Comparison of Habitats Near Spur Dikes, Continuous Revetments, and Natural Banks for Larval, Juvenile, and Adult Fishes of the Willamette River

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ABSTRACT

Natural banks, because they are diverse in structure, afford the best habitat for resident fishes of the mid-Willamette River (RM 118 to 142). Spur dikes contain a diversity of habitats in terms of velocities, depths, and cover unavailable at continuous revetments. The numbers of species of fishes and densities of larval and juvenile fishes at spur dike are intermediate between natural banks and continuous revetments. The numbers of species of adult fishes were similar to those found at the continuous revetments. The one important difference was that juvenile chinook salmon use this area during early spring and were observed to feed in the slack water between spur dikes during a hatch of mayflies. Juvenile chinook salmon were not captured from continuous revetments. Wood debris was observed to accumulate between spur dikes. We hypothesize that as the debris accumulates and as the riparian vegetation develops, habitat for adult fishes will improve, especially during the winter.

Relationships between habitat variables and juvenile fish density changed between major sampling periods. This is due to changes in habitat needs during growth, but also reflects that physical gradients such as temperature and velocities became less severe as time passed. Two factors were consistent: juvenile fishes avoided velocities greater than 11 cm/sec and were found at depths no greater than 30 cm.

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FOREWORD

The Water Resources Research Institute, located on the Oregon State University campus, serves the State of Oregon. The Institute fosters, encourages, and facilitates water resources research and education involving all aspects of the quality and quantity of water available for beneficial use. The Institute administers and coordinates statewide and regional programs of multidisciplinary research in water and related land resources. The Institute provides a necessary communications and coordination link between the agencies of local, state and federal government, as well as the private sector, and the broad research community at universities in the state on matters of water-related research. The Institute also coordinates the interdisciplinary program of graduate education in water resources at Oregon State University.

It is Institute policy to make available the results of significant water-related research conducted in Oregon's universities and colleges. The Institute neither endorses nor rejects the findings of the authors of such research. It does recommend careful consideration of the accumulated facts by those concerned with the solution of water-related problems.

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INTRODUCTION

Stone revetments have been used extensively on the Willamette River to stabilize stream banks and channels. To illustrate the magnitude of local losses, losses of up to 9 m/yr of prime agricultural land along an 800-m reach was occurring near river mile (RM) 136 of the Willamette River (Kehe and Klingeman, 1984). The first revetment on the Willamette River was constructed in 1888, and subsequently many bank stabilization techniques have been tried (Thornber, 1965; Thornber and Bubenik, undated). In part, the different techniques have been tried because of concerns for the impacts on the aquatic community. The Willamette River has changed in 20 years from a carrier of pulp mill effluent and municipal sewage (Gleeson and Merryfield, 1936; Westgarth and Northcraft, 1964; Britton, 1965) to a stream system that supports important salmonid runs and is a recreational asset. This was the result of an extensive clean-up program (Gleeson, 1972; Starbird, 1972; Council on Environmental Quality, 1973), an upstream reservoir system (Sherman, 1976), and development of the Willamette River Greenway System (Willamette Basin Task Force, 1969; Hansen, 1977; Deval, 1977).

In an attempt to conserve both agricultural soil and fish habitat, a series of 8 spur dikes, also called groins, were installed by the Army Corps of Engineers during the summer of 1983 (Kehe, 1984; Kehe and Klingeman, 1984). This was intended to protect farmland as well as to provide a more diverse habitat for fishes and wildlife, by creating slackwater and pools not afforded by standard, continuous stone revetments, also called riprap banks (Kehe and Klingeman, 1984).

A comparison of the aquatic fauna and selected physicochemical parameters of riprap banks and natural habits of the Willamette River was conducted in 1982 (Hjort et al., 1983). We found that the invertebrates and fishes inhabiting natural habitats and those associated with riprap banks were different. Briefly, high densities of a smaller number of species of fish were found in revetted habitats. These were fishes that fed on bottom-dwelling invertebrates or filamentous green algae and diatoms (plants using the large stones as substrate), and small fishes able to use interstices of the revetment as cover (Hjort et al., 1983). Fishes associated with natural banks were richer in species due to the greater diversity of the physical habitat. Invertebrates associated with revetments were characterized by adaptations to exploit interstices as habitat or to cling to rock surfaces in fast water (Hjort et al., 1983). The fauna was more typified by organisms requiring stable physical habitat than those found in natural banks. During this time, we observed larval fishes in the interstices of the riprap banks near shore, but were constrained from sampling them due to limitations of time and money.

The objectives of this study were to examine the use of continuous stone revetments, of spur dikes, and of natural stream banks as habitat for larval fishes and, time permitting, to compare the use of these habitats by adult fishes.

STUDY AREA

The study sites were located on the Willamette River, Oregon, between the town of Peoria (RM 142) and Bowman Park in the city of Albany (RM 118). The following types of habitats found in natural bank areas were sampled: backwaters of point bars, secondary channels, sloughs, ephemeral pools, and steep and shallow banks on the main channel. The nearshore interstices of continuous riprap structures were sampled. The following types of habitats were sampled at the spur dikes: the upstream side (backwash section), the tip (L-head section of Kehe, 1984), the downstream side (interior hook section), and the beach between the spur dikes. Greater detail of the spur dikes are available from Kehe (1984) and from Kehe and Klingeman (1984).

METHODS AND MATERIALS

The following definitions are used to classify the various life stages of fishes:

1. yolk-sac larvae -- Morphological structures are incomplete and/or are not fully developed. The yolk-sac is present.

2. larvae -- Morphological structures are incomplete and/or are not fully developed. Yolk-sac has been absorbed.

3. juvenile -- Morphological structures are complete but their sexual organs are not fully developed.

4. adult -- A reproductively capable individual.

Both yolk-sac larvae and larvae were enumerated using a wide variety of techniques. Viewing boxes, a battery-powered diaphragm pump, a manual bilge pump, and a modified surf zone sampler were used to test for presence or absence of larval fishes. Relative densities were gathered using dip nets and expressed in terms of fish per sweep. Absolute densities were estimated using two methods. A toss net 85 cm in diameter, 50 cm deep, shrouded with 707 micro m Nitex netting, was tossed randomly in the nearshore area and fishes were removed using pumps and dip nets. As over 96% of both stages of larval fishes are distributed within the nearest 15 cm of the shoreline (LaBolle, 1984), they are easy to inventory in areas of little shorelines and emergent vegetation. Thirty-meter transects 0.5 meters in width were conducted along the shorelines. Larval fishes of both stages were tallied on a hand counter. After two to three repeated counts, dip nets were used to collect individuals for identification and species composition. At least two methods were used; visual inspection was always one of them.

Juvenile fishes were sampled only as a by-product of samplng for larval fishes. Their presence was recorded, but no special effort was taken to gather population densities of this life stage.

Adult fishes were collected using an electroshocking boat that pulsed 3 to 4 amps of 120-130 volts of direct current at 120 cps. The electrical charge was conducted through booms used as anodes, the hull of the boat acting as the cathode. The shocking transect was made as close to the bank as possible. Transects of 152 m were made for the natural banks and for the continuous stone revetments. At the spur dikesthe continuous transects covered approximately 800 meters.

The following physical parameters were measured: water temperature, dissolved oxygen, depth at sampling locus, surface velocity, mean flow, slope of the bank, surface substrate composition, presence of instream cover, and substrate composition. Water temperature was measured using a thermometer. Dissolved oxygen was measured periodically using and YSI meter (model 504A); values were always saturated during the course of the study. Velocity was measured using an electromagnetic flow meter (Marsh-McBirney, model 201). Slope of the bank was obtained by aligning the graduated staff perpendicular to the bank at the sampling station and placing a clinometer along its length. Presence of instream cover, such as rootwads, woody debris and aquatic vegetation, was marked on a presence or absence basis. Composition of the surface substrate was visually estimated using size classes established by the Wentworth Particle Size Scale.

Sampling began 10 August 1983. No larval fishes were observed in any habitat. Sampling recommenced on 3 April 1984 (Julian day 94) on a weekly basis until 22 June 1984. The sampling schedule was based on previous work on larval fishes in the mid-Columbia River (Hjort et al., 1981).

RESULTS

Only young-of-the-year (YOY) juvenile fishes were found during 10 August 1983. Twelve sites were examined. None were observed near riprap banks or in the spur dikes. YOY fishes were observed only in natural habitats.

The first larval fish was caught 17 May 1984, Julian day 138 (see Table 1). Notable densities of fishes were not caught until Julian day 149. Because of the patterns observed, the data were grouped into four periods: Julian day 94 to 142, Julian day 149 to 158, Julian day 171 to 173, and Julian day 214-221. It was during Julian day 138 that we first witnessed spawning activity by any fish. Carp were spawning in backwaters off the main channel. The most notable factor distinguishing the first sampling period from the other two was temperature. Temperatures rose above 11 C only during the latter two sampling periods. Daily temperatures were recorded almost always between 14:00 and 18:00 hr, thus close to the daily maximum. Temperatures in the backwaters, regardless of sampling period, were at lest 2 C higher than in the main channel.

Table 1. Larval fish catch data for Julian days 94 to 142. The slashmarks separate visual counts from hoop catches. CP denotes catch per pass by dip net, + denotes presence of larvae.

Habitat	Julian Day								
	94	97	107	109	112	115	124	138	142
Spur Dikes									
Inside Hook		0/0							
L-head		0/0							
Backwash		0/0							
Beach		0/0							
Revetments	0/0		0/0		0/0	0/0			
Natural Habitats									
Main Channel [25°]*	0/0								
Main Channel [15°]									+/0
Main Channel [10°]				0/0					
Side Channel [20°]						0/0			
Point Bar Slough [9°]	0/0								0/0
Backwater [15°]								0.03 CP	

*Brackets enclose slope of bank

Very similar patterns of distribution were observed during the second and third sampling periods (see Tables 2 and 3). Highest densities were found in slower, warmer, shallow, sloped habitats. These habitats were characterized generally by higher percentages of sand, silt, clay, and small gravel. Table 4 gives the correlations for the relationship of density to these parameters. It is more important to note the sign of the correlation rather than the value; however, temperature plays an obviously important role. In part, the low correlations are due to step functions rather than continuous ones; that is, above or below a certain critical level, there is no great difference until another plateau is reached. These critical or cutoff values are given in Table 4. The highest recorded densities were taken from backwaters associated with instream structure such as tree stumps or rootwads (see Table 3). Slope seemed to make a difference within the spur dikes. The most larval fish were noted in a shallow, sloped beach habitat (6), but absent from a steeply sloped beach. All other factors were very similar. In general, natural habitats supported more larval fish, followed by spur dike habitats, and lastly by habitats associated with continuous revetments. All the larval fish captured were largescale suckers (*Catostomus macrocheilus*).

More species appeared in the samples during the fourth sampling period. Note from Table 5 that numbers of species are highest at natural banks, lowest at the continuous revetments, and intermediate for spur dikes (when habitats of the spur dike are considered). Three species were in the larval stage. These were the northern squawfish (*Ptychocheilus oregonensis*), redside shiner (*Richardsonius balteatus*), and speckled dace (*Rhinichthys osculus*). Table 6 shows that the natural bank habitats generally supported the greatest density of larval and juvenile fishes and that habitats of the revetments supported the lowest. Variation was great among spur dike habitats; but aside from the two beaches, densities observed were intermediate between natural bank and continuous revetements.

Young-of-the-year (YOY) juveniles were caught in the following habitats: beach of the spur dike, torrent sculpin (*Cottus rhotheus*); natural bank near the main channel, speckled dace (*Rhinichthys osculus*), and reticulate sculpin (*C. perplexus*); and backwaters off the main channel, three-spined sticklebacks (*Gasterosteus aculeatus*). Juvenile chinook salmon were captured and released in the slack water between the spur dikes. What appeared to be juvenile chinook salmon were observed feeding on a hatch of mayflies during 6 April between spur dikes 6, 7, and 8. Speckled dace juveniles were observed in water 10 cm deep, within 20 cm from shore, and among large gravel in water of approximately 22 cm/sec in various habitats including spur dikes, continuous revetments, and natural banks. Juvenile exotic fishes such as white crappie (*Pomoxis annularis*), and largemouth bass (*Micropterus salmoides*) were captured from backwater habitats.

Table 2. Larval densities (fish/dip net sweep) during days 149 to 158. Brackets enclose slope of bank.

	Julian Day		
Habitat	149	156	158
Spur Dike			
Inside Hook		0.35	
L-Head		0.00	
Backwash		0.20	
Beach		0.03	
Revetments			0.00
Natural Habitats			
Main Channel [5°]	0.00		
Backwater [3°]	1.80		

Table 3. Larval densities (fish/m^2 ± standard deviation) during days 171 to 173. Parentheses enclose sample size. Brackets enclose slope of bank.

Habitat	Julian Day 171	Julian Day 173
Spur Dikes		
Inside Hook		0.15 ± 0.06(3)
L-Head		0.05 ± 0.06(2)
Backwash		0.17 ± 0.16(3)
Beach [20%]		15.01 ± 3.62(3)
Beach [5%]		0.00(2)
Revetments	0.07(1)	0.02 ± 0.04(4)
Natural Habitats		
Main Channel [5°]	0.00(1)	
Main Channel [10°]	1.46(1)	
(backwater [5°] (near rootwad	203.72(1)	
(backater [10°] (near tree stump	>300 (1)	
(backwater [6°] (slough	107.72 ± 19.26(3)	

Table 4. Correlation coefficients (r) of larval fish density to various parameters during the second and third sampling periods. Parentheses enclose sample size.

Parameter	Sampling Period	
	II	III
Flow Velocity	-0.32	-0.26 [< 22 $\frac{cm}{sec}$]
Slope of Bank	-0.39	-0.53**
Temperature	+0.97* [> 12 C]†	+0.44*** [> 13 C]
% Sand, Silt, Clay) and % Small Gravel)	+0.24	+0.28

* (P < 0.01)

** (P < 0.05)

***(P < 0.10)

† Brackets enclose cutoff values above and below which no larvae are found.

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Table 5. Juvenile species composition in different habitats during Julian days 214-221. Parentheses percent composition.

Spur Dikes					
Backwash	Inside Hook	L-head	Beaches	Continuous Revetments	Natural Bank
northern squawfish (100)*	northern squawfish (47)*	northern squawfish (100)*	largescale sucker (43)	redside shiner (70)*	redside shiner (45)*
	redside shiner (29)*		redside shiner (29)*	largescale sucker (26)	northern squawfish (36)*
	largescale sucker (18)		reticulate sculpin (14)	northern squawfish (10)*	speckled dace (7)
	chiselmouth (6)		northern squawfish (14)*		speckled dace (5)*
					largescale sucker (4)
					reticulate sculpin (3)

*denotes larvae; other fish are juveniles.

Table 6. Larval densities (fish/m^2 ± standard deviation) during days 214 to 221. Parentheses enclose sample size. Brackets enclose slope of bank.

	Julian Day	
Habitat	214	221
Spur Dikes		
Backwash	30.5 ± 2.5 (3)	
Inside Hook	20.9 ± 2.0 (3)	
L-Head	18.1 ± 1.3 (3)	
Beach [11°]	8.2 ± 0.8 (3)	
Beach [6°]	6.2 ± 1.8 (3)	
Revetments		10.8 ± 2.4 (3)
Natural Bank [7° ± 1]		56.7 ± 36.5 (5)

Table 7 compares the numbers of adult species captured in different habitats. In descending order of species abundance were the following: natural banks, continuous revetments, and spur dikes. This was due, in part, to two factors. Temperatures were considerably cooler during 1984 than during 1982 when the data were gathered for the revetments and natural habitats. This may have influenced seasonal migration patterns that are heavily influenced by temperature. The spur dikes are new and may be in the early successional stages of aquatic plant, riparian vegetation, aquatic invertebrate, and fish community succession.

DISCUSSION AND CONCLUSIONS

The results of this survey suggest that continuous revetments are not good larval fish habitats. This is probably due to a proximity to fast water (above 11 cm/sec), a combination of steep grade (about 30°), and greater depth (greater than 30 cm) near shore, resulting in less area suitable for escape from sources in predation and lower temperatures than found in other habitats that have greater use. The temperature effect was pronounced during the early part of the year, but was not during the last sampling date, when coincidentally temperatures were more uniform and larval fishes were found in detectable numbers around stone revetments. Surprisingly, juvenile sculpins did not use riprap to any great degree, although they are often associated with rocky substrates. This might be attributable to well-known difficulties getting estimates of relative densities of sculpins because they are difficult to sample. We did use suction pumps in the interstices of the revetments and did catch an occasional sculpin along with larval suckers, so the interstices were used to some degree.

Spur dikes appeared to be intermediate in quality between the natural banks and continuous revetments. The diversity of habitats they afforded was observably greater than at continuous revetments. It will become more heterogenous in the future because wood debris accumulates between spur dikes, and riparian vegetation will increase through time. Beaches between spur dikes can be very good larval fish habitat, especially when the slope of the bank is shallow.

As natural habitats include secondary channels, fast and slack water banks, sloughs, and backwaters, physical diversity is higher and results in greater fish diversity. Interestingly, limited observations made in this study suggest that juvenile chinook salmon use this habitat. We do not know how long they use this habitat, but we believe that they were feeding there at the surface during April, and they were captured there in early June. All larval fishes captured were largescale suckers. We expected to capture a larger number of species because LaBolle (1984) found that several native cypriniform fishes were found in the same habitat at this life stage in the mid-Columbia River. We believe that this year was "slow" because of the high amount of rain.

Table 7. Presence (+) of various adult fishes of the Willamette River near Corvallis, Oregon.

Species	Spur Dikes (12 C)*	Revetments (16.6 C)†	Natural Banks (16.8 C)†
lamprey		+	
carp	+	+	
northern squawfish	+	+	+
peamouth			+
chiselmouth	+	+	+
largescale sucker	+	+	+
mountain sucker	+		+
redside shiner		+	+
speckled dace	+	+	+
leopard dace			+
mountain whitefish		+	+
chinook salmon	+		+
cutthroat trout		+	+
white crappie			+
largemouth bass			+
bluegill			+
channel catfish			+
yellow bullhead			+
prickly sculpin	+		+
torrent sculpin	+	+	+
reticulate sculpin			+
Piute sculpin			+

*Collection made 5 June 1984
†Collection made 9-11 June 1982

The local paper, The Corvallis Gazette Times, reported that 4.34 inches of rain fell in June of 1984. The 30-year average is 1.20 inches (Anonymous, 4 July 1984). This resulted in lower temperatures during early June. We recorded temperatures near 17 C during the period of 9-11 June 1982; temperature on 5 June 1984 was 12 C, and on 22 June 1984 was 14 C. A sudden release of water from Lookout Point Reservoir during early June "flushed out" many of the established study sites. Suckers typically have a broad spawning period (Hjort et al., 1981); that is why largescale suckers were the first to be observed. Our supposition is also supported by the differences in August samplings between 1983 and 1984. In 1983 we saw no larval or juvenile fishes at continuous revetments or at spur dikes. In 1984, fishes were found in detectable numbers. Species that spawn and develop later than the largescale sucker were observed as the water temperature increased and the season progressed.

Several collection methods were used. We were most satisfied with the visual transect method. It is fast and it is at least as accurate as the toss nets when larvae are at intermediate densities. In a pilot study, visual transects yielded an estimate of 15.01 ± 3.62, toss rings an estimate of 20.56 ± 23.99. Toss rings are effective when density is high; dip nets are the most effective gear when fishes are rare.

In summary, natural banks are the best fish habitats, as expected; but it appears that the spur dikes are providing better fish habitat than revetted banks when all life stages are considered. The spur dikes are new, and our recommendation is to conduct a follow-up study at intervals of 2, 4, 8, and 16 years to discern the results of increased riparian development and capture of woody debris on fish use at spur dikes. Rodnick and Li (in press) found that woody debris in slack water is prime winter habitat for Willamette River fishes.

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