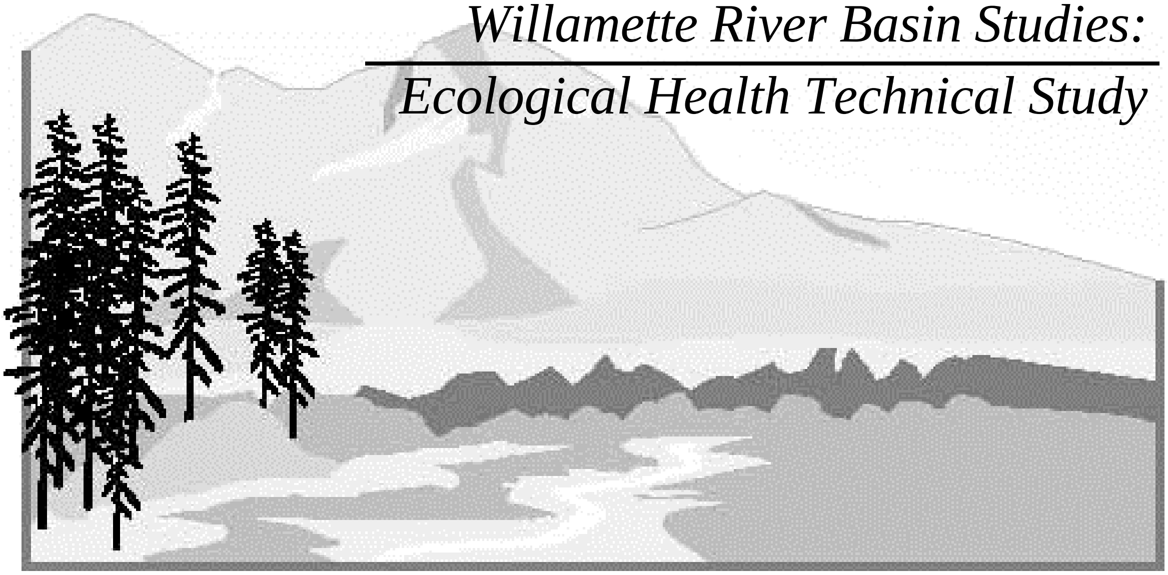
Willamette River Basin Studies:

Ecological Health Technical Study



CHARACTERIZATION OF SKELETAL DEFORMITIES IN THREE SPECIES OF JUVENILE FISH FROM THE WILLAMETTE RIVER BASIN

Prepared for

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Water Quality Division
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EVS Project No. 2/839-02

February 11, 2000

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Steven G. Ellis

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DEQ	Oregon Department of Environmental Quality
EVS	EVS Environment Consultants, Inc.
RM	river mile
WWTP	wastewater treatment plant

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The following individuals provided comments on an earlier draft of this report:

Dr. Gene Foster	Oregon Department of Environmental Quality
Mr. Rubin Jared	Oregon Department of Environmental Quality
Ms. Beth Woodward	Oregon Department of Environmental Quality
Dr. Duncan Gilroy	Oregon Health Division
Mr. Ken Kauffman	Oregon Health Division

1.0 INTRODUCTION

In the early 1990s, the Oregon Department of Environmental Quality (DEQ) initiated several studies to evaluate biological assessment techniques that could be used, along with Oregon State water quality standards, to manage and protect aquatic life within the Willamette River basin. The presence of skeletal deformities in juvenile fish was one of the assessment techniques evaluated. This assessment technique has been used extensively to monitor the condition of marine and freshwater fish populations (Mehrle et al. 1982; Slooff 1982; Baumann and Hamilton 1984; Bengtsson 1988; Mayer et al. 1988; Bengtsson 1991; Lindesjöö and Thulin 1992; Ellis et al. 1997). This assessment technique is useful for monitoring programs because 1) it has an uncomplicated, low cost methodology; 2) we have a general understanding of how individual fish fitness can be adversely affected by skeletal deformities; and 3) a wide range of environmental stressors can induce skeletal defects in fish (EVS 1999).

Studies conducted in 1992, 1993, and 1994 showed that the incidence of skeletal deformities in northern pikeminnow juveniles (formerly called northern squawfish, *Ptychocheilus oregonensis*) collected along the main stem of the Willamette River ranged from 1.1 to 74 percent (Ellis et al. 1997). The highest incidence of skeletal deformities was observed in fish collected within the Newberg Pool, a stretch of the Willamette River extending from Willamette Falls, at river mile (RM) 26.5, upstream to approximately RM 55 near the city of Newberg. Juvenile fish collected in the upper Willamette River, from RM 125 to RM 185, and near the mouth of the river at RM 3 showed a low incidence of skeletal deformities, within the range of 2–5 percent reported for unstressed natural fish populations and laboratory stocks (Gill and Fisk 1966; Wells and Cowan 1982).

This report describes the results of additional sampling, conducted during August–September 1998 to further characterize and evaluate the incidence of skeletal deformities in juvenile fish within the Willamette River. The specific objectives of this study were to:

- Further characterize the spatial occurrence of skeletal deformities in juvenile northern pikeminnow within the Willamette River by sampling locations not previously sampled

- More accurately determine where skeletal deformities first appear to increase above background levels in the upper Willamette River by conducting more intensive sampling between RM 125.5 and RM 113, the furthest upstream location where historical studies have shown that the incidence of skeletal deformities was elevated above background levels

- Compare current and historical percentages of skeletal deformities in juvenile northern pikeminnow at selected sites that previously showed both low and high incidences of skeletal deformities

- Characterize the incidence of skeletal deformities in additional fish species

This report is organized into seven main sections. The study objectives and report organization are provided in Section 1.0. A brief overview of the historical studies conducted within the Willamette River to characterize skeletal deformities in juvenile fish is provided in Section 2.0. The study design and the rationale for selecting sampling locations is described in Section 3.0. The field collection and laboratory processing methods are described in Section 4.0. The study results are provided in Section 5.0 and a brief discussion of the major findings of the study is provided in Section 6.0. References are provided in Section 7.0.

2.0
HISTORICAL STUDIES

In August 1992, August 1993, and July–August 1994, juvenile northern pikeminnow were collected from 19 locations along the main stem of the Willamette River and one location within the Luckiamute River, a tributary of the Willamette River. Between 131 and 339 juvenile fish from each location were processed using methods described in Ellis et al. (1997) and examined for skeletal deformities. The mean length of fish examined at each location ranged from 18.5 to 45.5 mm (Table 1). Each individual fish was examined for skeletal deformities under 12 times magnification with a dissecting microscope. A fish that displayed curvature of the spine in either the dorsal-ventral (lordosis) or lateral (scoliosis) plane, fused vertebrae, or deformed vertebrae was classified as exhibiting skeletal deformities. The incidence of skeletal deformities at each location was calculated as the percentage of individuals exhibiting one or more types of skeletal deformities.

The main stem of the Willamette River can be divided into the following four segments based on the measured incidence of skeletal deformities during 1992–94 and the amount data available to evaluate spatial trends:

- Lower Willamette River: RM 0–RM 26.5
- Newberg Pool: RM 26.5–RM 55
- Middle Willamette River: RM 55–RM 125
- Upper Willamette River: RM 125–RM 185

A description of the each of these four segments and the observed incidence of skeletal deformities in juvenile northern pikeminnow is provided below.

2.1 LOWER WILLAMETTE RIVER

The lower Willamette River is a 26.5 mile stretch of river extending from the mouth of the river where it discharges to the Columbia River upstream to Willamette Falls. This stretch of river flows through the Portland metropolitan area and represents the most highly urbanized section of the Willamette River. Four major municipal wastewater treatment plants (WWTPs), located at RM 18.5, RM 20.1, RM 20.3, and RM 25.2, and two major industrial facilities, located at RM 7.4 and RM 7.0, discharge wastewater to this stretch of the Willamette River. One major tributary, the Clackamas River, enters this stretch of the Willamette River at RM 25.

Table 1. Skeletal deformities in juvenile northern pikeminnow collected in the Willamette River basin, 1992–94

River Mile	Collection Date	Number Examined	Mean Size [a] (mm)	Size Range (mm)	Percent Deformed
Lower Willamette River					
3.0	8/12/92	285	39.5	21–60	1.1
	8/19/93	147	31.6	17–60	2.7
25.5	8/18/93	331	23.4	17–31	22.7
Newberg Pool					
28.5	8/18/93	332	23.1	17–45	22.6
34.0	8/18/93	318	21.3	13–31	28.6
38.5	8/18/93	311	21.3	13–35	32.8
40.5	8/17/93	339	21.8	15–27	33.3
48.5	8/17/93	300	21.4	13–29	51.0
49.7[b]	8/10/92	256	27.5	21–41	25.8
	8/17/93	318	22.6	15–31	30.8
49.7[c]	8/17/93	271	22.6	15–29	52.0
	7/21/94	131	23.3	19–35	74.0
51.0	8/17/93	259	21.4	13–29	48.6
	7/21/94	261	23.3	17–31	58.6
Middle Willamette River					
72.0	8/3/94	235	28.0	15–50	21.7
113.0	8/3/94	230	27.0	21–40	22.2
Luckiamute River[d]					
13.5[e]	8/30/93 and 9/4/93	312	37.3	19–65	1.6
Upper Willamette River					
125.5	8/11/92	250	27.9	21–39	3.2
	8/19/93	327	23.2	13–29	1.8
	8/1/94	246	23.5	17–33	5.3
141.0	8/1/94	249	27.8	19–35	2.0
144.8	8/23/93	315	23.6	13–35	2.5
147.4	8/23/93	270	25.5	13–65	2.2
151.0	8/1/94	249	45.5	31–50	2.0
185.4	8/13/92	250	29.9	21–39	1.6
	8/20/93	336	18.5	13–25	3.0

[a] Fork length.
[b] West bank.
[c] East bank.
[d] Enters the Willamette River at river mile 107.6.
[e] Helmick State Park; river mile 13.5 of the Luckiamute River.

The incidence of fish skeletal deformities in this stretch of the Willamette River has not been well characterized; only two sites have been sampled. In August 1993, the incidence of skeletal deformities in juvenile northern pikeminnow collected at RM 25.5 near the mouth of the Clackamas River was 22.7 percent (Figure 1).

The other site sampled within the lower Willamette River is located at RM 3 downstream of the city of Portland. The incidence of skeletal deformities in juvenile fish collected from this location was 1.1 percent for fish collected in August 1992 and 2.7 percent for fish collected in August 1993 (Figure 1). These values are similar to those observed in fish collected in the upper Willamette River. They are considered to represent background levels because they are within the range of 2–5 percent reported for unstressed natural fish populations and laboratory stocks (Gill and Fisk 1966; Wells and Cowan 1982).

2.2 NEWBERG POOL

The Newberg Pool is a 29 mile stretch of river extending upstream from Willamette Falls at RM 26.5 to approximately RM 55, where the Yamhill River enters the Willamette River. This stretch of river passes through or alongside the cities of Oregon City, Canby, Wilsonville, and Newberg. Three major municipal WWTPs located at RM 33, RM 39, and RM 50.3, and two major industrial facilities, located at RM 27.5 and RM 50, discharge wastewater to this stretch of the Willamette River. Four major tributaries enter this stretch of the Willamette River including the Tualatin River (RM 28), Pudding and Molalla Rivers (RM 36), and the Yamhill River (RM 55).

The Newberg Pool has been the most intensively studied stretch of the Willamette river. Samples of juvenile northern pikeminnow were collected from seven locations in this stretch of river during 1992–1994 (Table 1; Figure 1). The incidence of skeletal deformities was consistently high, ranging from 22.6 to 74 percent (mean = 49.7 percent, standard deviation [SD]= 16.2 percent). The incidence of skeletal deformities is highest at the upstream head of the Newberg Pool, with values declining in the downstream direction (Figure 1). Juvenile fish collected within a 2.5 mile stretch of river from RM 48.5 to RM 51 had the highest incidence of skeletal deformities (mean = 56.0 percent, SD = 14.1 percent).

2.3 MIDDLE WILLAMETTE RIVER

The middle Willamette River is a 71 mile stretch of river extending upstream from RM 55 to RM 125, which is approximately five miles downstream of the city of Corvallis. This stretch of river passes through the cities of Salem, Independence, and Albany. Land use along the river consists primarily of agriculture. Two major municipal WWTPs, located at RM 78.2 and RM 119, and one major industrial facility, located at RM 116.5, discharge wastewater to this stretch of the Willamette River. Three major tributaries enter this stretch of the Willamette River

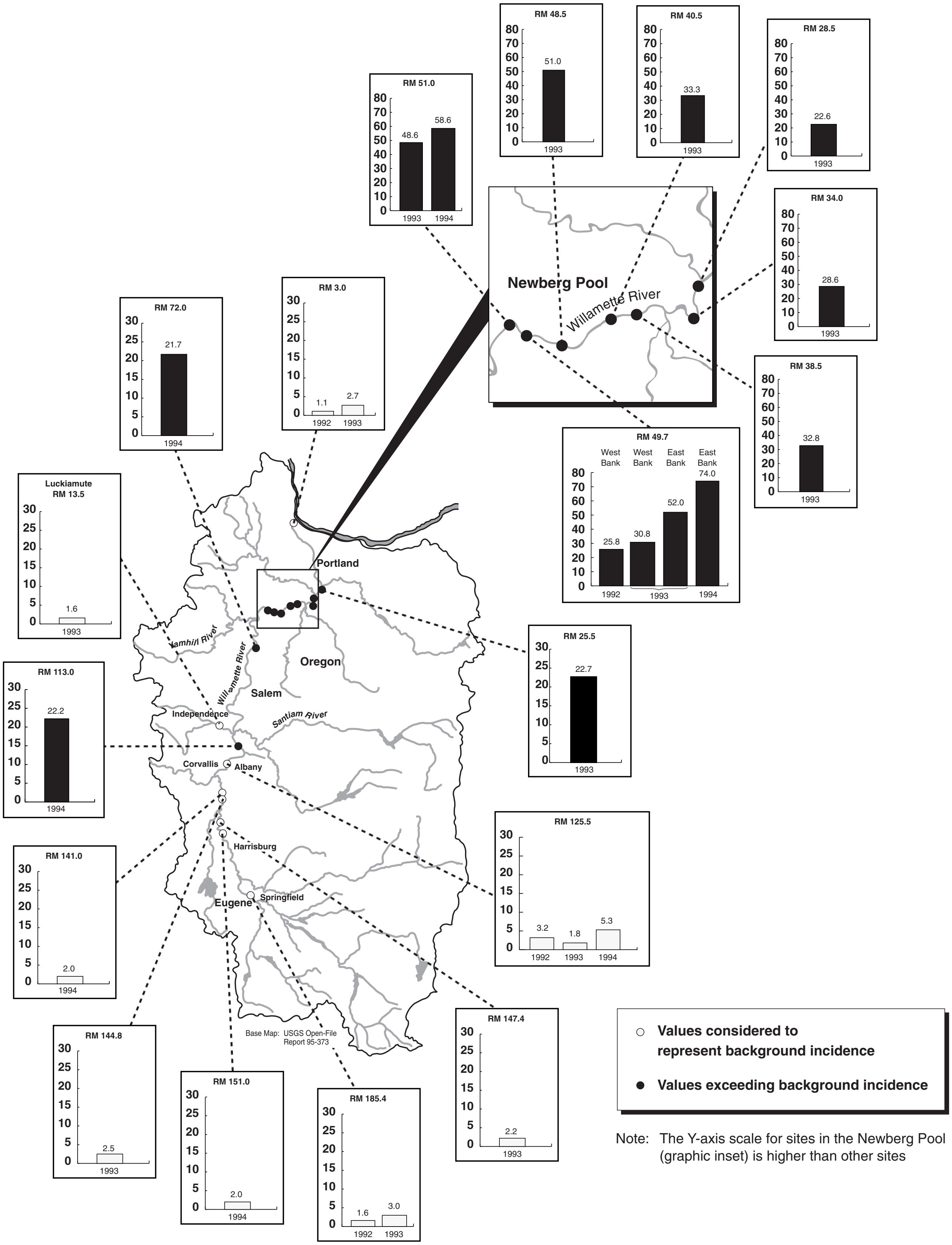


Figure 1. Percentage of skeletal deformities in juvenile northern pikeminnow, 1992–94

including the Luckiamute River (RM 107.6), Santiam River (RM 109), and Calapooia River (RM 120).

The incidence of fish skeletal deformities in this stretch of the Willamette River has not been well characterized; only two sites have been sampled. In August 1994, the incidence of skeletal deformities in juvenile northern pikeminnow was 22.2 percent in fish collected at RM 113, six miles downstream of the city of Albany, and 21.7 percent in fish collected at RM 72, six miles downstream of the city of Salem. Both of these values are significantly higher than the incidence of skeletal deformities measured in fish from the upper Willamette River.

In 1993, juvenile fish were collected from the Luckiamute River near Helmick State Park. This river discharges to the middle Willamette River at RM 107.6. This site was selected as a possible field reference site because of the absence of nearby point sources and the presence of relatively undisturbed forested land adjacent to the river. The incidence of skeletal deformities in northern pikeminnow collected from this site was 1.6 percent.

2.4 UPPER WILLAMETTE RIVER

The upper Willamette River extends 60 miles upstream of RM 125 to the cities of Eugene and Springfield. This stretch of river passes through the cities of Corvallis, Harrisburg, Eugene, and Springfield. Land use along the river consists primarily of agriculture. Two major municipal WWTPs, located at RM 131 and RM 178, and two major industrial facilities, located at RM 132.2 and RM 147.2, discharge wastewater to this stretch of the Willamette River. Three major tributaries enter this stretch of the Willamette River including the Marys River (RM 132), Long Tom River (RM 146), and the McKenzie River (RM 172).

Samples of juvenile northern pikeminnow were collected from six locations in the upper Willamette River during 1992–1994 (Table 1; Figure 1). The incidence of skeletal deformities at all sites was consistently low during the three years of sampling, ranging from 1.3 to 5.6 percent (mean = 2.6 percent, SD = 1.1 percent). These values are considered to represent background levels of skeletal deformities in juvenile northern pikeminnow because they are within the range of 2–5 percent reported for unstressed natural fish populations and laboratory stocks (Gill and Fisk 1966; Wells and Cowan 1982).

3.0
STUDY DESIGN

The study design to accomplish the objectives for this study was developed through a phased process. First, sampling sites were selected and then target fish species were selected based on the abundance of species collected at the selected sampling sites. The rationale for the selection of sampling sites is provided in this section.

A list of the ten sites that were initially selected for the analysis of skeletal deformities in juvenile fish is provided in Table 2 along with a brief rationale for selecting those sites. The selected sites were intended to meet the following study objectives:

- Determine the incidence of fish skeletal deformities in areas of the Willamette River basin that have not been historically sampled (Sites 2, 3, 4, 6, 7, 8, and 10)

- Attempt to locate more accurately the furthest upstream incidence of elevated fish skeletal deformities (Sites 2, 3, 4, and 5)

- Determine the incidence of fish skeletal deformities in the lower Yamhill River (Site 8), which discharges to the Willamette River five miles upstream of the site where the highest incidences of fish skeletal deformities have been measured in historical studies

- Measure fish skeletal deformities at sites sampled in the past to provide comparisons with the historical data (Sites 1, 5, and 9)

The resources available to DEQ for this study did not allow an intensive investigation of skeletal deformities to be conducted throughout the Willamette River. Therefore, to obtain information that might lead to a better understanding of the causes of high incidence of skeletal deformities in juvenile fish, it was decided to locate several of the sampling sites in the stretch of river between RM 113 and RM 125 to try to identify the most upstream location where the incidence of fish skeletal deformities is elevated above background levels measured in the upper Willamette River. It was hoped that further characterization of potential stressors in the vicinity of that most upstream location might assist DEQ in identifying the causes of skeletal deformities in juvenile fish. Figure 2 is a schematic diagram which shows the location of sampling sites, tributaries, and major and minor point sources in the stretch of the Willamette River between RM 85 and RM 135. RM 125.5, located approximately five miles downstream of the city of Corvallis was sampled in 1992, 1993, and 1994. The incidences of fish skeletal deformities measured at this site have been consistently low (mean = 3.4 percent, SD = 1.8 percent) and within the range of background levels of skeletal deformities found in natural unstressed fish

Table 2. Collection sites for the assessment of fish skeletal deformities in the Willamette River basin

Site No.	River	River Mile	GPS Coordinates	Description	Rationale
1	Willamette River	125.5	44° 35.256N 123° 11.170W	Downstream of Corvallis	**Comparison site:** sampled during each historical survey
2	Willamette River	121	44° 38.43N 123° 07.369W	Upstream of the City of Albany (RM 119.2) and Calapooia R. (RM 119.5), downstream of Adair Village (RM 122.5)	**New site** : selected to determine where upstream increase in deformities first occurs; evaluate point sources that discharge stressors known to cause deformities
3	Willamette River	117	44° 39.888N 123° 04.966W	Downstream of City of Albany (RM 119.2) and upstream of discharges from Willamette Industries (RM 115.5) and Truax Creek (RM 115.5)	**New site** : selected to determine where the most upstream increase in deformities first occurs; also selected to evaluate point sources that discharge stressors known to cause deformities
4	Truax Creek	0.25	44° 39.483N 123° 04.364W	Downstream from the Teledyne Industries discharge (RM 0.40)	**New site** : selected to evaluate potential impacts from Teledyne Industries
5	Willamette River	113	44° 41.483N 123° 07.320W	Downstream of Albany	**Comparison site** : selected to compare results with historical data collected in 1994; also selected along with Sites 2, 3 and 4, to evaluate point source discharges form City of Albany, Willamette Industries, and Teledyne Industries
6	Willamette River	88	44° 55.713N 123° 06.683W	Upstream of City of Salem	**New site** : selected along with Site 7 to evaluate Salem area contribution
7	Willamette River	77	No fish collected	Downstream of City of Salem	**New site** : selected to evaluate Salem area
8	Yamhill River	2 to 5	45° 14.368N 123° 02.772W	Yamhill River	**New site** : selected to determine whether potential impacts from the Yamhill River are contributing to the elevated incidence in Newberg Pool
9	Willamette River	49.7	45° 16.703N 122° 58.535W	Newberg Pool	**Comparison site** : location where the highest percent of skeletal deformities occurred in past studies
10	Willamette River	15	45° 28.897N 122° 39.458W	Downstream SE side of Ross Island	**New site** : selected to further characterize skeletal deformities in the lower Willamette River

NOTE: GPS – global positioning system

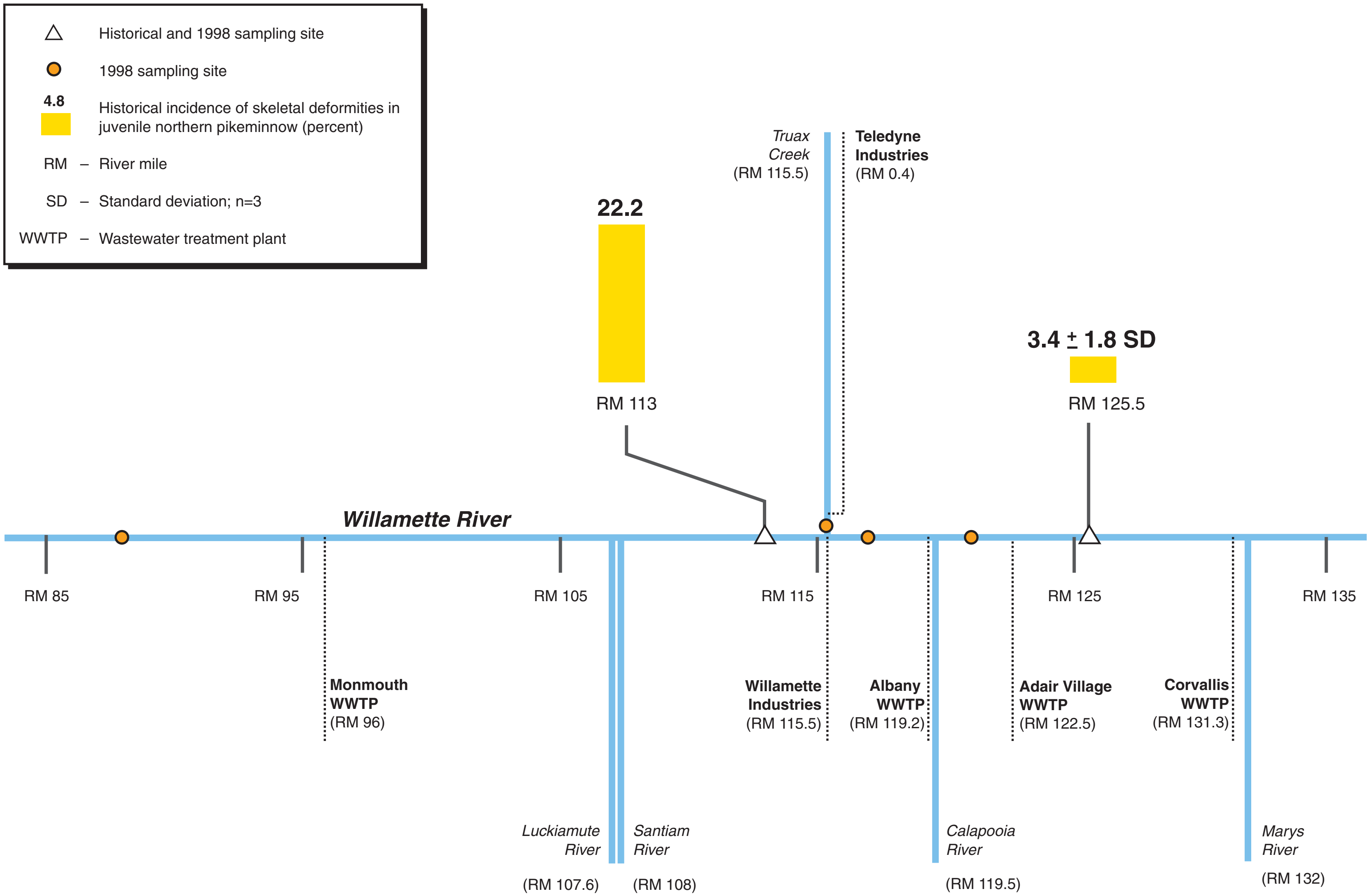


Figure 2. Schematic diagram of the Willamette River, river mile 85 to river mile 135, showing 1998 sampling sites, point sources, and incidences of skeletal deformities in northern pikeminnow, 1992–94

populations. In 1993, the incidence of skeletal deformities measured at RM 113 was 22.2 percent. As shown in Figure 2, two tributaries (Calapooia River and Truax Creek), two municipal WWTPs (Adair Village and Albany), and two industrial facilities (Teledyne Industries and Willamette Industries) discharge to the stretch of river between these two sites. To better characterize the transition point between background and elevated incidences of skeletal deformities in juvenile northern pikeminnow, sampling locations were located above and below the tributaries and point sources in this stretch of river (Figure 2). All of the major point sources within this stretch of river discharge trace metals that have been shown to cause fish skeletal deformities in laboratory studies (EVS 1999), thus it was not unreasonable to assume that these discharges might be affecting juvenile fish.

4.0 METHODS

4.1 FIELD COLLECTION

Juvenile fish were collected by staff from EVS and Taxon Aquatic Monitoring on August 25, 1998 and September 10–11, 1998 with an 18-ft beach seine with a mesh size of 0.1-in. The seine was repeatedly deployed in shallow water less than 4-ft deep while moving upstream along the river bank at each site to collect juvenile fish. Captured fish were placed in labeled glass containers containing buffered formalin and transported along with chain-of custody forms to a laboratory at Taxon Aquatic Monitoring in Corvallis, Oregon.

4.2 LABORATORY PROCESSING

Taxon Aquatic Monitoring staff verified receipt of the fish samples and began the initial processing of the samples. The fish from each collection site were measured (fork length), identified, and sorted by species into labeled containers containing buffered formalin. In December 1998, the processed samples were sent along with chain-of-custody forms to EVS Environment Consultants, Inc. (EVS) in Seattle, Washington. EVS staff verified that all samples were received in good condition.

Following discussions with DEQ staff to select the fish species that would be analyzed for this study, EVS delivered 15 samples of formalin-preserved fish to the University of Washington Fisheries Department laboratory on January 6, 1999 along with chain-of-custody forms for the 15 samples. The 15 samples included 8 samples of northern pikeminnow, 6 samples of chiselmouth, and 1 sample of largescale sucker. Receipt of the samples was verified by laboratory staff and catalogued into their tracking system.

A subsample of approximately 60–70 randomly selected individuals was removed from each sample for further processing. Each subsample of fish was processed through a series of steps to clear the fish tissue of any pigmentation and stain bone and cartilage red and blue, respectively, to assist in identifying the presence of skeletal deformities. The methods used to clear and stain the fish are similar to those reported by Taylor (1967) and Potthoff (1984). The subsamples of fish were dehydrated in a graded ethanol series from 50 to 95 percent for four days. Following dehydration, cartilage was stained by placing the fish in acidified alcian blue stain for 2-5 days, depending on the size of the fish. The stained fish were removed from the dye solution and neutralized in saturated sodium borate for two days. Next, the fish were bleached for two hours by immersion in a solution consisting of 15 parts 3 percent hydrogen peroxide and 85 parts 1 percent potassium hydroxide. Fish tissue was cleared using a trypsin enzyme buffer solution, which consisted of 35 parts of saturated sodium borate solution, 65 parts distilled water, and 0.25-gram trypsin enzyme. The fish were immersed in this solution for 7 to 10 days. Next, the bone was stained red with alizarin red-S dye in 1 percent potassium hydroxide buffer by placing the fish in the dye solution for 2 days. Following this period, the fish were again placed into a trypsin buffer solution until the tissue was cleared of red dye. The final preservation step consisted of placing the stained specimens into a 60 percent glycerin solution.

Each stained fish was measured (fork length) and examined under 12 times magnification for skeletal deformities. Skeletal deformities were classified into one of the following six categories depending on where in the skeletal structure they were observed:

- Spinal
- Caudal
- Fin
- Skull
- Jaw
- Rib

The incidence of skeletal deformities at each collection site was calculated as the percentage of individuals, of each species analyzed, exhibiting one or more types of skeletal deformities.

5.0
RESULTS

Table 3 shows the number, species, and size range of fish collected at the 10 sampling sites. Fourteen species of fish were collected. None of the fish species were collected at all sites. The fish species collected at six or more sites included, northern pikeminnow, largescale sucker, chiselmouth, redside shiner, and speckled dace.

Fish were collected from all sites except Site 7. The field team attempted to collect fish at this site on the afternoon of September 10, 1998 between approximately 1300 and 1530. Twenty-two separate beach seine deployments were carried out during this period over a distance of approximately 300 yards along the east bank of the river. No fish were captured, although a small number of large bass were sighted during the seining operation. The habitat in this area appeared similar to other upriver sites where fish were successfully captured. The substrate at Site 7 varied from medium cobble to sand. The water depth gradually increased to a distance of approximately six feet from shore and then rapidly increased to a depth that did not permit beach seining.

5.1 NORTHERN PIKEMINNOW

Northern pikeminnow juveniles from 8 sites were examined for skeletal deformities. The size range of fish examined ranged from 24 to 55 mm (Table 4), which is within the size range of 13–65 mm examined for skeletal deformities during 1992–1994 (Table 1). The incidence of skeletal deformities at the 8 sites ranged from 3.1 to 21.1 percent (Figure 3). The highest value was observed for fish collected in the lower Yamhill River (RM 2.5). Table 5 identifies the types of skeletal deformities observed in northern pikeminnow. Most skeletal deformities, 87.0 percent, were associated with the spinal column and included lordosis (Figure 4a), fused vertebrae (Figure 4b), and bifurcated vertebral rays (Figure 4c). Four individuals showed rib deformities (Figure 4d). One skull deformity and one caudal deformity were also observed.

A large number of northern pikeminnow showed evidence of parasites, which appeared as blue ovate structures in the stained specimens when examined at 12 times magnification (Figure 5a). Closer examination of tissue sections removed from parasitized fish showed that the ovate structures appeared to have at least two forms: an “open” form with a distinct outer membrane surrounding a clear undifferentiated interior (Figure 5b) and a “full” form which showed stained tissue within the outer membrane (Figure 5c). Positive identification of the parasites was not possible (Kocan pers. comm. 1999).

Table 3. Number, species, and size range of fish collected in the Willamette River basin, 1998

Species (Size Range)[a]	Willamette River								Truax Creek	Yamhill River
	RM 15 Site 10	RM 50 Site 9	RM 77 Site 7	RM 88 Site 6	RM 113 Site 5	RM 117 Site 3	RM 121 Site 2	RM 125.5 Site 1	RM 0.25 Site 4	RM 2 - 5 Site 8
Northern pikeminnow (15.00 - 54.00 mm)	–	75	–	150	153	162	155	119	152	19
Largescale sucker (25.00 - 64.99 mm)	–	4	–	28	14	45	6	64	63	–
Chiselmouth (20.00 - 49.00 mm)	71	–	–	174	75	132	–	166	131	–
Redside shiner (20.00 - 49.00 mm)	–	–	–	138	30	64	157	3	150	–
Speckled dace (20.00 - 49.00 mm)	–	–	–	19	19	14	13	8	3	–
Longnose dace (25.00 - 44.99 mm)	–	–	–	3	3	2	3	–	–	–
Mosquitofish (25.00 - 49.00 mm)	126	–	–	–	–	1	–	–	5	1
Banded killifish (15.00 - 49.00 mm)	–	44	–	6	–	–	–	–	–	4
Bluegill (25.00 - 45.00 mm)	54	–	–	–	–	–	–	–	–	155
Largemouth bass (45.00 - 64.99 mm)	8	–	–	–	–	–	–	–	–	–
American shad (45.00 - 64.99 mm)	–	33	–	–	–	–	–	–	–	–
Yellow bullhead (35.00 - 44.99 mm)	–	2	–	–	–	–	–	–	–	–
Sandroller (20.00 - 39.99 mm)	–	–	–	–	99	–	–	–	–	–
Leopard dace (20.00 - 44.99 mm)	–	–	–	–	27	–	–	–	–	–

NOTE: – - no fish collected
RM - River Mile
Shaded cells indicate samples that were analyzed for skeletal deformities

[a] Fork length

Table 4. Skeletal deformities in fish collected in the Willamette River basin, 1998

River Mile	Collection Date	Species Collected	Number Examined	Mean Size[a] (mm)	Size Range (mm)	Percent Deformed
Willamette River						
15	9/11/98	Chiselmouth	71	36.4	26–47	19.7
49.7[b]	8/25/98	Northern pikeminnow	72	41.9	30–55	13.9
88	9/11/98	Northern pikeminnow	63	31.3	24–37	4.8
	9/11/98	Chiselmouth	75	36.2	28–41	30.7
113	9/10/98	Northern pikeminnow	65	28.2	24–33	3.1
	9/10/98	Chiselmouth	75	35.2	26–43	25.3
117	9/10/98	Northern pikeminnow	63	28.8	24–33	9.5
	9/10/98	Chiselmouth	75	33.8	24–47	29.3
121	9/10/98	Northern pikeminnow	66	29.7	24–35	15.2
125.5	8/25/98	Northern pikeminnow	74	28.9	24–35	6.8
	8/25/98	Chiselmouth	75	30.8	24–37	17.3
	8/25/98	Largescale sucker	65	36.5	26–49	3.1
Truax Creek						
0.25	9/10/98	Northern pikeminnow	67	31.2	26–35	9.0
	9/10/98	Chiselmouth	75	35.2	28–39	26.7
Yamhill River						
2.5	9/11/98	Northern pikeminnow	19	32.8	28–54	22.2

[a] Fork length.
[b] West bank.

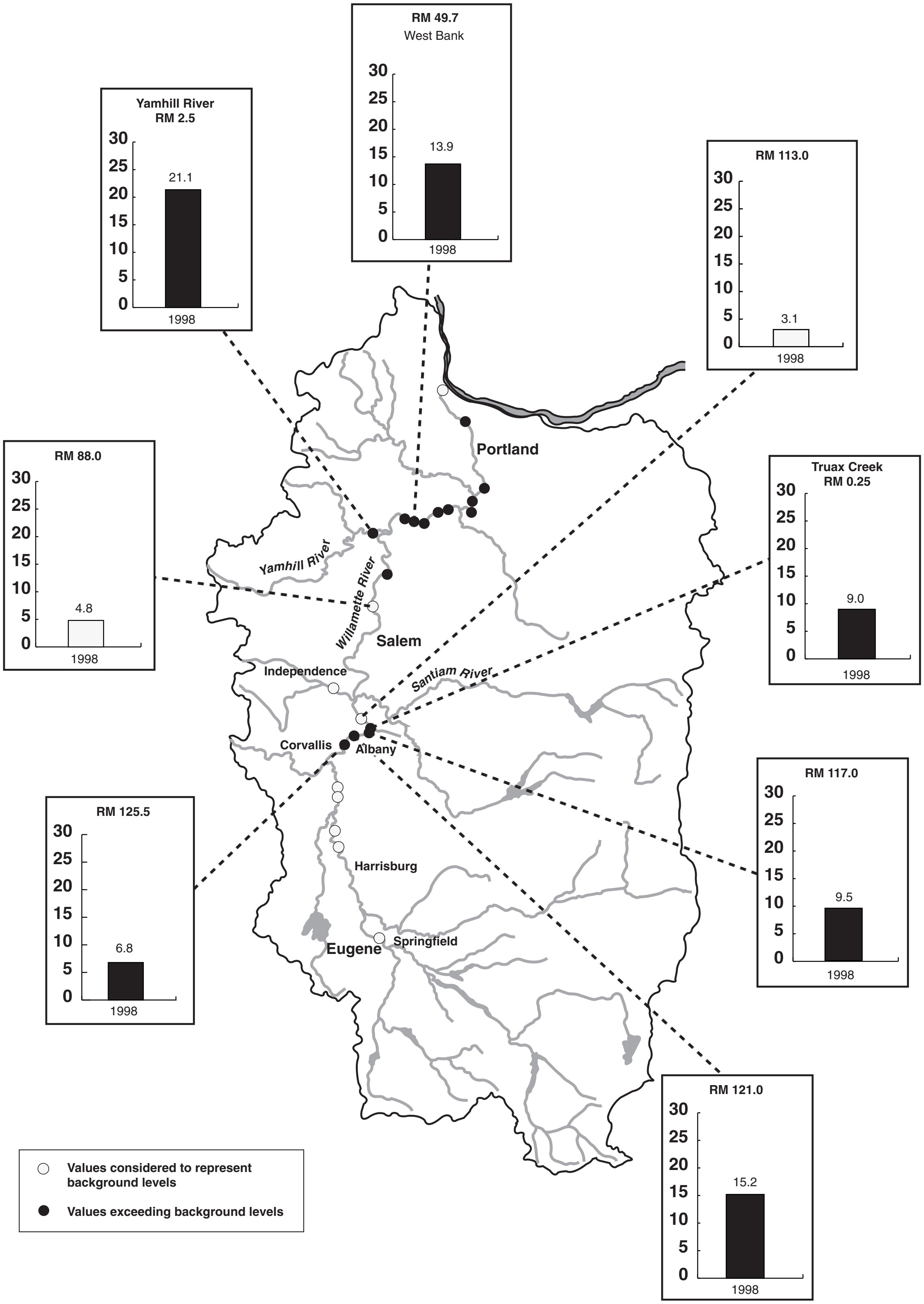


Figure 3. Percentage of skeletal deformities in juvenile northern pikeminnow, 1998

Table 5. Types of skeletal deformities observed in three species of juvenile fish from the Willamette River basin, 1998

Species	Site	Water Body	River Mile	Number Examined	Number Deformed	Type of Deformity					
						Spinal	Caudal	Fin	Skull	Jaw	Rib
Northern pikeminnow											
	1	WR	125.5	74	5	5	–	–	–	–	–
	2	WR	121	66	10	9	–	–	–	–	1
	3	WR	117	63	6	4	–	–	1	–	1
	4	TC	0.25	67	6	4	1	–	–	–	1
	5	WR	113	65	2	2	–	–	–	–	–
	6	WR	88	63	3	3	–	–	–	–	–
	8	YR	3.5	19	4	3	–	–	–	–	1
	9	WR	49.7	72	10	10	–	–	–	–	–
Total				**489**	**46**	**40**	**1**	**0**	**1**	**0**	**4**
Percentage						**87.0%**	**2.2%**	**0**	**2.2%**	**0**	**8.7%**
Chiselmouth											
	1	WR	125.5	75	13	12	–	–	–	–	1
	3	WR	117	75	19	16	1	1	–	–	1
	4	TC	0.25	75	20	16	–	1	–	–	3
	5	WR	113	75	22	20	–	1	1	–	–
	6	WR	88	75	23	19	1	–	2	–	1
	10	WR	15	71	14	13	–	1	–	–	–
Total				**446**	**111**	**96**	**2**	**4**	**3**	**0**	**6**
Percentage						**86.5%**	**1.8%**	**0**	**2.7%**	**0**	**5.4%**
Largescale sucker											
	1	WR	125.5	65	2	2	–	–	–	–	–
Total				**65**	**2**	**2**	–	–	–	–	–
Percentage						**100%**					

NOTE: TC – Truax Creek
WR – Willamette River
YR – Yamhill River
– - not observed

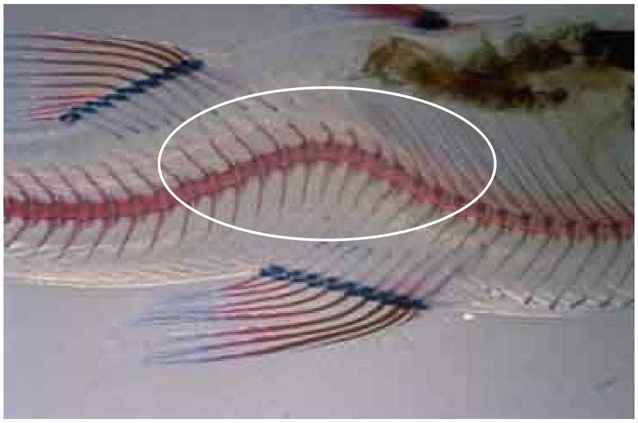


Figure 4a. Lordosis in northern pikeminnow

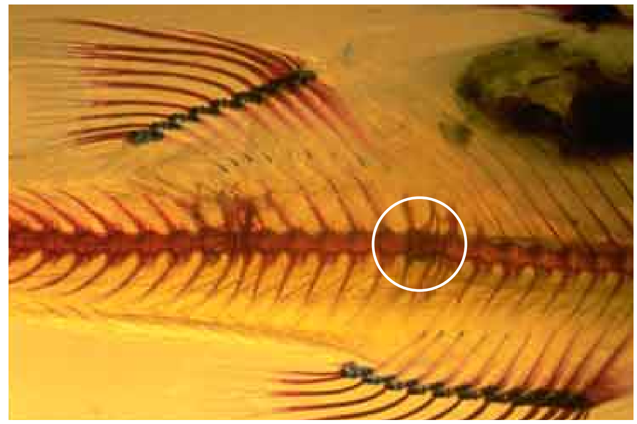


Figure 4b. Fused vertebrae in northern pikeminnow

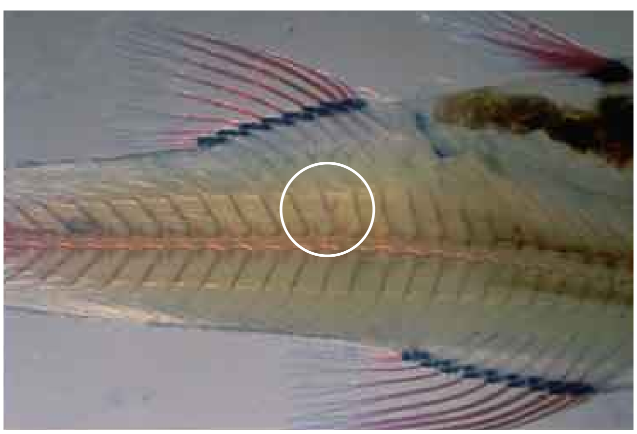


Figure 4c. Bifurcated vertebrae in northern pikeminnow

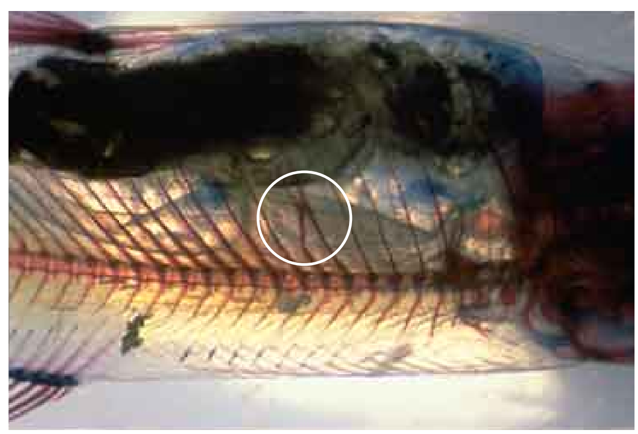


Figure 4d. Rib deformity in northern pikeminnow

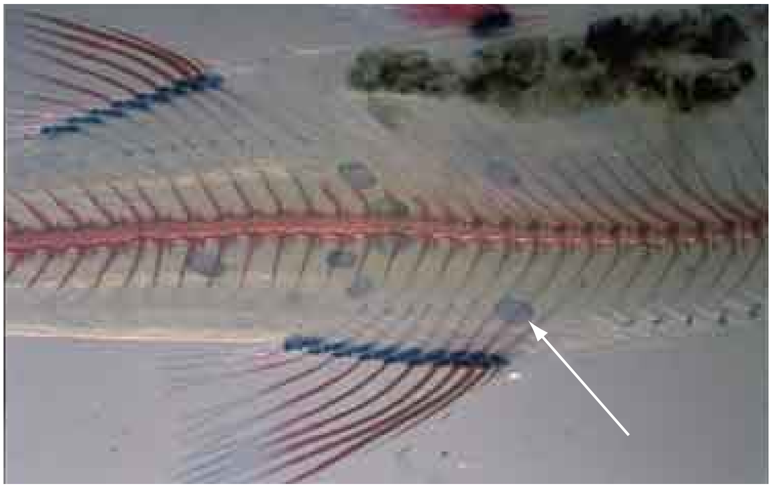


Figure 5a. Example of parasites in northern pikeminnow

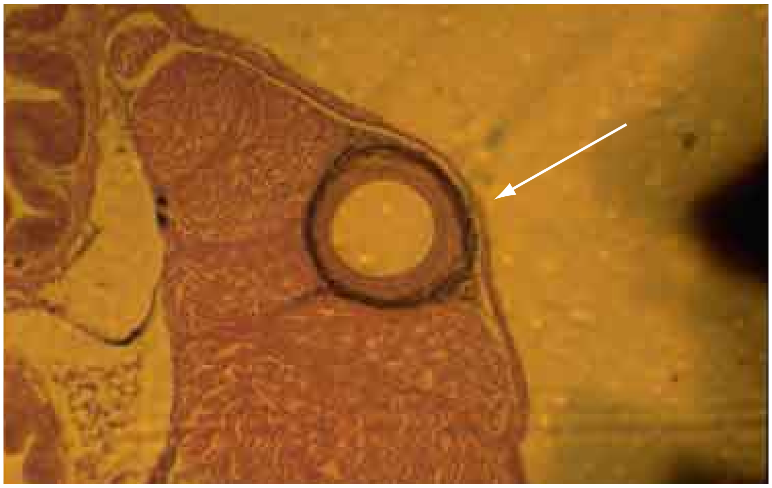


Figure 5b. "Open" form of parasite in northern pikeminnow

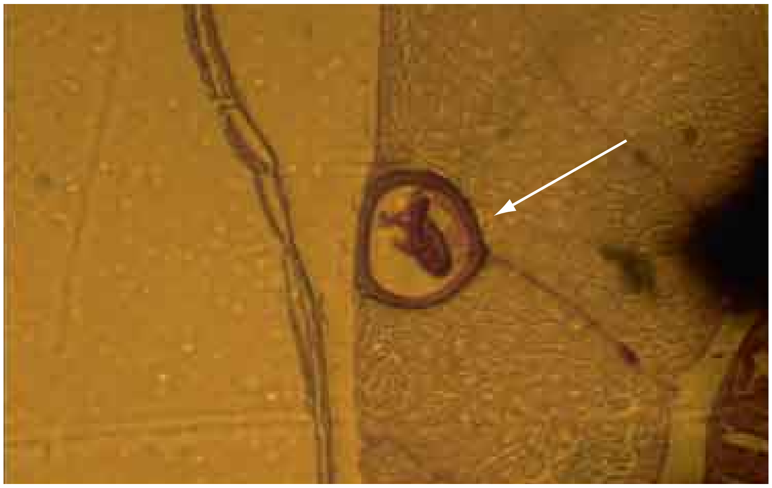


Figure 5c. "Full" form of parasite in northern pikeminnow

Table 6 shows the percentage of northern pikeminnow exhibiting evidence of parasites at the eight sites sampled. The lowest percentage, 1.4 percent, was observed in fish collected at RM 125.5 downstream of the city of Corvallis; the highest percentage, 88.1 percent, was observed in fish collected at RM 0.25 in Truax Creek, which discharges to the Willamette River downstream of the city of Albany at RM 115.5. The median percentage of northern pikeminnow from all 8 sites showing evidence of parasites was 53.9 percent.

Previous studies had shown that the incidence of skeletal deformities in northern pikeminnow collected in the upper Willamette River, from RM 125.5 to RM 185.4, ranged from 1.6 to 5.3 percent (Table 1), with a mean of 2.6 percent. As discussed above, these values were considered to represent a background incidence of skeletal deformities for this species. To try to determine the most upstream location where the incidence of skeletal deformities first appears to be elevated above background levels, juvenile northern pikeminnow were collected at five sites between RM 113 and RM 125.5. Figure 6 shows the incidence of skeletal deformities observed during 1998 in this stretch of river. The highest incidence of skeletal deformities, 15.2 percent, was observed at RM 121, which is located 1.5 miles downstream of the Adair Village WWTP. The incidence of skeletal deformities declined at collection sites located farther downstream at RM 117 and RM 113. The fish collected at RM 0.25 on Truax Creek had an incidence of skeletal deformities similar to that observed at RM 117.

Northern pikeminnow were collected at three sites during 1998 that had been sampled during previous studies conducted in 1992–1994. A comparison of the current and historical incidences of skeletal deformities at these sites is shown in Figure 7. During 1998, the incidence of skeletal deformities at RM 113 was significantly lower than the incidence measured in 1994 (Tukey type multiple comparison test [Zar 1996]; $p < 0.05$). A similar result occurred at RM 49.7, where the incidence of deformities measured in 1998 was significantly lower than that measured during 1992 and 1993 ($p < 0.05$). At RM 125.5, the incidence of skeletal deformities measured in 1998 was slightly higher, but not significantly different ($p > 0.05$) than that measured in previous studies.

5.2 CHISELMOUTH

Juvenile chiselmouth were collected from 6 sites and examined for skeletal deformities. The fish examined had a fork length ranging from 24 to 47 mm (Table 4). The incidence of skeletal deformities at the 6 sites ranged from 17.3 percent to 30.7 percent (Figure 8). The lowest value was observed for fish caught at RM 125.5, downstream of the city of Corvallis, while the highest incidence of skeletal deformities was observed for fish caught at RM 88. The types of skeletal deformities observed in chiselmouth were similar to those found in northern pikeminnow (Table 5). Most skeletal deformities, 86.5 percent, were associated with the spinal column. A small number of individuals also showed deformities associated with the ribs, fins, skull, and caudal region.

Table 6. Percentage of juvenile fish with skeletal deformities and parasites

SPECIES	SITE	WATER BODY	RIVER MILE	NUMBER EXAMINED	SKELETAL DEFORMITIES (percent)	EVIDENCE OF PARASITES (percent)
Northern pikeminnow	1	WR	125.5	74	6.8	1.4
	2	WR	121	66	15.2	39.4
	3	WR	117	63	9.5	69.8
	4	TC	0.25	67	9	88.1
	5	WR	113	65	3.1	70.8
	6	WR	88	63	4.8	68.3
	8	YR	3.5	19	21.1	16.7
	9	WR	49.7	72	13.9	20.3
				Median	**9.3**	**53.9**
Chiselmouth	1	WR	125.5	75	17.3	40
	3	WR	117	75	25.3	41.3
	4	TC	0.25	75	26.7	84
	5	WR	113	75	29.3	74.7
	6	WR	88	75	30.7	78.7
	10	WR	15	71	19.7	76.1
				Median	**26.0**	**75.4**
Largescale sucker	1	WR	125.5	65	3.1	7.7

NOTE: TC – Truax Creek
WR – Willamette River
YR – Yamhill River

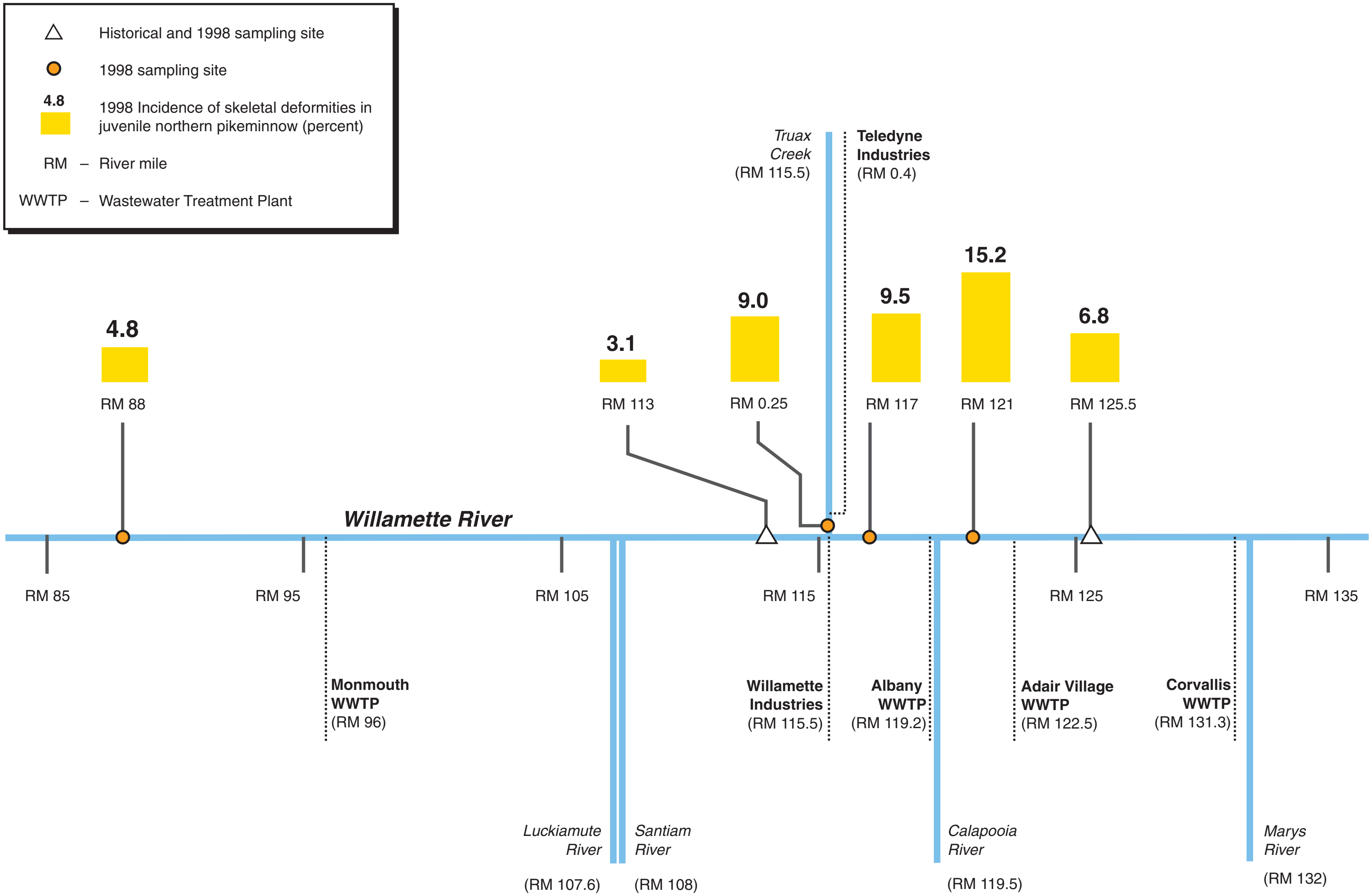
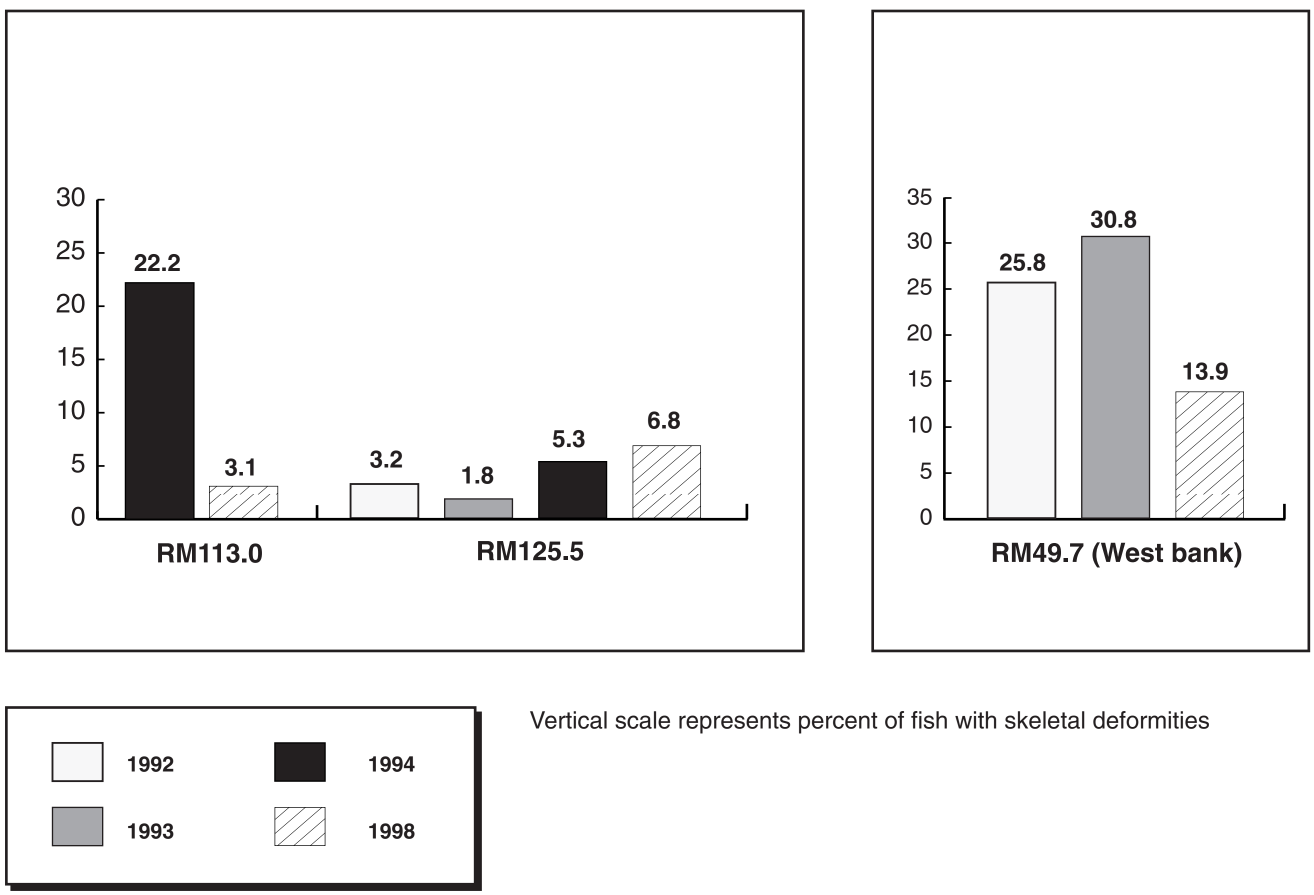
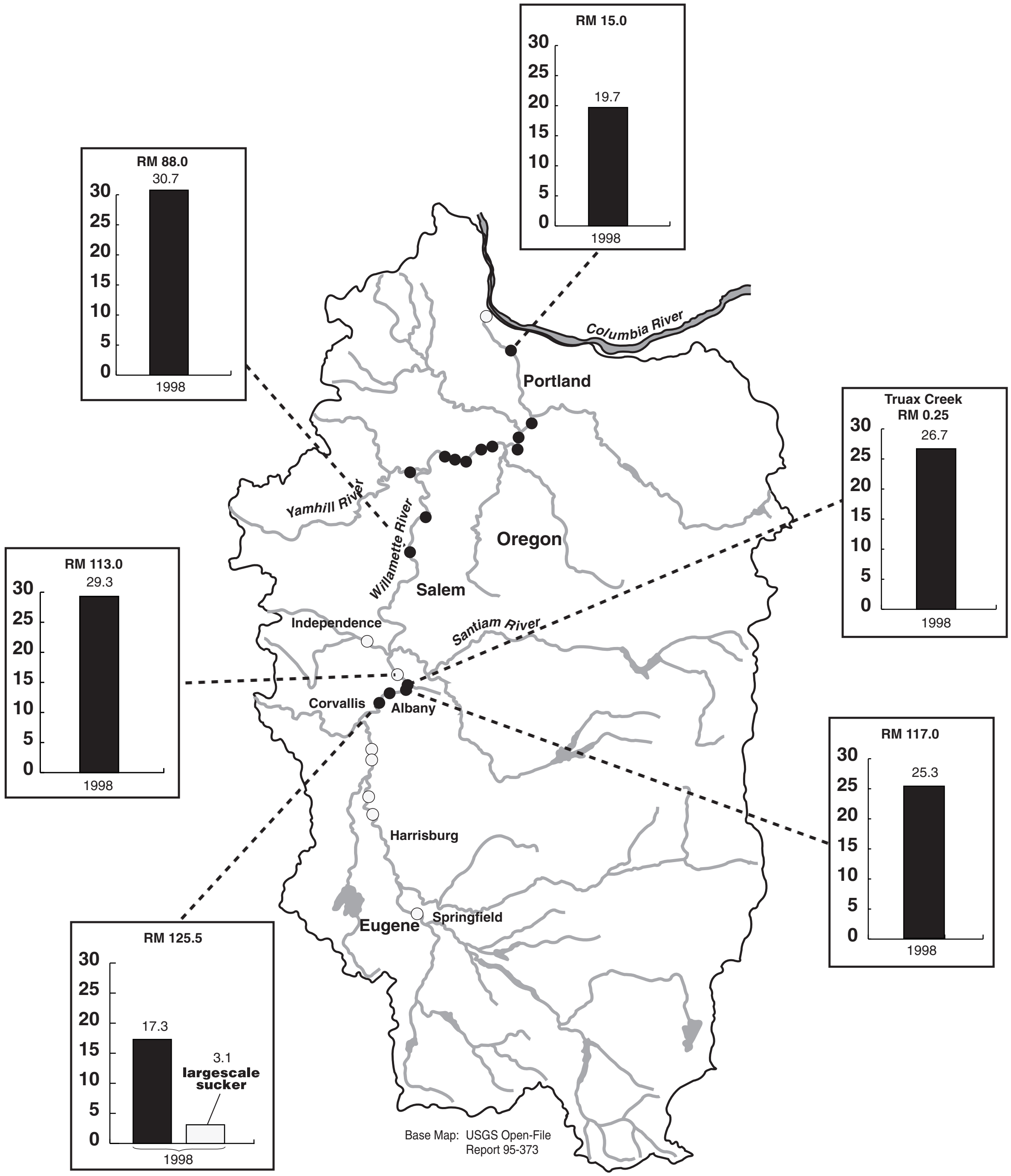


Figure 6. Schematic diagram of the Willamette River, river mile 85 to river mile 135, showing point sources, tributaries, and incidences of skeletal deformities in northern pikeminnow, 1998



Vertical scale represents percent of fish with skeletal deformities

Figure 7. Comparison of skeletal deformities in juvenile northern pikeminnow at three sites within the Willamette River, 1992 – 94 and 1998



All species are chiselmouth unless otherwise noted

- ○ Historical sampling sites for northern pikeminnow where background levels of skeletal deformities were observed
- ● Historical sampling sites for northern pikeminnow exceeding background levels of skeletal deformities

Figure 8. Percentage of skeletal deformities in juvenile chiselmouth and largescale sucker, 1998

Similar to northern pikeminnow, a substantial number of chiselmouth showed evidence of parasites. These parasites appeared as blue ovate structures in the stained specimens when examined at 12X magnification and could not be distinguished from similar structures observed in northern pikeminnow. The percentage of fish containing parasites at each of the 6 collection sites ranged from 40.0 percent at RM 125.5 to 84 percent at RM 0.25 in Truax Creek (Table 6). The median percentage of chiselmouth from all 6 sites showing evidence of parasites was 75.4 percent.

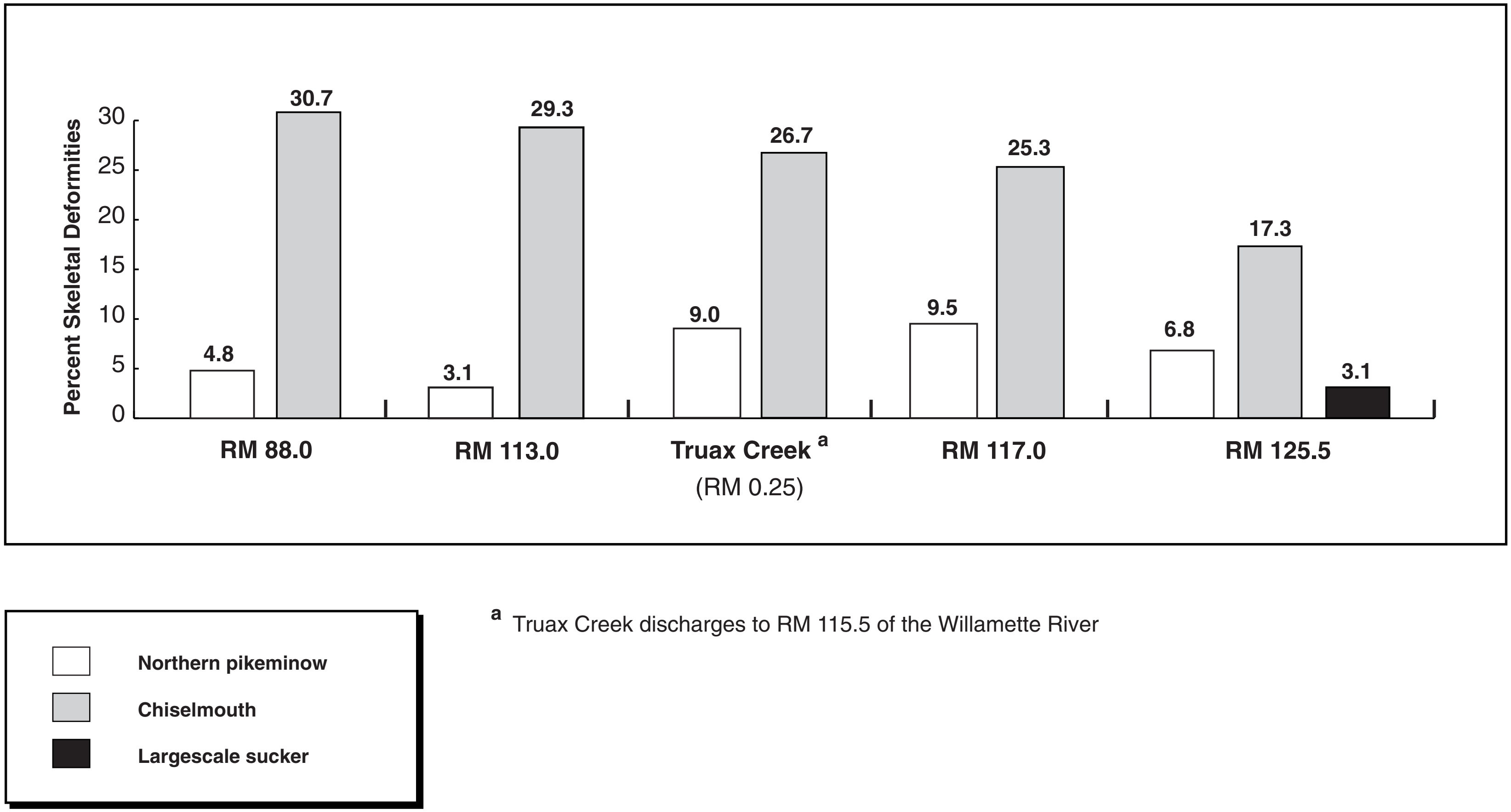
5.3 LARGESCALE SUCKER

Juvenile largescale sucker were analyzed for skeletal deformities only at RM 125.5. The length of fish examined ranged from 26 to 49 mm (Table 4). The incidence of skeletal deformities for this species at this site was 3.1 percent (Figure 8). All observed deformities were associated with the spinal column (Table 5). Relatively few individuals, 7.7 percent, showed evidence of parasites (Table 6).

5.4 INTERSPECIES COMPARISONS

Comparisons between northern pikeminnow and chiselmouth can be made at the 5 sites where both species were collected. Chiselmouth had a significantly higher incidence (Tukey type multiple comparison test; $p < 0.05$) of skeletal deformities than northern pikeminnow (Figure 9). The average incidence of skeletal deformities in chiselmouth at these sites (25.9 percent) was approximately four times greater than that observed for northern pikeminnow (6.6 percent). Comparisons between these species and largescale sucker are limited to one site, RM 125.5 (Figure 9). At this site, largescale sucker showed the lowest incidence of skeletal deformities; approximately 2 and 6 times lower than observed in northern pikeminnow and chiselmouth, respectively.

Similar comparisons can be made among the three fish species for the percentage of fish containing parasites (Figure 10). The average percentage of chiselmouth containing parasites at the 5 sites, 63.7 percent, was slightly higher than for northern pikeminnow, 59.7 percent. However, with the exception of RM 125.5, the percentage of parasites for both species were similar at most sites. The percentage of largescale sucker containing parasites at RM 125.5 was approximately 5 times less than that observed for chiselmouth and approximately 5 times greater than that observed for northern pikeminnow.



[a] Truax Creek discharges to RM 115.5 of the Willamette River

Figure 9. Interspecies comparison of the incidence of skeletal deformities, 1998

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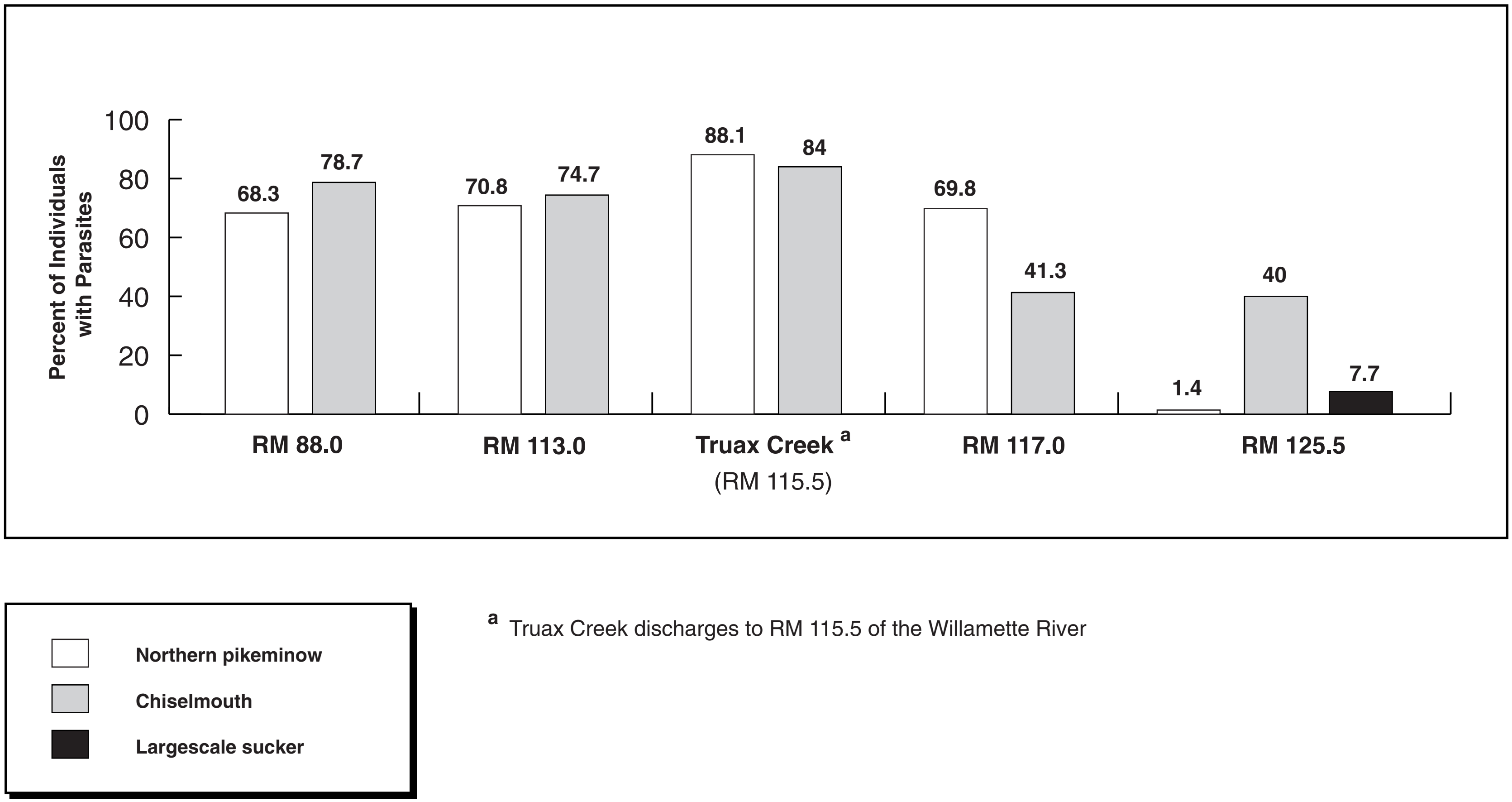

[a] Truax Creek discharges to RM 115.5 of the Willamette River

Figure 10. Interspecies comparison of the percentage of juvenile fish containing parasites, 1998

6.0 DISCUSSION

The objectives established for this study were to further evaluate spatial trends in the incidence of skeletal deformities in the Willamette River, compare 1998 results to historical studies, and evaluate the incidence of deformities in additional fish species. Each of these objectives is discussed below. In addition, a discussion is provided on parasites known to occur in northern pikeminnow and chiselmouth.

6.1 SPATIAL TRENDS

As discussed in Section 2.0, the historical studies of skeletal deformities in northern pikeminnow allow the Willamette River to be divided into four segments based on the measured incidence of skeletal deformities and the amount of data available to characterize each of these segments. At the onset of this study, the lower Willamette River (RM 0–RM 26.5) and the middle Willamette River (RM 55–RM 125) were the two river segments that had not been sufficiently sampled to fully characterize spatial trends in northern pikeminnow skeletal deformities. For this study, one location was sampled in the lower Willamette River at RM 15, the southeast side of Ross Island. Unfortunately, northern pikeminnow were not found at this location so comparison with historical data is not possible. The incidence of skeletal deformities in chiselmouth collected at this site was 19.7 percent. This value is lower than the observed incidence of 25.3–30.7 percent skeletal deformities in chiselmouth collected upstream between RM 88 and RM 117, and higher than the observed incidence of 17.3 percent skeletal deformities in chiselmouth collected at RM 125.5. While the chiselmouth data provides useful information to evaluate skeletal deformities in the lower Willamette River, this region of the river remains insufficiently characterized.

One of the main objectives of this study was to more intensively sample the upstream stretch of the middle Willamette River segment between RM 113 and RM 125.5. This effort was undertaken to better characterize the transition point between background (RM 125.5) and elevated incidences of skeletal deformities in juvenile northern pikeminnow measured at RM 113 during 1994. Sampling sites were located upstream and downstream of the two tributaries and four point sources that discharge to this stretch of the Willamette River to assist in evaluating potential impacts from these discharges. The results showed that the incidence of skeletal deformities were at background levels at RM 125.5. The highest incidence of deformities was observed 4.5 miles downstream of this site at RM 121. The incidence of skeletal deformities declined at sites located farther downstream reaching background levels at RM 113.

The stretch of river between RM 121 and RM 125.5 receives wastewater discharge from only a single minor WWTP for the city of Adair Village. This facility is located 1.5 miles upstream of the site where the highest incidence of skeletal deformities was observed. No other tributaries or known contaminant sources have been identified in the stretch of river from RM 121 to RM 125.5. The average discharge during low flow conditions, July–September, for this facility is 30,000 gallons per day. The National Pollutant Discharge Elimination System monitoring requirements for this facility do not require monitoring of any of the chemical stressors that have been shown to cause fish skeletal deformities (Table 7). Therefore, without additional information it is not possible to assess the likelihood that this facility's discharge may be associated with the increased incidence of skeletal deformities.

Table 7. Stressors and laboratory exposure concentrations that have caused skeletal deformities in fish

Stressor	Species Name	Age	Exposure Concentration	Exposure Medium	Reference
Trace Metals					
Arsenic	Fourhorn sculpin	juvenile	0.75 ± 0.05 *m*g/L[a]	sw	B.-E. Bengtsson and Larsson (1986)
Cadmium	Himedaka	eggs	13 *m*g/L	fw	Yasuda et al. (1980)
	Fourhorn sculpin	juvenile	<0.1 *m*g/L[a]	sw	B.-E. Bengtsson and Larsson (1986)
	Anabas testudineus	adult	0.25 μg/L 1.00 μg/L	fw	Vijayram et al. (1990)
	Minnows	adult	7.5–4,890 *m*g/L	sw	B.-E. Bengtsson et al. (1975)
	Carp	adult	10 *m*g/L	fw	Muramoto (1981a)
Copper	Fourhorn sculpin	juvenile	0.63 ± 0.23 *m*g/L[a]	sw	B.-E. Bengtsson and Larsson (1986)
Iron	Red tilapia	fry	17,048 *m*g/L	fw	Mukhopadhyay and Konar (1988)
Lead	Rainbow trout	larvae	2.9 ± 1.9 *m*g/L, 28 ± 12 *m*g/L, and 87 ± 36 *m*g/L	sw	Hodson et al. (1980)
	Zebra danio	fry	600–1,000 *m*g/kg fry food	fw	Newsome and Piron (1982)
	Brook trout	juvenile	119 *m*g/L	fw	Holcombe et al. (1976)
	Fourhorn sculpin	juvenile	<0.7 *m*g/L[a]	sw	B.-E. Bengtsson and Larsson (1986)
Mercury	Fourhorn sculpin	juvenile	0.06 ± 0.02 *m*g/L[a]	sw	B.-E. Bengtsson and Larsson (1986)
Zinc	Minnows	adult	1–20 *m*g/L	sw	B.-E. Bengtsson (1974)
	Himedaka	eggs	960 *m*g/L	fw	Yasuda et al. (1980)
	Fourhorn sculpin	juvenile	3.9 ± 3.0 *m*g/L[a]	sw	B.-E. Bengtsson and Larsson (1986)
Pesticides					
Organochlorines					
Chlordecone, Kepone®	Sheepshead minnow	adult	0.8 *m*g/L	sw	Couch et al. (1977)
	Sheepshead minnow	adult	0.05 *m*g/L	sw	Hansen et al. (1977)
	Sheepshead minnow	juvenile	0.08 *m*g/L	sw	Hansen et al. (1977)
	Sheepshead minnow	eggs	0.08 *m*g/L	sw	Hansen et al. (1977)

Table 7, continued

STRESSOR	SPECIES NAME	AGE	EXPOSURE CONCENTRATION	EXPOSURE MEDIUM	REFERENCE
PESTICIDES (continued)					
Toxaphene	Fathead minnow	juvenile	55 *m*g/L	fw	Mehrle and Mayer (1975)
Organophosphates					
Axiom, Akton®	Bluegill	adult	196–2,500 *m*g/L	fw	McCann and Jasper (1972)
	Rainbow trout	not reported	not reported	fw	McCann and Jasper (1972)
Azinphos-methyl, Guthion®	Golden shiner	not reported	not reported	fw	Meyer (1966)
Chlorpyrifos, Dursban®	Bluegill	not reported	not reported	fw	Dow Chemical Company (1966)
Demeton, Systox®	Bluegill	adult	33–68 *m*g/L	fw	McCann and Jasper (1972)
Malathion	Golden shiner	not reported	not reported	fw	Meyer (1966)
	Fathead minnow	not reported	200 *m*g/L	fw	Mount and Stephan (1967) as cited in McCann and Jasper (1972)
	Sheepshead minnow	eggs	3,000–10,000 *m*g/L	sw	Weis and Weis (1976)
Methyl parathion	Bluegill	adult	3,900–6,900 *m*g/L	fw	McCann and Jasper (1972)
	Snakehead	adult	880 *m*g/L	fw	Bhaskaran and Pandian (1987)
Parathion	Golden shiner	not reported	not reported	fw	Meyer (1966)
	Brown bullhead	not reported	600 *m*g/L	fw	Mount and Boyle (1969) as cited in McCann and Jasper (1972)
Phosalone, Zolone®	Bluegill	adult	67–1,420 *m*g/L	fw	McCann and Jasper (1972)
Trichlorfon, Dylox®	Bluegill	adult	24,500–50,000 *m*g/L	fw	McCann and Jasper (1972)
	Grass pike	not reported	197 *m*g/L	fw	McCann and Jasper (1972)
	Golden shiner	not reported	not reported	fw	Meyer (1966)
Trichlorfon, Neguvon®	Bluegill	adult	8,000–52,000 *m*g/L	fw	McCann and Jasper (1972)
Other					
Anilazine, Dyrene®	Bluegill	juvenile	158–320 *m*g/L	fw	McCann and Jasper (1972)
	Rainbow trout	not reported	not reported	fw	McCann and Jasper (1972)
Trifluralin, Treflan®	Brown trout	parr	100 *m*g/L	fw	Wells and Cowan (1982)
	Sheepshead minnow	juvenile	5.5 *m*g/L	sw	Couch et al. (1979)
	Yellowtail	juvenile	> 71 µg/L	sw	Koyama (1996)
	Japanese flounder	juvenile	30 µg/L	sw	Koyama (1996)
	Black sea bream	juvenile	19 µg/L	sw	Koyama (1996)
	Longchin goby	juvenile	23 µg/L	sw	Koyama (1996)

Table 7, continued

STRESSOR	SPECIES NAME	AGE	EXPOSURE CONCENTRATION	EXPOSURE MEDIUM	REFERENCE
Other (continued)					
	Girella	juvenile	31 µg/L	sw	Koyama (1996)
	Red sea bream	juvenile	<6 µg/L	sw	Koyama (1996)
	Mullet	juvenile	5 µg/L	sw	Koyama (1996)
	Grunt	juvenile	19 µg/L	sw	Koyama (1996)
	Herring	juvenile	13 µg/L	sw	Koyama (1996)
	Jacopever	juvenile	>74 µg/L	sw	Koyama (1996)
OTHER ORGANIC COMPOUNDS					
Polychlorinated biphenyls					
Aroclor 1254	Brook trout	eyed eggs	0.43 mg/L	fw	Mauck et al. (1978)
Industrial discharges					
Bleached kraft mill effluent[b]	Fourhorn sculpin	juvenile	0.6% pine effluent	sw	Härdig et al. (1988)
Bleached kraft mill effluent[b]	Fourhorn sculpin	juvenile	0.6% birch effluent	sw	Härdig et al. (1988)
TCQ (tetrachloro-1,2-benzoquinone)	Fourhorn sculpin	adult	100 mg/L[c]	sw	B.-E. Bengtsson et al. (1988)
DBP (di-n-butylphthalate; plasticizer)	Cyprinodontiform fish	adult	1,000 mg/L[c]	sw	Davis (1988)
PHYSICAL MEASUREMENTS					
Temperature	Fathead minnow	fry	26–34°C	fw	Brungs (1971)
	Killifish	eggs	13.5–24.5°C	sw	Gabriel (1944)
	Pike	juvenile	5–18°C	fw	Orska (1962)
Dissolved oxygen	Salmonids	eggs	7–37% saturation	fw	Blaxter 1969
	Pike	eggs	12–41% saturation	fw	Blaxter 1969
	Herring	larvae	27–64% saturation	sw	Blaxter 1969
Ultraviolet Radiation	Medaka	eggs	1,450 µwatt/cm^2	fw	Bass and Sistrun (1997)
NUTRITIONAL DEFICIENCIES					
Vitamin C in diet with toxaphene	Channel catfish	juvenile	63–5,000 mg/kg of vitamin C combined with 0–0.475 mg/L of toxaphene in diet	not reported	Mayer et al. (1978)
Vitamin C	Rainbrow trout	fry	25–2,087 mg/kg	in diet	Madsen and Dalsgaard (1999)
Tryptophan deficiency	Chum salmon	fry	Tryptophan-deficient diets containing 50 mg tryptophan/100 g of diet	fw	Akiyama et al. (1989)
Ascorbic acid deficiency	Rainbow trout	fry	2 mg ascorbic acid/100 g of diet	fw	Sato et al. (1983)

NOTE: fw - freshwater
sw – saltwater

[a] Measured in ore smelter effluent.
[b] Bleached kraft mill effluent constituents include: 2,4-Dichlorophenol, 2,4,6-Trichlorophenol, 2,4,5-Trichlorophenol, 4,5-Dichloroguaiacol, 2,3,4,6-Tetrachlorophenol, 3,4,5-Trichloroguaiacol, 4,5,6-Trichloroguaiacol, Pentachlorophenol, 3,4,5-Trichlorocatechol, Tetrachloroguaiacol, Tetrachlorocatechol.
[c] Measured in bleached kraft mill effluent.

6.2 COMPARISON TO HISTORICAL LEVELS

One of the objectives of this study was to compare the incidence of skeletal deformities in juvenile northern pikeminnow with levels that had been measured during studies conducted during 1992–1994. The three sites selected for comparison included two sites that had shown an elevated incidence of skeletal deformities in past studies (RM 49.7 and RM 113) and a site which had consistently shown a low incidence of skeletal deformities (RM 125.5). The incidence of skeletal deformities in 1998 was significantly lower than in past studies at the two sites that had historically shown elevated incidences of skeletal deformities. Inferences regarding this result should be made with caution. Since we do not know what may be causing skeletal deformities in northern pikeminnow, we cannot infer from this result that we are observing a trend that would indicate similar or lower levels of skeletal deformities at these sites in the future.

This study provides additional evidence that northern pikeminnow collected at RM 125.5, approximately 5 miles downstream of the city of Corvallis, consistently have a low incidence of skeletal deformities that is consistent with background levels reported for unstressed natural fish populations and laboratory stocks (Gill and Fisk 1966; Wells and Cowan 1982). This site has been sampled during 1992, 1993, 1994, and 1998. The average incidence of skeletal deformities measured during these studies is 4.3 percent (SD = 2.2). The low and consistent results for this site suggests that it would be a good choice for a reference site for making comparisons to assess impacts to northern pikeminnow at other locations within the Willamette River Basin.

6.3 INTERSPECIES DIFFERENCES

The incidence of skeletal deformities in fish species other than northern pikeminnow was examined to help determine whether problems identified in past studies were confined to a single species or had broader ecological significance. Chiselmouth were found to have a significantly higher incidence of skeletal deformities than northern pikeminnow. The incidences of skeletal deformities in chiselmouth at the six sites sampled substantially exceeded levels that appear to represent background levels for northern pikeminnow. At RM 125.5, the measured incidence of skeletal deformities in chiselmouth was 17.3 percent compared to the average value of 4.3 percent measured for northern pikeminnow at this site between 1992 and 1998. Given the limited number of sites that were sampled for chiselmouth, and in particular the lack of additional data for sites in the upper Willamette River where low levels of deformities have been observed for northern pikeminnow, it is not possible to determine what the background incidence of skeletal deformities is for this species or whether this species is likely to show spatial trends of skeletal deformities similar to those observed for northern pikeminnow.

While northern pikeminnow and chiselmouth are both found in similar habitat, the feeding characteristics of the two species differ. Larval chiselmouth are approximately 0.3 inches in length at hatching (Wydoski and Whitney 1979). After reaching a length of approximately 0.6 inches, the mouth develops a sharp cartilaginous lower jaw which is used to scrape periphyton from bottom substrate. The characteristic lower jaw, well-developed grinding teeth in the pharynx, and the long intestine are considered to be adaptations for feeding on plant matter and adults are considered to feed primarily on diatoms (Wydoski and Whitney 1979). In contrast, small northern pikeminnow feed primarily on aquatic and terrestrial insects. As the fish grow in size they become more piscivorous. In the lower Columbia River, fish are reported to make up the majority of the diet for northern pikeminnow. The prey species, in order of decreasing importance, are juvenile salmon, sculpins, lampreys, trout, suckers, chiselmouth, stickleback, peamouth, and redside shiner (Wydoski and Whitney 1979). The feeding differences between northern pikeminnow and chiselmouth may suggest that exposure to chemicals that strongly bioconcentrate in the food web may not be likely candidates for the causes of skeletal deformities, as northern pikeminnow would be expected to be exposed to higher concentrations of these chemicals in their diet than chiselmouth. However, species-specific differences in chemical threshold levels for the occurrence of skeletal deformities could also account for differences between these species. Table 7 shows that the chemical concentrations that have been associated with skeletal deformities are quite variable among different fish species.

6.4 PARASITES

This study found that a high percentage of northern pikeminnow and chiselmouth juveniles contained parasites. Identification of the parasites was not possible, as positive identification requires that the adult stage be observed. The ecological significance of the high percentages of individuals with parasites is unknown; however, the percentages do not appear unusually high in comparison to at least one large regional study that was conducted in the 1950s (Bangham and Adams 1954).

Bangham and Adams (1954) conducted a survey of freshwater fish parasites from lakes and streams of the Columbia and Fraser River basins. Table 8 shows the parasites reported in their study for northern pikeminnow and chiselmouth. Four hundred eight northern pikeminnow from 32 locations were examined. Ninety one percent of the fish were infected with parasites. Encysted eye flukes, *Diplosomulum* sp., were observed in 40 percent of the northern pikeminnow at several of the collection areas sampled. Cysts of the strigeid fluke, *Posthodiplostomum minimum*, were also commonly observed in up to 36 percent of the individuals at many locations.

Other commonly observed parasites found in northern pikeminnow include the strigeid flukes, *Neascus* sp. and *Tetracotyle* sp. *Neascus* sp. was observed in 26 percent and *Tetracotyle* sp. was observed in 12 percent of the northern pikeminnow examined at many locations by Bangham and Adams (1954).

Bangham and Adams (1954) examined 32 chiselmouth from three locations within the Columbia River drainage. Eighty-four percent of the fish were infected with parasites. The most commonly detected parasites were *Rhabdochona cascadilla* (63 percent), *Neascus* sp. (47 percent), and *Posthodiplostomum minimum* (38 percent).

Table 8. Parasites reported in northern pikeminnow and chiselmouth in the Columbia River and Fraser River basins

	NORTHERN PIKEMINNOW	CHISELMOUTH
Phylum Platyhelminthes		
Class Trematoda – Flukes		
Diplostomulum sp.	X	
Posthodiplostomum minimum	X	X
Tetracotyle sp.	X	
Neascus sp.	X	X
Class Cestoda – Tapeworms		
Eubothrium salvelini	X	
Proteocephalus ptychocheilus	X	
Phylum Nematoda – Roundworms		
Class Secernentea		
Rabdodochona cascadilla	X	X
Hepaticola bakeri		
Philonema sp.	X	X
Phylum Acanthocephala – Roundworms		
Class Macracanthorhynchus		
Neoechinorhynchus rutili	X	
Pomphorhynchus bulbocolli	X	
Phylum Arthropoda (subphyla Crustacea)		
Class Copepoda – Copepods		
Ergasilus caeruleus		X

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