass at Chandler between April 1 and July 1, 2005 (Figure 16, 17 & 18). This passage includes both an estimated 860,000 bypassed smolts and nearly 2.2 million hatchery smolts released at Chandler from the Prosser Acclimation Ponds. If pelicans actually consume salmon smolts of all species in the proportion to their availability the 18.5% would represent consumption of 826,178 smolts, including 29,794 spring chinook, nearly 800,000 fall chinook (35.4% of the hatchery production), 16,015 coho and 1,339 steelhead.

![Pelicans congregating at Chandler Pipe](image)

*Pelicans congregating at Chandler Pipe*  
photo by Ann Stephenson
In 2004, based on the same worst case assumptions as above, pelicans at Chandler would have consumed 29.5% of the total smolt passage biomass. That passage includes both over 900,000 bypassed fish and 2.3 million hatchery fish released at Chandler from Prosser Acclimation Ponds. If pelicans consumed salmon in proportion to their availability, the 29.5% of fish biomass consumed would represent nearly 1.4 million smolts consumed, including 63,082 spring chinook, 1.3 million fall chinook (56.8% of the hatchery production), 16,696 coho and 1,721 steelhead.

However correlation analysis brings into question these huge fall chinook consumption estimates. Fall chinook smolts weighing 4-7 grams in size may be too small for pelicans to efficiently consume them and sustain themselves. Examining the degree of correlation between the various smolt runs and pelican numbers may indicate which runs, if any, are being targeted by pelicans.

**Smolt – Pelican Correlations at Chandler**

The arrival of pelicans at Chandler in spring suggests a relationship between smolt passage and predation by pelicans. The 2005 graph of total smolt passage, smolt passage by run and pelican numbers appears to indicate a significant relationship between the two (Figures 12, 13 & 14).

However a correlation analysis of fish passage and pelican numbers indicates the relative weakness of the relationship. Only the correlations between coho smolt passage and total salmon passage (all smolt species combined) show a moderate correlation, suggesting that less than ¼ of the pelican count variability can be explained by coho passage (Figure 19 & 20, Table 5). Hatchery spring chinook, total spring chinook and total fall chinook only show weak correlations. Wild spring chinook and steelhead passages show the lowest correlations. Other non-salmonid species, such as chiselmouth also show low, even negative correlations.
Figure 12. Total salmon smolt passage estimated at Chandler fish bypass. This data does not include fish released from Prosser Acclimation Ponds, predominately fall chinook.

Figure 13. Comparison of pelican numbers and total smolt passage estimates at Chandler. This data does not include fish released from Prosser Acclimation Ponds, predominately fall chinook. Bars indicate standard error.
The correlation analysis for the 2004 fish passage and pelican data shows a roughly similar pattern (Table 5). The highest, yet only moderate, correlation of pelican numbers is with the coho run, particularly the total coho run and hatchery coho run. There is a moderate correlation with the total salmonid run, the fall chinook run and steelhead run. There is no correlation with the total spring chinook run, with a weak correlation with the hatchery spring chinook run and a negative correlation with the wild spring chinook run. Again it is important to state that the best 2004 correlations are only moderate, with less than 1/3rd of the pelican count variability being explained by differences in hatchery coho and total coho passage (Table 5).

The correlation analysis gives credence to rejecting any assumption that pelicans are responding directly to smolt runs of spring chinook, fall chinook and steelhead and presumably consuming large numbers of them (Table 5). The correlations do suggest that pelicans may be responding to the relatively large run of coho smolts that are of sufficient size (> 30 g.) to serve as an energy efficient food source (Table 5, Figure 15).
Table 5. Smolt - Pelican Correlations.

Correlations between Smolt passage and Pelican and Gull counts at Chandler Bypass

<table>
<thead>
<tr>
<th></th>
<th>Pelicans (Chandler)</th>
<th>Gulls (Horn Rapids)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wild Spring Chinook</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>-0.412</td>
<td>-0.198</td>
</tr>
<tr>
<td>2005</td>
<td>0.221</td>
<td>0.250</td>
</tr>
<tr>
<td><strong>Hatchery Spring Chinook</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>0.241</td>
<td>0.235</td>
</tr>
<tr>
<td>2005</td>
<td>0.345</td>
<td>0.582</td>
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<tr>
<td><strong>Total Spring Chinook</strong></td>
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<tr>
<td>2004</td>
<td>0.058</td>
<td>0.132</td>
</tr>
<tr>
<td>2005</td>
<td>0.337</td>
<td>0.538</td>
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<tr>
<td><strong>Total Fall Chinook</strong></td>
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<td></td>
</tr>
<tr>
<td>2004</td>
<td>0.447</td>
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<td>2005</td>
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<td>0.453</td>
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<tr>
<td><strong>Wild Coho</strong></td>
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<tr>
<td>2004</td>
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<td>2005</td>
<td>0.486</td>
<td>0.663</td>
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<tr>
<td><strong>Hatchery Coho</strong></td>
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<tr>
<td>2004</td>
<td>0.564</td>
<td>0.792</td>
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<tr>
<td>2005</td>
<td>0.466</td>
<td>0.609</td>
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<tr>
<td><strong>Total Coho</strong></td>
<td></td>
<td></td>
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<tr>
<td>2004</td>
<td>0.564</td>
<td>0.790</td>
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<tr>
<td>2005</td>
<td>0.470</td>
<td>0.617</td>
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<tr>
<td><strong>Steelhead</strong></td>
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<tr>
<td>2004</td>
<td>0.232</td>
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<tr>
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<td>0.482</td>
<td>0.493</td>
</tr>
<tr>
<td>2005</td>
<td>0.425</td>
<td>0.650</td>
</tr>
</tbody>
</table>
Gulls at Chandler and Horn Rapids

Unlike pelicans, gulls do not spend all day at hotspots. The number of gulls at Chandler and Horn Rapids peaks at just before mid-day and declines in the afternoon (Figure 16). Based on observed successful foraging by gulls, the birds are estimated to have consumed only 672 smolts at Chandler in 2005, representing less than 0.08% of the smolts counted at Chandler. At Chandler in 2004, gulls were estimated to have consumed 11,977 smolts, representing an estimated 1.3% of the bypassed smolts.

Gulls remained the primary fish predator at Horn Rapids Dam as in 2004, with an average of 5.6 birds/day (high of 36.5) down from an average of 10.7 birds/day (high of 43) in 2004. This site had little pelican activity. Consumption by gulls at Horn Rapids accounted for over 96% of the total gull consumption of
smolts at both hotspots. Consumption of smolts by gulls at Horn Rapids decreased 82% from totals in 2004. Estimated consumption of juvenile salmonids by gulls at both hotspots combined in the spring was 19,108 fish, continuing the declining trend in total gull consumption since 2002 (112,850 fish in 2004, 141,349 in 2003 and 279,482 in 2002). The total observed gull consumption in 2005 represents 0.62% of the more than 3 million smolts that may have passed Chandler and Horn Rapids in 2005, which includes smolts counted at Chandler Bypass and nearly 2.2 million fall chinook smolts released from Prosser Acclimation Ponds. Those 2.2 million fall chinook smolts (average weight 4 g) represented 9,026.6 kg of fish biomass passing Horn Rapids Dam, with the 18,436 smolts consumed at Horn Rapids represented an estimated 0.84% of salmonid biomass consumed.

The 2005 gull consumption totals are more than 5 times lower than those in 2004. In 2004, Prosser Acclimation Ponds alone contributed over 2.3 million fall chinook smolts (average weight 5 g) representing 11,181.5 kg of fish biomass passing over Horn Rapids Dam. The total estimated gull consumption of 112,850 smolts at both hotspots in 2004 represented 3.5% of the over 3.2 million smolts that passed Chandler and Horn Rapids.

The 2005 graphs of fish passage (counted at Chandler including Prosser hatchery fish) and gull numbers at Horn Rapids appear to indicate a significant relationship (Figure 17). The highest, moderate, correlation between fish passage and gull numbers is for the wild coho run and total salmonid run (Table 5). The lowest is for the wild spring chinook, fall chinook and steelhead runs. Except for the low correlations for wild spring chinook, all the runs show moderate correlations. The highest correlations between gull numbers and the coho and total salmonid runs indicate that 44% of the variability in gull numbers can be explained by differences in the wild coho run or 42% of the variability can be explained by differences in the total salmonid run (Table 5).

Figure 17. Comparisons of estimated smolt passage at Chandler and gulls counted at Horn Rapids. The data includes fall chinook released from Prosser Acclimation Ponds. Bars indicate standard error.

The 2004 correlation analysis of fish passage (counted at Chandler including Prosser hatchery fish) and gull numbers at Horn Rapids, showed the highest correlation between coho passage and bird numbers (Table 5, Figure 18). This correlation was strong, indicating a high level of significance. The strong correlations between coho passage and gull numbers indicate that nearly 63% of the variability in gull numbers could be explained by differences in the hatchery or total coho run. Fall chinook correlations were moderate as were those of the total salmonid passage. About ¼ of the variability in gull numbers could be
explained by differences in the total salmon run. Correlations for spring chinook were weak and insignificant as were correlations with steelhead passage (Table 5).

![Gull Count vs Smolt Counts](image)

**Figure 18. Comparison of estimated coho smolt passage counted at Chandler with gulls counted at Horn Rapids.**

If the observed gull predatory behavior on smolts and correlation analysis above is accurate, it might be expected that birds feeding at Horn Rapids would be more likely to be feeding on coho smolts than any other salmonid species. Twenty-nine gulls (Ring-billed and California) were collected for stomach content analysis on May 27th at Horn Rapids. However, this was a poor test of whether gulls were tracking coho, because during late May only large numbers of fall chinook smolts were being released from Prosser Acclimation Ponds with few other salmonids moving through Chandler Bypass. Despite the large number of fall chinook smolts presumably present, none of the gulls appeared to have eaten fish and only two birds had eaten aquatic life of any kind (crustaceans or insects). The rest had consumed terrestrial organisms – insects, isopods, and rodents. Fat, meat, and plant material were also found. By far the most common food item (contained in 34% of the stomachs) was Hemipterans (*Acrosternum hilare*, commonly known as green stinkbugs). Four of the gulls had eaten a rodent. These findings suggest that on May 27 at least, gulls had been feeding either in agricultural fields or at waste disposal sites and only roosting at Horn Rapids Dam, despite the presence of large numbers of fall chinook smolts in the river released upstream at Prosser.

**Smolts Consumed at Acclimation Sites**

At the three spring chinook salmon acclimation pond sites in the upper Yakima River and its tributaries surveyed in winter 2005 (Clark Flat, Easton and Jack Creek), the most common birds preying on smolts were the Belted Kingfisher, Common Merganser and Great Blue Heron. If it is assumed that birds feeding in acclimation ponds are consuming smolts, based on an average number of counts at each site conducted over a 4 month period, daily energy requirements of birds, and the average size of smolts, it was estimated that these three bird species together consumed an estimated 703-832 smolts per site (average 757.3). Common Mergansers and Great Blue Herons consumed between 84-94% of the spring chinook smolts eaten by birds. At Clark Flat and Jack Creek in 2004, Belted Kingfishers were the most common avian predator with fewer numbers of Great Blue Herons and Common Mergansers. The three species consumed approximately 511 smolts total at both sites in 2004 (average 335.5), with a few pelicans consuming an estimated 160 more smolts at Clark Flat.
Surveys of a sample stretch of the Teanaway River, where the Jack Creek acclimation pond is located, indicated low levels of avian predation on fish. In spring and summer, a few Common Mergansers, Belted Kingfishers, and Great Blue Herons consumed an estimated total of 8.6 kilograms of fish biomass, representing 286 salmon smolts. This is a similar level of predation as in 2004, when an estimated total of 8.1 kilograms were consumed. The Jack Creek chinook acclimation site has not become a major attractant for piscivorous birds.

Belted Kingfishers and Common Mergansers were also the most common birds seen at the four coho acclimation sites in 2005 (Boone, Holmes, Stiles and Lost Creek). Great Blue Herons were only found at Stiles, where their consumption was minimal. If it is assumed that birds were consuming coho smolts alone, they consumed an estimated 24,784 smolts, with the Common Merganser alone consumed between 85-99.98% of the smolts eaten per site. However, 98% of the coho smolts (24,315) were consumed at one site, Boone, which averaged nearly 31 Mergansers per day. Common Merganser consumption represents 64% of the 38,000 coho smolts released at Boone. Holmes and Lost Creek lost an estimated average of 50 smolts per pond, with 369 smolts consumed at Stiles.

This pattern was fairly similar to that in 2004, when Belted Kingfishers, Common Mergansers and Great Blue Herons together consumed between 380 and 20,616 smolts per site, with the Common Merganser and Great Blue Heron being the most important predators, consuming between 90-99.98% of smolts eaten by birds. In 2004, Lost Creek and Holmes lost an average of 1,771 smolts per site, with Stiles losing 380 smolts. In 2004, coho consumption was dominated by Common Mergansers at Boone, consuming an estimated 24,315 coho smolts, equating to 20,616 smolts.

Boone, supporting high numbers of Common Mergansers in both 2004-2005, serves as a hotspot for coho smolts. Avian predation at other coho and spring chinook acclimation sites appears to be insignificant.

CONCLUSIONS

In the upper and middle river, based on biomass consumption estimates, Common Mergansers could potentially consume 46.4% of the hatchery and wild spring chinook and hatchery coho smolt biomass. Pelicans inhabiting the lower river reaches could potentially consume the entire 2005 hatchery production of fall chinook and coho salmon smolts released in the lower river (2.3 million smolts); yet only satisfy 22% of their dietary requirements. Actual smolt consumption by both species is likely far less, with both Common Mergansers and pelicans feeding on a diversity of fish appropriate to their size, including chiselmouth, northern pikeminnow, sculpin, dace, sucker and carp. Furthermore, preliminary analyses of Common Merganser diets and more ad hoc observations of pelican feeding and diets challenge popular perceptions of these two fish predators as key predators of salmon smolts under normal conditions. Common Mergansers are not showing a numeric response to hatchery supplementation of spring chinook and coho salmon smolts on the bird’s breeding grounds on the upper and middle Yakima River. However, Common Mergansers did congregate at Boone Pond coho acclimation site in winter and early spring in both 2004 and 2005, consuming an estimated 20,500 - 24,300 smolts each year.

If we assume that avian fish consumption estimates based on bird abundances and daily energy requirements are accurate, that birds consume juvenile salmonids in proportion to their availability at hotspots, and that all fish eaten at hotspots and acclimation sites are salmon smolts (a worst case scenario), the total number of smolts consumed by birds in 2005 at all hotspots and acclimation sites would total over 872,000 fish. This number is equal to 23% of the nearly 3.8 million hatchery smolts released in the Yakima Basin this year. In 2004, a year of significantly higher numbers of pelicans and gulls at hotspots, based on the same worst case scenario assumptions above, an estimated 1.5 million smolts
were consumed at all hotspots and acclimation sites, representing 37% of the 4.1 million hatchery smolts released.

However, a number of lines of evidence strongly challenge the assumptions embedded in these estimates. Many pelicans and gulls appear to use hotspots primarily for roosting and may not be consuming many fish at the sites. Pelicans have been observed consuming non-salmonid species of fish at hotspots, including northern pikeminnow, chiselmouth and sucker. Most of these non-salmonid fish taken were significantly larger than the average size of salmon smolts. Even if it is assumed the birds are targeting smolt runs, the correlation analysis suggests that pelican and gull predation on different smolt runs at hotspots is selective by run and not simply proportionate to the availability of smolts (ranging in size from 4-77 g), making the high smolt consumption estimates for pelicans, particularly of fall and spring chinook which are the smallest smolts in the Yakima River, extremely doubtful.

The correlations with the coho smolt run were the highest for gulls at Horn Rapids and pelicans at Chandler for both 2004 and 2005, suggesting selection for coho and not fall or spring chinook. Both pelicans and gulls at Chandler and Horn Rapids appear to be more closely tracking the coho smolt run than any other smolt run, increasing in numbers at these sites (and presumably consuming more coho smolts) when the fish are moving through the system. Coho smolts disoriented by water diversions at hotspots may be of sufficient body size, with their run occurring in high enough volume, to be an important spring food resource for pelicans and gulls.

Besides pelicans and gulls in the lower river, and Common Mergansers in the upper river, no other bird species appear to be of any real significance in terms of the smolt consumption in the Yakima Basin at the present time. Plans for the 2006 field season include continued monitoring of river reaches and at hotspots, with greater emphasis on evaluating pelican consumption. Pelicans will be color-marked and radio-collared at hotspots, river reaches and other locations to gather information on diet, movements and nesting.

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LITERATURE CITED


