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Julie A. Henning for the degree of Master of Science in Fisheries Science presented on February 28, 2005.

Title: Floodplain Emergent Wetlands as Rearing Habitat for Fishes and the Implications for Wetland Enhancement.

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Abstract approved: ______________________________

Robert E. Gresswell Ian A. Fleming

Seasonal emergent wetlands in the Pacific Northwest have not been regarded traditionally as fish rearing habitat, despite access to such habitat when river flows overtop riverbanks and connect to the floodplain. As a result, restoration and enhancement projects to remediate for the loss of such wetland habitat are being implemented for waterfowl and other wildlife with little consideration for fishes such as juvenile salmon (*Oncorhynchus* spp.). The objectives of this study were to examine the degree to which fish utilize emergent wetlands and to determine the influence of wetland enhancement on fish communities in the Chehalis River floodplain. Furthermore, I quantified the influence of enhanced wetlands on juvenile coho salmon. A minimum of 18 fish species utilized floodplain wetlands, and the most abundant were three-spine stickleback (*Gasterosteus aculeatus*) and Olympic mudminnow (*Novumbra hubbsi*). Both enhanced and unenhanced emergent wetlands had higher abundances of nongame native fishes than oxbow habitats. Coho salmon (*Oncorhynchus kisutch*) was the dominant salmonid at all sites and enhanced wetlands had significantly higher abundances of yearling coho salmon than unenhanced wetlands. Dissolved oxygen concentrations decreased in emergent wetlands throughout the season and were near lethal limits for juvenile salmon by June each year. Survival of fishes utilizing emergent wetlands was dependent on movement to the river before water quality decreased and/or the wetland became isolated and stranding occurred. Emigration patterns suggested that coho salmon yearling and young-of-the-year emigrated as habitat conditions declined. This was further supported by the results of the experimental release of yearling coho salmon. Yearling coho salmon benefited from rearing in enhanced wetland habitats where their growth and survival were comparable to studies of juvenile coho off-channel habitats.

Floodplain Emergent Wetlands as Rearing Habitat for Fishes and the Implications for Wetland Enhancement

by
Julie A. Henning

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Julie A. Henning, Author

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CONTRIBUTION OF AUTHORS

Bob Gresswell contributed in developing the experimental design and editing of Chapters 2 and 3.

Ian Fleming contributed in developing the experimental design and editing of Chapters 2 and 3.

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Chapter 1: Introduction

Emergent wetlands are common features of large river-floodplain systems and can maintain high production related to periodic flooding with the decomposition of organic matter and nutrients, and these materials can result in high yields of fish (Bayley 1991, 1995). These wetlands are on the floodplain, and under normal surface water conditions have no surface inlet to provide access for riverine fishes. During periods of high water, rivers may overflow onto the floodplain, establishing temporary connections between the two systems (Snodgrass et al. 1996) and providing fish access to wetland habitats. Degradation of floodplain wetlands (e.g., emergent marshes, beaver ponds, and remnant oxbows) has nearly eliminated opportunities to assess the importance of these habitats under historical conditions.

In recent years, however, we have become increasingly aware of the value of wetland habitats, and rehabilitation of degraded habitats has become an important tool to compensate for declines in wetland acreage and functional losses (Ratti et al. 2001). Common approaches to enhance wetlands on agricultural land often include a mechanism to retard the rate of water drainage. This is often accomplished by blocking drainage ditches or installing water control structures to retain water within the wetland floodplain area. In addition, decreasing the rate of drainage can facilitate longer connectivity between the river and floodplain.

In a floodplain environment of the Pacific Northwest, a variety of fishes, including salmonids, have the potential to access and benefit from seasonal emergent wetlands in a floodplain. Floodplain wetlands may serve directly as important rearing habitat (i.e., feeding and refuge) and indirectly as a source of primary and secondary production for the main river channel. Threatened and endangered Pacific salmon (*Oncorhynchus* spp.) and the Olympic mudminnow (*Novumbra hubbsi*), a Washington State Sensitive Species, inhabit floodplain wetlands and underscore the need to understand the effects of agricultural wetlands and floodplain wetland enhancements on fitness of these important native fishes. Uncertainties of river-floodplain relationships, the diversity of wetland habitats in floodplains, and the sampling problems associated with seasonal habitats contribute to the paucity of floodplain wetland fish literature (Sommer et al. 2001). Although wetland enhancement techniques (i.e., water control structures and water drawdowns) have focused on benefits for wildlife (Fredrickson and Taylor 1982; Fredrickson and Reid 1988), our knowledge about the suitability of such restoration measures for fishes and their use of floodplain emergent wetlands is minimal.

In this thesis, I synthesize data that describe the utilization of floodplain emergent wetlands by fishes in the Chehalis River. The second chapter examines the degree to which fish utilize emergent wetlands and evaluates the effectiveness of wetland enhancement for fishes. To evaluate wetland enhancement, fish abundance in enhanced emergent wetlands (with water control structures) was compared to unenhanced emergent wetlands (without water control structures) and oxbow habitats. The third chapter focuses on the influence that enhanced wetlands may have on juvenile coho salmon (*Oncorhynchus kisutch*). I describe growth, survival, and emigration of coho yearlings rearing in enhanced wetlands through observation of natural patterns, as well as by experimentation, and describe how wetland dissolved oxygen concentrations may influence those characteristics. The final chapter provides a summary of the major conclusions of the work.

Chapter 2: The role of enhanced seasonal wetlands for fishes in a temperate river-floodplain

Abstract

Frequently, wetland restoration and enhancement projects are undertaken to increase waterfowl and shorebird production and amphibian breeding, while providing conditions to promote the recruitment of native vegetation. The effects on fish populations, however, have received little attention, particularly for projects undertaken in seasonal floodplain habitats, where our understanding of habitat utilization by fish is rudimentary at best. The objective of this study was to examine the degree to which fish utilize emergent wetlands and to determine the effect of wetland enhancement on fishes in the Chehalis River floodplain. Fish utilization was examined in six study sites: four emergent wetlands and two oxbow habitats using fyke nets and emigrant traps. Eighteen fish species were captured, with the most abundant being three-spine stickleback (*Gasterosteus aculeatus*) and Olympic mudminnow (*Novumbra hubbsi*). Coho salmon (*Oncorhynchus kisutch*) was the dominant salmonid at all sites, and enhanced wetlands had significantly higher abundances of yearling coho salmon than unenhanced wetlands. Both enhanced and unenhanced emergent wetlands yielded higher abundances of nongame native fishes than oxbow habitats. However, oxbow habitats were dominated by coho salmon. Fish survival in wetland habitats was dependent on emigration to the river before water quality decreased (i.e., dissolved oxygen concentrations), and wetlands became isolated and stranding occurred. Wetland enhancement projects that have an outlet to the river channel can provide fish important temporary habitats if they have the opportunity to leave the wetland as habitat conditions decline.

Introduction

Conversion of wetlands to agricultural use is a major cause of wetland loss in the United States (Mitsch and Gosselink 1994) and other regions of the world (Finlayson and Davidson 1999), particularly in river floodplain valleys, where fertile soils are drained and cultivated to produce crops. Degradation of floodplain wetlands (e.g., emergent marshes, beaver ponds, and remnant oxbows) has nearly eliminated opportunities to assess the importance of these habitats under historical conditions. In addition, in most temperate river systems humans have substantially modified peak discharge and reduced the river-floodplain connection (Junk et al. 1989). The river-floodplain hydrological regimen is critical for maintaining biological and physical diversity (Bayley 1995; Poff et al. 1997; Michener and Haeuber 1998). In relatively undisturbed river-floodplains, floods inundate large areas, increasing the availability of food and shelter for fish and other aquatic and semi-aquatic organisms as floodwaters flow over riverbanks (Welcomme 1979). This flooding process can maintain high production due to the decomposition of organic matter and release of nutrients that ultimately influence the yields of fish (Bayley 1991, 1995).

The awareness of the value of wetland habitats has gradually increased, and the rehabilitation and creation of such habitats are becoming important tools for compensating for declines and functional losses (Ratti et al. 2001). Wetland restoration projects have focused on rehabilitating wetland hydrology to facilitate wetland habitat characteristics, including aquatic habitat connectivity, productivity, and native emergent vegetation. These characteristics provide critical habitat for migratory wildlife, and threatened and endangered aquatic and semi-aquatic wildlife and plant species. Wetland restoration and enhancement activities in North America have become an integral component of conservation efforts under such programs as the Natural Resources Conservation Service (NRCS) Wetland Reserve Program and U.S. Fish and Wildlife Service North American Wetlands Conservation Act. These agency programs have enhanced and protected over 9.5 million hectares of wetlands and associated uplands in North American since the initiation of these programs in 1989 and 1990 (North American Wetlands Conservation Act 2005; NRCS 2004).

Common approaches to enhance agricultural wetlands often include a mechanism to retard the rate of water drainage. This is often accomplished by blocking drainage ditches or installing water control structures to retain water within the wetland floodplain area. Decreasing the rate of drainage can facilitate longer connectivity between the river and floodplain. In addition, a water control structure can be manipulated to vary wetland water depths through the year. Enhancing wetland hydrology can reduce the impacts of nonnative invasive plants, such as reed canarygrass (*Phalaris arundinacea*), and enhance conditions for native emergent vegetation. Although, wetland restoration techniques (i.e., water control structures and water drawdowns) for vegetation and waterfowl are well established (Fredrickson and Taylor 1982; Fredrickson and Reid 1988), our knowledge of the implications of such restoration measures for fishes and their use of floodplain emergent wetlands remains rudimentary.

Temperate wetland studies have focused on invertebrates, waterfowl, and amphibian populations (Kaminski and Prince 1981; Murkin et al. 1982; Safran et al. 1997), but few studies have examined emergent wetlands as fish habitat. In a floodplain environment of the Pacific Coasts of the United States and Canada a variety of fishes, including salmonids, have the potential of accessing and benefiting from seasonal emergent wetlands in the floodplain. For example, Sommer et al. (2001) found that the lower Sacramento River floodplain provided better rearing habitat for juvenile Chinook salmon (*Oncorhynchus tshawytscha*) than adjacent river channels. Floodplain wetlands may serve directly as important rearing habitat (i.e., feeding and refuge) and indirectly as a source of primary and secondary production for the main river channel. Threatened and endangered Pacific salmon (*Oncorhynchus* spp.) and the Olympic mudminnow (*Novumbra hubbsi*), a Washington State Sensitive Species, inhabit floodplain wetlands and underscore the need to understand the affects of agricultural wetlands and floodplain wetland restorations on fitness of these important native fishes. Uncertainties of river-floodplain relationships, the diversity of wetland habitats in floodplains, and the sampling problems associated with seasonal habitats contribute to the paucity of floodplain wetland fish literature (Sommer et al. 2001).

The purpose of this paper was to examine the degree to which fish utilize emergent wetlands and to determine the effect of wetland restoration on fishes. This was done by quantifying and comparing fish use across two enhanced wetlands, two unenhanced wetlands, and two oxbow habitats.

Methods

Study Area

The study was conducted January - June 2003 in an agricultural floodplain landscape of the Chehalis River, in southwest Washington, USA (Figure 1). The Chehalis River Basin is the third largest river basin in the State of Washington, with a drainage area of approximately 6,900 km^2. Study sites were located in the lower Chehalis Basin (below river kilometer 60), where the river is unconstrained and moves sinuously through the floodplain in the broad flat valley floor. The basin was chosen for sampling because of the large size and relatively intact and minimally degraded floodplain. Although ditching and draining for conversion to cropland or pasture has occurred in the Chehalis River Valley, there are few levees and no mainstem dams to affect the hydrograph. The Chehalis River system is largely rain-fed with precipitation levels of 152-203 cm annually, and average temperatures are 3.3 °C to 4.4 °C in January and 15 °C to 17.8 °C in July.

Six study sites were sampled: four emergent wetlands and two oxbow habitats in the Chehalis River floodplain between river kilometer 27 and 60 (Figure 1; Table 1). Of the four emergent wetlands, two were enhanced sites with water control structures (E1 and E2), and two were unenhanced wetlands (U1 and U2) without water control structures. One oxbow site, O1, was a remnant oxbow with a beaver dam that contained permanent water and was connected to the river by a tributary, and the other oxbow site, O2, was a seasonal oxbow off the mainstem river (Table 1).

Enhanced Wetlands

Enhanced wetlands E1 and E2 contained rennie and salzer clays (U.S. Department of Agriculture, Soil Conservation Service 1986) and were drained as part of a local drainage district project to facilitate farming. These clays are deep, poorly drained, hydric soils that are subject to frequent periods of flooding from November to April (U.S. Department

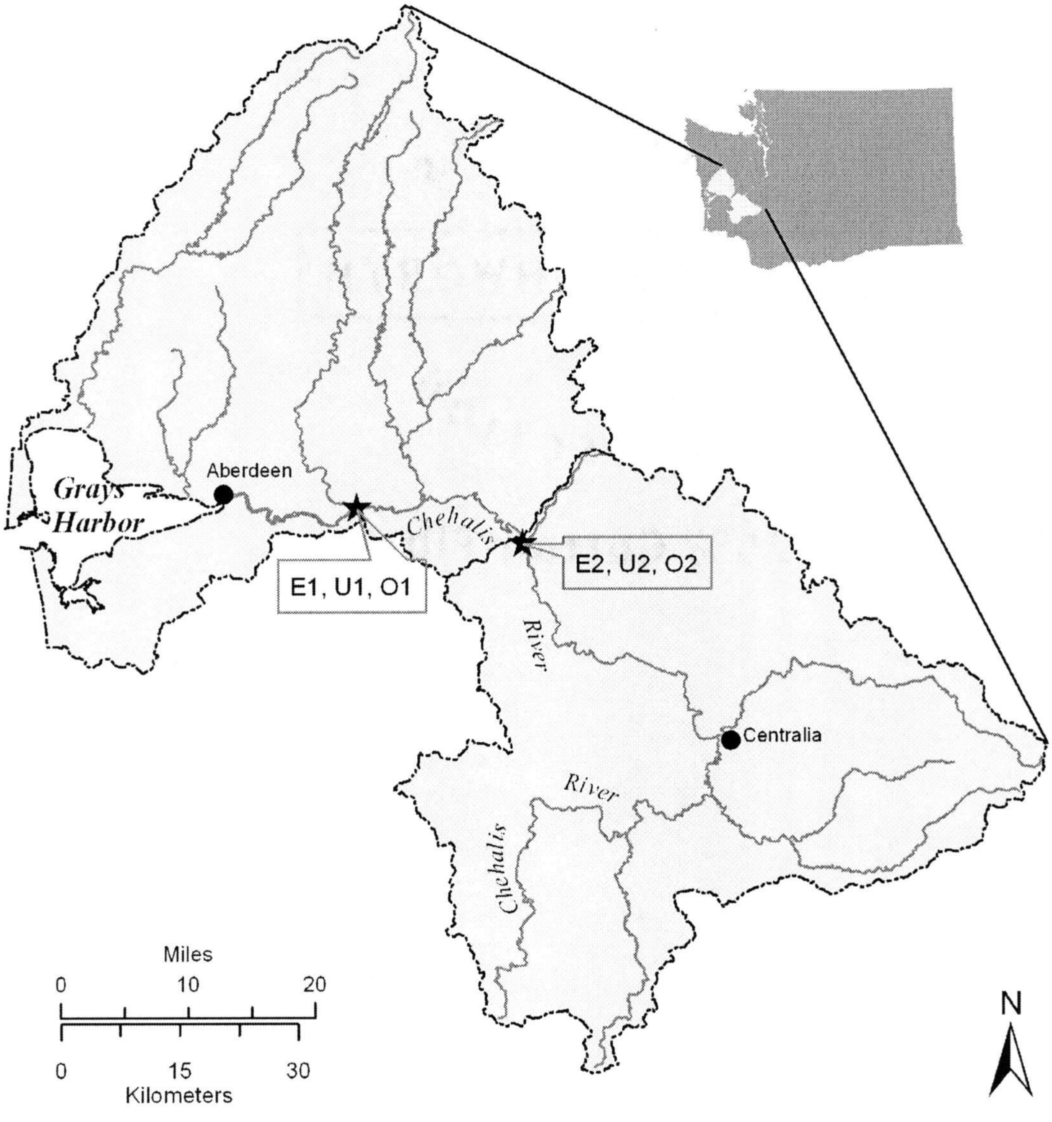

Figure 1. Location of study sites within the Chehalis River Basin, Washington. Enhanced wetlands E1 and E2, unenhanced wetlands U1 and U2, and oxbow habitats O1 and O2.

Table 1. Characteristics of the six study sites: two enhanced wetlands (E1 and E2), two unenhanced wetlands (U1 and U2), and two oxbow habitats (O1 and O2), in the lower Chehalis River, Washington. The months in parentheses represent the dates when sites U1, U2 and O2 became dry.

Study Site	River km	Surface Area (ha)		Winter Depth (m)	Water Sources (order of dominance)	Water Input	Dominant Vegetation
		Winter	Summer				Wetland Edge
E1	27.4	14.5	0.5	1.0	rain,river	Seasonal	*Phalaris arundinacea*
U1	27.4	3	0 (May)	0.5	rain, river	Seasonal	*P. arundinacea*
O1	30.6	4	4	3.0	spring, rain, river	Permanent	woody species
E2	57.9	7.3	1	1.5	rain, runoff, river	Seasonal	*P. arundinacea*
U2	59.5	1	0 (July)	1.0	rain, runoff, river	Seasonal	*P. arundinacea*
O2	53.1	3	0 (May)	1.0-3.0	river, rain, runoff	Seasonal	*P. arundinacea*

of Agriculture, Soil Conservation Service 1986). Wetland enhancements occurred in 1997-1998 and involved blocking drainage ditches by constructing water control structures and levees. Water control structures enhanced wetland hydrology by retaining water, and levees kept water within the project area to avoid flooding of adjacent lands. Water accumulation provided conditions for a diversity of emergent vegetation and reduced nonnative reed canarygrass. In addition, water control structures created a defined outlet without draining the wetland. This outlet connected the wetland to a stream and enhanced fish emigration. Fish access into the wetlands occurred during flood conditions.

Hydrologic patterns at E1 and E2 were similar (Table 1), but the hydrologic connection between the river and E1 was increased by freshwater tidal influences during periods of high discharge, and adjacent surface water contributed to water accumulation at E2. Winter water depths were similar at E1 and E2 (Table 1). During summer, E1 desiccated to 0.5 hectares, but E2 retained about 1 hectare of standing water. Dense, monotypic stands of invasive reed canarygrass dominated the vegetation at both wetlands prior to enhancement. After enhancement at E1, native emergent vegetation, including narrow leaf burreed (*Sparganium emersum*), mild waterpepper (*Polygonum hydropiperoides*), water-purslane (*Ludwigia palustris*), mannagrass (*Glyceria* sp.), slough sedge (*Carex obnupta*), and yellow pond lily (*Nuphar luteum*) increased. Surrounding vegetation consisted of row crops, grass, and a reed canarygrass wetland. At E2, the wetland was drawn down to allow vegetation to germinate during the growing season. Dominant vegetation was reed canarygrass, ladysthumb (*Polygonum persicaria*), narrowleaf burreed, marsh cudweed (*Gnaphalium uliginosum*), slough sedge, and bentgrass (*Agrostis* sp.). Lands adjacent to site E2 were mowed for grass hay production.

Unenhanced Wetlands

Unenhanced wetlands U1 and U2 lacked water control structures and were chosen based on their proximity and similarity to the enhanced wetlands, E1 and E2, respectively. Enhanced and unenhanced sites (E1 - U1 and E2 – U2) are connected to common water bodies. The unenhanced wetlands had not been ditched or drained and contained rennie and salzer clays. The unenhanced and enhanced wetlands exhibited similar hydrological patterns (Table 1), and river flows near U1, like E1, were freshwater tidal, which increased the hydrologic connection between the river and wetland during periods of high discharge. Neither of the unenhanced wetlands had surface water outlets, and aquatic species were often stranded as water levels receded. Surface water disappeared by May at U1 and in July at U2. The wetlands had free-flowing hydrologic connections to the mainstem river during periods of peak discharge. Emergent vegetation colonized the wetlands during desiccation. Wetland U1 was dominated by reed canarygrass and bordered by row crops (harvested corn). Vegetation at U2 consisted of reed canarygrass, creeping spikerush (*Eleocharis palustris*), narrowleaf bureed, sedge (*Carex* sp.), and water-purslane. Bordering lands contained grass for hay and reed canarygrass.

Oxbow Sites

The oxbow habitats O1 and O2 did not contain water control structures or emergent wetland characteristics. These oxbows had free-flowing hydrologic connection to the river during most of the sampling season. The oxbow O1 was a remnant oxbow channel with permanent water (Table 1) and connected to the same drainage as U1 and E1, but upstream. Water permanence in the oxbow was retained by spring inputs and a beaver dam. Site O1 was characterized by steep channel slopes, minimal emergent vegetation, and an abundance of large wood. Dominant vegetation was yellow pond-lily and largeleaf pondweed (*Potamogeton amplifolius*). The oxbow was bordered by reed canarygrass, willow (S*alix* sp.), spruce (*Picea sitchensis*), and Himalayan blackberry (*Rubus procerus*). Oxbow O2 was a seasonal oxbow channel directly connected to the river in winter, and depth and discharge were dependent on river stage. By mid-May, site O2 desiccated and reed canarygrass dominated the oxbow. The oxbow was surrounded by fields of grass used for hay production and reed canarygrass.

Wetland water quality

Wetland water temperature (°C) and dissolved oxygen concentrations ($mg{\cdot}L^{-1}$) were measured approximately once a week from 21 February - 2 June to evaluate the suitability of wetland water quality for fishes at all study sites. Measurements were taken approximately 0.5 m below the water surface using an YSI 85 probe (Yellow Springs, Ohio).

Fish abundance, species richness and diversity

Relative fish abundance was evaluated with fyke nets. Each net consisted of a five-ringed steel hoop net with two trapping throats that were 4.5 m long, 1.2 m wide, and covered with 4.76-mm mesh netting. The box trap on each net had a PVC frame that was 1.2 m long, 0.6 m wide, and covered with 3.17-mm mesh netting. A 1.2-m x 15-m lead line was attached to each fyke net to guide fish into the net. Nets were set perpendicular to the shoreline along the wetland perimeter and separated to maintain independence during each 24-hour sample. Differences in the number of fyke net sets among sites were due to wetland size, hydroperiod, and flooding (Table 2). Following capture, fish were counted and identified to species.

The number of fish captured in a fyke net over 24 hours was defined as a catch-per-unit-effort (CPUE). For each month of sampling, CPUE estimates were combined to obtain an average monthly CPUE for each study site. A two-way analysis of variance (ANOVA) compared relative fish abundance (CPUE) among wetlands and months. Data were log transformed ($\log_{10}$) to meet assumptions for parametric analysis. Student-Newman-Keuls test (SNK), with unequal sample sizes, was used to determine differences in fish abundance between wetland pairs for each sampled month (Zar 1974; Ramsey and Schafer 2002). A probability value of 0.05 was used for statistical significance in all tests.

Results from fish abundance sampling were used to calculate species richness, species diversity, and ratio of native to nonnative fishes for each wetland. Species richness (S) was the total number of species captured in each study site. The Shannon-Wiener index and the Simpson's index were used to measure diversity. The Shannon-

Table 2. Sampling schedule and number of fyke net nights each month (except in February where no nets were set) at enhanced wetlands (E1 and E2), unenhanced wetlands (U1 and U2), and oxbow habitats (O1 and O2) in Chehalis River floodplain, Washington, 2003.

Site	January	March	April	May
E1	5	15	8	4
E2	5	20	8	4
U1	4	11	4	--
U2	4	12	6	3
O1	5	9	8	4
O2	4	8	5	2
Total sets	27	75	39	17

(--) No traps were set due desiccation.

Wiener index was sensitive to changes in rare species, and the Simpson's index was more sensitive to changes in species abundances in a community (Krebs 1988).

One-way emigrant traps were installed downstream of study sites that contained a defined outlet (i.e., E1, E2, O1, and O2) to capture emigrating fish. This provided analternative method to compare fish abundance and assemblage between enhanced and oxbow sites. Each trap was operated from 3 March – 5 June 2003 and checked daily. When an individual site became desiccated, the trap was pulled. Each emigrant trap consisted of a 0.6-m x 1.2-m holding box attached to wing nets that channeled fish into the box. Fish captured in traps were counted and identified to species.

Fish access in and out of wetlands

Surface water connectivity between seasonal emergent wetlands and riverine habitat was essential for access. Fish entered wetlands during flood events when surface water (i.e., sheetwater) connected river and floodplain habitats. The duration of fish access to the wetlands between October 2002 and June 2003 was estimated by determining the elevation necessary for the river to flood into each site and relating these elevations to the river-stage values. The river-stage values were obtained from the Porter (12031000) and Montesano (12035100) U.S. Geological Survey instantaneous gage stations located at river kilometer 21 and 54 on the Chehalis River (U.S. Department of the Interior 2004). Measurements were taken in 15-minute intervals and summarized from October 2002 – June 2003. A Spearman rank correlation was calculated to determine if there was an association between fish abundance and the duration (in days) of fish access to emergent wetlands and oxbow habitats.

Results

Fish species richness and diversity

We captured 18 fish species representing 10 families. The most common species captured were three-spine stickleback (*Gasterosteus aculeatus*), Olympic mudminnow, and coho salmon (*Oncorhynchus kisutch*). These taxa were particularly dominant in April and May after young-of-the-year (YOY) emergence. Other common species included Northern pikeminnow (*Ptychocheilus oregonensis*) largescale sucker (*Catostomus macrocheilus*), reticulate sculpin (*Cottus perplexus*), brown bullhead (*Ameiurus nebulosus*), bluegill (*Lepomis macrochirus*), (juvenile) Chinook salmon (*Oncorhynchus tschawytscha*), Pacific lamprey (*Lampetra tridentata*), and redside shiner (*Richardsonius balteatus*) (Table 3).

Species richness (S) was higher in O2 (S=15) than all other wetlands. Enhanced wetlands had higher species richness (S=13-14) than the unenhanced wetlands (S=7-8). Although the number of nonnative species was higher in enhanced wetlands (S=3-4) than unenhanced wetlands (S=1-2), native species abundance comprised greater than 98% of the catch at all sites. At sites U2, O1, and O2, diversity indices were highest in March and declined in subsequent months (Table 4). In wetlands E2 and U1, diversity indices increased throughout the sample period, but at E1 Shannon-Weiner diversity indices decreased through the sampling period (Table 4).

The Olympic mudminnow, three-spine stickleback, redside shiner, and Northern pikeminnow all used the enhanced wetlands for spawning, which was determined by the capture of adults and YOY of these species in late spring. In addition, the Olympic mudminnow and three-spine stickleback were found to have spawned in the unenhanced wetland, U2. There was no evidence of spawning at sites U1, O1, or O2.

Fish abundance

Fish colonized all of the wetlands studied, with 142,814 fishes were captured in fyke nets and emigrant traps. Relative fish abundance among sites and months were statistically significant ($F_{5,145} = 12.24$, $P<0.01$; $F_{3,145} = 14.65$, $P<0.01$). For January, fish abundances in enhanced wetlands were significantly higher than in unenhanced wetlands and oxbow habitats (Student-Newman-Keuls test). In March, April, and May, differences in fish abundance were statistically significant among wetland pairs (Student-Newman-Keuls test). In May, U1 desiccated and was not included in the analysis. Enhanced wetlands (E1 and E2) and unenhanced wetland U2 generally had greater CPUE than U1, O1, and O2 (Student-Newman-Keuls test; Table 5), but the abundance of three-spine stickleback and Olympic mudminnow dominated comparisons.

Four species of salmonids were captured including coho salmon, Chinook salmon, chum salmon (*O. keta*), and coastal cutthroat trout (*O. clarki clarki*) (Table 3). None of the salmonids captured at the study sites had hatchery marks and thus, were presumed to be wild. Moreover, hatchery coho salmon are released in mid-April each year, when river flows usually do not permit access to the wetlands.

Table 3. Average catch per unit effort (number of fish per trap night) of each fish species captured in the fyke nets at two enhanced wetlands (E1 and E2), two unenhanced wetlands (U1 and U2), and two oxbow habitats (O1 and O2) in the Chehalis River floodplain, Washington, 2003.

Species	E1	E2	U1	U2	O1	O2
Lepomis macrochirus	0.06	0.46	0.05	0.12	0.00	0.21
Ameiurus nebulosus	0.06	0.84	0.00	0.00	0.15	0.00
Oncorhynchus tschawytscha	0.00	0.00	0.00	0.00	0.00	8.16
Oncorhynchus kisutch yearling	3.28	0.35	0.00	0.00	0.15	8.68
O. kisutch YOY	0.06	0.14	1.16	0.20	0.19	24.95
O. keta YOY	0.00	0.00	0.47	0.00	0.00	0.05
O. clarki clarki	0.00	0.19	0.00	0.08	0.00	0.32
Unidentified Cottidae	0.03	0.14	0.00	0.00	0.27	0.00
Catostomus macrocheilus	0.19	0.57	0.00	0.28	0.27	0.11
Ptychocheilus oregonensis	0.03	3.84	0.00	1.32	0.38	0.05
Novumbra hubbsi	325.41	3.14	0.47	38.56	0.85	0.11
Lampetra tridentata	0.00	0.03	0.63	0.00	0.04	0.05
Cottus asper	0.06	0.00	0.00	0.00	0.42	0.11
Ambloplites rupestris	0.00	0.00	0.00	0.00	0.00	0.05
Richardsonius balteatus	0.03	0.14	0.00	0.00	0.08	0.05
Cottus perplexus	0.22	0.70	0.05	0.00	0.15	0.00
Rhinichthys osculus	0.00	0.00	0.00	0.00	0.00	0.11
Gasterosteus aculeatus	196.84	80.22	15.63	101.00	23.31	0.16
Perca flavescens	0.03	0.03	0.00	0.00	0.08	0.05
Lepomis gulosus	0.00	0.00	0.00	0.04	0.00	0.00

Table 4. Fish community characteristics by month including species richness, Shannon-Wiener index, and Simpson's index in two enhanced wetlands (E1 and E2), two unenhanced wetlands (U1 and U2), and two oxbow habitats (O1 and O2) in the Chehalis River floodplain, Washington, 2003.

	January			March		
	Richness	Shannon	Simpson	Richness	Shannon	Simpson
E1	5	1.37	0.22	4	1.13	0.52
E2	6	0.23	0.05	9	0.74	0.21
U1	3	0.41	0.14	5	0.71	0.21
U2	2	1.00	0.50	3	1.58	0.67
O1	5	1.61	0.58	5	1.84	0.66
O2	2	0.47	0.20	3	1.52	0.80
	April			May		
	Richness	Shannon	Simpson	Richness	Shannon	Simpson
E1	9	1.04	0.49	4	0.91	0.44
E2	11	0.92	0.24	9	1.33	0.43
U1	6	1.26	0.42	--	--	--
U2	7	0.75	0.29	5	1.12	0.52
O1	9	0.70	0.18	6	0.55	0.15
O2	10	1.37	0.47	6	0.79	0.32

(--) No traps were set due to desiccation

Table 5. Total numbers of fish per trap night (CPUE) at two enhanced wetlands (E1 and E2), two unenhanced wetlands (U1 and U2), and two oxbow habitats (O1 and O2) in the Chehalis River floodplain, Washington, 2003.

	January		March		April		May	
Site	Mean	SE	Mean	SE	Mean	SE	Mean	SE
E1	62.6	22.6	167.7	44.4	531.0	176.1	2,409.0	620.9
E2	222.0	109.6	59.6	19.2	71.5	25.9	112.5	40.7
U1	34.0	17.8	13.6	7.3	16.5	13.5	--	--
U2	29.0	25.4	61.8	22.9	317.8	128.3	340.7	34.6
O1	4.2	0.8	6.4	2.0	61.8	40.7	32.5	9.6
O2	2.5	2.2	3.6	1.4	33.6	14.8	307.0	86.0

(--) wetland desiccated

Coho salmon were the dominant salmonid at all sites. Enhanced wetlands had significantly higher abundances of coho salmon yearlings than unenhanced wetlands (Welch's *t*-test: $T = 2.61$, $df = 63$, $P < 0.01$; Table 3). Juvenile coho salmon and Chinook salmon dominated the catch (salmonids were 96% of fish assemblage) at oxbow O2. Even though O2 had more salmon, the oxbow differed from the other sites with low numbers of nongame species. Oxbow O1 had lower salmon abundances and fewer Olympic mudminnows.

Salmon abundances in emigrant traps were higher in enhanced wetlands (1,507 fish·trap night^{-1} at E1; 175 fish·trap night^{-1} at E2) compared to oxbow sites (6 fish·trap night^{-1} at O1; 58 fish·trap night^{-1} at O2). Emigration was greatest in May at all sites, and this was directly related to an increase in the number of young-of-the-year fishes. Emigrating salmon were most abundant at E2 (60 salmon·trap night^{-1}) and O2 (55 salmon·trap night^{-1}), but the number of emigrants at E1 (40 salmon·trap night^{-1}) was significantly greater than estimates at O1 (1 salmon·trap night^{-1}).

Fish Movement

The 2003 sampling year had relatively average river flows ($x = 8.1 \pm 4.4$ m^{3}s^{-1} during the sampling period) compared to the average daily discharge from 1952 to 2003 in the Chehalis River at the Porter gage station (Figure 2). In 2003, winter flows were lower than average, but spring flows were higher than average at times (Figure 2). This suggests that overall flooding during the study period was similar to previous years, but that fish may have had slightly greater access during the spring months compared to previous years.

The distance from E1 and U1 to the river was longer than distance from E2 and U2 to the river. Fish could access E1 4% (~11 days) and U1 1% (~3 days) of the days between October 2002 and June 2003. During that same period, fish could access both E2 and U2 about 3% (~9 days) of the time. Access to the unenhanced wetland U2 was through the E2 wetland. Access from the river to O1 and O2 was 100% and 24% (275 days and 66 days) of the time, respectively, for the period between October and June. There was no correlation between fish abundance and duration of fish access into floodplain habitats (Spearman rank correlation: $r = 0.13$, $P > 0.50$).

Wetland water quality

Habitat conditions gradually became unsuitable for fishes in individual wetlands as water temperatures increased, dissolved oxygen concentrations decreased, and/or wetland water levels declined. Water temperatures ranged from 7-11 °C in March, 9–13 °C in April, and 10-22 °C in May (Figure 3). Dissolved oxygen concentrations (DO) ranged from 10-0 $mg \cdot L^{-1}$ and decreased throughout the sampled months (Figure 3). Dissolved oxygen levels decreased prior to increased water temperature, and declines occurred earlier in emergent wetlands compared with oxbow habitats (Figure 3). At E1 and U1, DO levels decreased by May, whereas, DO levels and temperature at O1 remained suitable for fishes throughout the sampling season.

Discussion

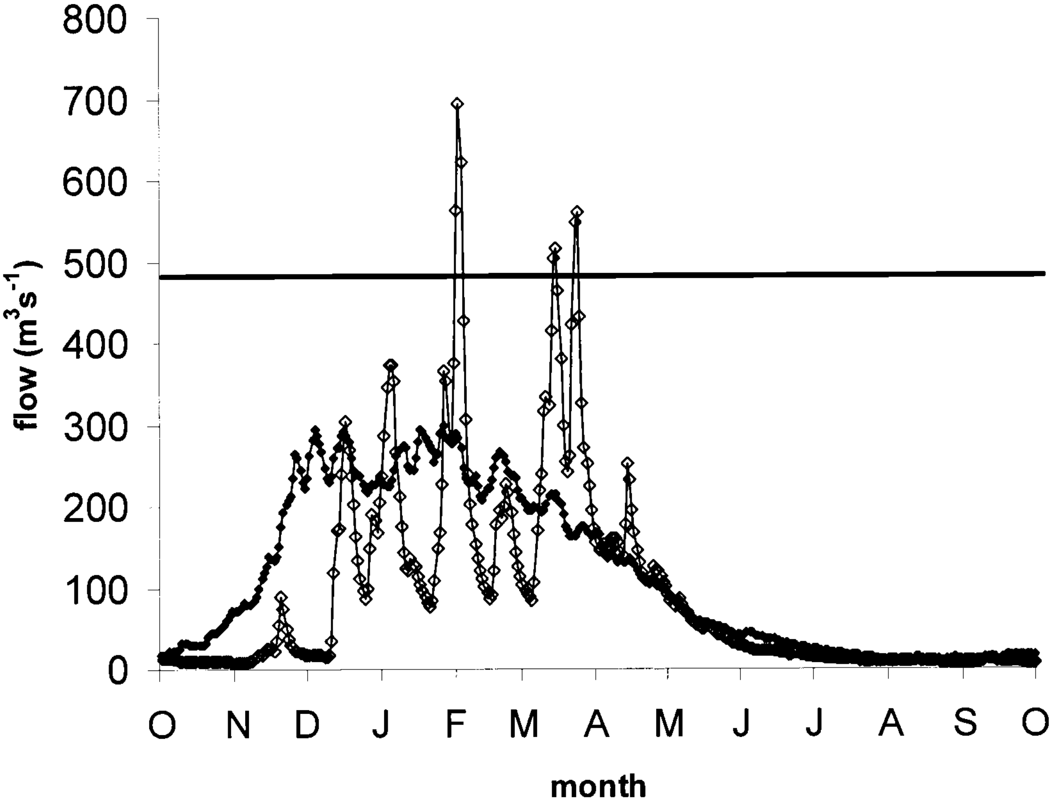

Figure 2. The combined daily mean flow ($m^3 \cdot s^{-1}$) in the Chehalis River for October 2002 – June 2003 (line with open diamonds) and for monthly mean flows from 1952 to 2003 in the Chehalis River at Porter gage station (line with filled diamonds). The straight-line represents the critical flow level when all study sites had hydrologic connections with the river.

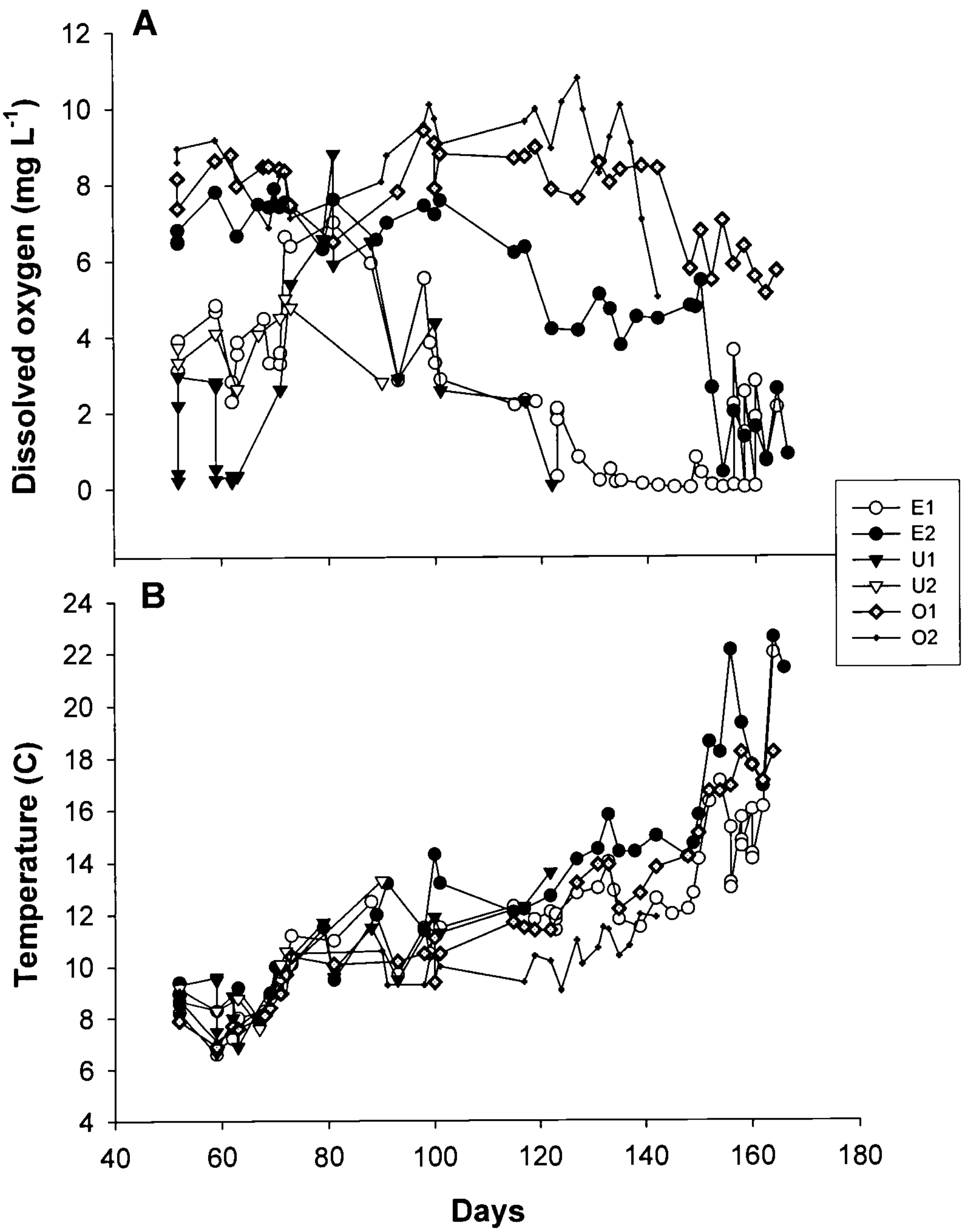

Figure 3. A comparison of (A) dissolved oxygen concentrations (mg·L^{-1}) and (B) water temperature (°C) in two enhanced wetlands (E1 and E2), two unenhanced wetlands (U1 and U2), and two oxbow habitats (O1 and O2) from 21 February 2003 through 2 June 2003, Chehalis River floodplain, Washington. (Days on the x-axis represents day of year starting from January 1). Note that U1 and O2 desiccated on 2 May and 15 May, respectively.

Fish sampling

Although fish use of off-channel areas in the Pacific Northwest, especially non-salmonid species, has not been well documented, emergent floodplain wetlands in this study were important for fishes. There were 142,814 individual fishes captured, encompassing 18 species. Moreover, three native species used these habitats for spawning. Fishes were found in all floodplain habitats sampled, but abundances were highest in enhanced wetlands. In late spring (April and May), floodplain wetlands appeared to support higher abundances of fishes than in winter months. This was related to the emergence of YOY fishes (i.e., three-spine stickleback and Olympic mudminnow) and accessibility to wetlands due to flooding. The enhanced wetlands had higher fish abundances than the unenhanced wetland U1, but not U2. Site U2 had a longer hydroperiod than U1, which provided spawning conditions for Olympic mudminnow and three-spine stickleback. Species richness and abundance of coho salmon yearling were higher in the enhanced wetlands than the unenhanced wetlands. These results may be related to site-scale habitat suitability and fish access. Furthermore, unenhanced wetlands had no defined outlet for fish emigration, and fish that did not emigrate as floodwaters receded were probably stranded.

Salmon used enhanced wetlands but in lower numbers than the oxbow habitat, O2. High densities of salmon rearing in off-channel sites are well documented (e.g., Bustard and Narver 1975; Brown and Hartman 1988; Swales and Levings 1989). In this study, salmon abundances appear to be related to the duration of access to the habitat, water quality conditions (temperature and dissolved oxygen), water velocities, and hydroperiod. At the oxbow O2, water depth and current were related to river flows, and water quality at O2 was similar to water quality conditions of the river. Although the oxbow site had higher abundances of salmon compared to the other sampled wetlands, it had low abundances of nongame fish species such as Olympic mudminnow and three-spine stickleback. Olympic mudminnow were probably less abundant in the oxbow habitats because the species has a documented low tolerance for flowing waters (Meldrim 1968).

The oxbow beaver pond, O1, had the appearance of suitable fish habitat; however, few fish, including salmon, were captured. The site had deep water, continuous connection to the creek, a woody riparian shoreline, adequate water quality conditions, and contained large wood. These results contrast with reports of the importance of beaver pond habitat for juvenile salmon, particularly coho salmon (Sanner 1987; Leidholt-Bruner et al. 1992; Nickelson et al. 1992). This discrepancy likely reflects local characteristics of the beaver pond. Most studies concerning the relationship between coho salmon and beaver ponds have been conducted on small creeks and tributaries, where dams are built within the stream channel. These dams maintain in-river pool depth, which has been shown to correlate with density of juvenile coho salmon (Nickelson et al. 1992). Moreover, these dams tend to be ephemeral, and are often destroyed by high winter flows and rebuilt each summer (Leidholt-Bruner et al. 1992). In the Chehalis system, beaver dams are frequently imbedded in the floodplain of agricultural ditches and remnant oxbows. Beaver dams are in relatively stable environments, where dam damage results from beaver abandonment rather than high discharges.

The low abundance of fish, including salmon, at the oxbow beaver pond could be related to predation and food availability. For example, piscivorous largemouth bass (*Micropterus salmoides*) and brown bullhead that inhabit the oxbow beaver pond may prey on juvenile salmon. Moreover, steep banks and deep water limit emergent vegetation and limit invertebrate production (Eldridge 1990; Murkin et al. 1992).

Olympic mudminnow are also susceptible to predation by nonnative species. For example, Beecher and Fernau (1982) found that Olympic mudminnow were absent from areas in the Chehalis River Basin where nonnative species were present. Our results suggest, however, that the Olympic mudminnow are most frequently found in shallow emergent wetlands with muddy substrate, dense vegetation, and little or no current, regardless of whether nonnative species are present. These habitat characteristics were exhibited by the enhanced wetlands, and thus, Olympic mudminnow presence at the enhanced wetland sites may be related more to habitat preference than competitive exclusion by nonnative species.

Species richness was similar to that reported in other studies of temperate floodplains (Baber et al. 2002; King et al. 2003), but much lower than that for fish assemblages sampled in the Amazonian floodplain, which can exceed 90 species (Silvano et al. 2000; Petry et al. 2003). In the Chehalis Basin, approximately 26 native fishes have been documented (Wydoski and Whitney 2003), and 46% of those native species were found in the seasonal floodplain wetlands. Species richness of the Chehalis wetlands was greater than that of off-channel habitats located in small headwater streams, where juvenile coho salmon dominate (Peterson and Reid 1984; Scarlett and Cederholm 1984; Swales and Levings 1989). Lowland streams and rivers usually support a greater number of fish species than headwater areas (Landers et al. 2002). In addition, within a given region, it has been suggested that the number of species inhabiting a system is largely a function of the size of the river or drainage area, which influences the number of ecological niches (Welcomme 1979).

Wetland water quality

The unenhanced wetlands became isolated earlier in the year (beginning of April) than the enhanced wetlands. As water quality decreased, fish could leave the enhanced wetlands because of the availability of an outlet. By contrast, fish in the unenhanced wetlands could not emigrate, and any fish captured in April and May was inevitably stranded. Water quality in the enhanced wetlands decreased (e.g., 0 $mg \cdot L^{-1}$ DO in June) before the wetlands became isolated. Water levels decreased more slowly at the enhanced than the unenhanced wetlands, maintaining the wetted area for a longer duration. This may be particularly important for fishes that use the floodplain for spawning and rearing, and can thereby increase fish productivity (Welcomme 1985).

Water temperatures did not reach the lethal limits for salmon (25 °C; Brett 1952) during the study in any of the sampled wetlands. However, the wetlands did exceed preferred coho salmon rearing water temperatures of 12-14 °C (Brett 1952). Dissolved oxygen concentrations, which were at or near lethal levels for many fishes in June (<1.0 $mg \cdot L^{-1}$ in emergent wetlands), were probably more of a limiting factor than water temperatures. Lengthy inundation of floodplain habitats often results in low dissolved oxygen levels (i.e., anoxia; Mitsch and Gosselink 1993; McKinnon 1997). Such conditions can limit activity and growth in some fish (Brett 1979). For example, the

Olympic mudminnow can tolerate dissolved oxygen levels as low as 0.18 $mg \cdot L^{-1}$ (Meldrim 1968), but juvenile coho salmon show reduced food consumption and weight loss at dissolved oxygen concentrations of 2 $mg \cdot L^{-1}$ (Colt et al. 1979). Henning (Chapter 3) suggested that declining dissolved oxygen concentrations in the wetlands may trigger a volitional emigration of salmon from these wetland habitats.

Fish access to wetlands

Fish abundance was not correlated to the duration of fish access to the wetlands. Enhanced wetlands had a longer duration of access and higher fish abundance than unenhanced wetlands. However, oxbow habitats had the greatest duration of access and lower fish abundance than enhanced wetlands. The high abundance of fish in the enhanced wetlands was related to the emergence of YOY three-spine stickleback and Olympic mudminnow. Salmon abundance was highest in the oxbow habitat O2, which may be associated with access and/or distance from the mainstem river. Oxbow habitats connected and recharged by the river provided rearing for coho salmon that differed from the main river channel or seasonal floodplain wetlands. Bustard and Narver (1975) found that during winter, juvenile salmon used sidepools or alcoves, which are on the channel margin protected by the stream bank. In their study, these habitats were more similar to stream habitat than seasonal emergent wetland habitat because of water recharge, velocity, and river connectivity. The amount of connectivity between the river and floodplain relate to the types of fish present in a floodplain wetland habitat.

Implications

Human influence has degraded watersheds and impacted wetlands creating the need for restoration and enhancement. Wetland restoration projects in the Chehalis River floodplain maintain wetland habitat and provide wetted habitat for a longer duration than currently exists on the floodplain. They provide rearing habitat for numerous fishes, including coho salmon, and provide breeding habitat for amphibians (Henning 2004). Modifications of the floodplain (i.e., ditching and draining) may have the greatest affect on nongame fishes that depend on wetlands for the majority of their life cycle. Seasonally flooded wetlands with water control structures allow fish a greater amount of time for spawning, rearing, and emigration as river water levels recede. Fish survival is dependent on emigrating from enhanced wetlands before water quality conditions become harmful.

Floodplain habitats in this study differed in fish assemblage and habitat characteristics. In the Chehalis River Basin emergent wetlands appear to fulfill a niche for native nongame fishes that beaver ponds and oxbows are not providing. Habitat characteristics such as hydroperiod, water quality, current, vegetation, and productivity appear to influence biological responses in floodplain habitats. Off-channels habitats, oxbows, beaver ponds, emergent wetlands, and enhanced wetland habitats are supporting a diversity of fishes, and floodplain management should focus on maintaining this habitat complexity. Research is just beginning to elucidate the roles that emergent floodplain habitats play in fish community composition and productivity, particularly in regions such as the Pacific Northwest where these habitats have been generally overlooked and substantially reduced by land-use practices. Future research should focus on how the patterns we observed compare with wetlands in other regions, and what wetland characteristics influence fish spawning, feeding, and survival in emergent habitats. Such information can be used to better predict the importance of individual floodplain aquatic habitats for fish and provide insight into the design of wetland restoration projects that can benefit native fish species.

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Chapter 3: Are emergent wetlands potential rearing habitats for juvenile salmonids? A case study of wetland enhancement in the Chehalis River, WA

Abstract

A recent trend of enhancing emergent wetlands for waterfowl and other wildlife has raised concern about the effects of such measures on juvenile salmonids. I undertook this study to quantify the degree and extent of juvenile salmon utilization of enhanced and unenhanced emergent wetlands within the floodplain of the lower Chehalis River, Washington, and to determine the fate of salmon using them. Enhanced emergent wetlands contained water control structures that provided an outlet for fish emigration and a longer hydroperiod for rearing than unenhanced wetlands. Coho salmon (*Oncorhynchus kisutch*) (YOY and yearling) were the most common salmonid at all sites, with enhanced wetlands having significantly higher yearling abundance than unenhanced wetlands that were a similar distance from the mainstem river. Yearling coho salmon were benefiting from rearing in enhanced wetland habitats where their specific growth rate (1.43 $g.g^{-1}d^{-1}$ and 1.37 $g.g^{-1}d^{-1}$, respectively) and estimates of minimum survival (30% and 57%, respectively) were comparable to other side-channel rearing studies. Dissolved oxygen concentrations decreased in emergent wetlands throughout the season and were near lethal limits to juvenile salmon by May or June each year. Emigration patterns suggested that yearling and YOY emigrated as habitat conditions decline. This observation was further supported by the results of the experimental release of coho salmon. Survival of fishes utilizing emergent wetlands was dependent on movement to the river before water quality decreased and/or the wetland became isolated and stranding occurred. Thus, our results suggest that enhancing wetlands using water control structures can benefit juvenile salmonids by providing conditions for high growth and survival.

Introduction

Annual inundation of floodplains is the principal force determining productivity and biotic interactions in river-floodplain systems (Junk et al. 1989; Bayley 1995). Emergent wetlands are common features of river-floodplain systems that have received little attention from fish biologists and managers. These wetlands are usually on the higher portion of the floodplain, and under normal surface water conditions have no surface inlet to provide access for riverine fishes. During periods of high water, rivers may overflow onto the floodplain, establishing temporary connections between the two systems (Snodgrass et al. 1996). Floodplain emergent wetlands can maintain high production related to periodic flooding with the decomposition of organic matter and nutrients, and these materials can result in high yields of fish (Bayley 1991, 1995).

In the Pacific Northwest and British Columbia, studies have shown the significance of slow-water side pools and beaver ponds as important overwintering habitat for juvenile coho salmon (*Oncorhynchus kisutch*) (e.g., Bustard and Narver 1975; Brown and Hartman 1988; Swales and Levings 1989). Most studies, however, have been limited to coastal watersheds (10-300 km^2 river drainage) with narrow floodplains and low discharges. These habitats have been described as off-channels, seasonal tributaries, side-channels, backwater ponds, riverine ponds, and beaver ponds (Bustard and Narver 1975; Peterson 1982; Scarlett and Cederholm 1984; Swales et al. 1986). The off-channel ponds are typically small (0.05-1.0 hectares), with good water quality (dissolved oxygen concentration, 6-8 $mg \cdot L^{-1}$; Swales et al. 1986), and are often directly connected to the mainstem river during fall and winter.

Floodplain emergent wetlands are significant features of many river systems in the Pacific Northwest and British Columbia. Although their role in the life history of salmonid fishes is poorly understood, studies in this region have shown that slow-water side pools and beaver ponds can be important overwintering habitat for juvenile coho salmon (e.g., Bustard and Narver 1975; Brown and Hartman 1988; Swales and Levings 1989). Floodplain emergent wetlands appear to be functionally similar to these off-channel ponds; however, they also differ in critical ways, such as size, river connectivity, water quality, and location within river systems. Thus, while emergent wetlands are often lumped with the off-channel fish literature (e.g., Beechie et al. 1994), such wetlands differ considerably from oxbows, side-channels, and off-channel habitats that are continuously connected to the stream by a channel.

Juvenile salmon have only recently been documented in floodplain emergent wetlands during the spring (Sommer et al. 2001; Baker and Miranda 2002; Henning 2004), and the significance of this association is unclear. In part, this is related to the perception that floodplain emergent wetlands are atypical salmonid habitat. Seasonal development of anaerobic conditions, intermittent connection with the river system, shallow depth, and lack of woody cover are dominant characteristics of these systems. However, the shallow depths of emergent wetlands contribute to increased water temperatures and emergent vegetation, both of which are correlated with high invertebrate production, particularly during the spring (Eldridge 1990; Fredrickson and Reid 1998). Such conditions may enhance prey resources, providing opportunities for fish growth and survival that are superior to those found in the main river channel. Thus, during the spring, floodplain emergent wetlands may provide excellent habitat for juvenile salmonids, but these factors can be offset by the risk of stranding as the wetland desiccates and oxygen levels decline.

Wetland restoration and enhancement activities have focused on improving habitat characteristics, including aquatic connectivity, productivity, and native emergent vegetation, that are critical for migratory wildlife and threatened and endangered aquatic and semi-aquatic wildlife and plant species. Unfortunately, wetland enhancement techniques (i.e., water control structures and water drawdowns) have focused on benefits for wildlife (Fredrickson and Taylor 1982; Fredrickson and Reid 1988), and our knowledge of the benefits of such enhancement measures for fish remains rudimentary.

The purpose of this study was to quantify the use of floodplain wetlands by juvenile coho salmon in a large river system. Initially, we sought to determine if patterns of fish use are similar in enhanced wetlands (with water control structures), unenhanced wetlands (without water control structures), and oxbows. To accomplish this goal, we compared juvenile salmon abundance in enhanced and unenhanced wetlands with two oxbow habitats. Subsequently, I evaluated the influence of water temperature and dissolved oxygen concentrations on the use of enhanced wetlands by juvenile coho salmon. Patterns of growth, survival, and emigration were assessed for wild coho salmon yearlings and individuals of hatchery origin that were introduced experimentally.

Methods

Study Area

The study was conducted January - June in 2003 and 2004 on the floodplain of the Chehalis River, southwest Washington, USA (Figure 1). The Chehalis River Basin is the third largest river basin in the State of Washington with a drainage area of approximately 6,900 km^2 and a mean annual discharge of 116 $m^3 \cdot s^{-1}$ (Washington State Department of Ecology 1980). The study sites were located in the lower portion of the basin (below river kilometer 60), where the river is unconstrained and moves sinuously through the floodplain in a broad flat valley floor. The basin was chosen for sampling because of the large size and minimally degraded floodplain. Although ditching and draining for conversion to cropland or pasture has occurred in the Chehalis River Valley, there are few levees and no mainstem dams to affect the hydrograph. Generally, flood events are triggered by heavy winter rainfall most years in the Chehalis Basin.

Four seasonal emergent wetlands and two oxbow habitats between river kilometer 27 and 58 of the Chehalis River were selected for sampling (Figure 1; Table 1; see Chapter 2 for further details). The emergent wetlands included two enhanced sites with water control structures (E1 and E2) and two unenhanced wetlands (U1 and U2; Figure 1). The enhanced wetlands E1 and E2 were similar, with shallow depths, minimal currents, an abundance of emergent vegetation, and large surface areas during winter that declined in size during summer due to desiccation (Table 1). The wetlands were drained previously as part of a county drainage district project to facilitate farming. Soils are predominantly rennie and salzer clays that are deep, poorly drained, hydric soils (U.S. Department of Agriculture, Soil Conservation Service 1986), and the area is subject to frequent periods of flooding from November to April.

Wetland enhancement occurred in 1997-1998, when drainage ditches were blocked, and water control structures and levees constructed. Water control structures enhanced the wetlands by retaining water and creating a defined outlet that connected each wetland to an adjacent tributary stream of the Chehalis River and provided for fish emigration. Wetland levees kept water within the project area to avoid impacting adjacent lands. Primary goals of the enhancements were directed towards wildlife and wetland management, and fish rearing was only a secondary consideration. Dense, monotypic stands of invasive reed canarygrass (*Phalaris arundinacea*) dominated the vegetation prior to restoration, with native emergent vegetation increasing afterwards.

The unenhanced emergent wetlands (U1 and U2) in this study lacked water control structures and were chosen based on their proximity and similarity to the enhanced wetlands, E1 and E2, respectively (Table 1). The paired sites (E1 - U1 and E2 – U2) have free-flowing hydrologic connections to the mainstem during periods of peak discharge. However, unlike the enhanced wetlands, the lack of a surface water outlet results in the complete desiccation of the unenhanced wetlands during the summer, and precludes the ability of aquatic species to emigrate once flood flows have declined.

The oxbow habitats O1 and O2 did not contain water control structures. They were chosen for this study because of their proximity to the other study sites and because these sites had free-flowing hydrologic connections to the river during most of the sampling season (Table 1). In addition, physical characteristics of the oxbow sites seemed to be typical salmon off-channel rearing habitat. Oxbow O1 was connected to the same drainage as U1 and E1, but upstream. It was a remnant oxbow channel with spring inputs and a beaver dam. This beaver dam oxbow was characterized by steep channel slopes, minimal emergent vegetation, and an abundance of large wood. Oxbow O2 was a seasonal oxbow side-channel directly connected to the river in winter (Table 1).

The depth and discharge at the side-channel oxbow O2 were dependent on river stage, and it desiccated by mid-May.

Water quality

Water temperature (°C) and dissolved oxygen concentrations ($mg \cdot L^{-1}$) were measured approximately once a week in March - June 2003 and January - June 2004. Measurements were taken approximately 0.5 m below the water surface near the outlet (E1, E2, O1, and O2) or middle of the wetland (U1 and U2) using a YSI 85 probe (Yellow Springs, Ohio).

Differences in dissolved oxygen concentrations among habitats were analyzed using an unbalanced one-way ANOVA model with wetland type as a fixed factor (Zar 1974). A Welch's *t*-test was used to compare dissolved oxygen concentration between years at the enhanced wetlands.

Fish sampling

Fyke net sampling 2003

In 2003, fish abundance was compared among all sites and evaluated with fyke nets from January-May, except in February when no nets were set. Fish abundance was the number of fish captured in a fyke net over 24 hours and expressed as catch-per-unit-effort (CPUE). Each fyke net consisted of a five-ringed steel hoop net with two trapping throats that were 4.5 m long, 1.2 m wide, and covered with 4.8-mm mesh netting. The box trap of each net consisted of a PVC frame that was 1.2 m long, 0.6 m wide, and covered with 3.2-mm mesh netting. A 1.2-m x 15-m line was attached to each fyke net to guide fish into the net. Nets were set perpendicular to the shoreline, along the wetland perimeter and usually separated by a minimum of 100 m to maintain independence during each 24-hour sample. Five to twenty fyke nets were set per month at each site. Differences in the number of sets among sites were due to wetland size and hydroperiod.

Emigration sampling 2003 and 2004

In 2003, one-way emigrant traps were installed downstream of study sites that contained a defined outlet (i.e., E1, E2, O1, and O2) to examine abundance and emigration patterns of coho salmon. Traps at all four sites were operated from 4 March – 5 June 2003. At E1 and E2, emigration patterns were reexamined in 2004 to evaluate emigration, residence duration, growth, and survival of coho salmon. Emigration traps operated from 7 January – 4 June 2004. Each emigrant trap consisted of a 0.6-m x 1.2-m holding box attached to wing nets that channeled fish into the box for identification and counting. These traps were operated continuously, except during floods when trapping became inefficient, or when the site desiccated and the trap became dry. Traps were checked every 48 hours, and captured yearling coho salmon were measured (fork length ±1 mm) and weighed (±1.0 g).

Experimental Release

To experimentally assess emigration patterns, particularly in relation to dissolved oxygen concentrations, 157 and 176 hatchery coho salmon yearlings were released during 2004 in the enhanced wetlands E1 (22 March) and E2 (26 March), respectively. The fish were obtained from the Washington Department of Fish and Wildlife Aberdeen Hatchery, where they had been reared commonly and marked with visible implant fluorescent elastomer dye (VIE) prior to release. Emigration timing was monitored through the traps and compared between the enhanced wetlands. In addition, the median date of emigration was compared to that of wild coho salmon yearlings during the same period (i.e., the day after release until the end of trapping).

Coho salmon growth

In 2004, yearling coho salmon captured in the fyke nets at the enhanced wetlands were marked uniquely for subsequent determination of growth rate. They were anesthetized with MS-222 (tricanine mesthanesulfonate), examined for VIE marks, measured (fork length; ±1 mm), and weighed (±1.0 g). All yearlings without marks were marked with a VIE dye in a unique location and color combination. Yearling coho salmon were allowed to recover following marking and returned to their original habitat.

Specific growth rates were calculated for recaptured juveniles (>1 week after initial capture) as:

$$G = (\log_e W_{t2} - \log_e W_{t1} / t_2\text{-}t_1) * 100 \quad \text{(Ricker 1979)}$$

where G is the specific growth rate, W_{t1} is the initial weight, W_{t2} is the weight at recapture, t_1 is the initial date, and t_2 is the date of recapture. Specific growth rate differences among months and emergent wetlands were compared using a two-way ANOVA model with month and wetland type as fixed factors. A probability value of 0.05 was used for statistical significance in all tests.

Results

Fish access

Fish access to the floodplain habitats was estimated with discharge data from a Chehalis River gage station (river kilometer 30; U.S. Department of Interior 2004). At approximately 480 $m^3 \cdot s^{-1}$ the river was connected to the floodplain at all study sites (Figure 4). At the E- and U-sites this occurred for a few days in February, mid-March, and end of March in 2003, and in 2004 it occurred for a few days in mid-November and early February. By contrast, the oxbow habitats had about 55 more days of hydrologic connection to the river between November - July 2003, and 70 more days of connection to the river between November - July 2004, than the E- and U-sites.

Salmon wetland use

A total of 116,806 fishes from 18 species were captured emigrating the floodplain habitats in 2003, but in 2004 there were only 26,751 fishes from 17 species. In 2003, four species of salmonids were collected (coho salmon, Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), and coastal cutthroat trout (*O. clarki clarki*), but in 2004, only two species of salmonids were captured (coho salmon and coastal cutthroat trout) (Table 6). Juvenile coho salmon were the most abundant salmonid captured in the wetlands, and two age groups were collected, yearlings and young-of-the-year (YOY). All of the salmonids captured in the study had adipose fins and thus were presumed to be wild because the adipose fin is removed routinely from all hatchery fish in the Chehalis River system.

The CPUE of yearling coho salmon in fyke nets was highest at the oxbow O2 site in all months except January, when the enhanced wetland E1 had greater estimates (Table 7). In contrast, no yearling coho were captured in the unenhanced wetlands (U1 and U2). Coho salmon YOY were captured in all wetlands, with CPUE peaking in April at the unenhanced and enhanced wetlands and in May at the oxbow habitats (Table 7). The noticeable increase in CPUE of YOY coho salmon in the U-wetlands during April was associated with the concentration of fish due to wetland desiccation.

Emigrant abundances were considerably higher at the enhanced wetlands (3,014 fish·trap night^{-1} at E1; 351 fish·trap night^{-1} at E2) than the oxbow habitats (12 fish·trap night^{-1} at O1; 116 fish·trap night^{-1} at O2; Table 6) in 2003. Overall, salmon constituted 3% and 35% of the fish assemblage at the enhanced wetlands E1 and E2, respectively, in 2003, and 2% and 3% in 2004 (Table 6). The dominant fish emigrating from these sites was the three-spine stickleback (*Gasterosteus aculeatus*). At the oxbow habitats, however, salmon were a far more prominent component of the emigrant assemblage (95% at oxbow O2 and 17% at oxbow beaver pond O1). Yet, in absolute terms, emigrating salmon were most abundant at the E2 wetland (120 salmon·trap night^{-1}) compared with O2 (110 salmon·trap night^{-1}) and E1 (79 salmon·trap night^{-1}; Table 6) in 2003. The lowest number of emigrating salmon occurred at O1 (2 salmon·trap night^{-1}; Table 6). Capture of emigrants increased in May at all sites, and emigration of YOY fishes peaked at this time. The densities of yearling coho salmon at O2 were higher than in the enhanced wetlands during 2003. In 2003, minimum densities in the oxbow sites and the enhanced wetlands ranged from 0.0002 – 0.007 yearlings per m^2.

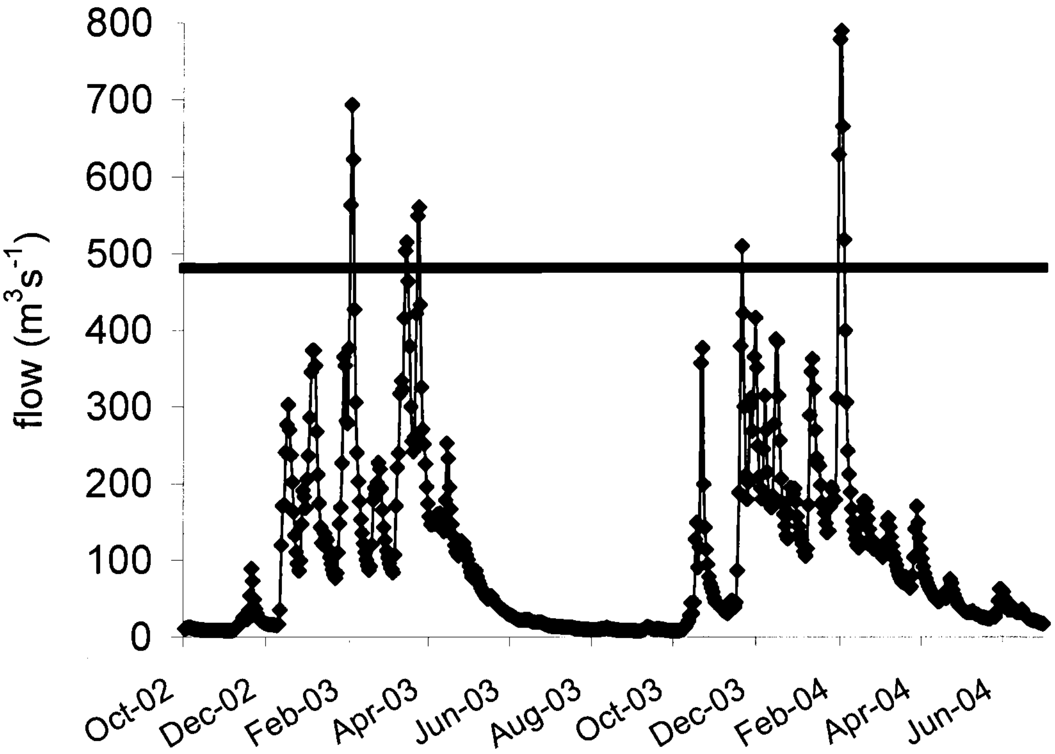

Figure 4. Average daily discharge ($m^3 \cdot s^{-1}$) in the Chehalis River at Porter (gage 12031000) from October 2002 to July 2004. The straight line at 481 $m^3 \cdot s^{-1}$ represents the approximate discharge at which the riverbanks were flooded and the river was connected to the study locations.

Table 6. One-way emigrant trap catches in oxbow habitats (O1 and O2) and enhanced wetlands (E1 and E2) in the Chehalis River floodplain, Washington during the 2003 and 2004 sampling periods. Note: O2 had flooding and was the earliest site to desiccate, reducing trap nights.

	2003				2004	
Site	O1	O2	E1	E2	E1	E2
Total fish	401	1,798	102,513	12,094	20,735	16,016
Yearling coho salmon	9	179	619	485	290	282
YOY coho salmon	51	1,416	1,802	3,680	150	168
YOY Chinook salmon	0	111	1	14	0	0
YOY chum salmon	0	6	276	0	0	0
Cutthroat trout	0	1	1	9	0	2
Trap nights	32	16	34	35	55	64

Table 7. Catch per unit effort (CPUE) of coho salmon yearlings and young-of-the-year (YOY) captured in fyke nets at two enhanced wetlands (E1 and E2), two unenhanced wetlands (U1 and U2), and two oxbow wetlands (O1 and O2), Chehalis River floodplain, Washington, 2003.

	January		March		April		May	
Site	yearling	YOY	yearling	YOY	yearling	YOY	yearling	YOY
E1	8	0	0.3	0	0.5	0.2	0	0
E2	0	0	0.5	0	0.9	0.3	0.5	0.3
U1	0	0	0	0.7	0	9	--	--
U2	0	0	0	0	0	0.5	0	0
O1	0	0	0	0	0	0	1	1.3
O2	2.3	0	0.5	0	12.2	3.8	17	61

(--) No sampling occurred due to wetland desiccation

Coho salmon was the dominant species among the salmonids captured in the emigrant traps, and catches were greater in 2003 than 2004 at the enhanced wetlands, the only locations monitored both years (Table 6). Coho yearling emigrants in 2003 were about twice that in 2004, and YOY emigrants were over 12 times greater.

There were temporal differences in utilization of wetlands by yearling and YOY coho salmon. Yearling coho salmon emigrated from the wetlands earlier than YOY (Figure 5). The numbers of yearling emigrants decreased considerably by the end of May, but YOY coho salmon were not captured until mid-March, and YOY CPUE increased until June. The median date of emigration of yearling coho salmon was noticeably earlier at the enhanced wetlands than at the oxbow habitat O2 (E-sites: 31 March for E1 and 17 April for E2; O2 site: 30 April), but the pattern for YOY coho salmon was similar among sites. The O1 site was not included in the analysis because few emigrating salmon were captured. The median date of emigration between yearlings and YOY varied among years at all sites, but differences at E2 (25 days and 44 days in 2003 and 2004 respectively) were greater than at E1 (11 days and 5 days). At O2, median date of emigration of yearling coho salmon was 6 days earlier than YOY in 2003.

Coho salmon yearlings resided in E2 significantly longer than in E1 (t-test: $T = -6.45$, $P < 0.01$). Residence duration averaged 51 days in E1 and 66 days in E2 with the longest mark-recapture residence of 104 days.

Water quality and related emigration patterns

Habitat conditions gradually became unsuitable for fishes in emergent wetlands as water temperatures increased, dissolved oxygen concentrations decreased, and/or wetland water levels dropped. In 2003, water temperatures at all sites increased throughout the sample season, ranging from 6-22 °C. However, water temperatures were below 17 °C most of the sampling period (until end of May). Dissolved oxygen concentrations were at, or near, lethal levels for fish in June (<0.8 mg·L^{-1}) and oxygen was likely a more significant limiting factor than temperature in the wetlands. Dissolved oxygen concentrations decreased throughout the sampling season and ranged from 10-0 mg·L^{-1}. Enhanced and unenhanced wetlands had significantly lower dissolved oxygen concentrations than oxbow habitats ($F_{5,182} = 62.12$, $P<0.01$). The oxbows O1 and O2 had water quality suitable for fishes throughout the sampling season, but minimum dissolved oxygen levels in the unenhanced and enhanced wetlands were below 1.0 mg·L^{-1}. Although dissolved oxygen concentrations in the oxbow O2 did not approach critical levels for fish survival, fish were stranded when the outlet channel desiccated. At wetlands E1 and E2, dissolved oxygen concentrations were significantly higher in 2003 than 2004 ($P< 0.01$; $P< 0.01$). In 2003, low dissolved oxygen concentrations did not occur until the end of April, but in 2004, substantial declines (<2 mg·L^{-1}) occurred by the end of February in E1 and by May in E2.

Dissolved oxygen concentrations appeared to influence the emigration patterns of YOY and yearling coho salmon in the enhanced wetlands. In 2003, dissolved oxygen concentrations decreased to less than 1.0 mg·L^{-1} at the end of April at E1, and YOY and yearling coho salmon continued to emigrate until 18 May (Figure 5). At E2, coho YOY emigrants increased until 2 June when dissolved oxygen concentrations fell below 1.5 mg·L^{-1} (Figure 5). At the oxbow O2, the outlet channel desiccated before dissolved oxygen levels declined (5.0 mg·L^{-1}), thus stranding fish. In 2004, dissolved oxygen levels at E1 decreased below 2.0 mg·L^{-1} at the end of February, and yearling and YOY coho salmon continued to emigrate until mid-April when dissolved oxygen levels were below 0.5 mg·L^{-1}. At E2, coho yearlings emigrated until 22 May when dissolved oxygen levels decreased below 1.5 mg·L^{-1}, but YOY continued to emigrate until 6 June when the trap was pulled.

Release experiment and survival

The patterns of emigration of released coho salmon were similar to that of the wild yearlings at both enhanced wetlands. The median date of emigration of released coho salmon at E1 was within 1 day of that of wild coho salmon, and at E2, the median emigration date of released yearlings followed wild yearling coho salmon by 2 weeks. Similarly, patterns of emigration between wetlands were significantly different (median = 1 day after release and 51 days after release) for wetlands E1 and E2, respectively. The dissolved oxygen concentration at E1 was low (~ 1.0 mg·L^{-1}) when the coho salmon were released, and 70% emigrated within the first week. In contrast, dissolved oxygen concentration at E2 remained higher (3.0-5.0 mg·L^{-1}), and only 14% of the released coho salmon emigrated during the first month following release.

Survival rates for the released yearlings were 38% at E1 and 22% at E2 wetland. Because estimates were calculated by dividing the number of released yearlings that emigrated by the total number released in the wetland, survival rates were considered minimum estimates. Although, emigration after the traps were pulled was probably not likely at E1 where dissolved oxygen was less than 1.0 mg·L^{-1}, coho salmon in E2 could

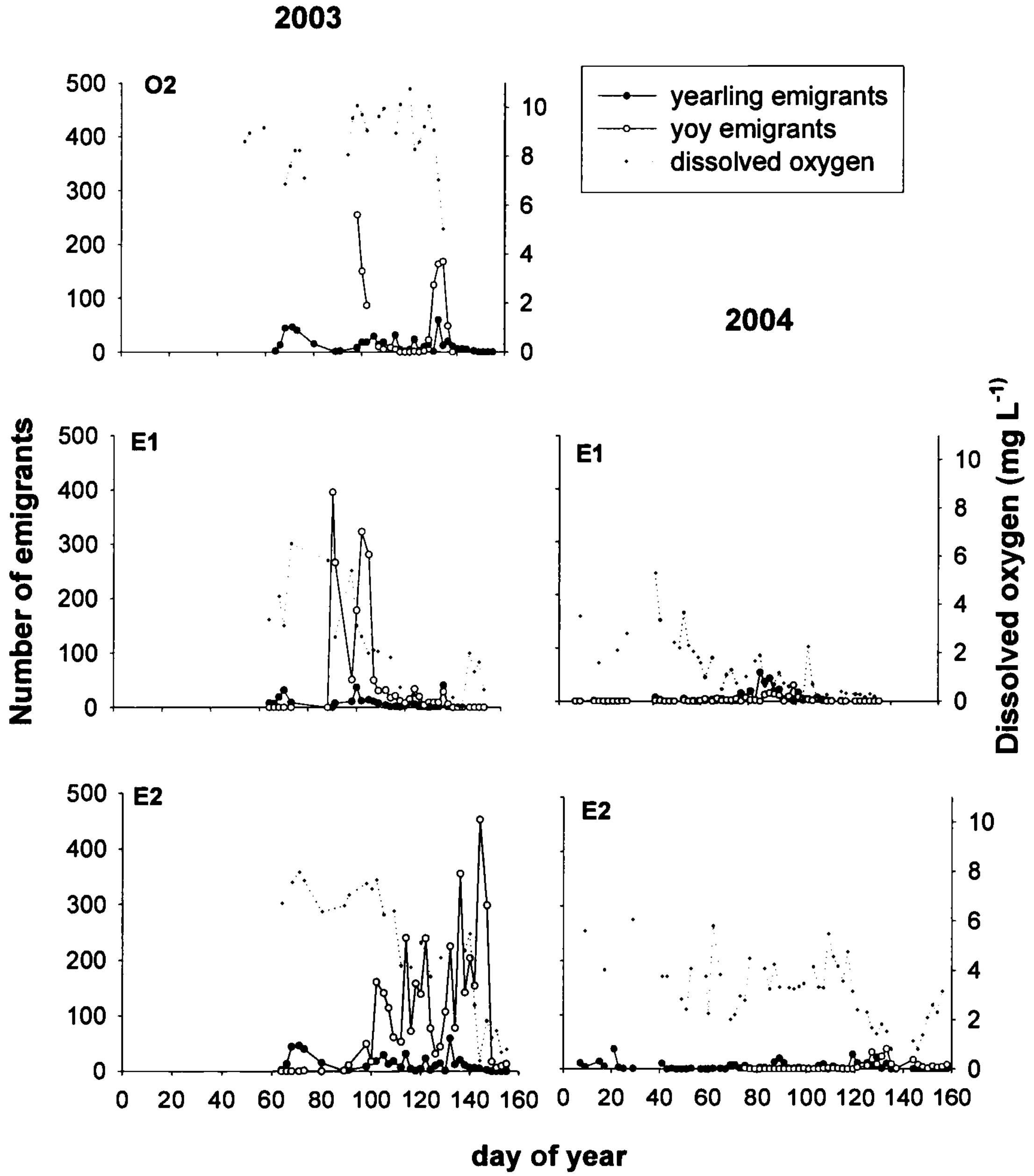

Figure 5. Emigration patterns of coho salmon yearlings and YOY in enhanced wetlands during 2003 and 2004 sampling season. Emigration patterns for oxbow O2 are included for 2003. All emigration patterns are graphed with dissolved oxygen concentrations ($mg \cdot L^{-1}$) on the secondary x-axis.

have continued to emigrate for a short time, as dissolved oxygen was greater (1.4 – 3.1 $mg \cdot L^{-1}$). Minimum survival rates for wild yearling coho salmon (determined in 2004 from the uniquely marked individuals) were 57% at E1 and 30% at E2. Actual survival rates were likely higher because of the reasons given above, and also because flood events earlier in the season may have allowed fish to emigrate without passing through the trap. Survival estimates for wild yearlings marked before the flood and recaptured after the flood were 65% and 67%, suggesting that there was minimal emigration during the flood events.

Coho salmon growth

In 2004, yearling coho salmon had an average specific growth rate of 1.37 $g.g^{-1}d^{-1}$ (SE = 0.06, n = 107) at E1 and 1.43 $g.g^{-1}d^{-1}$ (SE = 0.05, n = 134) at E2. Although there was no difference in specific growth rate between the two wetlands ($F_{1,125} = 3.17$, P = 0.07), there were significant differences in growth among months ($F_{3,125} = 6.79$, P < 0.01). Specific growth rates were higher for fish recaptured in March and April than for fish recaptured in February or May.

Discussion

Enhanced wetlands on the floodplain of the Chehalis River appear to play an important role in the life history of juvenile coho salmon. Coho salmon were more abundant than other salmonid species rearing in the study sites, but they were rarely the dominant fish species (except in the oxbow side-channel O2). This was particularly true in the enhanced wetlands where native non-salmonid species, such as three-spine stickleback and Olympic mudminnow (*Novumbra hubbsi*) were far more common (Chapter 2). Enhanced wetlands were important habitats for juvenile coho salmon; and densities frequently surpassed those recorded in the unenhanced emergent wetlands and oxbow habitats.

Juvenile coho salmon utilized enhanced emergent wetlands more extensively than unenhanced emergent wetland habitats. No yearling coho were captured in unenhanced wetlands, and it appears that these wetlands contribute little, if anything, to the Chehalis River yearling coho production. The principal differences between the unenhanced and enhanced habitats are that the latter have outlets that allow prolonged fish emigration to the river, longer hydroperiod, slightly greater water depth, and a diversity of emergent vegetation that can enhance food resources for fish. During flood events, riverine fishes had similar access to the enhanced and unenhanced wetlands (sheetwater); however, as water levels receded, unenhanced wetlands became isolated from the river, and fish became stranded.

Moreover, yearling coho salmon growth and survival suggests that juvenile salmon benefited from rearing in the enhanced wetland habitats. Growth of coho salmon yearlings in enhanced wetlands was higher than estimates from off-channel ponds in the Clearwater River, Washington (Cederholm et al. 1988). Moreover, minimum survival rates observed (30-57%) in this study are comparable to overwinter survival estimates in other off-channel ponds (49-79%; Peterson 1982, 54-87%; Swales et al. 1986, 56%; Cederholm et al. 1988). These survival estimates suggest that the coho salmon in the enhanced wetlands were able to emigrate successfully before water quality declined. In the unenhanced wetlands, coho salmon YOY captured and released after the last flood (1 April 2003) suffered 100% mortality. Similarly, juvenile coho salmon captured and released in oxbow O2 were stranded in the pond after the outlet desiccated (mid-May) and presumably died.

Beaver ponds have been shown to be productive habitats for juvenile coho salmon (Sanner 1987; Leidholt-Bruner et al. 1992; Nickelson et al.1992). Although the oxbow beaver pond appeared to have habitat features that would attract juvenile coho salmon (i.e., low water velocity, abundant cover and large wood, adequate water quality and depth (3 m), and year-around connection to the river system), few salmon were captured. Despite similarities with other beaver pond habitats, several factors may explain the observed differences. One major distinction is dams built within the stream channel tend to be ephemeral and are often destroyed by high winter flows and rebuilt each summer (Leidholt-Bruner et al. 1992). In the Chehalis system, beaver dams are frequently imbedded in the floodplain of agricultural ditches and remnant oxbows and are more permanent than in-stream beaver dams. In addition, nonnative fishes are abundant in oxbow lakes of the Chehalis drainage, and they can often affect the presence of native species (Beecher and Fernau 1982). For example, piscivorous largemouth bass (*Micropterus salmoides*) and brown bullhead (*Ameiurus nebulosus*) that inhabit the oxbow beaver pond we studied may prey on juvenile salmon. Moreover, steep banks and deep water limit emergent vegetation and invertebrate production (Eldridge 1990; Murkin et al. 1992). Finally, floodplain ponds are less likely to experience the immigration of juvenile salmon by downstream drift than are beaver ponds located within stream channels where salmon spawning may occur immediately upstream.

Temporal variation in emigration was observed across the floodplain, between age groups of coho salmon, and between sample years. Lengthy inundation of floodplains and their emergent wetland habitats often results in low dissolved oxygen levels (i.e., anoxia; Mitsch and Gosselink 1993; McKinnon 1997), and the seasonal pattern of juvenile salmon emigration in this study appeared to reflect changing oxygen levels. Emigration was earlier in 2004 than 2003 paralleling the earlier decline in dissolved oxygen concentrations. Moreover, differences in the patterns of emigration between the two enhanced wetlands reflected the patterns of dissolved oxygen concentrations. Results of the experimental release exhibited similar patterns. In addition, low dissolved oxygen concentrations in wetlands may limit spring residency of juvenile coho salmon. Average residence of wild coho salmon yearlings and the released cohorts were greater in the enhanced wetland with higher dissolved oxygen concentrations.

There were also temporal differences in utilization of the wetlands that appeared to be related to the timing of YOY emergence and a lower physiological tolerance of yearlings. Furthermore, the onset of smoltification may have affected the earlier emigration of yearlings. Yearlings can often access floodplain habitat prior to the emergence of YOY in late February. In contrast, YOY coho salmon appeared more tolerant of low dissolved oxygen concentrations than yearlings, and YOY emigrated from the enhanced wetlands later than yearlings. Although dissolved oxygen concentrations were below lethal limits for juvenile coho ($<1.0\ mg \cdot L^{-1}$; Colt et al. 1979), continued emigration from the enhanced wetlands suggests that numerous individuals survived these conditions. Low dissolved oxygen thresholds are known to relate to fish size, age and physiological state, temperature, and acclimation to low dissolved oxygen concentrations (Herrmann 1956, Colt et al. 1979). Although low dissolved oxygen levels may have influenced emigration patterns, concomitant increases in ammonia, urea, and nitrites (Brett 1979) may also affect observations.

Not surprisingly, there was temporal variation in coho salmon abundance between years of the study. Salmon abundance in the enhanced wetlands (E1 and E2) was five and nine times higher in 2003 than 2004. Smolt production forecast for the Chehalis River was 30% higher in 2003 than in 2004 (WDFW, unpublished data), which could account in part for the higher yearling abundance in wetlands in 2003. In contrast, the number of spawners in 2002 and 2003 were similar, which does not explain the difference in YOY abundances between 2003 and 2004 (WDFW, unpublished data). The frequency and timing of flooding each year likely determines accessibility to, and use of, off-channel emergent wetlands by riverine species (cf. Brown and Hartman 1988). Floods occurred more often and later in 2003 (late March) than 2004 (early February), and therefore, wetlands were more accessible to riverine species. Increased fish access to the wetlands later in the season may explain the greater abundance of fish, especially YOY coho salmon, in the wetlands in 2003.

Off-channel habitats in large river-floodplains, such as habitats sampled in this study, may function differently than off-channel habitats in small headwater streams in relation to features such as basin size, amount of available off-channel habitat, river gradient, and discharge. Moreover, the floodplain of the lower Chehalis River is over 2 km wide, with an extensive network of off-channel habitat types that provides winter rearing habitat for natural coho salmon production (WDFW, unpublished data). By contrast, smaller systems with limited off-channel habitat for winter rearing, such as the Clearwater River (Peterson and Reid 1984; Cederholm et al. 1988), may lead to higher juvenile coho densities but lower total numbers than observed in the present study.

Although the sample size of wetland types was small, the study demonstrated that heterogeneity in habitat and salmon use exists across the floodplain. Salmon abundances varied among emergent wetlands, and not all off-channel sites supported salmon. This spatial heterogeneity shows that generalizing habitat types across the floodplain is difficult. Thus, I suggest that flooded habitat within a floodplain should not be interpreted as quality salmon habitat without classifying the habitat and determining fish presence (see also Brown 1987). Wetland characteristics such as continuous connectivity to the river system, the length of the hydroperiod, the distance from the main river channel, and adequate dissolved oxygen and temperature during the rearing season are critical factors that affect juvenile salmon use. Moreover, these results are especially important because of the large abundance of yearlings captured in enhanced wetland areas that are generally considered atypical rearing habitat. The enhanced and unenhanced wetlands studied developed anaerobic environments with limited dissolved oxygen, lacked cover and minimal flow, and were only available to fish when river flows overtopped the riverbanks. However, the enhanced wetlands exhibited features, such as increased the rearing surface area and prolonged hydroperiod, and opportunities for emigration, which transformed them into important habitat for juvenile coho salmon.

There can be considerable spatial and temporal variation in the structure and function of off-channel habitats in an individual floodplain. In addition, there can be profound temporal affects, such as flooding, that influence fish access to, and residency in floodplain habitats. Habitats that have an abundance of fish one year may be inaccessible another year. In addition, fish rearing in ephemeral habitats risk stranding and anoxia, and these risks may be outweighed by faster growth and higher survival than in main river channel habitats. It is important to recognize the variable nature of habitats across a floodplain and to assume these habitats vary in suitability to salmon. Agricultural landscapes with rehabilitated emergent wetlands, even when the habitat is only accessible to fish during floods, can offer valuable rearing habitat to riverine species. Although wetland enhancement and restoration is often undertaken for purposes other than salmon conservation (e.g., mitigation, vegetation, birds, and amphibians), our research shows that juvenile salmon can benefit from such activity if outlet structures are included to allow fish emigration. Lastly, by providing for exploitation of floodplain habitats, emergent wetlands and side-channels in large coastal river systems may be important in sustaining a unique aspect of the life history of wild juvenile coho salmon in these systems.

<u>Acknowledgements</u>

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Chapter 4: Conclusion

The findings of this thesis contribute to our understanding of fish rearing in floodplains by providing new information on emergent wetlands as important habitat for many fish species. Fishes were found in all floodplain habitats sampled, but emergent wetlands are fulfilling a niche for native nongame fishes that other floodplain habitats such as beaver ponds and oxbows are not providing. For example, emergent wetlands are critical for some fish species, such as the Olympic mudminnow and the three-spine stickleback, that rely on wetland habitats for spawning and rearing. The protection and enhancement of seasonal emergent wetlands can contribute to the conservation of our native fishes.

Although wetland enhancement and restoration projects are designed for purposes other than salmon conservation (e.g., mitigation, vegetation, birds, and amphibians), juvenile salmon can benefit from such activity if outlet structures are included to allow fish emigration. Coho salmon (YOY and yearling) were the most common salmonid at all sites, and yearling coho salmon were benefiting from rearing in enhanced wetland habitats where their growth and survival were comparable to other side-channel studies. Seasonal emergent wetlands had declining water levels and dissolved oxygen concentrations during the spring, but emigration patterns suggested that coho yearlings leave the wetlands, as conditions decline.

Anthropogenic activities have affected most floodplains and their wetland habitats. Removing these anthropogenic effects may be impossible, and therefore, other techniques to mimic floodplain-river hydrology are increasingly valuable. Wetland enhancement using water control structures is one management option to restore the integrity of a wetland (e.g., native vegetation, hydrology). Wetland enhancement in floodplains can benefit fishes and sustain species that rely on wetland rearing during their life history. Lastly, aquatic habitat heterogeneity exists across the floodplain. Floodplain emergent wetlands were utilized by a range of fish species, and their abundances varied among individual habitats. Therefore, it is important to conserve these different habitat types across the landscape to accommodate a range of species and life-history types.

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