Floodplain Wetland Restoration and Pacific Salmon
2002 Annual Report to NMFS

Cyndi Baker, Fisheries Biologist, Ducks Unlimited, Inc.

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Executive Summary

In the past, land managers have used water-control structures to enhance wetlands for waterfowl habitat and invoke a positive response of native vegetation while discouraging invasive species. In this era of ESA listed salmon in the Pacific Northwest, these land managers must use a multi-species management approach and consider the fate of juvenile salmon that may venture into a wetland whose water levels are partially controlled by structures.

Structures can enhance habitat restoration in that they can be used to mimic the historic hydrologic regime in terms of duration that water is on the floodplain wetlands and the rate that water recedes from these seasonal wetlands after spring runoff. Native biota are adapted to predictable, seasonal hydrologic cycles and the seasonally available, highly productive, off-channel habitat in the river floodplain. Historically, there was greater connectivity of these floodplain wetlands in the upper Columbia River estuary with the river. The goal of using water-control structures is to stabilize the disrupted hydrology using the natural flow regime as a template.

Ducks Unlimited, Inc. (DU), Oregon Department of Fish and Wildlife, and the U.S. Natural Resource Conservation Service built two water-control structures on the north end of Sauvie Island in 2000 and Metro partnered with DU to install one on the west bank of the Multnomah Channel in 2001. A consultation with the National Marine Fisheries Service resulted in a biological opinion that called for monitoring fish passage through the structures. One site was managed with water-control capability while the other two were managed as reference sites for the first two years of monitoring. Fish monitoring efforts from November 2001 to July 2002 are summarized in this report with comparisons to the results from the previous year.

Two approaches to sampling fish were used; two-way, vertical-slot traps were used to monitor fish movement in and out of the wetlands and set nets were used to sample fish within the wetlands. Relative abundance of native species was greatest in catches during the winter and early spring. Introduces species abundances increased in the spring along with water temperature. Most salmon that were caught entering wetlands in the two-way traps were caught before April while 70% to 80% of salmon leaving were caught in April and May. Most salmon caught by both sampling approaches were caught at the site west of Multnomah Channel, possibly due to proximity of the main channel. Both 0+ and 1+ age classes of spring chinook, as well as 1+ coho and steelhead were observed at this site. Salmon were able to pass through the water-control structure on Sauvie Island and were caught in the outbound two-way trap and released. Salmon left these wetlands with spring runoff before water temperatures reached the critical Oregon State water-quality standard.

Despite the limited number of sites, this data provides an example of fish use of these floodplain wetlands and passage capability through a full-round riser water-control structure. Floodplain wetlands may provide a stable habitat for juvenile salmon that is highly productive in which to rear during the winter. Juvenile salmon use of this habitat provides an opportunity to further explore habitat selection during the winter by juvenile salmon and dispersal patterns, especially among YOY and yearling juveniles in the pre-smolt stage.

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Introduction

Restoration of degraded wetlands and of declining salmon populations are both important issues in the Pacific Northwest, but are usually thought of as mutually exclusive undertakings. Many agencies and groups are working to restore hydrologic function of floodplain wetlands, in which juvenile salmon have access, and are faced with the intersection of these two specialized areas of restoration biology.

In the upper Columbia River Estuary, where the hydrology has been altered from the historic pattern, land managers at times use water-control structures of various types in an effort to mimic the natural flow regime *sensu* Poff (1997). Water-control structures allow the opportunity to mimic the natural floodplain hydrology by increasing the duration and predictability of water on the floodplain. A major theme of wetland restoration is controlling non-native, invasive, plant species and encouraging native vegetation. Using water-control structures to maintain more predictable water levels in floodplain wetlands, as well as a combination of mechanical and chemical methods, have been shown to be an effective restoration technique for controlling the non-native reed canary grass (*Phalaris arundinacea L.)* that plagues wetland habitat in the region (Naglich 1994) and enhancing native vegetation (Paveglio 2000).

Water-control structures have been an effective tool for wetland restoration where they have been used in the southern U.S. Use of water-control structures for wetland enhancement and restoration has expanded westward and they are currently in use in the Pacific Northwest. There needs to be a reasonable level of confidence that water-control structures do not negatively affect Pacific salmon. The direct result of the water-control structures is to increase habitat, which is likely to benefit salmon. What has not been documented is the salmon's ability to pass through these structures.

Juvenile salmon use off-channel, riverine, habitats for winter rearing and refuge during high-flow events (Brown and Hartman 1988, Bustard and Narver 1975, Nickleson et al. 1992, Peterson 1982, Swales et al. 1986). It has only recently been a topic of research that they use floodplain wetlands for the same purpose (Sommer 2001a, Sommer 2001b). There has been no research available, that the author is aware, on passage of salmon or any other fishes in the Northwest through any type of water-control structure.

Project Objective

The goal of this work undertaken in 2000 and continued this year is to document floodplain wetland habitat use by salmon and other native and introduced fishes and amphibians; and to confirm passage capability of salmon through various types of water control structures on a regional basis. This report is a subset of a larger effort and demonstrates fish passage through one type of structure, a full-round riser water-control structure. It attempts to address the concern of juvenile salmon stranding and migration delay that may be associated with this structure, as well as describe fish use of this wetland compared with two nearby control sites.

Study Site

The Sauvie Island (Ruby and Wigeon Lakes) and Metro North sites are located northwest of Portland, Oregon toward the town of St. Helens (Figure 1, see appendices for all figures and tables). Ruby and Wigeon Lakes are located on the north end of Sauvie Island Wildlife Area and are connected to the Multnomah Channel by Cunningham Slough (Figure 2). The pond and associated channels and wetlands at Metro North (Metro Parks and Greenspaces) are adjacent to Multnomah Channel (Figure 3). The study sites are seasonal wetlands that dry up during the summer except for some water that remains in the shallow ponds and sloughs. There are no upland streams feeding Ruby and Wigeon Lakes so fish enter from Cunningham Slough, which is a secondary channel of the Columbia River, or Multnomah Channel. The Columbia River is tidally influenced in this area. The water control structure in place at Ruby Lake is a full-round risers with reverse tide-gates and has an experimental fish bypass adjacent to it (Figure 4). When the tide is higher than water behind the water control structure, the reverse tide-gate opens allowing fish to enter or leave through the water-control structure as water flushes into the wetland. When the tide goes back down, the tidegate shuts, holding water in the wetland. There are three other ways that fish may enter or leave the wetlands with this type of water-control structure: 1) over the dike and water-control structure during a high-flow event; 2) over the riser boards when water is flowing over or is backed up from the slough; and 3) through the experimental fish bypass.

Project Background - Wetland Restoration on Sauvie Island and nearby Metro land

DU, Oregon Department of Fish and Wildlife (ODFW), and the Natural Resources Conservation Service (NRCS) built water-control structures at Ruby and Wigeon Lakes on the Sauvie Island North Unit during the summer of 2000. The Sauvie Island project went through formal consultation with National Marine Fisheries Service (NMFS). The consultation resulted in a Biological Opinion (BO) [OSB1999-0282-RI] that called for a Reasonable and Prudent Measure. The BO stipulated that the NRCS will: 1) monitor the bypass outfall structures to learn if juveniles are successfully passing through the bypass structure; 2) monitor the extent of juvenile stranding within the lakes; 3) analyze migration delay that may be occurring within the lakes; and 4) provide a monitoring report of these activities to NMFS at the end of each migration period. The partners agreed to the monitoring requirement and Ducks Unlimited, Inc.

(DU) launched a fish-monitoring program during the fall of 2000. On behalf of NRCS, DU and ODFW have completed two years of monitoring, to date.

A similar consultation was completed between NRCS and NMFS for a wetland restoration project on nearby Multnomah Channel property owned by Metro Parks and Greenspaces. Installation of the water-control structures at the Metro project was postponed in 2000, but completed during the summer of 2001.

ODFW is the agency that manages the operation of the water-control structures at Ruby and Wigeon Lakes. Metro operates the structure at Multnomah North. After completion of the structures, DU's role is only to monitor fish use of the floodplain wetland habitat and passage capability through the structures as they are managed. Thus far, DU has collected two years of data at three sites. At Ruby Lake, the water-control structure was operating as designed during the two years of monitoring. Wigeon Lake was used as a control (the water-control structure was installed but riser boards to control the water level were not installed). The north pond at Metro was also used as a control both years but in 2002, the water-control structure was in place but riser boards were not installed so that the water was free flowing.

Methods

Two-way fish traps

Two-way fish traps (Figure 5) were used to monitor fish entering and exiting the wetlands at all three sites. Traps were checked three times per week unless overtopped by water. Fishes were removed from the traps with a dip net, held in 5-gallon buckets and species, lengths, wet weight (salmonids only), and direction of travel were recorded. In addition, salmonids greater than 70mm entering the floodplain wetlands were marked with a passive integrative transponder (PIT) tag so that individuals could be identified if they were recaptured in the out-going trap or elsewhere down-river. The fishes were released on the other side of the trap to continue in their original direction of travel.

PIT tagging

PIT tags were inserted into the body cavity using a 12-gauge hypodermic needle and modified syringe (Prentice 1990) after anesthetizing the fish with a bath containing 70mg tricaine methanesulfonate (MS-222) L^{-1} buffered with sodium bicarbonate to a pH of 7 and kept in a bath for 90s after losing equilibrium (Summerfelt 1990).

Standard Seasonal Wetland Sampling

Sampling within wetlands was done throughout the period December to July using two types of trap nets: box traps and fyke nets, both with 3/16 inch mesh (Figure 6). The standard seasonal wetland sampling (SSWS) has three objectives: first, to capture salmonids in the wetlands prior to encountering the structures in order to tag the fish so that they may be captured later below the structure to show passage, duration of stay and perhaps growth; second, so that catch of the assemblage of fishes in the wetlands, which may not include the more mobile fishes caught at the traps below the water control structures, can be documented on a seasonal basis and a comparison made with catch at the control structures, which were monitored more continuously than the SSWS; and third, because the sampling is done similarly at all sites, a comparison of relative abundance (catch per unit effort) and species composition can be made between sites.

Trap, location, set, species, fork length (± 1mm) and wet weight (± 0.1g) (salmonids only) were recorded for fish caught during the SSWS. Weights of most fishes were not recorded but for data analysis, weights using length-weight regressions from large samples of species from Willamette River surveys, compiled by Dr. Peter Bayley (Dept. of Fish and Wildlife, Oregon

State University), were calculated. Salmonids were scanned for previous PIT tags and were PIT tagged (if > 70mm) if no previous tag had been inserted.

Results

A total of 9 native species and 14 introduced species were caught by all gears at the three sites, Ruby and Wigeon Lakes and Multnomah North (Table 1). Multnomah North had the overall greatest species diversity for native (9) and introduced fishes (13) caught in both two-way traps and wetland sampling. Species diversity was greater at all sites for two-way trap data compared with SSWS data. Mosquitofish (*Gambusia affinis*) were the only fish caught in the wetlands (at Ruby Lake and Multnomah North) that were not caught in the two-way traps. Conversely, steelhead/rainbow trout (*Oncorhynchus mykiss*) and goldfish (*Carassius auratus*) were caught in two-way traps (at Multnomah North) but not in set gear within the wetlands.

Two-way traps

Two-way traps were fished from November 23rd and 26th, 2001 at Ruby Lake and Multnomah North, respectively, and fishing began at Wigeon Lake January 16th. Traps were decommissioned at all three sites on July 29, 2002. There were periods that water overtopped the traps and they could not be checked. From November 28, 2001 to January 16th,2002 the water was too deep for the traps to be checked. They were checked January 16th, but the water came up again and the technician could not get to them until early February. Water overtopped the traps for a long time during spring runoff, too. Traps were checked May 22, 2002 and not again until mid-July, except for getting in at low tide at Multnomah North June 18th and checking the traps from a boat with about 4 inches of water over them. This was a very different scenario from last year, when drought conditions existed. Figure 7 shows the adjusted inflow volume for the Columbia River at The Dalles where the average is 104.2 million acre-ft (maf) during the period

1961 to 2002 (runoff January-July). Last year, the inflow volume was a little more than half of normal (58.2 maf) and it was about average this year (103.8 maf).

The only improvement made to the traps this year was using ¼ inch-mesh hardware cloth (48 inches tall) with a strip of knitted, nylon mesh on top so that the top of the block-net was flush with the top of the two-way traps. There was some repair done to the mesh, usually where it was attached to the two-way traps, but overall, we were able to fish the traps more efficiently than last year when we used nylon block-net material in which animals were able to chew holes through it. The problem area this year was at Wigeon Lake where we did not get the block-net material up before the high water, which delayed our beginning date. A few large logs washed in and landed on the traps and block-nets after that first high water event in December. ODFW helped to install a log boom across the channel at Wigeon Lake to prevent the logs from washing into the traps. The remaining problem at the Wigeon trap was that the channel had scoured underneath the traps such that, at a moderate water level, the traps were almost completely inundated. This reduced our ability to fish these traps because they were inaccessible more often that the other traps. The base of the channel was repaired with aggregate and the traps set back in place on a more stable bed that is closer to the invert of the water-control structure culvert.

Catch in all three pair of two-way traps was 5,181 fish (Table 2, see Tables 3-8 for greater detail in appendix). More introduced fishes were handled at the Sauvie Island sites than at Multnomah North, where most of the salmonids were caught.

Table 2. Summary of Native* and Introduced Fishes Caught in all Two-Way Traps.

Site	Inbound		Outbound	
	Native	Introduced	Native	Introduced
Ruby Lake	138 (33)	992	166 (31)	762
Wigeon Lake	307 (18)	587	206 (9)	492
Multnomah North	291 (45)	266	512 (52)	462

*Salmonids are reported in parenthesis.

Most of the native fishes, by numbers, at Ruby Lake were three-spined stickleback (*Gasterosteus aculeatus*) and prickly sculpin (*Cottus asper)* and introduced species were carp *(Cyprinus carpio)* and brown bullhead *(Ameiurus* nebulosus), although coho (*O. kisutch*) and chinook (*O. tschawytscha*) salmon, made up 24% of the inbound and 19% of the outbound catch. By weight, prickly sculpin, coho salmon, and peamouth (*Mylocheilus caurinus*) (outbound only) dominated the catch. Juvenile coho and chinook salmon contributed to 40% of the inbound and 37% of the outbound catch, by weight. Catch was similar at Wigeon Lake but there were a large number of banded killifish (*Fundulus diaphanous*) and a few more Centrarchids. Juvenile salmon were fewer than at Ruby Lake, contributing only 6% and 4% of the catch by numbers inbound and outbound, respectively, and 10% and 4% by weight, respectively. Although there were twice as many salmon caught entering the wetland as leaving, the traps were overtopped for weeks at a time, occasionally, and fish likely moved in and out of the wetland during these high water conditions without our detection. At Multnomah North, the assemblage of native species was similar as the Sauvie Island sites, except that there was a greater number of prickly sculpin, by numbers. Juvenile salmon made up 8% of the inbound and 5% of the outbound catch, by number. By weight, they were 4% and 1% of the catch, respectively. The introduced species were dominated by Centrarchids, mostly black crappie (*Pomoxis nigromaculatus*), especially in the outbound trap; there were also moderate numbers of carp and brown bullhead. By weight, a few big largescale suckers (*Catostomus macrocheilus*) out-weighed the numerous prickly sculpin inbound but the situation was reversed in the outbound trap.

Amphibians, crawfish and Asian freshwater shrimp (*Exopalaeomon modestus*) caught in the traps were also recorded (Table 9).

Table 9. Non-fish Species Caught in Two-way Traps.

Site	Bullfrog tadpoles		Crawfish		Asian f.w. shrimp	
	In	Out	In	Out	In	Out
Ruby Lake	0	11	0	13	35	42
Wigeon Lake	6	2	4	3	16	48
Multnomah North	438	12	11	26	12	47

Overall, there were small numbers of crawfish, and Asian freshwater shrimp and bullfrog tadpoles (*Rana catesbiana*), except for the inbound trap at Multnomah North, where all but one (437) were caught on 7/29/02. Asian freshwater shrimp and bullfrog tadpoles are introduced. There are species of crawfish native to the area but the taxonomy of those in the catch is unknown.

Figures 8-10 show catch, by numbers, of native and introduced species of fishes summarized on a weekly basis. The line shows the average weekly stage of the Columbia River at Vancouver. A common pattern among these graphs is that there are more native fishes in the catch early in the sample period but are surpassed by introduced fishes later in the sample period. The large numbers of introduced fishes at the end of the sampling period are mostly young-of-the-year (YOY) carp and brown bullhead at Ruby Lake, YOY carp, banded killifish, black crappie, and brown bullhead at Wigeon Lake, and YOY carp and brown bullhead at the inbound trap at Multnomah North. The outbound trap at Multnomah North did not demonstrate the same pattern of juvenile fish movement, although a fair number of yellow perch (*Perca flavescens*) and carp were recorded. Another pattern is that large catches appear to be associated with a change in water level.

A total of 185 juvenile chinook and coho salmon were caught at all traps during the sampling period from November 2001 to July 2002 (Table 10). In addition, two steelhead (205 and 257mm) were caught inbound at Multnomah North on May 1, 2002. The larger of the two was found with an implanted (gastric) radio transmitter. It was released into the wetland and subsequently caught two days later in the outbound trap and released back into the Multnomah Channel. Of the 185 chinook and coho salmon caught, none of them were previously tagged. DU PIT tagged 159 of the 185. Of the 159 PIT tagged, 60 chinook salmon were inbound and none of these were subsequently recaptured in the two-way traps and likely left the wetland when the water level was over the traps. The Pacific States Marine Fisheries Commission PITAGIS database was queried to see if fish that were tagged at Sauvie Island or Multnomah North were recaptured downstream and no recaptures were reported. There were only one adipose clipped salmon caught out of the 185. It was a 104 mm coho salmon caught at Ruby Lake in the inbound trap on 12/26/01.

Over 90% of salmon caught were less than 140mm. Of the larger size class, 145-178mm, all but one (out of 22) was caught moving out of the wetland and all moved between March 15th and May 13th. Most (77%) of the larger salmon were coho.

Table 10. Chinook and Coho Salmon in Two-way Traps.

Site	In/Out	Chinook		Coho	
		n	range (mm)	n	range (mm)
Ruby	In	10	60-110	23	65-124
	Out	7	92-178	24	70-175
Wigeon	In	4	55-82	14	70-145
	Out	4	75-101	5	65-125
Multnomah North	In	16	69-149	27	47-115
	Out	40	70-114	11	65-149

Figures 11-13 shows salmon movement in and out of the wetlands during the sampling period. At Ruby Lake, 82% of the fish that moved in came before April. Seventy-seven percent of the salmon leaving Ruby Lake left in April or May, the last one caught was on May 17th, just before the traps were overtopped. Most of the documented salmon movement out of the wetland was associated with the first peak in the hydrograph that represents spring runoff. A low swale on the north end of the wetland likely provides an alternate ingress/egress to the wetland (pers. comm. Randy Van Hoy, DU engineer). This reduces chances of capturing juvenile salmon at the two-way traps. At Wigeon Lake, where fewest salmon were caught, two-thirds of the inbound fish came in before April and all but one caught leaving was in April and May, the last was caught May 15th. Over half (51%) of the salmon caught in any of the traps was caught at Multnomah North. Here, about half the fish that came into the wetland moved in before April and half after. Most (85%) of the fish left the wetland during April and May. Three salmon were caught in the outbound trap between June 18th and July15th, after the water from the spring runoff subsided enough for the traps to be above the water level. All the traps were fished through July 29th. Draw-down of water at Ruby Lake was begun July 22nd, during wetland sampling. A $5^1/_2$-inch riser board was removed each day for three days (7/22-24) and the rest of the boards were removed August 6th by ODFW.

Standard Seasonal Wetland Sampling

Sampling within the wetlands was done periodically at all sites using the same number and type of trap nets in the wetlands, and nearby sloughs that were shallow enough for the fyke nets or box traps, set for the same length of time. Multnomah North was sampled at a greater frequency than Ruby or Wigeon Lakes to test if enough salmon could be marked and recaptured for a population estimate. Wigeon Lake was sampled more infrequently; the January round of SSWS was not done because water in the wetland was not deep enough to set nets. It was later realized that this would be the typical water level throughout the sampling season. The next best location to sample was the slough near the trap where it branches off to Wigeon Lake (Figure 14). Effort was only half of normal during the July sample because area was limited and catch was very high. Multnomah South is Metro property adjacent to Metro North (Figure 15). It was originally going to be monitored this past year but, the experimental fishway, a sloping-weir fishway, was not permitted to have the riser boards installed until very late in the season. The SSWS was done at this site mid-June, 2002 to document fish presence.

Total catch, by number and weight, for the SSWS is reported in Tables 11-14 (see also Tables 15-16). By far, the most numerous native species, caught throughout most of the season at all sites, was the threespine stickleback (*Gasterosteus aculeatus*). Introduced species did not dominate the catch until the post-drawdown sampling in mid-July when juvenile carp, brown bullhead, and crappie were present in large numbers, which is the same pattern that occurred in the two-way trap sampling.

A total of 62 juvenile chinook and coho salmon were caught in wetlands by standard seasonal wetland sampling. Fifty-eight, in the range of 32-130mm were caught at Multnomah North from late-December to early April. Two coho (91 and 98 mm) were caught in Ruby Lake mid-January, and two chinook (61 and 69 mm) were caught in the slough near Wigeon Lake early April. As mentioned previously, there was greater sampling effort at Multnomah North than the other sites. After standardizing catch of juvenile salmon among sites, Multnomah North still has the highest catch value, 1.32 salmon per 24-hour net set compared to 0.09 salmon/set at Ruby Lake and 0.17 salmon/set at Wigeon Lake.

Few fish caught were larger than 200mm. The only large fish were the carp and bullhead at all sites but Multnomah South, except for a large (242mm) yellow perch and largescale sucker (440mm) in Multnomah North. The only fish that may pose a predatory threat to juvenile salmon that were present in the catch are Northern pikeminnow (*Ptychocheilus oregonensis*) and largemouth bass (*Micropterus salmoides*), in which the largest caught were only 141mm and 80mm, respectively.

Catch per unit effort (CPUE) was variable from time-to-time at each site (Table 17). The catch by weight smoothes the variability out somewhat. CPUE at Ruby Lake went from 821 to 20 to 2306 fish caught (by numbers) from January to April to July. The same variablility exists at Wigeon and Multnomah North. Catch is also variable between sites for the same month and the same site does not always produce the most fish. For example, Ruby Lake catch (by numbers) was greatest in January, least in April, and intermediate in July.

Box traps and fyke nets were equally effective, however. Catch in each gear type was averaged on a per site per sample period basis and standard deviations calculated (Tables 18-19) then, the mean of the means and standard errors were calculated. The average catch of all of the box trap sets were 218.2 fish/set (95.3 se) and the average catch of all the fyke net sets were 222.9 fish/set (88.1 se).

Table 17. Comparison of CPUE by Numbers and Weight.

Site	Sampling period	CPUE (by numbers)	CPUE (by weight)
MN	December	1882	4216
RL	**January**	**821**	**1192**
MN	**January**	**244**	**1292**
MN	March	54	773
RL	**April**	**20**	**3582**
WL	**April**	**238**	**1352**
MN	**April**	**648**	**4296**
MN	June*	72	3056
MS	June	4878	2379
RL	**July**	**2306**	**3558**
WL	**July***	**3138**	**4576**
MN	**July**	**4925**	**3962**

*Lower effort was adjusted to compare CPUE

The most numerous non-fish species caught by SSWS were the Asian freshwater shrimp (Table 20). The majority of these were caught during the April round of sampling at Wigeon Lake and during the July round of sampling at Ruby Lake and Multnomah North. Multnomah South had many rearing red-legged frog tadpoles (*Rana aurora*) and bullfrog tadpoles were abundant in Ruby Lake and Multnomah South in July and June, respectively. Only two painted turtles (*Chrysemys picta*) and northwestern salamanders (*Ambystoma gracile*) were caught, at Ruby Lake and Multnomah South, respectively.

Table 20. All Non-fish Species Caught in Wetlands.

Site	Asian F.W. Shrimp	Red-legged Frogs	Bull Frogs	Northwestern Salamanders	Painted Turtles
Ruby	487	1	100	0	2
Wigeon	248	3	0	0	0
Mult. N.	114	0	0	0	0
Mult. S.	0	133	142	2	0

Temperature

Temperature in the wetlands was monitored on a limited basis. Onset, Inc. Hobo® temperature probes were used at each site, and set to record temperature on an hourly basis. Probes at Ruby and Wigeon Lakes were placed in the channels on the wetland side of the water-control structures and about one-half to one meter beneath the water surface. The probe at Multnomah North was placed in the deepest area of the pond. Very few useable data were recovered at Multnomah North, though, due to interference of the probe by curiosity-seekers and a software problem in which the power conservation features that shuts off the computer's communications port would engage within seconds after launching a probe causing the logger to stop logging. The software problem affected some but not all of the temperature probes, apparently depending on how quickly the probe was disconnected from the computer after launching. Onset, Inc. issued a patch to correct the problem.

Figures 16-17 display the seven-day daily maximum average temperatures at Ruby and Wigeon Lakes and the stage of the Columbia River (USGS Vancouver), which was also averaged over a seven-day period. As a reference, the 20°C standard was used from the Oregon water quality standards (OAR 340-041-0120[11]), which states that no measurable surface water temperature increase resulting from anthropogenic activities is allowed "in the Columbia River or its associated sloughs and channels from the mouth to river mile 309 when surface water temperatures exceed 68.0 °F (20.0°C)." Temperature in Ruby Lake exceeded this limit May 25, 2002, last year the limit was exceeded on May 20th. Temperature in Wigeon Lake exceeded the standard July 3rd, 2002, last year the limit was exceeded April 25th, according to data collected by DU. At both sites juvenile salmon outmigrated before temperatures in the wetlands exceeded the water temperature standard. Temperature data from the spring of 2001 at Multnomah North is not available.

Water Levels in the Columbia River and Floodplain Wetlands

The staff gage in the Columbia River at Vancouver records water-surface elevations (WSE) every 15 minutes. This data was related to observations at staff gages on the slough side of the water-control structure at Ruby Lake and gages at Wigeon Lake and Multnomah North. The WSE of the wetland at Ruby Lake is independent of the river when the water level in the slough is below the elevation of the riser boards of the water control structure, except for tidal recharge through the tide-gate and groundwater flow. The 24-inch, cast, tide-gate can open when there is the slightest difference in hydraulic head in which the slough side is greater than the wetland side, according to Waterman Industries. Groundwater flow is assumed a minor influence of WSE.

There is no positive water source feeding this wetland so, water does not continually drain from the wetland into the slough. Drainage from the wetland occurs when the water level from the slough drops more quickly than water drains from the wetland through the water-control structure if water is above the height of the riser boards. A high-water event topped the dike from April 16-19 that would have allowed fish to pass over the water-control structure.

Fish have the opportunity to enter or leave the wetland through the water-control structure when: 1) water is above the riser board either from the slough backing up into the wetland and topping the riser boards (WSE slough>WSE wetland) or water draining from the wetland spills over the riser boards (WSE slough<WSE wetland), or when a high-flow event causes water to top the dike and water-control structure; and 2) the reverse tide-gate is open (WSE slough>WSE wetland). Observations from the staff gage on the slough side of the water-control structure at Ruby Lake were correlated with the USGS staff gage in the Columbia River at Vancouver by regression (r^2=0.85) to predict how often water from the slough backed up over the height of the riser boards. Figure 18 shows that the predicted WSE is above the riser board height 30% of the time from November 2nd, 2001 to July 15th, 2002. The longest time that water did not flow over the riser boards was 40 days, from 2/1/02 to 3/13/02. There were 20 fish caught in the outbound trap during this time, however. They were 2 carp, 37 prickly sculpin, 1 pumpkin seed, 4 three-spine stickleback, 5 white crappie and 1 yellow perch. At this time, the wetland side of the water-control structure was higher than the slough WSE therefore; the reverse tide-gate would not have been open. It is unclear how these fish entered the outbound two-way trap if water levels did not afford them the opportunity to pass through the structure. Possibly a piece of wood got caught in the gate and held it open or they passed through structure when water levels would have allowed but did not continue into the trap and remained in front of it until later during the 40 day period. A more remote possibility is that they found a way past the block net from the inbound side and entered the outbound trap. The nets were maintained during the sampling period and inspected after the season when water in the sloughs receded and fish had little opportunity to get around or through holes in the block-nets.

The water-control structure provides a quantifiable benefit in terms of increased water level, which translates into increased surface area of wetland behind the structure. Figure 19 shows the water level of the wetland compared to the water level in the slough at Ruby Lake. Thirty-seven observations of WSE in the wetland at Ruby Lake were made from November of 2001 to July 2002. These were plotted with the predicted daily WSE on the slough side and the riser board elevation. This data shows that when the wetland is filled from water backing up from the slough, the WSE on the wetland side reaches or exceeds the riser board elevation. It should remain at the elevation of the riser board but it appears that after a period when the slough WSE remains low that the WSE of the wetland draws down. Water was observed leaking through the riser boards. Other minor sources of water loss may be due to groundwater flow and evaporation. Overall, the water-control structure kept about two additional feet of water in the wetland during much of the time when water filled the wetland to the elevation of the riser board and water in the slough dropped to around 4 feet (Figure 19).

Fish can travel through the reverse tide-gate when open. Calculations, based on the angle the reverse tide-gate is hung, its weight and the force of water, predict that a 3.1 inch difference in hydraulic head would open the tide-gate 4 inches. When the tide-gate is fully submerged, it should take 2.5 to 3 inches of hydraulic head to open the tide-gate 4 inches (pers. comm. Randy Van Hoy, DU engineer), which may be a large enough crack for a small salmonid through which to swim. A more conservative value may be chosen but WSE data from the wetland and slough at Ruby Lake are not available to the extent needed to calculate the time that fish had access to pass through the reverse tide-gate. However, Figure 19 demonstrates that whenever the WSE of the slough is greater the observed WSE of the wetland the reverse tide-gate would have been open, which would have given fish an additional passageway through the water-control structure.

Discussion

Fish Use of Seasonal Floodplain Wetland Habitat

Three interesting patterns emerged with respect to fish use of floodplain wetland habitat, and they are: 1) relative abundance of native species decreased from winter to spring; 2) most salmon that were caught in the inbound trap were caught before April and most caught in the outbound trap were caught in April and May; and 3) the majority of salmon caught, in both two-way traps and SSWS, were at Multnomah North. Both two-way trap and SSWS data show that native fishes dominated the catch in the winter and early spring and greater abundances of introduced fishes were caught later in the spring. The non-native fishes, such as the warm-water, mid-western Centrarchids, might be present in the wetlands during the winter but are likely to be inactive due to their metabolism. Their increase in presence in the catch later in the season is likely due to the warmer water temperature in the spring, in which the non-natives become active and reproduce, as seen by the large catch of YOY in the early summer. The large rise in numbers and biomass of non-natives, which were mostly YOY, occurred after salmon left the wetland with the spring run-off and water temperature rose in the wetlands. Differences in habitat use may serve to reduce predation of juvenile salmon by warm-water predators, such as bass, although few have been caught. Avian (herons, kingfishers, mergansers) or mammalian (river otters, mink, weasels) predators may be a more serious threat but these rates are unknown.

Salmon use of wetlands and movement patterns

Most salmon moved into the wetland from November to April and most moved out in April and May (Figures 11-13). A number moved in after the first high water event that overtopped the traps from late November to late December. These were 1+ chinook and coho in the two-way traps at Ruby Lake and Multnomah North. It is not known how long these salmon stayed because they were not recaptured. They may have left during high water when the traps were overtopped or through an alternate ingress/egress channel.

In early winter, the wetland sampling at Multnomah North produced juvenile salmon in the range 38 to 41mm. These appeared to be button-up fry so small that it was not clear whether they were chinook or coho. After sampling the wetland for months watching the cohort develop, they were determined to be chinook. These YOY chinook were found in the wetland at Multnomah North late December (3, average 39mm), late January (7, average 42mm), early March (9, average 45mm), and early April (13, 50-79mm). Based on the very small sample size, the cohort appeared to grow about 3mm per month until April when it was not clear whether fish in the 70mm range were from the same cohort sampled in the wetland in January through March. In late March, juvenile salmon in the size range 65 to 80mm began entering the wetland through the two-way trap, except for one 47mm salmon, identified as a coho (but at this size it could have been a chinook), which was caught 3/27/02 in the inbound trap. The traps were not overtopped since late-December when wetland sampling was done in April. If the 13 fish caught in April are from the same group, the average fork length is 71mm. It seems unlikely that they would have grown an average of 26mm in one month but Conner et al. (2001) documented sub-yearling spring-summer chinook growth between 1.0 and 1.3 mm/d in shoreline habitat of the Snake River during spring 1993, 1994 and 1997. Other salmon in this size-class were documented entering the wetland at this time so larger individuals recruiting to the within-wetland population may have boosted the average length.

The increase in temperature, based on Ruby and Wigeon Lakes, from a maximum of about 8°C in early March to 13 or 14°C in early April (Figures 16-17) puts the salmon in their optimal temperature range for growth in April, however. The optimal growth range for juvenile chinook is from 10 to 15.6°C but the thermal bounds for positive growth is between 4.5 to 19.1°C (Armour 1990). The optimal temperature range, based on daily average temperature, is reached from mid-March to early-May in Ruby Lake and late-March to mid-June in Wigeon Lake.

Floodplains are known to be highly productive for fish (Bayley 1991, 1995) and invertebrates (Gladden and Smock 1990). Water temperatures in off-channel habitat can be higher than adjacent riverine habitat in the winter (Sommer et al. 2001b), which can be advantageous if river temperatures are lower than the optimal thermal range for a fish's growth. Sommers et al. (2001b) found that juvenile chinook that used the Yolo Bypass, a wetland/secondary channel adjacent to the Sacramento River, in which to migrate grew at a greater rate, decreased their travel time and had similar or greater survival rates as their riverine counterparts. Wetland habitat in the lower Columbia River likely provides a benefit to juvenile salmon, as well.

Abundance of juvenile salmon at Multnomah North

Greater numbers of juvenile salmon were caught at Multnomah North than at Ruby or Wigeon Lakes in both two-way traps and SSWS. Fifty-one percent of the juvenile salmon caught in the two-way traps and 94% of the salmon caught by SSWS were from Multnomah North. The most obvious difference between Multnomah North and Ruby and Wigeon Lakes is the proximity of the wetlands to the main channel. The wetland and connecting sloughs at Multnomah North are immediately adjacent to the Multnomah Channel (Figure 3). In order for salmon to get to Ruby or Wigeon Lakes, they have to travel 1.1 and 0.6 miles, respectively, down Cunningham Slough to enter those wetlands (Figure 2). Juvenile salmon have been known to travel great distances (Bradford and Taylor, 1997 and Connor et al. 2001) but fish that are too small to swim against current may not be as likely to get washed into these wetlands that are further off channel. Other factors that may explain this pattern include water temperature, predation risk, food availability, or differences in capture efficiencies between sites.

Freshly emerged salmon fry are susceptible to being swept downstream by strong currents (Irvine 1986). Bradford and Taylor (1997) confirmed that newly emerged chinook fry on the upper Fraser River, B.C. that have a stream-type life-history, are flow-sensitive during their first two weeks. But, they found that fry migrate at night which indicates that downstream movement during this sensitive period is not passive because all fish in their study can find refuge and avoid being swept down during the day. They found fry that moved as far as 100 km downstream within a few days of emergence. There was considerable variation in individual behavior with respect to downstream dispersal but it followed a predictable ontogenetic pattern where the greater number of downstream migrants moved within the first two weeks of emergence and fish that moved downstream were slightly larger than those fish that held position in the channel. Wild sub-yearling spring and summer chinook salmon in the Snake River basin have dispersed from natal streams to the Lower Granite and Little Goose Dams from 172 to 810 km downstream (Connor et al. 2001) during the spring. Connor et al. (2001) found that chinook that disperse into the Snake River and use shoreline habitat grow more rapidly than members of their cohort that remain in the more unproductive natal streams. Mean fork-length range for chinook in the Snake River caught between May and June (1993, 1994 and 1997) were between 60mm and 117mm and chinook in streams in the upper basin would not reach these lengths until mid-summer or fall.

It is not known from where the chinook fry that over-wintered in the Multnomah North wetland originated but these two examples show that they may have traveled a great distance and, even though it is common for fall-run chinook fry to disperse downstream, those with a stream-type life history may also use this strategy. Fall-run chinook are known to spawn upstream from Multnomah North in the lower Clackamas and Santiam Rivers, tributaries of the Willamette River. It is possible, however, that these may be spring chinook from the McKenzie or Clackamas Rivers. Chinook fry pass through the Leaburg Dam on the McKenzie River in January (Kirk Schroeder, ODFW research fisheries biologist, pers. comm.). Chinook fry are observed throughout the year, downstream at the hydroelectric facility at Willamette Falls on the Willamette River in Oregon City (Dan Domina, PGE fisheries biologist, pers. comm.), although there is currently no reliable method for determining their stock (Kirk Schroeder, ODFW research fisheries biologist, pers. comm.).

Further, this dispersal behavior may not be a passive occurrence but it may be a life-history strategy in the population where the risk of traveling downstream is compensated by increased productivity and more stable habitat with which to over-winter. Wetland habitat may provide productive, stable habitat if water levels do not fluctuate artificially in response to large, main-stem dams. Liston and Chubb (1985) studied fish use of wetlands in Michigan and found that maintenance of relatively high, stable water levels during post-spawning periods is important for production of food for larval fishes, especially after they absorb their yolk sack. Water-control structures may increase stability of these habitats making them more beneficial to rearing salmonids by mimicking historic hydrologic patterns as long as there is sufficient connectivity to allow movement of fishes in and out of these habitats.

The term stability, when used with respect to the flood pulse concept (Junk et al. 1989), confers the predictable inundation and dewatering on the floodplain as the mechanism that controls adaptations of most biota. Bayley (1995) regards departures from the average hydrologic regimen, such as the prevention of floods, as a disturbance. The predictable pattern of water advancing and retreating onto the floodplain increases habitat complexity resulting in patches of stable, floodplain wetland habitat relative to the whole river in an undisturbed system. Water in a floodplain wetland does not remain static. The goal of using water-control structures is to stabilize the disrupted hydrology using the natural flow regime as a template while maintaining exchange between the river and floodplain.

Comparison of salmon catch in 2001 and 2002 sampling years – two-way traps

There were by far fewer salmon caught in the two-way traps during the 2001 sampling season (January to mid-June) compared with 2002 (November to mid-July), probably due to the low flows in the Columbia River in 2001 (Figure 7). A total of 56 chinook and coho were caught in the two-way traps in 2001 (Ducks Unlimited, Inc., 2001) compared with 185 caught in 2002.

Both years, most fish caught in the two-way traps were caught at Multnomah North, 51 (91%) in 2001 and 94 (51%) in 2002. Fifty-one percent of the catch at the two-way traps at Multnomah North in 2001 were 1+ hatchery, spring-chinook salmon from the McKenzie River fish hatchery, which were planted at all three sites in the wetlands in an effort to boost numbers of salmon in the wetlands to study habitat use and passage capability. There were 100 planted at each of the three sites on 2/2/01 and 70 planted at each site on 3/7/01. Many of the hatchery fish that were recaptured at the two-way traps left the wetland immediately after being planted. This differs from the pattern of use emerging from YOY salmon, but it is not clear how 1+ wild salmon use the wetlands, whether they are stopping in and leaving or staying to over-winter. Figure 20 shows the timing and number of salmon entering and leaving two-way traps at Multnomah North in 2001. Ruby and Wigeon Lakes are not represented because catch of salmon in the two-way traps were so low, three and two salmon, respectively. Hatchery chinook recaptured from the two-way traps left the wetland within two days after being planted. Twentytwo wild, sub-yearlings were caught in the 50 to 95mm range. The bulk of the wild salmon caught leaving the wetland was during the first week of April 2001. These fish may have entered the wetland in the early winter, before the traps were installed in January. More wild salmon were recorded leaving the wetland as entering. This could be due to inefficiencies in capture but, also that juveniles probably entered before the traps were installed and/or because they were too small to be detected and passed through the mesh of the two-way traps. The YOY salmon were not detected leaving through the two-way trap at Multnomah North in 2001 until 3/25/01. If catch of YOY salmon in the Multnomah North wetland in 2002 is an indication, they may have been there since the early winter in 2001. YOY chinook salmon were caught in the wetland at Multnomah North in 2002 using box traps and fyke nets during the early winter through spring. This gear was not used in 2001. The first salmon from this cohort was not detected in the two-way trap until 3/27/02 at 47mm. This suggests that the salmon in the 0+ age class may be entering the wetland early in the winter and over-wintering and leaving in the early spring. There were wild 1+ chinook and coho using the wetland throughout the sample period in 2002 but there is no indication if they are using the wetland in a transient manner or staying for a period because none were recaptured. Many probably left when water overtopped the traps during spring run-off or through alternate ingress/egress channels.

Most of the non-hatchery salmon caught in the two-way traps in 2001 were chinook; 27 compared with one coho in Ruby Lake and four steelhead in Multnomah North. In 2002, coho outnumbered chinook in the two-way trap catch, 104 coho to 81 chinook, and there were three occasions of steelhead being caught. It has been well-documented that coho use off-channel habitat since the mid-1980's from studies in the Pacific Northwest and British Columbia (Brown and Hartman 1988, Bustard and Narver 1975, Nickleson et al. 1992, Peterson 1982, Swales et al.

1986). More recently Richards (1992) documented juvenile chinook use of off-channel habitat in streams in Idaho and Summers (2001) found that juvenile chinook use floodplain wetlands in the Sacramento River. Steelhead, especially of the size captured (197-219 in 2001 and 205-257 in 2002) during late spring, probably are not likely to stay in the off-channel habitat but may be foraging for food on their seaward migration.

The peak of non-hatchery salmon migration out of the wetlands was sooner in 2001 compared to 2002. During the 2001 water year (WY), the hydrograph was very flat, even during the time when spring run-off should have occurred (Figure 21). The peak was 4.67 feet on 5/24/01. In contrast, most of the salmon caught leaving Multnomah North in 2002 were from May 1st through 3rd (Figure 13). There were two peaks during spring run-off: one was 14.6 feet on 4/17/02 and another 12.96 feet on 6/7/02.

Comparison of salmon catch in 2001 and 2002 sampling years – wetland sampling

Wetland sampling is not directly comparable from year to year because different gear was used. Gillnets (one net has five, 25 ft. panels, 6 ft. deep, 0.75 to 2.5 inch mesh), hoop nets (30 inch rings, 1 inch mesh), and Gee minnow traps (1/4 inch mesh) were used in 2001 and box traps and fyke nets were used in 2002 (3/16 inch mesh, 2 and 3 feet tall, respectively). In 2001, 18 24-hour gillnet sets averaged 3.8 fish/set (std. dev. = 5.1 fish/set). Fish lengths caught in gillnets ranged from 88 to 440 mm. Thirteen, planted, hatchery chinook were caught at Ruby Lake on 5/4/01 and one wild coho was caught at Multnomah South on 5/10/01 (length range 160-185mm) using gillnets. Four hoop-net sets at Ruby Lake produced no fish and 36 minnow trap sets averaged 31.4 fish/set (std. dev. = 32.4 fish/set). Range of fish lengths caught in the minnow traps was limited, only 50 to 92 mm and mostly threespined stickleback. Catch per trap on a 24-hour basis with box traps and fyke nets were much higher in 2002, 197.4 (std. dev. = 390.2) and

212.2 (std. dev. = 531.2) fish/set on average (but note large standard deviations), and ranged from 18 to 589 mm and 17 to 540 mm, respectively. The broader size-range of fishes that can be captured with the fyke nets and box traps is clearly advantageous.

More salmon were caught in the wetlands in 2002 than 2001 but these results are not directly comparable since different gear with different capture efficiencies were used and there were unusually low water levels in 2001. Sixty-two juvenile salmon (38 chinook and 24 coho) were caught with trap nets in 2002, ranging in length from 32 to 130 mm using the SSWS protocol. Ninety-four percent of these juvenile salmon were caught at Multnomah North. Low water levels may have affected capture efficiency in the wetlands during 2001 but there were many non-salmonids still present in the wetlands subject to capture, especially since sampling occurred in May when water temperature was warm enough for the introduced fishes to be active.

Using different sizes of trap nets provides great flexibility, which is needed with the fluctuating water levels in this type of habitat. The gear used in 2001 was limited due to size of the fish able to be caught by the minnow traps and gillnets and depth of the water and available surface area needed to fish the gill nets (gillnets are 6 feet deep and 125 feet long and the smallest mesh size is 0.75 inches). However, Dr. Bayley (Oregon State University, Dept. Fish and Wildlife, pers. comm.) pointed out that continuing to use the gillnet fleet provides a comparison with other floodplain-habitat sampling (Bayley et al. 2002) and that capture efficiencies for fishes similar to salmonids exist for gillnets (Bayley 2001) so that probability of presence or abundance estimates may be calculated.

Passage capability of salmon through the full-round riser water-control structure

Seven chinook and 24 coho were caught in the outbound trap at Ruby Lake, the site of the operational full-round riser water-control structure. A total of 166 native fishes and 762 introduced fishes were caught in this trap. These fish had left the wetland, passed through the water-control structure, and were caught in the out-bound trap. This demonstrates that fish can pass through the water-control structure. Fish can pass through this structure a variety of ways. They can go over the riser boards as water spills, through the reverse tide-gate when it is open, or with the water as it overtops the structure and dike. Hydrologic data taken at Ruby Lake and correlated with the staff gage in the Columbia River at Vancouver shows that fish had the opportunity to pass over the riser boards 30% of the time from November through mid-July. Additionally, there were also times when they would have been able to pass through the reverse tide-gate and, for a brief period, they could have gone over the top of the dike.

There had been concern that fish could not pass through the structure as it was designed so a bypass culvert (10" pipe set 36" below the top of the highest riser in the structure) was installed adjacent to the water-control structure. The bypass is set at a higher level than the water-control structure because it was designed to remain open. If it were set lower, it would simply drain the wetland, negating the purpose of the structure. There is a gate on the wetland side of the bypass culvert, which was never opened during the 2002 sampling season. Features additional to the water-control structure may not prove to be helpful if they require more attention of the management agency. Water in the wetland was often observed below the height of the bypass culvert (4.8 ft. NGVD 29). Had the bypass gate remained open, the access for fish to leave or enter the wetland would have theoretically increased in accordance with the time that WSE on the slough was between 6.35 ft. NGVD 29 (elevation of the riser board) and 4.8 ft.

NGVD 29 (elevation of the invert of the bypass), which was 48% of the time instead of 30%. There is a very large assumption that fish can find and will pass through a 10-inch pipe and over the riser board within that structure. An attempt to monitor fish passage through the bypass with radio-telemetry was made but, at the time, water was below the invert of the bypass. Another strategy may be used the following field season.

The last salmon recorded moving out of Ruby and Wigeon Lakes was May 17th and 15th, respectively. A few lingered at Multnomah North, straggling out June 18th, July 12th and July 15th. Temperature in the wetlands did not exceeded the Oregon State standard of 20°C for a 7-day average maximum temperature until May 20th at Ruby Lake and July 3rd at Wigeon Lake after the salmon had left. This data is not available for Multnomah North but the data roughly tracks that of the other two sites from April 12-24, 2002 (Figure 22).

Salmon migration delay and stranding

Ruby Lake, the site with the operational full-round riser water-control structure, did not appear to delay salmon migration compared to the control sites, Wigeon Lake and Multnomah North. Figures 11-13 show similar patterns among all sites where salmon are entering the wetlands in the winter and leaving in the spring. Temperature data shows that they leave the wetlands before levels become critical (Figures 16-17). The last salmon caught leaving Ruby Lake, right before the second peak from the spring runoff, was caught on May 17, 2002. No salmon were caught in the wetland after that with the SSWS. Since salmon and other fishes, amphibians, and decapods can pass through the water-control structure, migration delay and stranding seem to be a moot point, at least when there is sufficient flow throughout the winter and spring to provide passage opportunity.

Conclusions

The proportion of fishes using floodplain wetland habitat was greatest for native fishes in the winter and early spring until temperature warmed enough for the introduced fishes to become active. The greatest number of juvenile Pacific salmon that were documented moved into these habitats during the winter and early spring and most left during April and May with the spring run-off. One of the most difficult challenges of sampling fish movement into and out of these floodplain wetlands occurs during high-flow events when it is expected that most of the movement occurs. Sampling with set gear in the wetland at Multnomah North during the winter indicated that chinook fry were transported into the wetland during the high flows in December. Average length of fish from this cohort increased monthly suggesting growth of the within-wetland population. Despite current assumptions about high fidelity to natal rearing sites by juvenile salmon, a large number of larval fry moved into this wetland during the winter. The greatest numbers of juvenile salmon were caught in the floodplain wetland at Multnomah North compared to Ruby or Wigeon Lakes. It is not clear whether proximity to the main channel or some other factor such as habitat suitability, predation or sampling bias explains this pattern.

Fish passage was documented at the full-round riser water-control structure at Ruby Lake. Fish had the opportunity to pass over the riser boards 30% of the time during the sample period and additionally through the reverse tide-gate. Frequency that the tide-gate was open could not be calculated due to lack of stage data on the wetland side of the structure. Salmon left the wetlands before temperature reached the critical level set by the State of Oregon. Salmon movement out of the control sites (Wigeon and Multnomah North) occurred at about the same time or later than the last salmon that left Ruby Lake so, the water-control structure did not appear to impede migration. No salmon were caught in the wetland after draw-down in the early summer after the water from the spring run-off finally receded in mid-July. This supports the assertion that the water-control structure did not contribute to, or cause, stranding of juvenile salmon.

Passage capability, thus limited migration delay and stranding, look promising for juvenile salmon with respect to the full-round riser water control structure at Ruby Lake. Fish passage capability may be quite different at lower water levels if fish do not have the opportunity to pass over the riser boards or through the reverse tide-gate periodically throughout the winter and spring. More management of the riser boards may be required if low water conditions exist causing limited passage opportunity.

Despite the limited number of sites, this data provides an example of fish use of these floodplain wetlands and passage capability through a full-round riser water-control structure. During the next field season, all three water-control structures will be operating as designed. Additionally, there will be two sites added. Both sites are immediately upstream from Multnomah North. One has a structure with an experimental sloping-weir fishway and the second will provide a control. This expansion will allow the investigation of fish response to water-control structures with slight variations in design and differences in proximity to the main channel and wetland morphometry so that data may be generalized to other like habitats with appropriate qualifications.

Floodplain wetlands may provide a stable habitat for juvenile salmon that is highly productive in which to rear during the winter. Juvenile salmon use of this habitat provides an opportunity to further explore habitat selection during the winter by juvenile salmon and dispersal patterns, especially among YOY and yearling juveniles in the pre-smolt stage.

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Figure 1. Vicinity of Sauvie Island and Metro North sites.

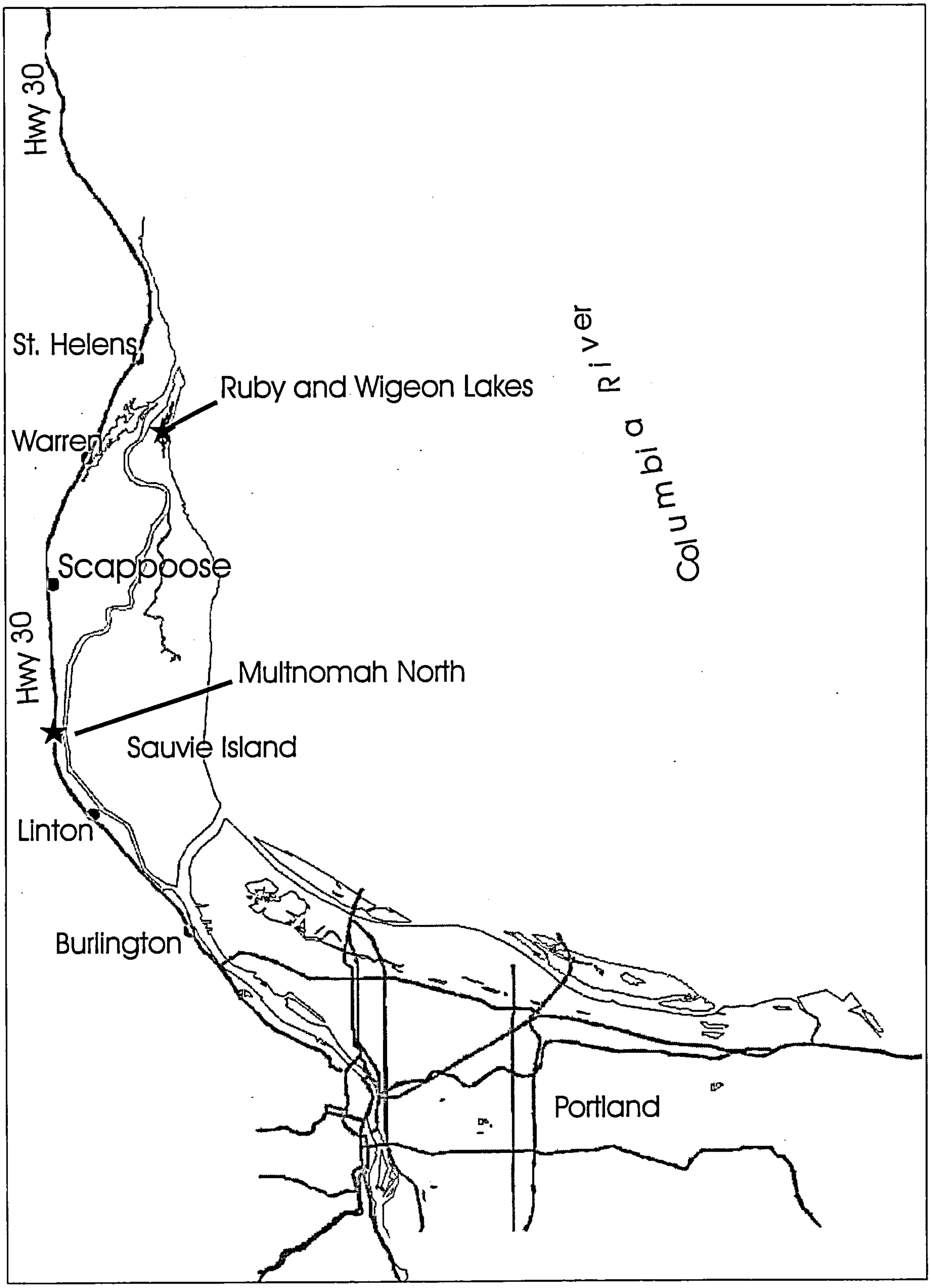


Figure 2. Ruby and Wigeon Lakes on Sauvie Island

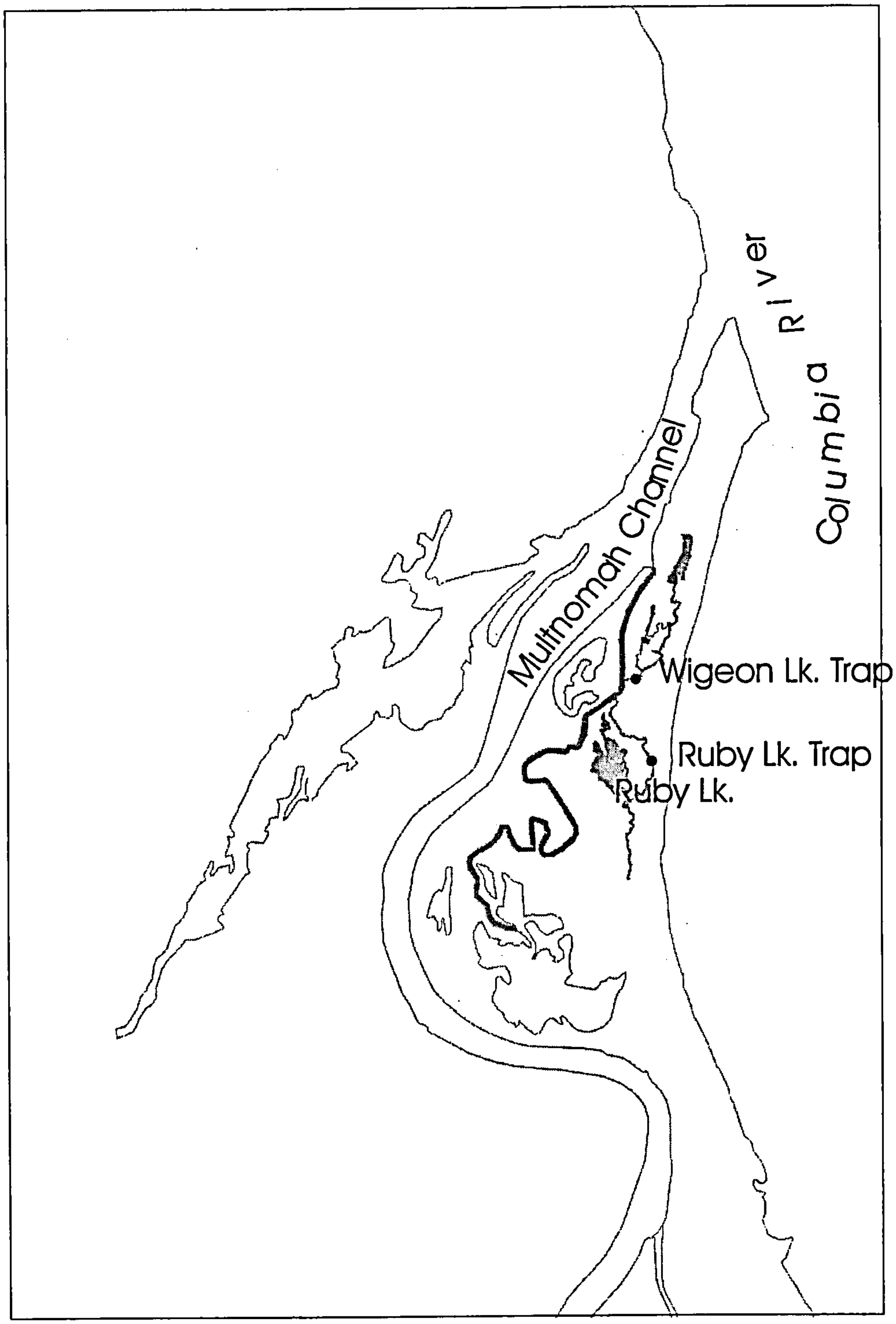


Figure 3. Multnomah North site.

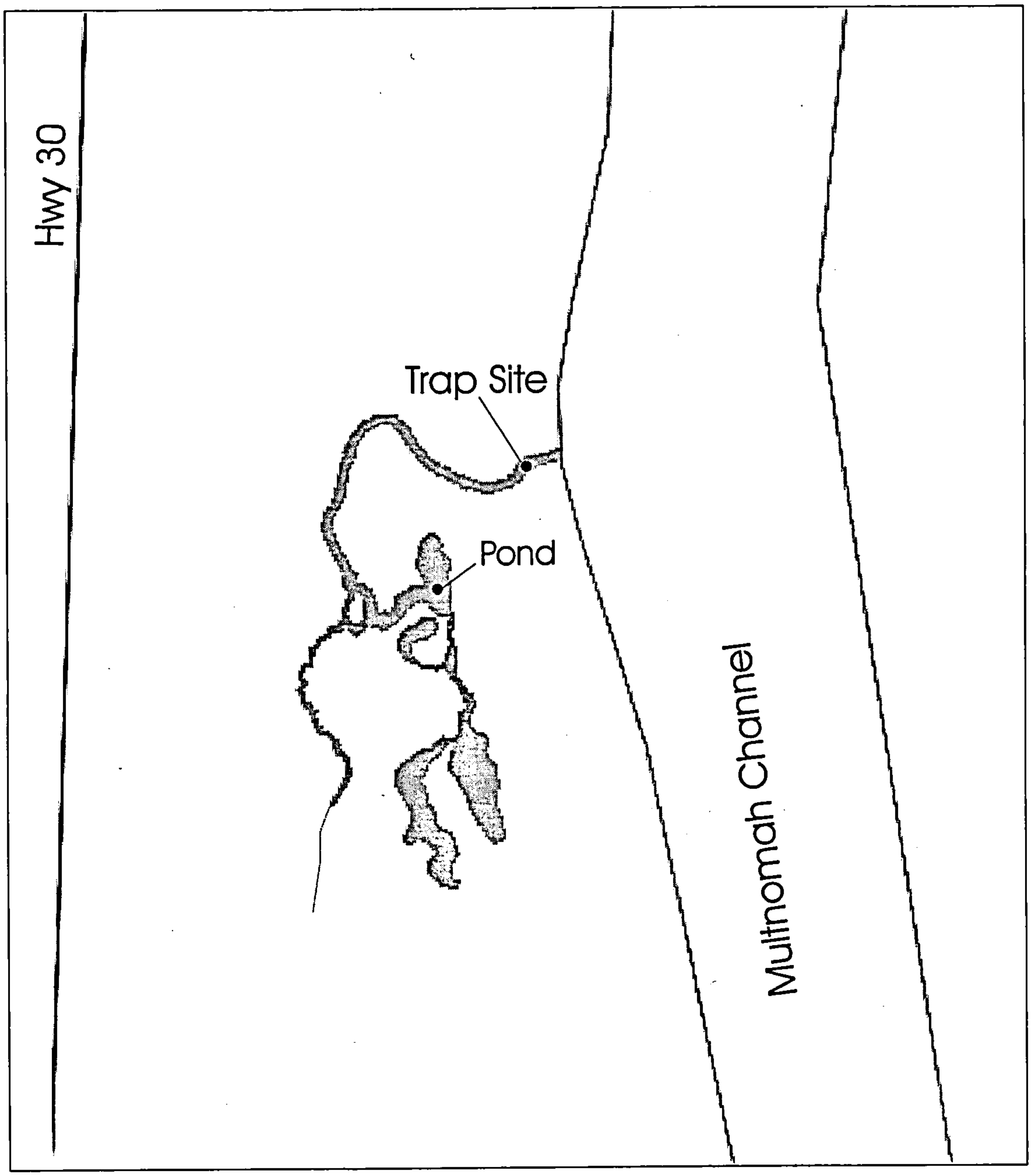


Figure 4. Full-round riser water-control structure

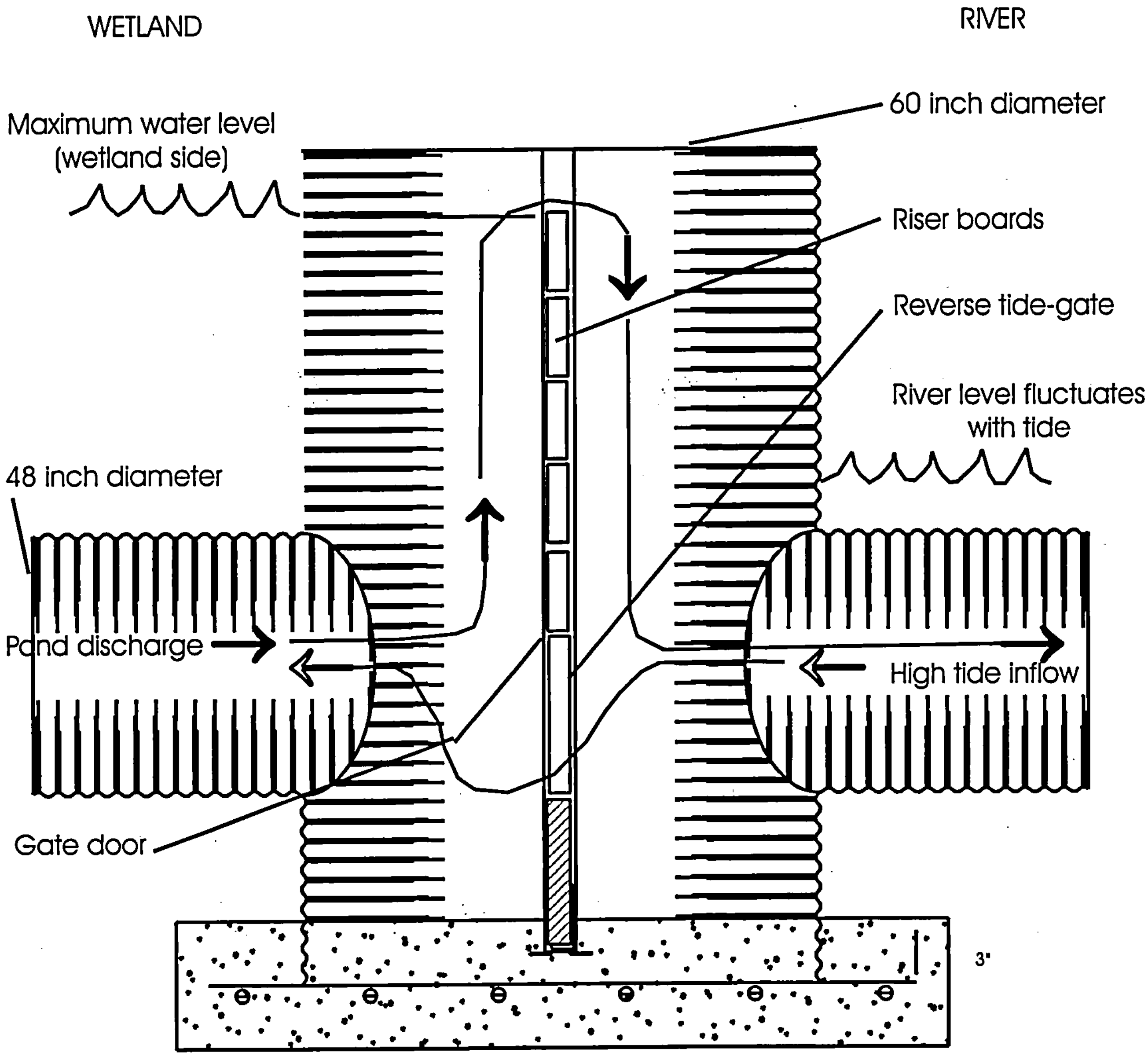
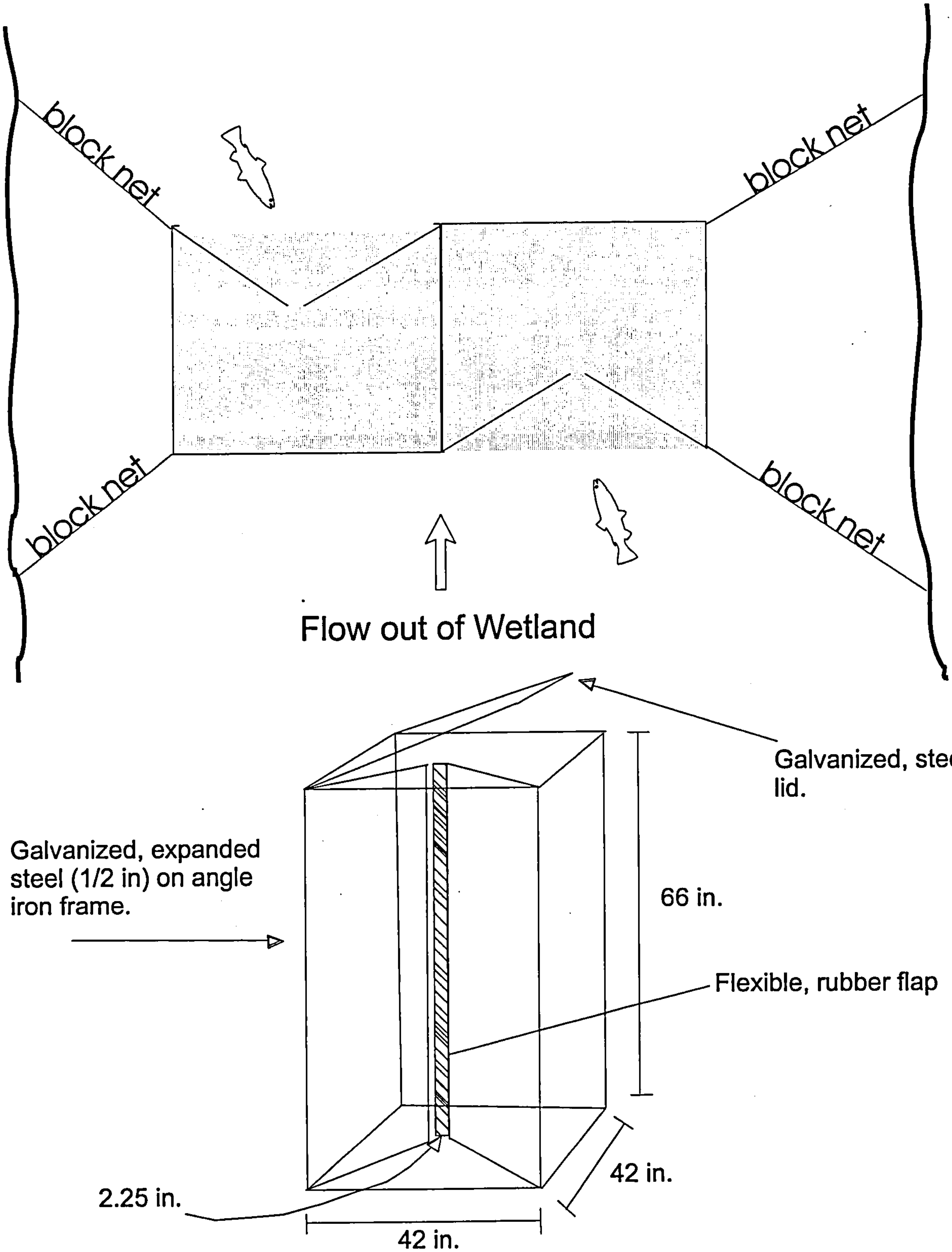
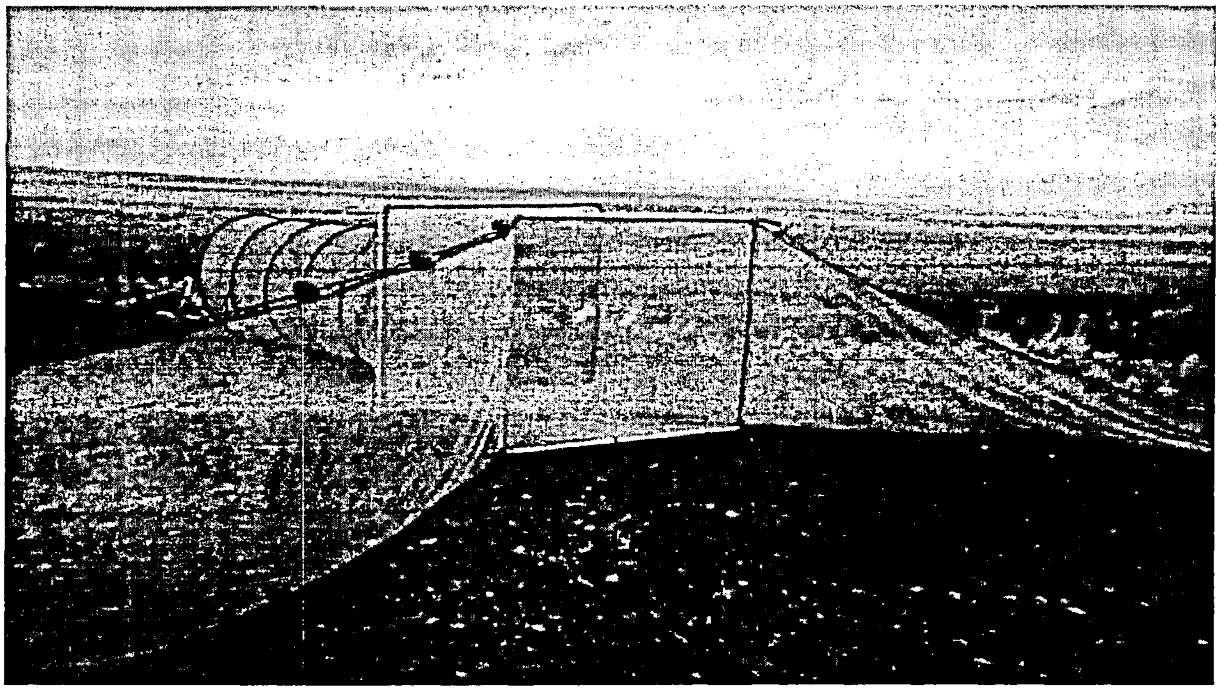


Figure 5. Plan and side views of vertical-slot traps.

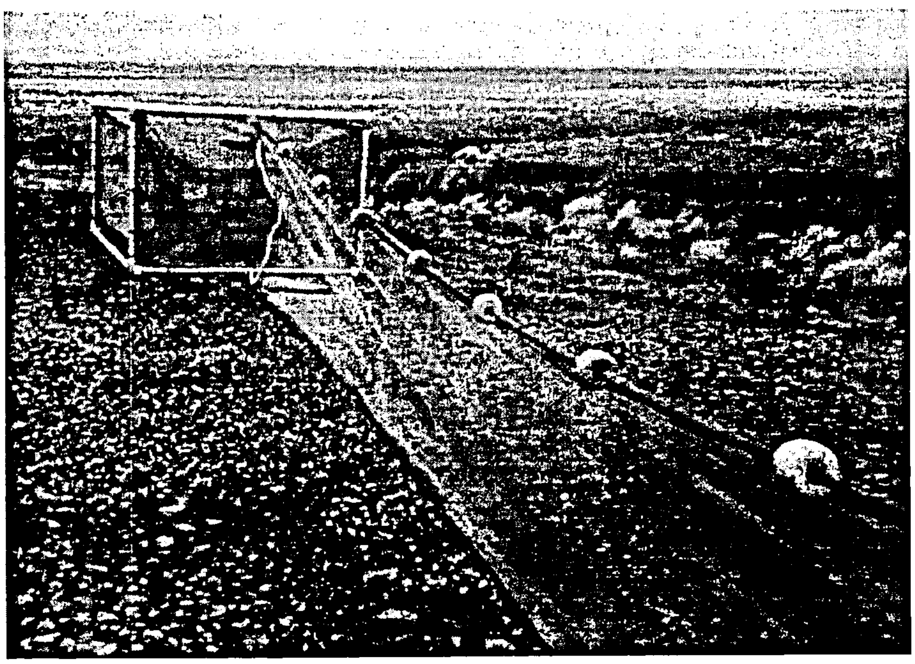


Trap design by Dr. Peter Bayley, Dept. Of Fish and Wildlife, Oregon State University

Figure 6. Set nets used in wetland sampling.



Fyke net with 3 x 4 ft frame, 30" rings (5), 3/16" mesh, and 25ft wings



Box trap with 5(l) x 3(w) x 2(h) ft. Frame 3/16" mesh and 25ft lead

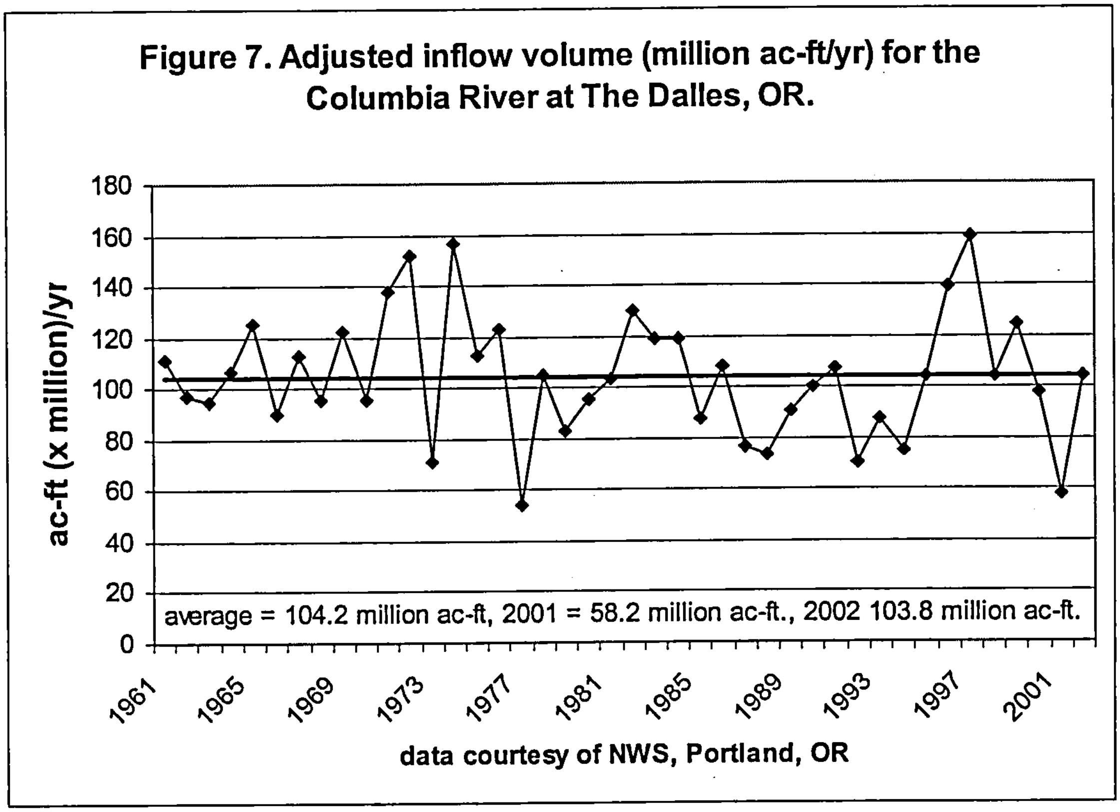
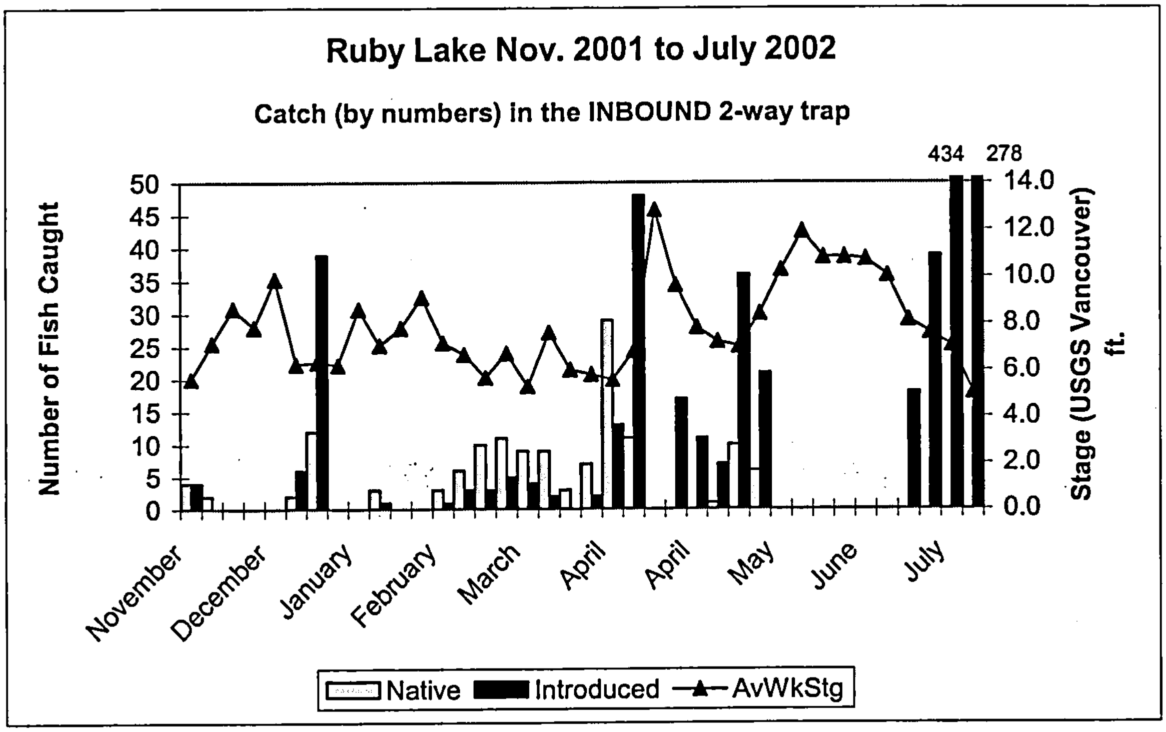
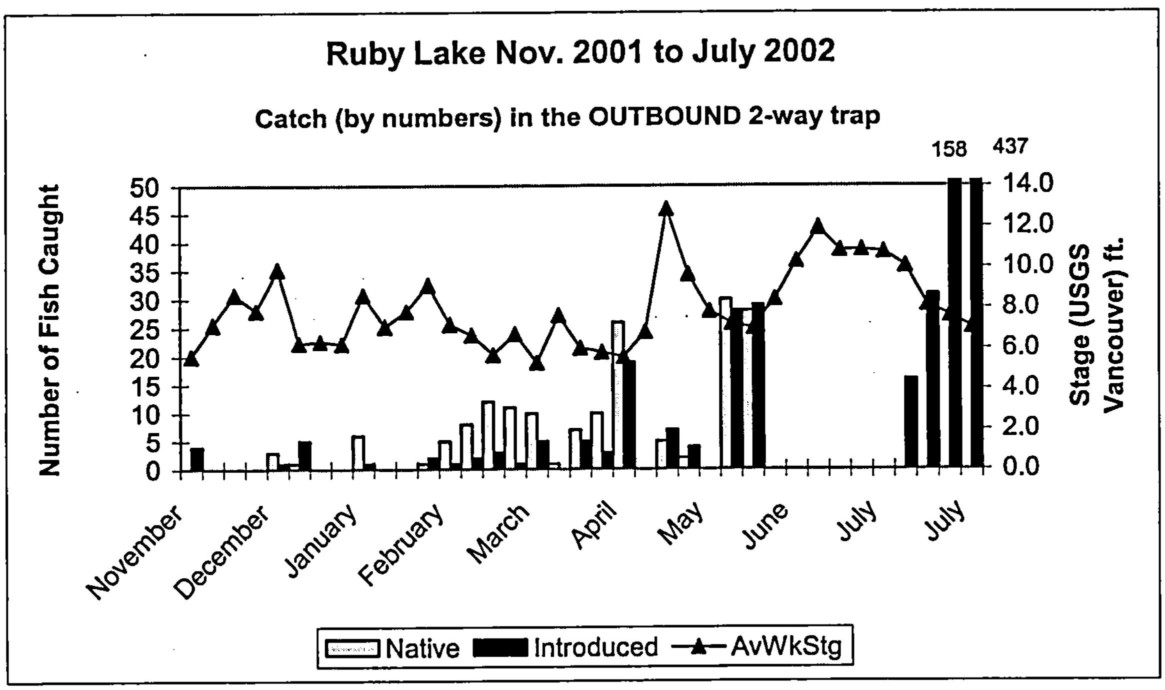


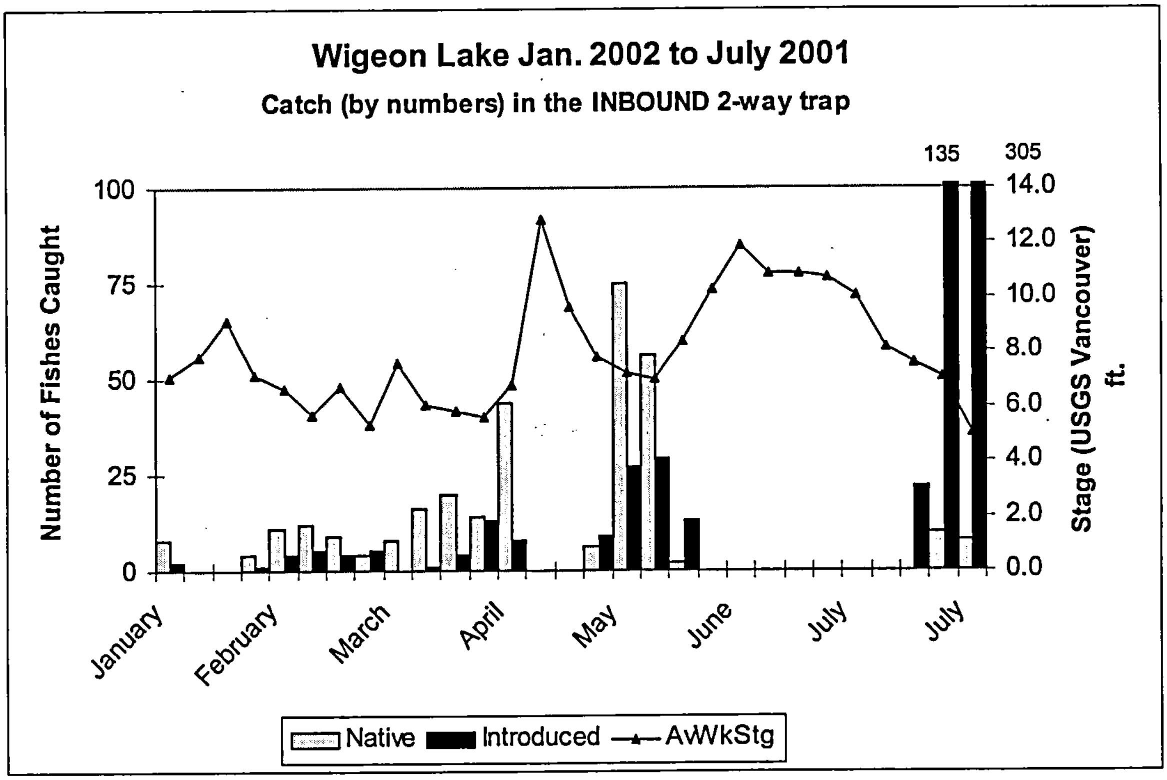
Figure 7. Adjusted inflow volume (million ac-ft/yr) for the Columbia River at The Dalles, OR.
ac-ft (x million)/yr
180
160
140
120
100
80
60
40
20
0
average = 104.2 million ac-ft, 2001 = 58.2 million ac-ft., 2002 103.8 million ac-ft.
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
data courtesy of NWS, Portland, OR

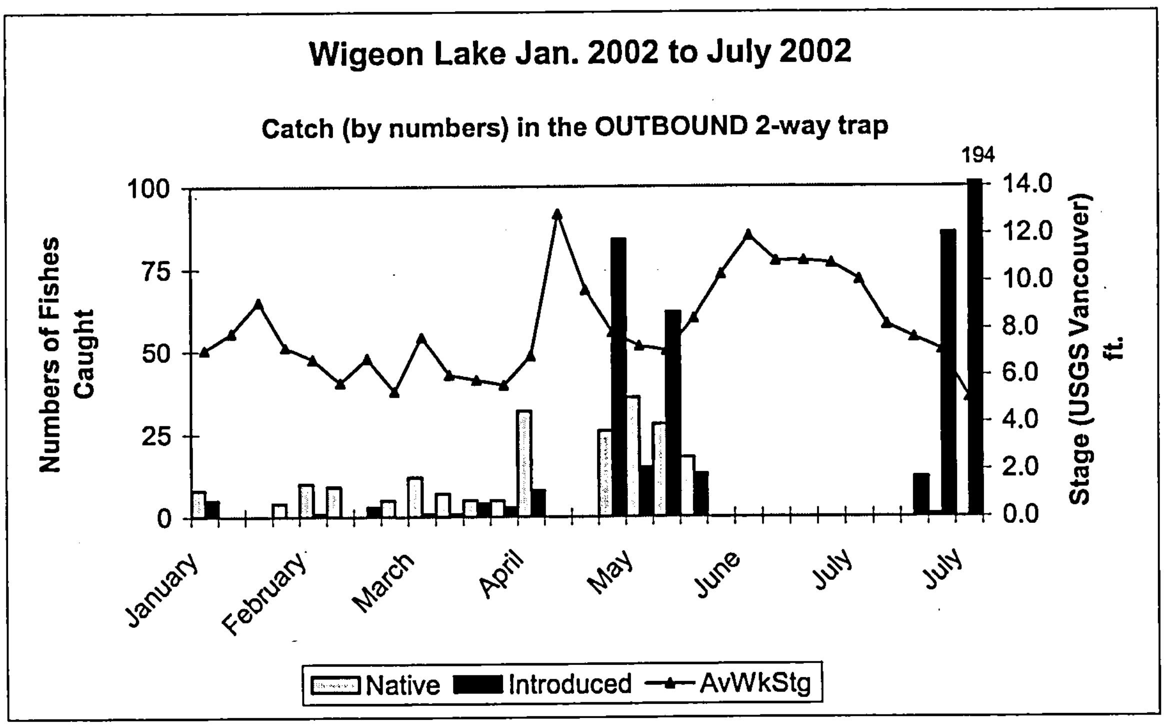
Figures 8. Numbers of native and introduces fishes in two-way traps at Ruby Lake.



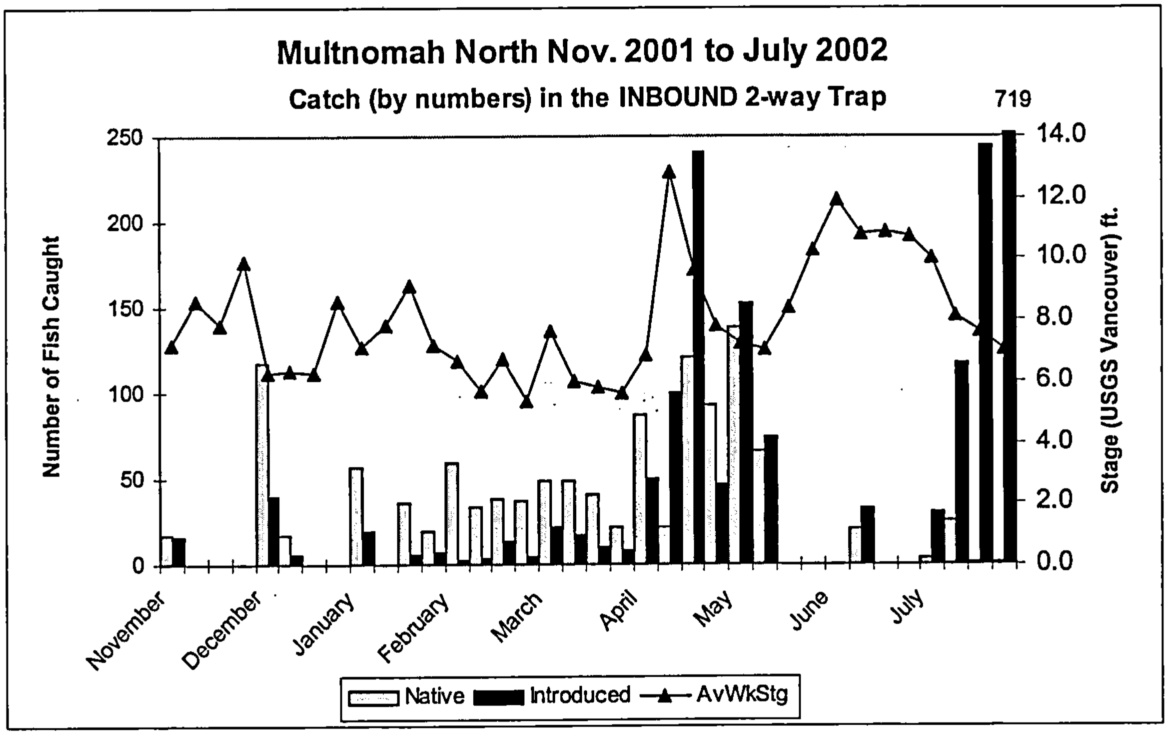


Figures 9. Numbers of native and introduced fishes in two-way traps at Wigeon Lake.





Figures 10. Numbers of native and introduced fishes in two-way traps and Multnomah North.



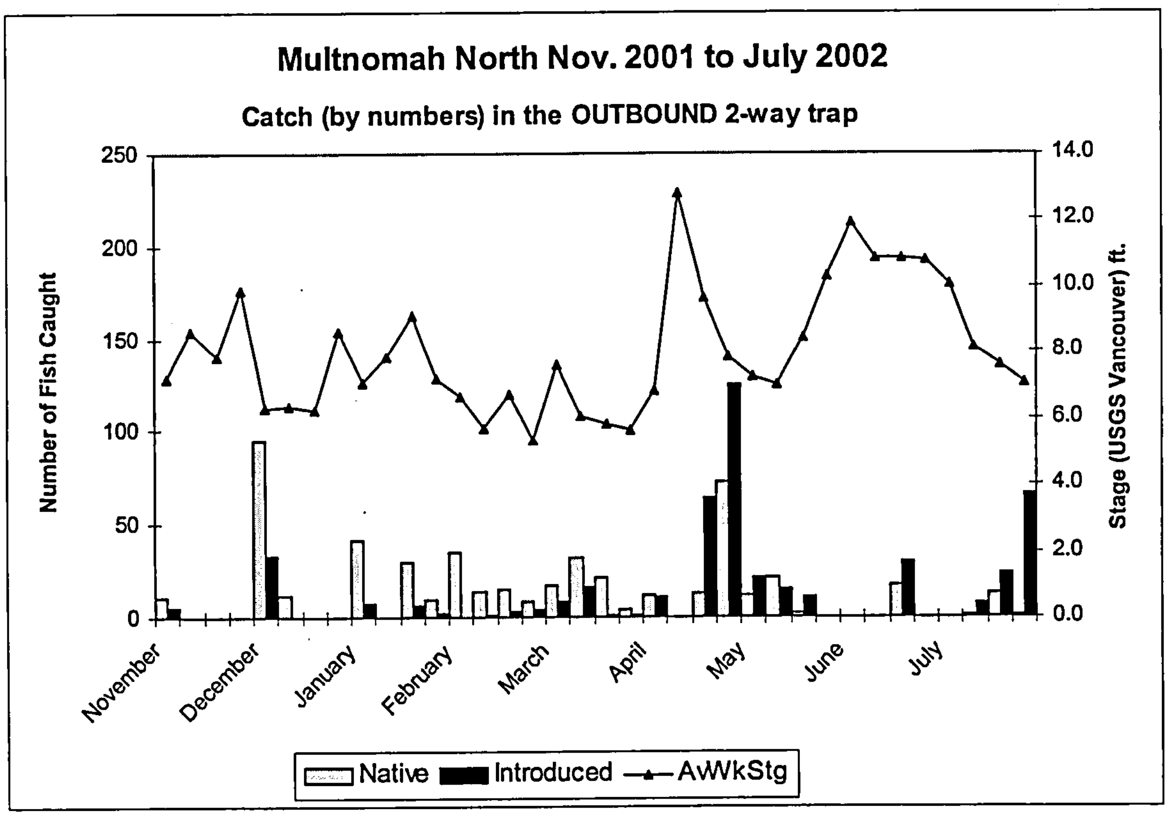


Figure 11. Juvenile salmon in 2-way traps at Ruby Lake.

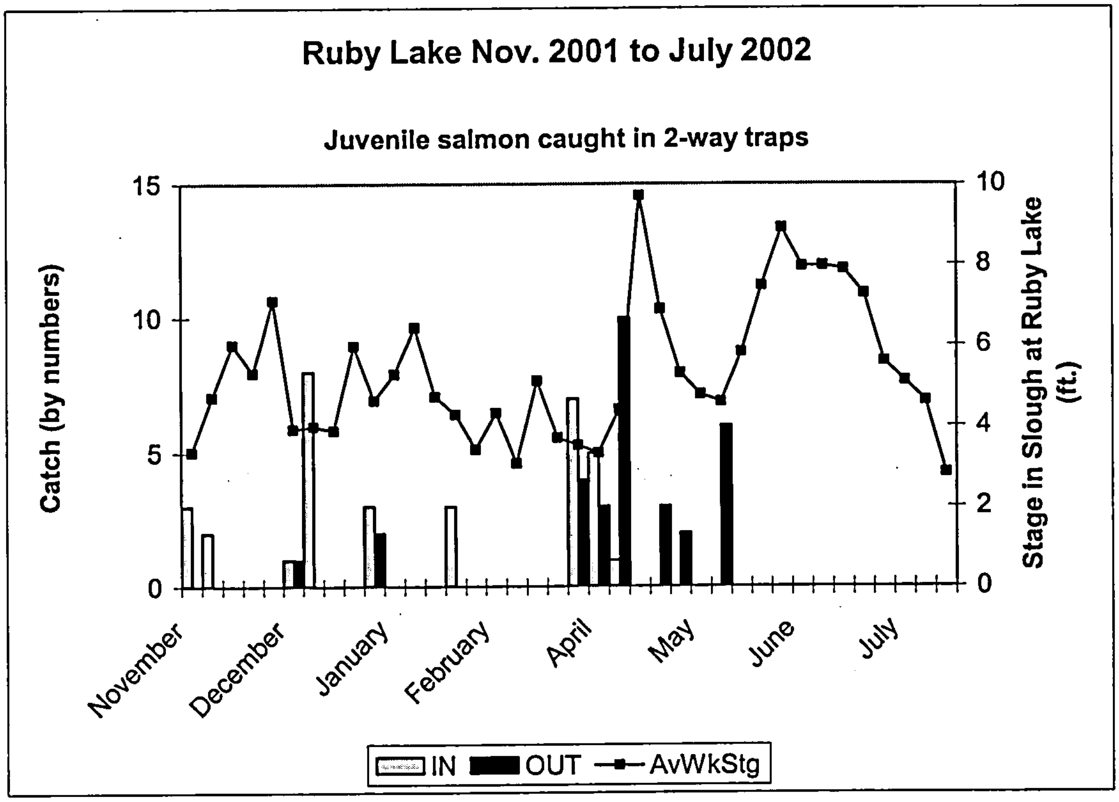


Figure 12. Juvenile Salmon in 2-way traps at Wigeon Lake.

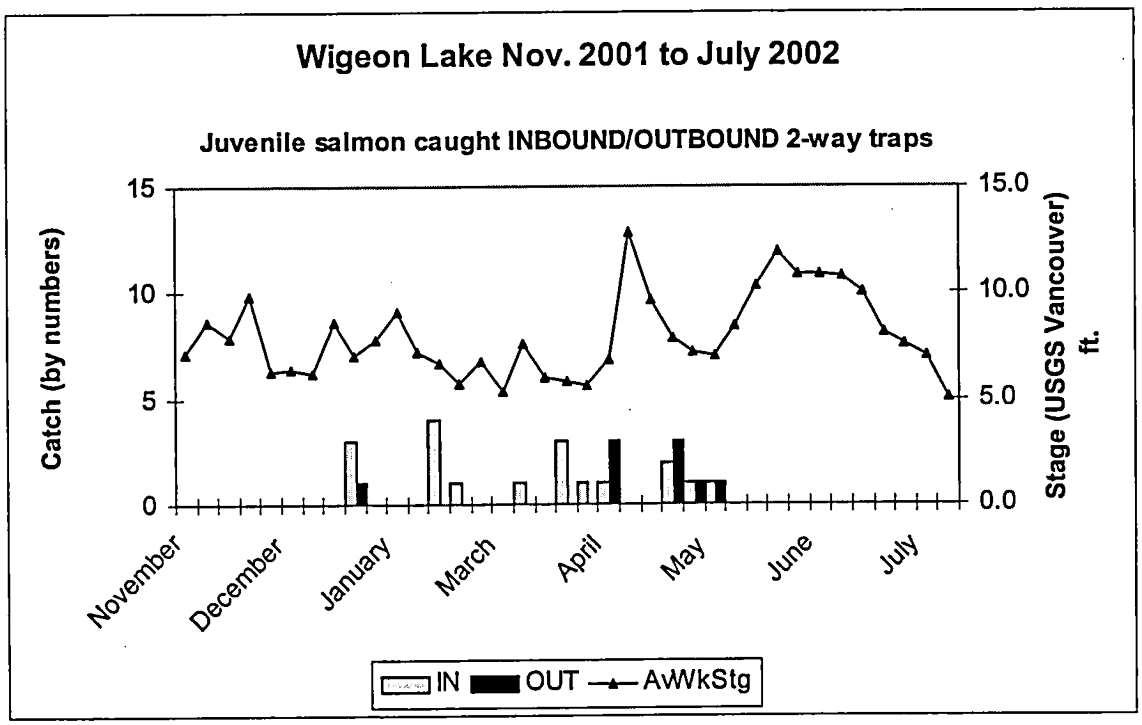


Figure 13. Juvenile salmon in 2-way traps at Multnomah North.

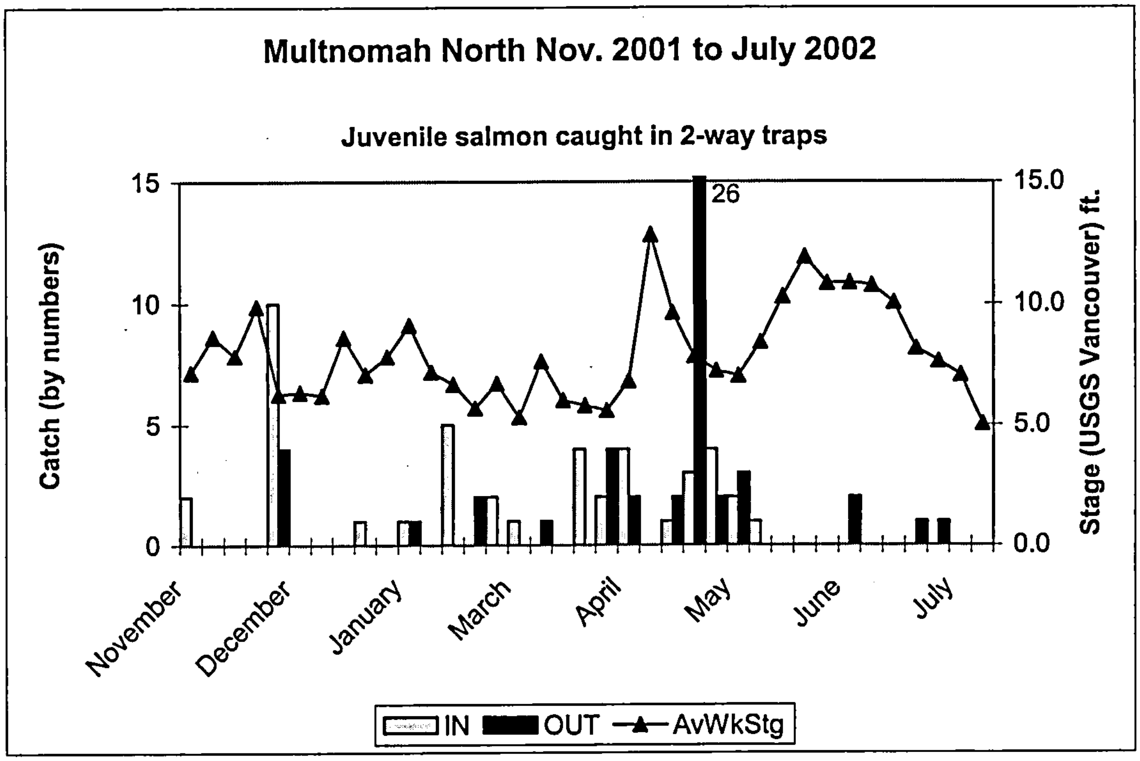


Figure 14. Sampling Location at Wigeon Lake.

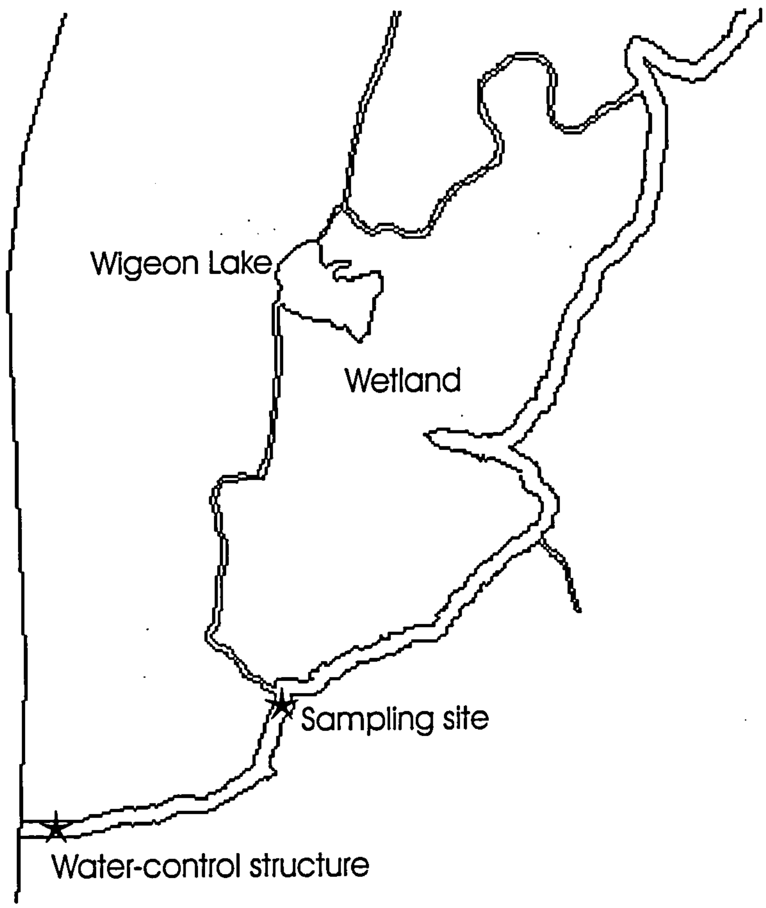


Figure 15. Vicinity Map of Multnomah North and South.

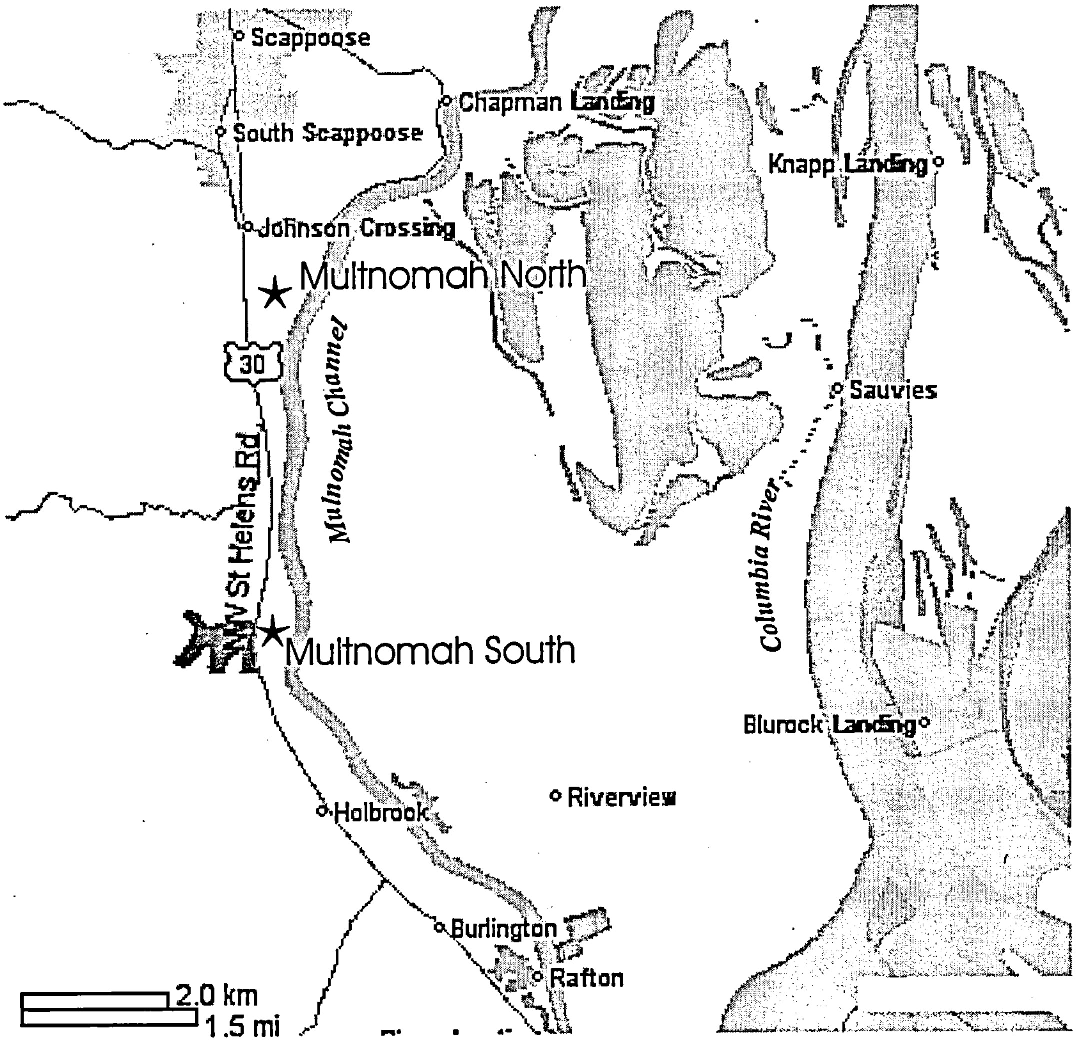


Figure 16. Seven Day Average Maximum Temperature and Stage (USGS Vancouver) at Ruby Lake December through July, 2002

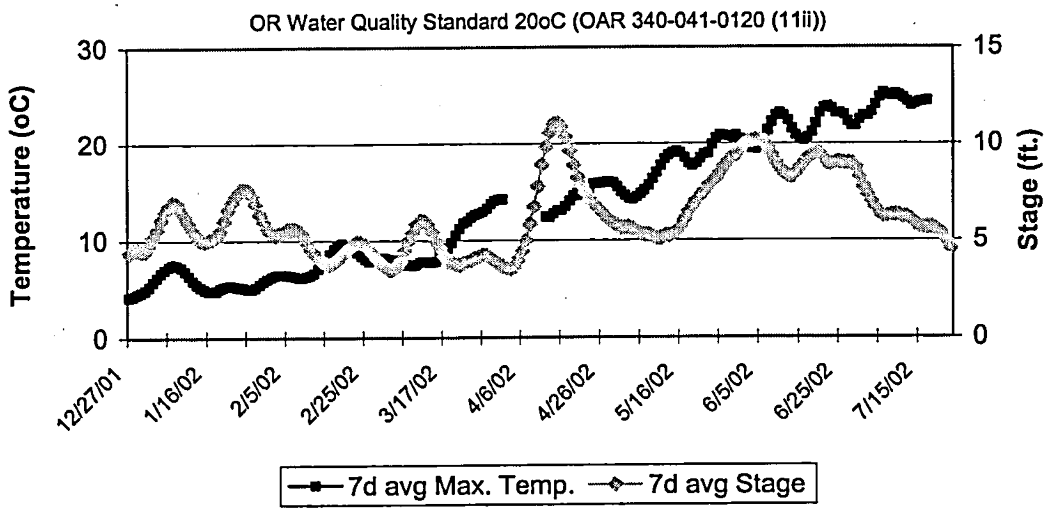


Figure 17. Seven Day Average Daily Maximum Temperature and Stage (USGS Vancouver) at Wigeon Lake December through July, 2002

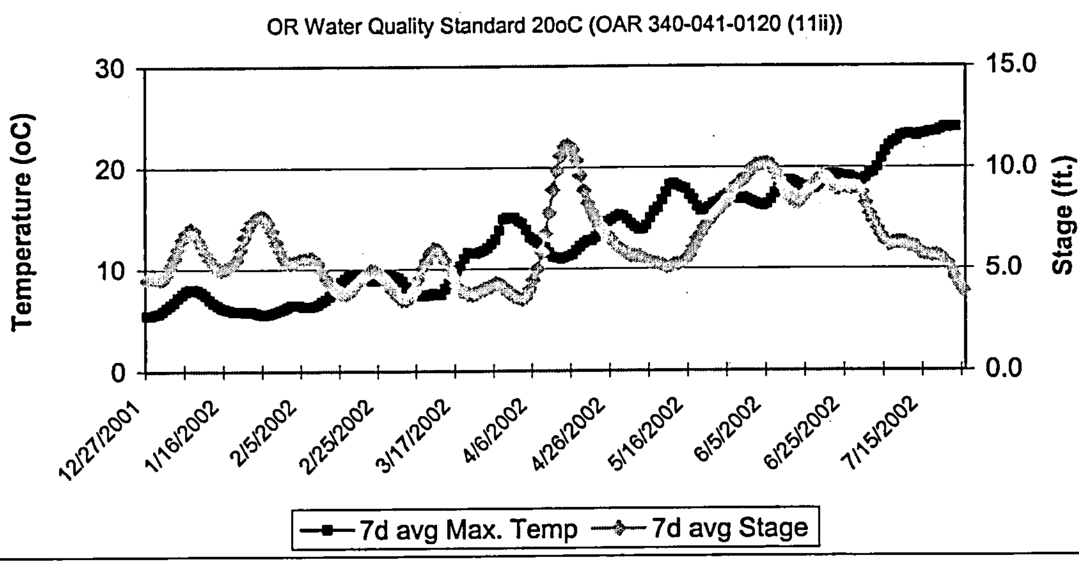


Figure 18. Predicted Water Surface Elevation (WSE) in Slough at Ruby Lake
Nov. 2001- Aug. 2002

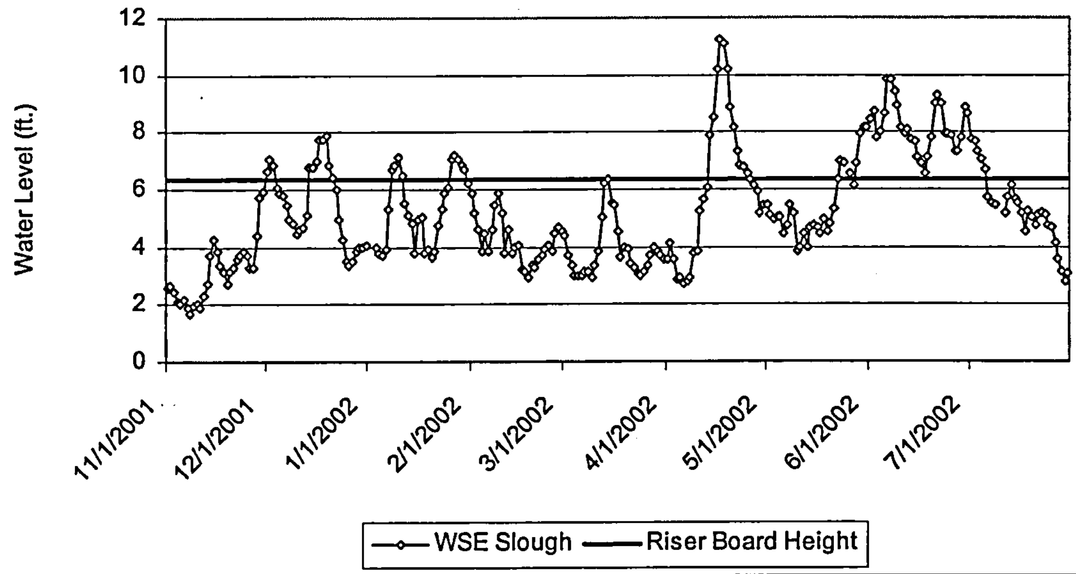


Figure 19. Observed WSE on the wetland side of the structure at Ruby Lake
Nov. 2001-Aug. 2002

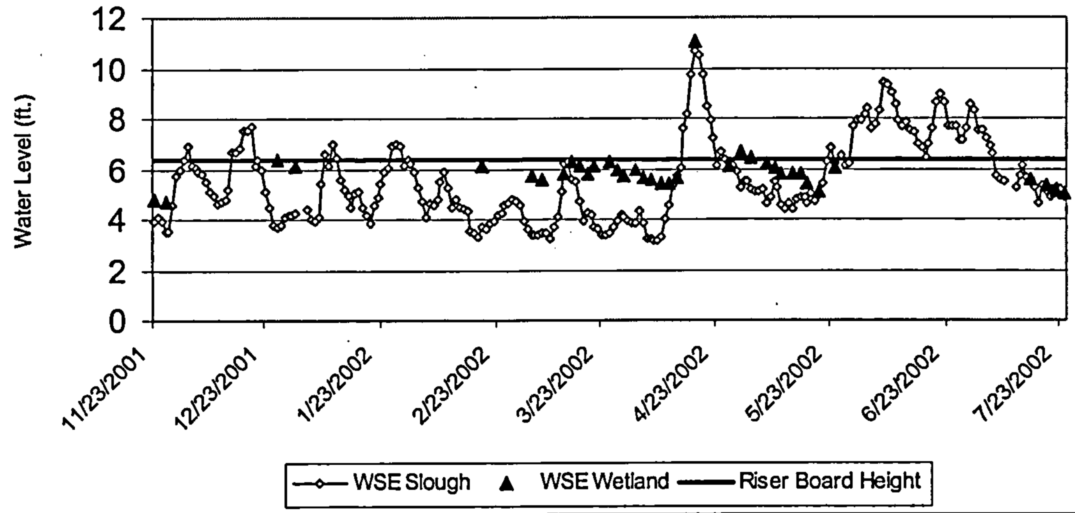


Figure 20. Chinook and coho salmon caught in 2-way traps in 2001 at Multnomah North.

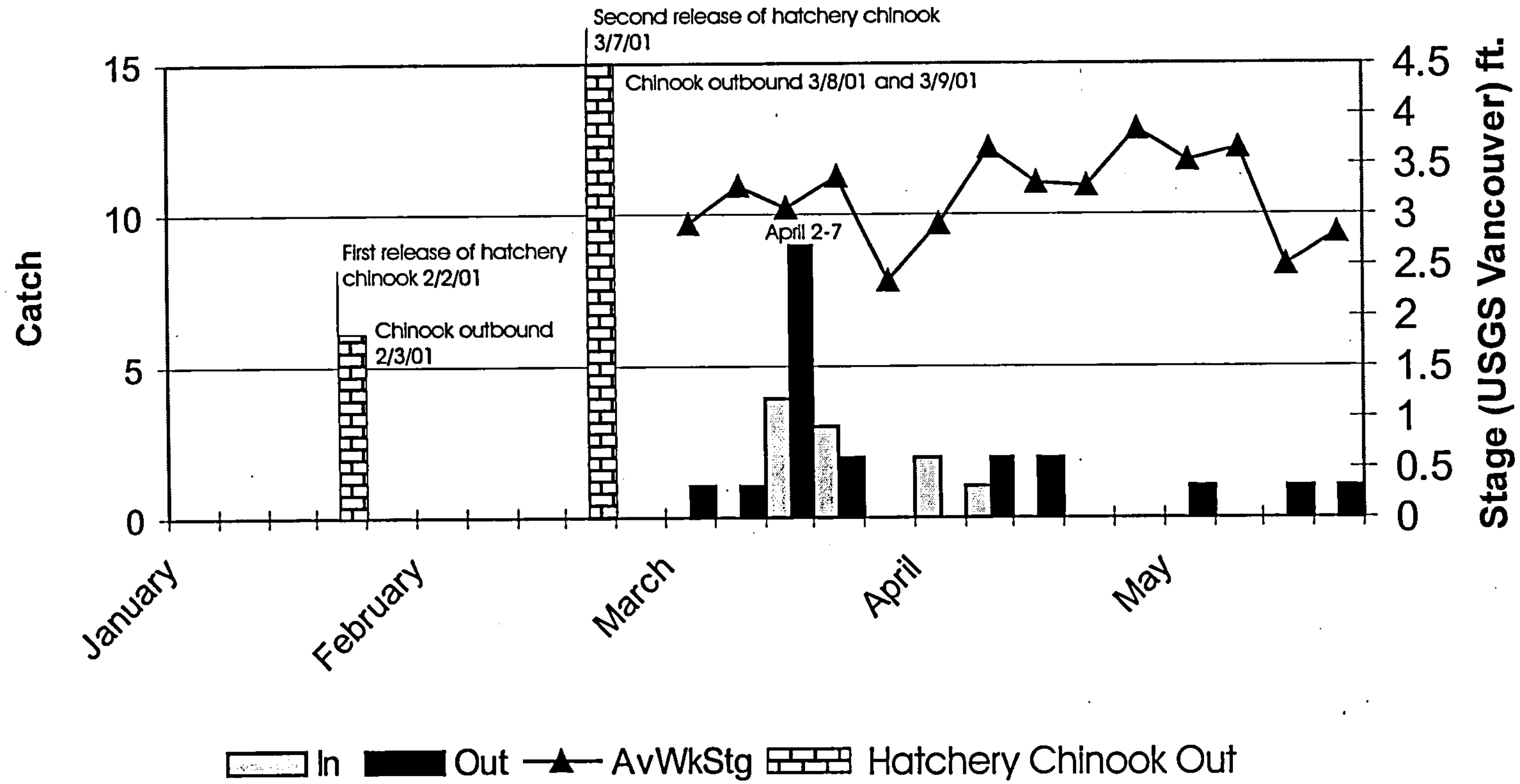


Figure 21. Spring Run-off in the Columbia River at Vancouver, Washington 2001 and 2002

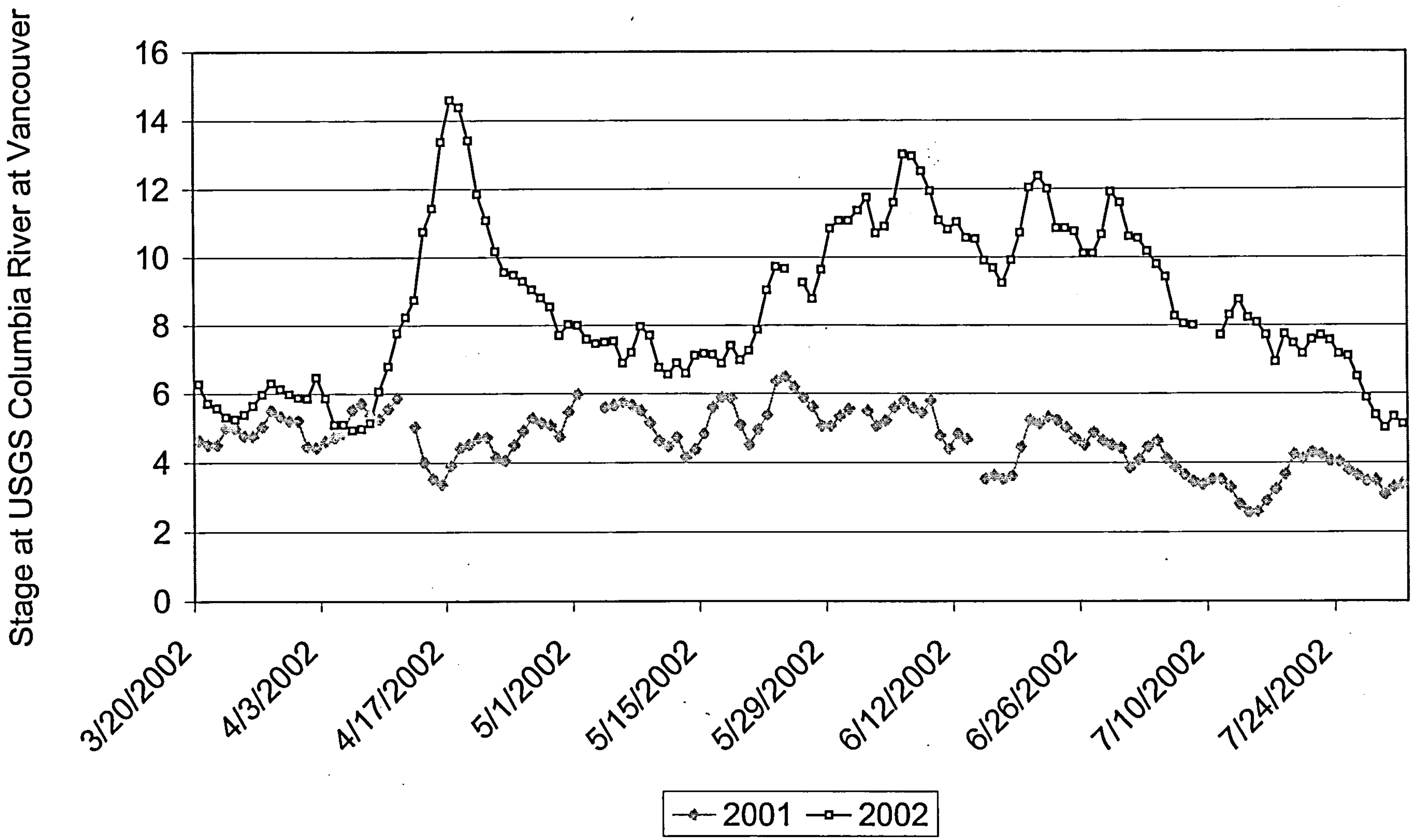


Figure 22. Comparison of Maximum Daily Temperatures at three sites from April 12-24, 2002

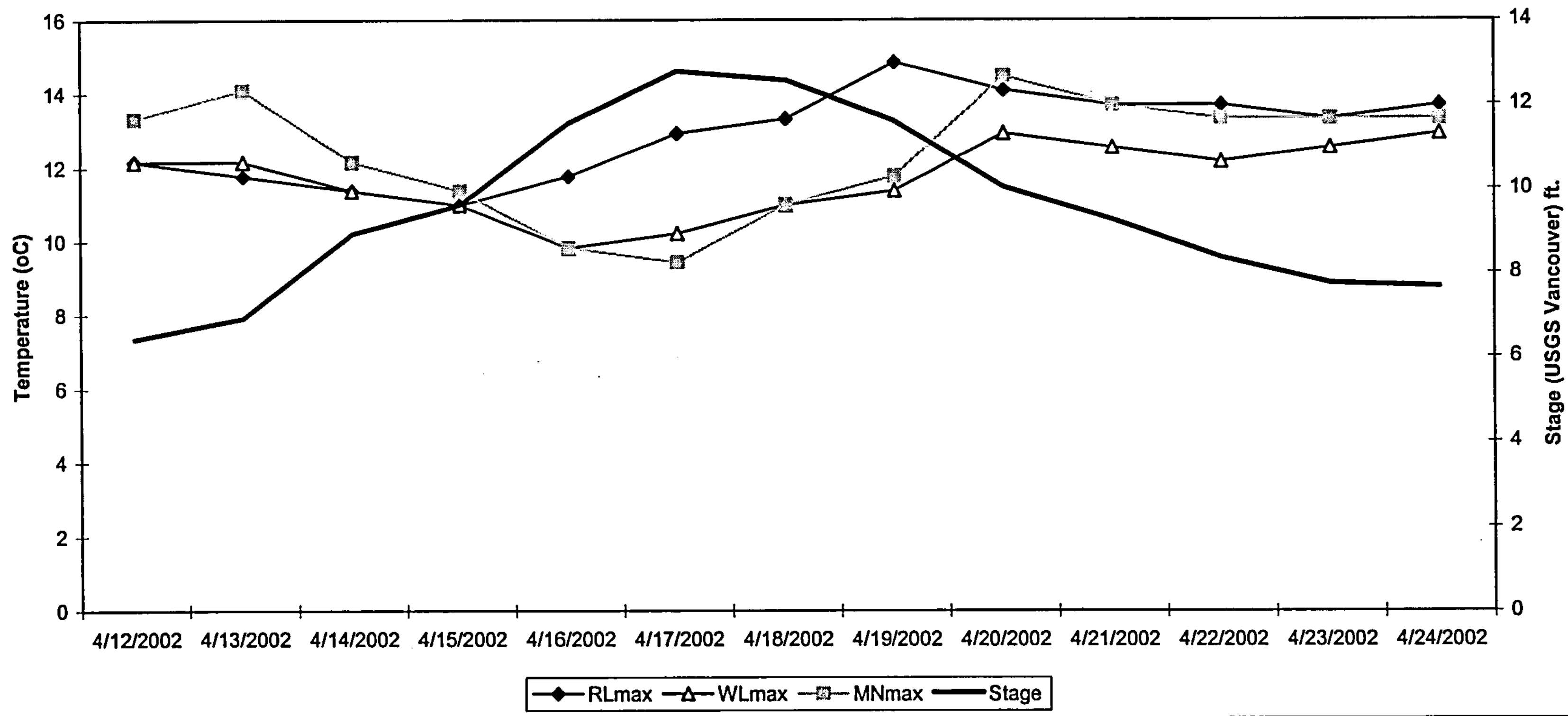


Table 1. List of species presence from catch in two-way traps and wetland sampling (WS).

NATIVE	FAMILY	RL* TRAP	RL WS	WL TRAP	WL WS	MN TRAP	MN WS
Largescale sucker	Catostomidae		X	X		X	X
Prickly sculpin	Cottidae	X	X	X	X	X	X
Northern pikeminnow	Cyprinidae	X	X	X	X	X	X
Peamouth	Cyprinidae	X		X		X	X
Redside shiner	Cyprinidae	X	X	X	X	X	X
Threespined stickleback	Gasterosteidae	X	X	X	X	X	X
Chinook salmon	Salmonidae	X		X	X	X	X
Coho salmon	Salmonidae	X	X	X		X	X
Rainbow trout	Salmonidae					X	
TOTAL NATIVE		**7**	**6**	**8**	**5**	**9**	**8**
INTRODUCED	**FAMILY**	**RL TRAP**	**RL WS**	**WL TRAP**	**WL WS**	**MN TRAP**	**MN WS**
Black crappie	Centrarchidae	X	X	X	X	X	X
Bluegill	Centrarchidae	X	X			X	X
Largemouth bass	Centrarchidae	X	X	X	X	X	X
Pumpkinseed	Centrarchidae	X	X	X	X	X	X
Warmouth	Centrarchidae	X		X		X	X
White crappie	Centrarchidae	X	X	X	X	X	X
Oriental weatherfish	Cobitidae			X	X	X	X
Common carp	Cyprinidae	X	X	X	X	X	X
Goldfish	Cyprinidae					X	
Banded killifish	Cyprinodontidae	X	X	X	X	X	X
Brown bullhead	Ictaluridae	X	X	X	X	X	X
Yellow bullhead	Ictaluridae	X				X	X
Yellow perch	Percidae	X	X	X	X	X	X
Mosquitofish	Poeciliidae		X				X
TOTAL INTRODUCED		**11**	**10**	**10**	**9**	**13**	**13**
GRAND TOTAL		**18**	**16**	**18**	**14**	**22**	**21**

*RL=Ruby Lake, WL=Wigeon Lake, MN=Multnomah North

Table 3. All fishes caught in INBOUND 2-way trap at Ruby Lake.

Family	Common Name	Number	MIN_FL (mm)*	MAX_FL (mm)	WT (g)
Cottidae	Prickly sculpin	36	30	160	417
Cyprinidae	Northern pikeminnow	2	80	86	12
Cyprinidae	Peamouth	3	95	170	93
Gasterosteidae	Threespined stickleback	64	45	70	128
Salmonidae	Chinook salmon	10	60	110	112
Salmonidae	Coho salmon	23	65	124	311
Total Native		**138**			**1072**
Centrarchidae	Black crappie	16	39	260	828
Centrarchidae	Bluegill	1	47	47	2
Centrarchidae	Crappie spp.	9	43	83	23
Centrarchidae	Largemouth bass	8	40	221	169
Centrarchidae	Pumpkinseed	9	43	80	44
Centrarchidae	Warmouth	1	60	60	6
Centrarchidae	White crappie	37	60	185	406
Cyprinidae	Common carp	664	30	350	2042
Cyprinodontidae	Banded killifish	10	71	97	67
Ictaluridae	Brown bullhead	236	42	260	20722
Ictaluridae	Yellow bullhead	1	240	240	200
Total Intro		**992**			**24511**
Grand Total		**1130**			**25583**

Table 4. All fishes caught in the OUTBOUND 2-way trap at Ruby Lake.

Family	Common Name	Number	MIN_FL (mm)	MAX_FL (mm)	WT (g)
Cottidae	Prickly sculpin	52	38	178	992
Cyprinidae	Peamouth	4	194	265	697
Cyprinidae	Redside shiner	2	95	95	20
Gasterosteidae	Threespined stickleback	77	41	73	160
Salmonidae	Chinook salmon	7	92	178	208
Salmonidae	Coho salmon	24	70	175	885
Total Native		**166**			**2965**
Centrarchidae	Black crappie	13	75	215	724
Centrarchidae	Crappie spp.	66	40	78	97
Centrarchidae	Largemouth bass	1	76	76	5
Centrarchidae	Pumpkinseed	7	50	125	108
Centrarchidae	Warmouth	3	43	65	12
Centrarchidae	White crappie	27	55	260	1398
Cyprinidae	Common carp	352	35	185	770
Cyprinodontidae	Banded killifish	63	57	164	342
Ictaluridae	Brown bullhead	224	42	245	3432
Ictaluridae	Yellow bullhead	1	218	218	149
Percidae	Yellow bullhead	5	70	152	140
Total Intro		**762**			**7182**
Grand Total		**928**			**10147**

*Minimum and Maximum FL=fork length

Table 5. All fishes caught in the INBOUND 2-way trap at Wigeon Lake.

Family	Common Name	Number	MIN_FL (mm)*	MAX_FL (mm)	WT (g)
Cottidae	Prickly sculpin	86	40	183	1767
Cyprinidae	Peamouth	1	110	110	16
Cyprinidae	Redside shiner	1	87	87	8
Gasterosteidae	Threespined stickleback	201	21	76	378
Salmonidae	Chinook salmon	4	55	82	25
Salmonidae	Coho salmon	14	70	145	245
Total Native		**307**			**2439**
Centrarchidae	Black crappie	1	85	85	10
Centrarchidae	Crappie spp.	32	45	104	99
Centrarchidae	Largemouth bass	35	40	80	80
Centrarchidae	Pumpkinseed	24	43	110	291
Centrarchidae	Warmouth	1	85	85	17
Centrarchidae	White crappie	11	45	125	76
Cobitidae	Oriental weatherfish	1	145	145	60
Cyprinidae	Common carp	247	35	120	437
Cyprinodontidae	Banded killifish	160	40	99	694
Ictaluridae	Brown bullhead	57	40	238	421
Percidae	Yellow perch	18	49	170	193
Total Intro		**587**			**2377**
Grand Total		**894**			**4816**

Table 6. All fishes caught in the OUTBOUND 2-way trap at Wigeon Lake.

Family	Common Name	Number	MIN_FL (mm)	MAX_FL (mm)	WT (g)
Cottidae	Prickly sculpin	66	40	166	1289
Cyprinidae	Northern pikeminnow	4	85	155	66
Cyprinidae	Peamouth	10	170	255	1385
Gasterosteidae	Threespined stickleback	117	50	75	232
Salmonidae	Chinook salmon	4	75	101	46
Salmonidae	Coho salmon	5	65	125	71
Total Native		**206**			**3088**
Centrarchidae	Black crappie	53	40	240	2555
Centrarchidae	Crappie spp.	4	45	65	6
Centrarchidae	Largemouth bass	4	44	62	6
Centrarchidae	Pumpkinseed	5	70	130	171
Centrarchidae	Warmouth	2	60	63	13
Centrarchidae	White crappie	8	45	231	417
Cobitidae	Oriental weatherfish	2	67	68	11
Cyprinidae	Common carp	86	35	198	229
Cyprinodontidae	Banded killifish	173	39	95	732
Ictaluridae	Brown bullhead	151	40	240	829
Percidae	Yellow perch	4	73	90	25
Total Intro		**492**			**4994**
Grand Total		**698**			**8082**

*Minimum and Maximum FL=fork length

Table 7. All fishes caught in the INBOUND 2-way trap in Mulnomah North.

Family	Common Name	Number	MIN_FL (mm)*	MAX_FL (mm)	WT (g)
Catostomidae	Largescale sucker	4	365	397	2415
Cottidae	Prickly sculpin	77	35	190	1777
Cyprinidae	Northern pikeminnow	5	90	145	113
Cyprinidae	Peamouth	1	229	229	147
Cyprinidae	Redside shiner	1	53	53	2
Gasterosteidae	Threespined stickleback	158	23	70	275
Salmonidae	Chinook salmon	16	69	149	273
Salmonidae	Coho salmon	27	47	115	322
Salmonidae	Rainbow trout	2	205	257	0
Total Native		**291**			**5323**
Centrarchidae	Black crappie	12	145	235	1311
Centrarchidae	Bluegill	1	70	70	7
Centrarchidae	Crappie spp.	25	26	56	16
Centrarchidae	Largemouth bass	1	70	70	4
Centrarchidae	Pumpkinseed	36	40	170	1013
Centrarchidae	Warmouth	14	52	147	322
Centrarchidae	White crappie	21	85	265	1419
Cobitidae	Oriental weatherfish	2	190	240	419
Cyprinidae	Common carp	27	29	240	367
Cyprinidae	Goldfish	1	210	210	86
Cyprinodontidae	Banded killifish	87	59	96	394
Ictaluridae	Brown bullhead	20	110	269	3233
Ictaluridae	Yellow bullhead	3	241	255	657
Percidae	Yellow perch	16	70	205	718
Total Intro.		**266**			**9966**
Grand Total		**557**			**15289**

Table 8. All fishes caught in the OUTBOUND 2-way trap at Multnomah North.

Family	Common Name	Number	MIN_FL (mm)	MAX_FL (mm)	WT (g)
Catostomidae	Largescale sucker	12	275	400	6278
Cottidae	Prickly sculpin	375	43	202	12104
Cyprinidae	Northern pikeminnow	3	65	165	56
Cyprinidae	Peamouth	1	120	120	20
Gasterosteidae	Threespined stickleback	69	39	70	127
Salmonidae	Chinook salmon	40	70	114	425
Salmonidae	Coho salmon	11	65	149	228
Salmonidae	Rainbow trout	1	258	258	0
Total Native		**512**			**19241**
Centrarchidae	Black crappie	194	65	234	18603
Centrarchidae	Crappie spp.	4	60	65	8
Centrarchidae	Largemouth bass	4	65	84	18
Centrarchidae	Pumpkinseed	25	40	167	724
Centrarchidae	Warmouth	1	93	93	22
Centrarchidae	White crappie	48	35	238	2913
Cyprinidae	Common carp	57	40	418	10294
Cyprinidae	Goldfish	3	56	243	222
Cyprinodontidae	Banded killifish	17	60	90	90
Ictaluridae	Brown bullhead	22	127	315	4177
Percidae	Yellow perch	87	70	275	4025
Total Intro.		**462**			**41101**
Grand Total		**974**			**60342**

*Minimum and Maximum FL=fork length

Table 11. All fishes caught in SSWS at Ruby Lake (January, April, July 2002).

Family	Common Name	Number	MIN_FL (mm)*	MAX_FL (mm)	WT (g)
Catostomidae	Largescale sucker	1	65	65	3
Cottidae	Prickly sculpin	1	141	141	35
Cyprinidae	Northern pikeminnow	2	68	116	19
Cyprinidae	Redside shiner	12	40	106	53
Gasterosteidae	Threespined stickleback	2180	30	71	1738
Salmonidae	Coho salmon	2	91	98	27
Total Native		**2198**			**1874**
Centrarchidae	Black crappie	1	92	92	12
Centrarchidae	Bluegill	4	22	138	57
Centrarchidae	Crappie spp.	154	30	80	222
Centrarchidae	Largemouth bass	20	40	80	50
Centrarchidae	Pumpkinseed	4	65	105	65
Centrarchidae	White crappie	2	87	92	15
Cyprinidae	Common carp	298	55	540	5015
Cyprinodontidae	Banded killifish	23	58	91	110
Ictaluridae	Brown bullhead	433	42	219	978
Percidae	Yellow perch	9	53	184	112
Poeciliidae	Mosquitofish	1	40	40	1
Total Intro		**949**			**6637**
Grand Total		**3147**			**8511**

Table 12. All fishes caught in SSWS at Wigeon Lake (April, July 2002).

Family	Common Name	Number	MIN_FL (mm)	MAX_FL (mm)	WT (g)
Cottidae	Prickly sculpin	21	36	188	693
Cyprinidae	Northern pikeminnow	4	38	95	11
Cyprinidae	Redside shiner	3	54	65	8
Gasterosteidae	Threespined stickleback	330	25	65	334
Salmonidae	Chinook salmon	2	61	69	10
Total Native		**360**			**1057**
Centrarchidae	Bluegill	3	40	56	6
Centrarchidae	Crappie spp.	72	39	58	67
Centrarchidae	Largemouth bass	105	34	57	98
Centrarchidae	Pumpkinseed	3	45	118	69
Centrarchidae	White crappie	1	82	82	5
Cobitidae	Oriental weatherfish	1	100	100	19
Cyprinidae	Common carp	1224	29	205	1747
Cyprinodontidae	Banded killifish	27	32	90	84
Ictaluridae	Brown bullhead	6	42	260	476
Percidae	Yellow perch	5	62	71	19
Total Intro		**1447**			**2592**
Grand Total		**1807**			**3650**

*Minimum and Maximum FL=fork length

Table 13. All fishes caught in SSWS at Mulnomah North (Dec. 2001, Jan., Mar., Apr., June, July 2002).

Family	Common Name	Number	MIN_FL (mm)*	MAX_FL (mm)	WT (g)
Catostomidae	Largescale sucker	69	30	440	940
Cottidae	Prickly sculpin	91	82	194	3157
Cyprinidae	Northern pikeminnow	20	34	75	23
Cyprinidae	Peamouth	6	56	89	32
Cyprinidae	Redside shiner	74	25	97	68
Gasterosteidae	Threespined stickleback	2643	17	79	3818
Salmonidae	Chinook salmon	17	50	119	156
Salmonidae	Coho salmon	22	83	130	373
Salmonidae	Unknown salmon	19	32	58	34
Total Native		**2961**			**8601**
Centrarchidae	Black crappie	7	66	91	65
Centrarchidae	Bluegill	43	25	107	114
Centrarchidae	Crappie spp.	77	29	60	56
Centrarchidae	Largemouth bass	6	55	76	19
Centrarchidae	Pumpkinseed	26	42	137	706
Centrarchidae	Warmouth	10	50	145	351
Centrarchidae	White crappie	2	189	193	191
Cobitidae	Oriental weatherfish	7	97	170	498
Cyprinidae	Common carp	4833	18	589	5740
Cyprinodontidae	Banded killifish	9	61	110	52
Ictaluridae	Brown bullhead	2	103	175	88
Ictaluridae	Yellow bullhead	1	236	236	190
Percidae	Yellow perch	5	65	242	356
Poeciliidae	Mosquitofish	2	24	25	0
Total Intro		**5030**			**8425**
Grand Total		**7991**			**17026**

Table 14. All fishes caught in SSWS at Multnomah South (June 2002).

Family	Common Name	Number	MIN_FL (mm)	MAX_FL (mm)	WT (g)
Gasterosteidae	Threespined stickleback	24	57	4620	767
Petromyzontidae	Pacific lamprey	120	140	3	11
Total Native				**4623**	**779**
Centrarchidae	Bluegill	41	63	2	7
Centrarchidae	Pumpkinseed	105	115	5	166
Centrarchidae	Warmouth	107	107	1	34
Cobitidae	Oriental weatherfish	120	190	17	1281
Cyprinodontidae	Banded killifish	57	57	1	2
Poeciliidae	Mosquitofish	25	51	229	111
Total Intro				**255**	**1601**
Grand Total				**4878**	**2380**

*Minimum and Maximum FL=fork length

Table 15. Comparison of Fishes Caught (by numbers) at all sampling sites and periods.

Site	Sampling period	%Native	%Intro	Total No. Fish Caught	Dominant Fish	No. salmon
MN	December	97	3	1882	TSS (94%)	19
RL	**January**	**99**	**1**	**821**	**TSS (98%)**	**2**
MN	**January**	**98**	**2**	**244**	**TSS (80%)**	**9**
MN	March	87	13	54	PRS (30%)	15
RL	**April**	**70**	**30**	**20**	**TSS (65%)**	**0**
WL	**April**	**92**	**8**	**238**	**TSS (81%)**	**2**
MN	**April**	**96**	**4**	**648**	**TSS (90%)**	**15**
MN	June*	67	33	36	TSS (58%)	0
MS	June	95	5	4878	TSS (95%)	0
RL	**July**	**60**	**40**	**2306**	**TSS (59%)**	**0**
WL	**July***	**9**	**91**	**1569**	**CAP (78%)**	**0**
MN	**July**	**4**	**96**	**4925**	**CAP (98%)**	**0**

*Effort was only half of regular SSWS
MN=Multnomah North, MS=Multnomah South, RL=Ruby Lake, WL=Wigeon Lake
TSS=threespine stickleback, PRS=prickly sculpin, CAP=carp

Table 16. Comparison of Fishes Caught (by weight) at all sampling sites and periods.

Site	Sampling period	%Native	%Introduced	Total Grams Fish Caught	Dominant Fish
MN	December	94	6	4216	TSS (64%)
RL	**January**	**89**	**11**	**1192**	**TSS (81%)**
MN	**January**	**84**	**16**	**1292**	**PRS (54%)**
MN	March	87	13	773	PRS (68%)
RL	**April**	**2**	**98**	**3582**	**CAP (98%)**
WL	**April**	**74**	**26**	**1352**	**PRS (51%)**
MN	**April**	**43**	**57**	**4296**	**CAP (39%)**
MN	June*	38	62	1528	CAP (70%)
MS	June	33	67	2379	OWF (54%)
RL	**July**	**26**	**74**	**3558**	**CAP (39%)**
WL	**July***	**2**	**98**	**2288**	**CAP (76%)**
MN	**July**	**2**	**98**	**3962**	**CAP (73%)**

* Effort was only half of regular SSWS
OWL=oriental weatherfish

Table 18. Average catch (by numbers) in all box traps.

Site	Month	Mean	Std. Dev.	N
Ruby	Jan	113.3	114.6	4
Ruby	July	133.5	66.2	4
Wigeon	April	47.8	52.2	4
Wigeon	July	547.0	328.1	2
Mult. N.	Dec	36.5	44.0	4
Mult. N.	Jan	31.5	25.0	4
Mult. N.	Mar	5.0	7.4	4
Mult. N.	April	153.8	197.5	4
Mult. N.	Jun	13.0	4.2	2
Mult. N.	July	1044.5	842.5	4
Mult. S.	Jun	274.5	221.1	4
	Mean =	218.2		
	SE =	95.3		

Table 19. Average catch (by numbers) in all fyke nets.

Site	Month	Mean	Std. Dev.	N
Ruby	Jan	92.0	60.1	4
Ruby	July	443.0	523.3	4
Wigeon	April	11.8	11.0	4
Wigeon	July	237.5	116.7	2
Mult. N.	Dec	434.0	360.8	4
Mult. N.	Jan	29.5	17.2	4
Mult. N.	Mar	8.5	6.9	4
Mult. N.	April	8.3	6.6	4
Mult. N.	Jun	5.0	1.4	2
Mult. N.	July	237.3	221.8	4
Mult. S.	Jun	945.0	1553.9	4
	Mean =	222.9		
	SE =	88.1		