

RELATIONSHIPS BETWEEN BANK TREATMENT/NEARSHORE DEVELOPMENT AND ANADROMOUS/RESIDENT FISH IN THE LOWER WILLAMETTE RIVER

ANNUAL PROGRESS REPORT

MAY 2000 - JUNE 2001



Prepared for:

**City of Portland
Bureau of Environmental Services
Endangered Species Act Program
1120 SW 5th Avenue; Room 1000
Portland, Oregon 97204**

Prepared by:

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**Oregon Department of Fish and Wildlife
17330 SE Evelyn Street
Clackamas, Oregon 97015
503-657-2000**



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REPORT SUMMARY

In response to recent Endangered Species Act listings of multiple salmonid stocks found in the lower Willamette River, the City of Portland initiated a proactive, multi-year investigation to evaluate relationships between fish communities and waterway developments. During this first year of the study, we quantified available habitat in the study area and assessed fish abundances associated with specific bank treatment and nearshore development types by season. Radio telemetry was used to determine migration, movements, and habitat association of juvenile salmonids *Oncorhynchus* spp. and resident fish.

Seasonal abundances of juvenile salmonids based on catch rates varied considerably by gear type and time of day. Peak catches occurred during April-May and November-January, although salmonids were present during all months. Chinook salmon *O. tshawytscha* was the most common salmonid species collected. Unmarked sub-yearling chinook salmon were abundant from February through June. Surprisingly, unmarked juvenile salmonids were present throughout the year, indicating that rearing may occur in the study area, or there is a continual influx of new fish. Mean catch rate of juvenile salmonids was three-fold higher at sites with no rock revetment or nearshore structures than at other habitat types.

Mean migration rates of juvenile salmonid cohorts ranged from 7.3 km/d for sub-yearling chinook to 15.5 km/d for steelhead *O. mykiss*. Absolute periods of residency in the study area for individual fish ranged from 31 h to almost 2 months. Relocations of radio-tagged salmonids adjacent to different bank habitat types were relatively consistent with availability, except near rock outcrops where recoveries of most species were higher than expected.

Northern pikeminnow *Ptychocheilus oregonensis* was the most common piscivorous fish species collected but predator fish were not abundant during any season. We found few significant differences in catch rates of resident fish groups among bank and general habitat types. Radio-tagged northern pikeminnow and smallmouth bass *Micropterus dolomieu* were commonly relocated within 1.6 km of release sites, although smallmouth bass were more sedentary than other species. Recoveries of radio-tagged smallmouth bass and northern pikeminnow were disproportionately high near piling structures allowing light.

Beach was the most common bank habitat type throughout the study area but undeveloped habitat types were most abundant in the upper study area. Fluctuating river levels affected available bank habitat and made quantification difficult. Likewise, collection of representative habitat data at sampling sites was difficult due to a variety of confounding factors. We did not detect any significant correlations between various habitat parameters and catch rates of juvenile salmonids or resident fish at 19 sampling sites in our study reach.

Additional sampling is needed before hypotheses of the study can be addressed with certainty. During 2002, we will refine our juvenile and resident fish sampling, repeat 2001's radio telemetry work, and begin to address new tasks such as diet analyses.

INTRODUCTION

The lower Willamette River (downstream of Willamette Falls) is used by large numbers of juvenile and adult anadromous salmonids *Oncorhynchus* spp. annually. Four races or

evolutionarily significant units (ESU) of anadromous salmonids that use the lower Willamette River have been listed as threatened by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA): upper Willamette River winter steelhead *O. mykiss* and spring chinook salmon *O. tshawytscha*, and lower Columbia River winter steelhead and chinook salmon. Naturally produced coho salmon *O. kisutch* in the lower Columbia River are listed as endangered by the State of Oregon. Cutthroat trout *O. clarki* have also been proposed for listing as threatened by the U. S. Fish and Wildlife Service. Other fish species of commercial, tribal, or recreational importance found in the lower Willamette River include Pacific lamprey *Lampetra tridentata*, American shad *Alosa sapidissima*, and white sturgeon *Acipenser transmontanus*. Farr and Ward (1993) identified 39 fish species from 17 families in the lower Willamette River, of which 20 species from 10 families were native.

The lower Willamette River also serves as a harbor to a busy commercial shipping industry. During the previous century, the river has been deepened and widened by dredging, numerous structures have been built to accommodate shipping, and much of the natural shoreline has been replaced by rock revetment (hereafter referenced as riprap) or vertical walls for flood control. The effects of bank and near shore developments on fish populations have been coming under increased scrutiny by natural resource agencies with requirements that bank stabilization methods include “fish friendly” methods. However, the actual benefits of these activities on fish and aquatic ecosystems, particularly in large systems like the Willamette River, have not been thoroughly evaluated. The Port of Portland and the Oregon Department of Fish and Wildlife (ODFW) previously investigated the effects of harbor development in the lower Willamette River on the migration and behavior of juvenile salmonids (Ward et al. 1994); however, the evaluation was limited to Port developments and many questions could not be addressed.

In June of 1999, the City of Portland’s ESA Program held a workshop with regional scientists, agency representatives, and NMFS to address the state of the science of fish ecology and to determine what environmental conditions salmon need to survive. Participants agreed that the lower Willamette River is an important migration corridor for adult and juvenile salmonids, and some areas may provide juvenile rearing habitat. The group also concluded that detailed information on use of the lower Willamette River by fish is desirable, especially considering the specific urban conditions and ESA issues confronting the City of Portland.

In May 2000 the Portland City Council awarded ODFW funding for a comprehensive four-year scientific study. The goal of this project is to provide new and updated information about fish use of currently available habitat, thus improving the City’s ability to make informed decisions regarding planning, permitting, and enforcement actions along the lower Willamette River. The information will be used to meet the City’s goal to work proactively with NMFS, to develop a citywide programmatic response to ESA listings, and to support the recovery of native salmonids in the lower Willamette River. Specific goals of the project include:

- (1) Describe and quantify bank treatment and near shore development types in the lower Willamette River.
- (2) Evaluate relationships between bank treatment and near shore development types in the lower Willamette River and habitat use and migration of juvenile salmonids.
- (3) Evaluate relationships between bank treatment and nearshore development types in the lower Willamette River and distribution, abundance, and diet of native and introduced resident fish.

- (4) Evaluate relationships between bank treatment and near shore development in the lower Willamette River and distribution and abundance of native and exotic invertebrates.

In this report we describe progress from May 2000 through June 2001 toward study objectives listed above and associated tasks (Table 1). Because this is a multi-year study scheduled for completion in 2004, few tasks were completed during the reporting period, though many were initiated. The complexity of determining fish use of interspersed specific habitat types absolutely necessitates multiple years of sampling to address many of these tasks and answer testable hypotheses.

METHODS

TASK 1.1: SELECTION OF SAMPLING SITES

The study was conducted in the lower Willamette River from Willamette Falls at river mile (rm) 26.5; river kilometer (rkm) 42.6, downstream to the confluence with the Columbia River (rm 0.0; rkm 0.0) (Figure 1). To determine fish use of available habitat in this area, we developed a list of potential sampling sites representing five general habitat types. General habitat categories included: 1) no riprap on shoreline, no structure present; 2) riprap on shoreline, no structure present; 3) no riprap on shoreline, structure present, 4) riprap on shoreline, structure present, and 5) vertical wall shoreline. Alternative habitat type classifications also used for reporting results throughout this report are 1) undeveloped, 2) riprap, 3) piling structures, 4) floating structures, and 5) vertical wall.

A list of potential sampling sites was developed based on bank qualification data modified slightly from Greenworks et al. (2000). For reference, each site was identified by a location code consisting of the rm and shore (e.g. 000W denotes a site with a lower bound at rm 0.0 located on the west bank). Some sites (048E, 051E, 100W) were considered for inclusion because they had been used in a previous study (Ward et al. 1994) or were specifically identified by the City of Portland (006E, 136E). From this list, we randomly selected at least two replicate sites of each habitat type. Several sites were replaced based on reconnaissance surveys during May 2000 when factors such as distribution within the study area, proximity to nearby sites, consistency of bank habitat, access, and navigational hazards were considered. When significant differences existed between sites of a general habitat type, they were assigned to subcategories. Selection of subcategory replicates was attempted but was not always possible due to the criteria identified above and a limitation on the overall number of sites that could be sampled. This process resulted in the selection of 21 sites distributed throughout the study area from rm 0.6 to 24.3 (rkm 1.0-39.1). We made further modifications to the list of sampling sites following initial sampling during May and June 2000 that identified unforeseen complications. A bio-engineered revetment site (133W) was also added in October 2000 resulting in a total of 22 sites; 19 to be sampled by electrofishing and gillnetting and five to be sampled by beach seining (all three gears were used at two sites). A description of sites selected for repeated sampling during the reporting period is provided in Table 2.

Objective, Task	Year of study	Hypotheses/Tasks
Objective 1		
Task 1.1	1	Identify sampling sites between Willamette Falls and the confluence of the Willamette and Columbia rivers.
Task 1.2	1-3	Complete a detailed inventory of habitat characteristics at each sampling site.
Objective 2		
Task 2.1	2-3	<i>Ho</i> : Distribution of radio-tagged juvenile salmonids among bank treatment and nearshore development does not differ from the distribution of bank treatment and nearshore development types.
Task 2.2	1-3	<i>Ho</i> : Mean weight of juvenile salmonids does not change during migration through the lower Willamette River.
	1-3	<i>Ho</i> : Catch of juvenile salmonids does not vary among bank treatment and nearshore development types.
Task 2.3	2-3	<i>Ho</i> : Diet composition of juvenile salmonids does not differ from food items available. <i>Ho</i> : Diet composition of juvenile salmonids does not differ from diet composition of introduced fish species.
Objective 3		
Task 3.1	1-2	<i>Ho</i> : Distribution of radio-tagged resident predator fish among bank treatment and nearshore development types does not differ from the distribution of bank treatment and nearshore development types.
Task 3.2	1-3	<i>Ho</i> : Fish assemblages do not differ among bank treatment and nearshore development types.
Task 3.3	2-3	<i>Ho</i> : Diet composition of juvenile salmonids does not differ from diet composition of introduced fish species.
	2-3	<i>Ho</i> : Predation on juvenile salmonids does not differ among bank treatment and nearshore development types.
Objective 4		
Task 4.1	2-3	<i>Ho</i> : Benthic invertebrate assemblages do not differ among bank treatment and nearshore development types or time of year.
	2-3	<i>Ho</i> : Diet composition of juvenile salmonids does not differ from food items available.
Task 4.2	2-3	<i>Ho</i> : Sediment composition does not differ among bank treatment and nearshore development types or time of year.
Task 4.3	2-3	<i>Ho</i> : Surface invertebrate assemblages do not differ among bank treatment and nearshore development types or time of year.
	2-3	<i>Ho</i> : Diet composition of juvenile salmonids does not differ from food items available.

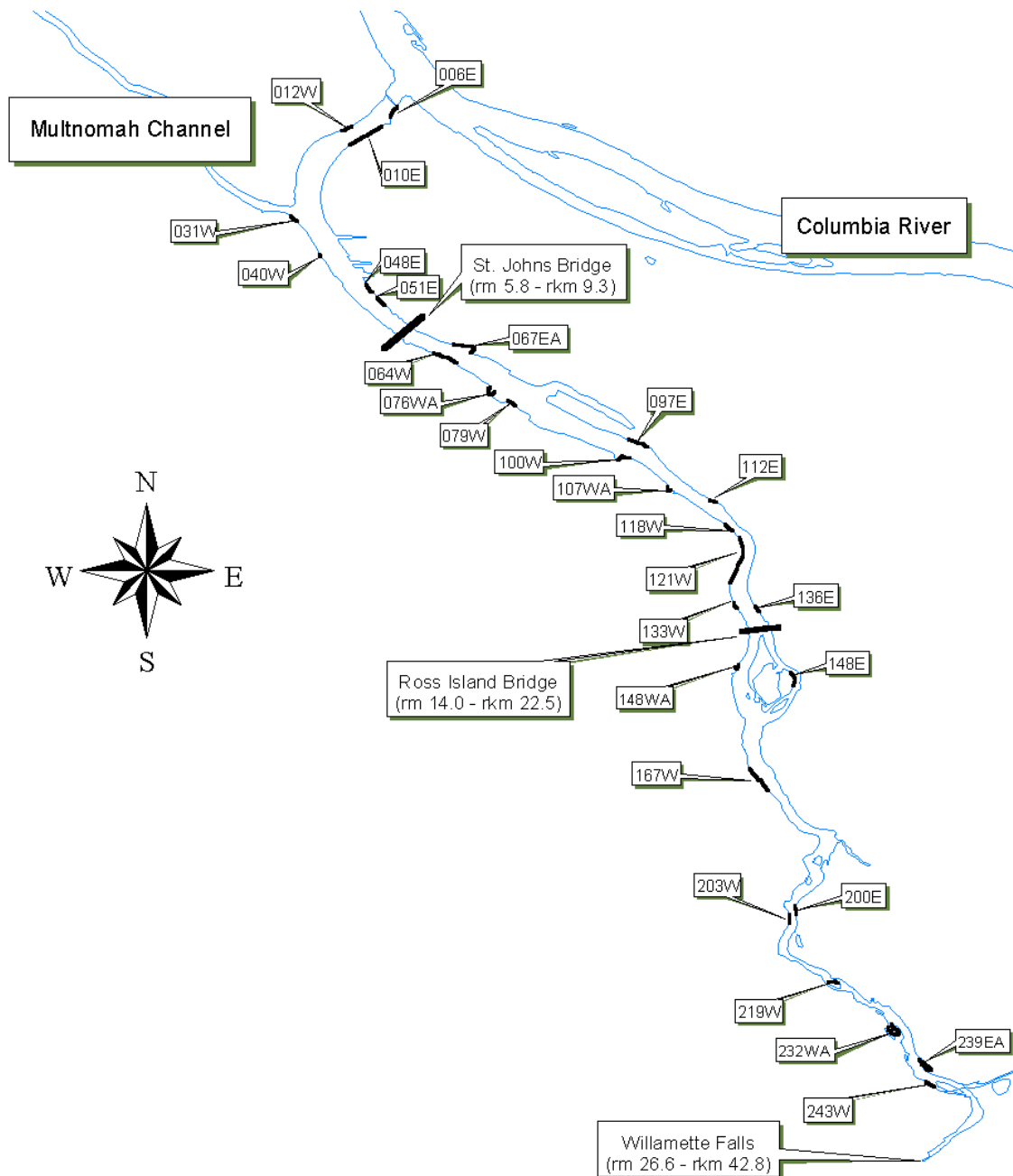


Figure 1. Lower Willamette River study area. Sampling site numbers denote river mile (xx.x) and east or west shore (E or W). A = alcove site; rm = river mile; rkm = river kilometer.

Table 2. Description of sampling sites in the lower Willamette River, May 2000 through June 2001.

Habitat classification	Transect ^a	River kilometer	Length (m)	Gear ^b	General bank type ^c	Location/description
Undeveloped						
Beach (7)	006E	1.0-1.3	364	BS,ES,GN ¹	B	Kelley Point
	031W	5.0-5.3	220	ES,GN ¹	B	Head of Multnomah Channel
	040W	6.4-6.5	64	BS	B	Across from Terminal 4
	097E	15.6-16.1	456	BS	B	Across from Terminal 2
	148E	23.8-25.0	526	ES,GN ¹	B	Behind Ross Island
	167E	26.9-27.8	804	BS,ES,GN ¹	B	Powers Marine Park
	243E	39.1-39.4	264	BS	B	Downstream of Goat Island
Rock outcrop (2)	200E	32.2-32.6	333	ES,GN ¹	RO	Lake Oswego Railroad Bridge
	219W	35.2-35.6	328	ES,GN ¹	RO	Hog Island
Rock revetment (riprap)						
Vegetated (2)	012W	2.0-2.3	240	ES,GN ¹	RR	Between Coast Guard #6 and #10
	136E	21.9-22.0	183	ES,GN ^{1,2}	RR	OMSI
Non-vegetated (2)	064W	10.3-11.0	564	ES,GN ^{1,2}	Mix (RR/B)	Doan Point
	118W	19.0-19.3	260	ES,GN ¹	RR	Between Steel and Broadway
Bio-engineered (1)	133W	21.4-21.6	186	ES,GN ¹	Mix (BE/B)	Downstream of Marquam Bridge
Vertical wall						
Concrete wall (1)	121W	19.5-21.0	1,542	ES,GN ¹	VW	Waterfront Park seawall
Metal sheetpile (1)	048E	7.7-8.0	286	ES,GN ¹	VW	Terminal 4
Pilings						
Allowing light (3)	010E	1.6-2.4	905	ES,GN ^{1,2}	Mix (B/RR)	3 T-docks above Columbia Slough
	079W	12.7-13.0	255	ES,GN ^{1,2}	RR	Olympic Tug T-dock
	112E	18.0-18.2	141	ES,GN ¹	Mix (RR/UNC)	T-dock above Fremont Bridge
Limiting light (1)	100W	16.1-16.2	78	ES,GN ^{1,2}	RR	Terminal 2
Floating						
Allowing light (1)	203W	32.7-33.0	262	ES,GN ¹	Mix (RO/B)	Crown Zellerbach pulp mill dock
Limiting light (1)	051E	8.2-8.7	310	ES,GN ^{1,2}	Mix (RR/B)	Terminal 4 ship hull

^a First two digits represent river mile, third digit represents river mile tenth. W=West bank, E=East bank.

^b BS=Beach seine; ES=Electrofishing; GN¹=Gill net nearshore; GN²=Gill net near structure (mid-shore).

In response to a request at a project review workshop in September 2000, we randomly selected six additional sampling sites representing off-channel habitat. These supplemental sampling sites included two natural alcoves, two "natural" refugia, and two manmade refugia distributed from rm 6.7 to 23.9 (rkm 12.2-38.9). Identification codes for these sites included river mile and shore as noted for the "standard" sites except a postfix "A" was added to denote alcove (e.g. 000WA). A description of these sites is provided in Table 3.

TASK 1.2: HABITAT EVALUATION

Habitat Inventory of Study Area

We conducted an inventory of available bank habitat types and nearshore structures in the study area during January and August 2001 to quantify available habitat types. Mean river stage (MRS), defined as the average river elevation for a given sampling period, was based on datum from the U. S. Geological Survey gauge (14211720) at the Morrison Bridge and ranged from 1.9-4.2 feet. Fourteen habitat types were identified according to criteria in Table 4. The inventory was conducted by driving a boat as close as possible to the shoreline and recording beginning and ending waypoints (latitude and longitude) of each bank type along all shorelines from rm 0.0 to 26.6 (approximately 53.0 shoreline miles). If the shoreline of a continuous habitat unit was sinuous, multiple waypoints were logged to increase accuracy. For any habitat unit <30 m in length, one mid-length waypoint was recorded and length (± 1 m) was measured with a laser rangefinder (Bushnell Yardage Pro 1000). We logged waypoints with a handheld Global Positioning System (GPS) receiver (Garmin GPS III) equipped with a differential antenna (± 3 m accuracy). Data was layered onto an Oregon Lambert-projected ortho-photo (2' resolution) with ArcView 3.2a (ESRI) software. Waypoints were repositioned onto the shoreline and the length (m) of each bank habitat unit was measured as the distance between waypoints less any microhabitats. Lengths (m) of nearshore structures (piers, docks, wharves, and other stationary structures incorporated into, or adjacent to the riverbank) were measured directly from the ortho-photo.

Transition of Bank Habitat at Sampling Sites

Although consistent bank type was an important consideration in initial selection of sampling sites, record low precipitation before and during the reporting period resulted in abnormally low river stage levels. As river levels dropped during the study period, it became apparent this anomaly could potentially reduce the homogeneity of bank substrate within 11 sampling sites as river levels receded to the zone of transition between the bank treatment (lower shore zone) and the river bed (aquatic zone). Undeveloped sites and vertical walls remained consistent regardless of river stage.

To evaluate the potential degree of change in bank material within sampling sites, and to determine if bank types should be reclassified seasonally, we evaluated bank substrate from about 5 feet below to 10 feet above ordinary low water (+3 feet; City of Portland datum) (Greenworks PC, et al. 2000) during December 2000 and January 2001. Percentages of each bank substrate type were visually estimated throughout each site length in 1-foot elevation increments using criteria in Table 4. Similarly, underwater substrate type was qualified below the waterline by tapping and "feeling" the bottom with a PVC pole throughout the length of the

Table 3. Description of supplemental alcove and refugia sampling sites in the lower Willamette River, May 2000 through June 2001.

Habitat classification	Transect ^a	River kilometer	Length (m)	Gear ^b	Bank type ^c	Description
Alcoves (natural)	232WA	37.3-37.7	1029	ES	B	Upstream of Cedar Oak boat ramp
	239EA	38.5-38.9	580	ES	B	Back side of Meldrum Bar
Refugia (natural)	067EA	10.8-11.1	577	ES	Mix (RR/B)	Downstream of Doane Point RR
	148WA	23.8-24.0	206	ES	Mix (B/UNC)	Above Spaghetti Factory
Refugia (artificial)	076WA	12.2-12.4	317	ES	Mix (B/PAL)	Downstream of Chevron piers
	107WA	17.2-17.4	396	ES	Mix (PAL/UNC)	Below Fremont Bridge

^a First two digits represent river mile, third digit represents river mile tenth. W=West bank, E=East bank.

^b BS=Beach seine; ES=Electrofishing; GN¹=Gill net nearshore; GN²=Gill net near structure (mid-shore).

^c Bank habitat type: B=Beach; RR=Rock revetment (riprap); UNC=Unclassified fill; PAL=Pilings-allowing light. For sites with mixed bank substrates, the predominant type appearing above normal low water is listed first. For comparisons, bank types are classified seasonally to account for differences in river stage elevations.

Table 4. Definitions of bank, nearshore, and offshore habitat types in the lower Willamette River, May 2000 through June 2001.

Habitat type	Description
Offshore	Not a bank habitat or bank treatment type; open water offshore. Arbitrarily defined as 11-89% of the river width (nearshore represents $\leq 10\%$ and $\geq 90\%$).
Beach	This is a shallow shelving shoreline that consists of sand, silt, or fine gravel up to 64 mm. This may also include native bank materials in their natural position and are undisturbed by humans (e.g. clay bank). Vegetation cover varies but may include canopy, understory, and ground cover.
Rock outcrop	Natural bedrock formations consisting of angular ledges, protrusions, and sheer rock faces. May include some associated boulders.
Rock	Natural, round river rock >64 mm that does not fit into the riprap categories.
Seawall	These are impervious vertical retaining walls, generally composed of concrete, timber, or sheet pile, that extend beyond ordinary low water. These habitats are uniformly deep and homogenous (e.g. house foundations in the water, bulkheads).
Vegetated riprap	Continuous stone revetments mechanically placed to curtail erosion and prevent alterations to the main channel. Vegetative cover various but may include canopy, under story, and groundcover that occupy a minimum of 20% of the active bank below flood state (lower shore zone).
Non-vegetated riprap	Continuous stone revetment devoid ($<20\%$) of vegetation.
Bio-engineered	Engineered banks that incorporate vegetation as a visible component of revetment banks, but inert and man-made materials provide the physical structure that ensures bank stability. Bio-engineered banks rely on vegetation and natural fabric materials for banks stability (e.g. site 133W, upstream of Newport Bay Restaurant).
Unclassified fill	These areas appear to have been filled over time with miscellaneous unconsolidated materials (e.g. cement slabs). The surfaces of banks composed of unclassified fill have not been covered with engineered riprap or structures. Such banks generally contain debris of various types and may have become unstable due to erosion by river forces.
Pilings-allowing light	Stationary support structures consisting of concrete, metal, or timber used to elevate docks, buildings, etc. above the water. Elements of construction allow varying amounts of light to penetrate to the underlying habitat (e.g. T-docks)
Pilings-limiting light	Stationary support structures used to elevate docks, buildings, etc above water. Construction is such that underlying habitat is not directly exposed to ambient light (e.g. site 100W).
Floating-allowing light	Structures such as loading docks and piers that maintain buoyancy atop the water and move with fluctuating river levels. Design and construction materials allow light to penetrate the habitat below.
Floating-limiting light	Buoyant structures that do not allow light to penetrate the underlying habitat.
Microhabitat	Any bank type with a linear shoreline distance less than or equal to 30m ($\sim 100'$) is classified as microhabitat.



site. By standardizing these classifications to the U. S. Geological Survey river gauge (14211720) at the Morrison Bridge (rm 12.7; rkm 20.4), the waterline bank substrate type at all sites could be estimated at any river stage (Table 5).

To ensure that catch-rate data was applied to the appropriate bank habitat type, the waterline bank substrate needed to remain predominant ($\geq 80\%$) to a depth three feet below MRS for a given sampling period (Table 6). If a different substrate became predominant from MRS-3' and below, then bank substrate was classified as such for that specific

sampling season. If a site did not meet either of these criteria (no predominant substrate type), catch-rate data specific to that site and season were not used in analyses. These rules were adopted to ensure that the bank type penetrated the water to a depth sufficient to realistically have an effect on fish use.

Habitat Characteristics of Sampling Sites

We collected measurements of onshore and nearshore habitat parameters at each of the 22 sampling transects to determine the correlation of each of these variables with fish use. Sampling was conducted in autumn 2000 (late September through November) to represent conditions typical of low river stages (MRS 3.0). We attempted to repeat all measurements in spring 2001 (March) to represent high river stages, but due to the abnormal water year, conditions scarcely differed (MRS 3.4) from the previous autumn, so these efforts were discontinued. Onshore parameters evaluated included bank slope, shoreline substrate, vegetative cover, number of outfalls (drain pipes), and buffer width. Nearshore parameters included depth contour, temperature, conductivity, dissolved oxygen, transparency, velocity, overhead cover, artificial light density, and number of pilings. Sampling methods were designed to collect representative samples of each parameter throughout each sampling site; however, most parameter measurements were reduced to a mean value or score for each site to simplify analyses. A description of habitat parameters and measurement methods are provided in Tables 7 and 8. Shoreline substrate data was field verified in November 2001.

TASK 2.1: JUVENILE SALMONID RADIO TELEMTRY

Tags and Tagging

Juvenile salmonids were surgically implanted with radio transmitters (hereafter referenced as radio tags) and monitored to determine habitat association and migration rates. Two models of coded microprocessor transmitters manufactured by Lotek Engineering Incorporated were used. Most fish received 1.5-volt NTC-3-1 “nano” tags. Tag size was 4.5 x 6.3 x 14.5 mm and averaged 0.95 g (air weight) including antennae. Some fish were fitted with 3.0-volt MCFT-3KM tags measuring 7.3 x 18 mm with an air weight of 1.4 g. All tags were programmed with a continuous 4-s burst rate.

Table 5. Bank substrate percentages by river stage at select sampling sites in the lower Willamette River, May 2000 through June 2001.

Stage ^a	Sampling site and bank substrate type																						
	010E		012W		051E		064W		079W		100W		112E			118W		133W		136E		203W	
	B	RR	B	RR	B	RR	B	RR	B	RR	B	RR	B	RR	UNC	B	RR	B	BE	B	RR	B	RO
13.1-14.0	75	25	0	100	0	100	0	100	0	100	0	100	0	56	44	0	100	0	100	0	100	37	63
12.1-13.0	75	25	0	100	0	100	0	100	0	100	0	100	0	56	44	0	100	0	100	0	100	37	63
11.1-12.0	75	25	0	100	0	100	0	100	0	100	0	100	0	56	44	0	100	0	100	0	100	37	63
10.1-11.0	75	25	0	100	0	100	0	100	0	100	0	100	0	56	44	0	100	0	100	0	100	37	63
9.1-10.0	87	13	0	100	0	100	0	100	0	100	0	100	0	56	44	0	100	0	100	0	100	37	63
8.1-9.0	87	13	0	100	0	100	0	100	0	100	0	100	0	56	44	0	100	0	100	0	100	37	63
7.1-8.0	87	13	0	100	0	100	0	100	0	100	0	100	0	56	44	6	94	0	100	0	100	37	63
*6.1-7.0	87	13	0	100	0	100	19	81	0	100	0	100	0	56	44	0	100	0	100	0	100	37	63
5.1-6.0	87	13	0	100	13	87	19	81	0	100	0	100	0	56	44	0	100	38	62	0	100	37	63
4.1-5.0	87	13	0	100	13	87	19	81	0	100	0	100	0	56	44	0	100	38	62	0	100	37	63
**3.1-4.0	87	13	0	100	13	87	19	81	0	100	0	100	0	56	44	0	100	50	50	0	100	50	50
2.1-3.0	94	6	0	100	19	81	38	62	6	94		^c	6	50	44	0	100	50	50	0	100	50	50
1.1-2.0	100	0	0	100	28	72	63	37	25	75		^c	6	50	44	0	100	87	13	0	100	50	50
0.1-1.0	100	0	0	100	81	19	94	6	88	12		^c	6	50	44	0	100	94	6	19	81	50	50
-1.0- 0.0	100	0	100	0			100	0	88	12		^c	68	12	19	44	56	94	6	57	43	50	50
-2.0- -1.1	100	0	100	0			100	0	88	12		^c	81	6	13	68	32	94	6	94	6		

^a Stage based on U. S. Geological Survey gauge 142411720 at the Morrison Street Bridge (river mile 12.7).

^b B=Beach; RR=Riprap; UNC=Unclassified fill; BE=Bio-engineered; RO=Rock outcrop

^c Either riprap or cement, but likely riprap

* Spring 2000 mean river stage (MRS)=6.2; ** Summer 2000-Spring 2001 MRS=3.1-3.5

Ranges of consistent bank substrate are highlighted. The dashed line indicates normal low water elevation.

Table 6. Mean river stage^a (MRS) for periods of sampling and habitat mapping in the lower Willamette River, May 2000 through June 2001.

Activity	Season	Dates	MRS
Fish collection	Spring 2000	5/22/00-6/29/00	6.2
	Summer 2000	8/7/00-9/12/00	3.1
	Autumn 2000	10/30/00-12/4/00	3.2
	Winter 2001	1/29/01-3/9/01	3.4
	Spring 2001	5/21/01-6/1/01 and 6/20/01-6/28/01	3.5
Juvenile telemetry	Spring 2001	4/25/01-4/28/01	3.7
		5/2/01-5/5/01	4.2
		5/9/01-5/11/01	3.4
		5/15/01-5/17/01	4.2
		6/6/01-6/8/01	4.1
Habitat parameter measurements	Autumn 2000	9/28/00-10/25/00 and 11/8/00-11/28/00	3.0
		Winter 2001	3/13/01-3/28/01
Bank habitat mapping	Winter 2001	1/8/01-1/17/01	4.2
	Summer 2001	8/21/01-8/27/01	1.9
Bank transition zone mapping	Autumn 2000-Winter 2001	12/28/00 and 1/4/01	3.6

^a Average river stage elevation for a given sampling period based on datum of U. S. Geological Survey gauge 142411720 at Morrison Bridge. Datum available at http://oregon.usgs.gov/rt-cgi/gen_stn_pg?station=14211720

Table 7. Description of nearshore habitat parameter measurements at sampling sites in the lower Willamette River, May 2000 through June 2001.

Parameter	Equipment	Measurements	Description of methods
Temperature (°C)	Hydro-lab Quanta multimeter	24	Measured at surface (1 m below), mid-water, and bottom (1 m above substrate) at 1 random site within 0-25 m and 26-50 m from shore by site quartile (0-25, 26-50, 51-75, and 76-100 % of site length).
Conductivity (mS/cm)	Same as above	24	Same as temperature.
Dissolved oxygen (mg/L)	Same as above	24	Same as temperature.
Depth (m)	Fathometer (various models)	35	Measured at 5, 10, 15, 20, 30, 40, and 50 m from shore along five equally spaced axes oriented perpendicular to the shoreline. These axes originate at 0, 25, 50, 75, and 100% of the site length. Note that 0% represents the upstream end of the site and 100% represents the downstream end.
Velocity (cm/s)	General Oceanics mechanical flow meter (model 2030R)	8	Measured at surface (1 m below) and bottom (1 m above substrate) at 1 random site within each site quartile. Conduct measurements 0-25 m from shore in quartiles 2 and 4 and 26-50 m from shore in quartiles 1 and 3. All measurements should be taken from a stationary boat (anchor or tie to piling).
Water transparency (cm)	Secchi disk (20 cm)	8	Measured at 1 random site within each site quartile at 0-15 m and 15-50 m from shore. Lower the disk into shaded water until it disappears and record the depth. Lower the disk deeper and slowly raise until it reappears and record this depth. Average the two depths.
Artificial light density (Lux)	Extech light meter (model 401025)	8	Measured (Lux; scale 1-1999, slow) at 1 random site at 0-25 m and 26-50 m from shore by site quartile (0-25, 26-50, 51-75, and 76-100 % of site length).
Piling density	NA	1	Count of all piling types in site.
Overhead cover density	Geographic Resource Solutions densitometer	40	Measured percent presence/absence of overhead cover at 0, 5, 10, 15, 20, 30, 40, and 50 m from shore along five equally spaced axes oriented perpendicular to the shoreline. These axes originate at 0, 25, 50, 75, and 100% of the site length.

Table 8. Description of onshore habitat parameter measurements at sampling sites in the lower Willamette River, May 2000 through June 2001.

Parameter	Equipment	Measurements	Description of methods
Bank slope(degrees)	Suunto Clinometer	5	Measured at five perpendicular axes to the shoreline (0, 25, 50, 75, and 100% of site length).
Vegetative cover (%)	Tape measure	5	Measured within a 2 m wide by 10 m long swath perpendicular to the water line at five axes perpendicular to the shoreline (0, 25, 50, 75, and 100% of site length). Estimate the percentage makeup of each type of vegetation. Classifications are: No vegetation, grasses, forbes, shrubs, trees.
Outfall density	NA	1	Separate counts of active (visible flow) and inactive (no flow) outfalls (sewer or drain pipes) within site.
Buffer width (m)	Bushnell Yardage Pro 1000 laser rangefinder	5	Measured as the distance (m) from the shoreline to the nearest impervious structure or surface (paved road, building, etc.) at five equally spaced axes oriented perpendicular to the shoreline. These axes originate at 0, 25, 50, 75, and 100% of the site length.
Shoreline substrate type	NA	1	Measured as the percentage of each substrate type at 1 m above the waterline within each quartile of the site. Substrate classifications are: Beach (0-64 mm); Rock (>64 mm); Small riprap (65-256 mm); Large riprap (257-512 mm); Boulders (>513 mm); Bedrock; Seawall; Artificial fill.

Minimum estimated battery life for the MCFT-3KM and NTC-3-1 tags was 12 and 15 d, respectively. Transmitting frequencies were 149.420, 149.440, and 149.460 MHz. A summary of tag types applied is provided in Table 9.

Fish were collected during day or night seining between rm 16.7 and 25.8 (rkm 26.9-41.5) or at the smolt evaluator bypass facility at the Portland General Electric Sullivan Plant at Willamette Falls. Both hatchery and naturally-spawned fish including yearling (age 1+ and 2+) steelhead, yearling coho salmon, and both yearling and sub-yearling chinook salmon were tagged to approximately represent the salmonid population in the study area. Only fish in good condition were selected for tagging. Criteria for rejecting fish included: de-scaling, injuries, excessive handling, or insufficient size. Weight of tags placed in yearling fish (all species) never exceeded 5.0% of the fish's weight; a level deemed acceptable by other researchers (Adams et al. 1998b; Brown et al. 1999). Very few sub-yearling chinook salmon met this size requirement; therefore, only the largest subyearlings (≥ 13 g) were selected for tagging, and tag weight never exceeded 6.5% of the fish's weight.

We transported fish suitable for tagging from collection sites to a holding site in Clackamas Cove near the confluence of the Clackamas and Willamette rivers in covered 19-L plastic buckets. Maximum loading density was ≤ 30 g/L and transfer times were < 25 minutes. Fish were moved to covered, 125-L plastic garbage cans suspended in the cove within floating frames constructed of plastic (PVC) pipe for approximately 16-48 hours pre-tagging to allow for evacuation of stomach contents. Pre-tagging holding densities were ≤ 5 g/L. We did not use supplemental oxygen during the collection and transportation process, but water was replaced periodically to maintain dissolved oxygen.

All tags were surgically implanted in the body cavity using sterile procedures described by Adams et al. (1998a). Tagged fish were held approximately 12-36 hours post-tagging to allow for tag-weight compensation. Immediately prior to release, fish were visually inspected to ensure only actively swimming fish in "good" condition were released. Mortalities and fish in poor condition were sacrificed and autopsied to determine cause of death or injury. We initially attempted to verify all tags were functioning immediately prior to release but found this difficult due to the concentration of activated tags that caused signal "bleeding". Therefore, proper function of all tags was verified at time of implantation.

Fixed Sites

Fixed sites were established at eight locations to create five "gates" or passage lanes to monitor migration of radio-tagged juvenile salmonids through the study area. Gates were established at (1) Sellwood Bridge (rm 16.6; rkm 26.7), (2) Albers Mill Building and Cargill Inc. Irving Elevator (rm 11.6; rkm 18.7), (3) City of Portland Water Pollution Control Laboratory and U. S. Army Corp of Engineers Portland District (rm 5.9; rkm 9.5), (4) U. S. Coast Guard navigation aid for Multnomah Channel (rm 3.0; rkm 4.8), and (5) U. S. Coast Guard navigation aids #3 and #4, rm 0.7; rkm 1.1) (Figure 2). Fixed sites consisted of a receiver (Lotek Engineering; model SRX-400), power supply (12-v deep cycle battery), single or multiple, four and six-element (Cushcraft Corp.; models P150-4 and PLC-1426) yagi-style antenna arrays, antenna leads, and mounting hardware. Multiple antenna sites incorporated ASP-8 antenna switching units to process multiple signals, line amplifiers (Advanced Receiver Research; model

Table 9. Summary of radio transmitters implanted in steelhead (STH), coho (COH), yearling chinook (CHY), and sub-yearling chinook (CHS) in the lower Willamette River, April-June 2001.

Species	Channel	Code	Frequency	Tag type ^a
CHS	6	36	149.420	NTC-3-1
CHS	6	38	149.420	NTC-3-1
CHS	6	39	149.420	NTC-3-1
CHS	6	42	149.420	NTC-3-1
CHS	7	35	149.440	NTC-3-1
CHS	7	37	149.440	NTC-3-1
CHS	7	42	149.440	NTC-3-1
CHS	7	47	149.440	NTC-3-1
CHS	8	29	149.460	NTC-3-1
CHS	8	35	149.460	NTC-3-1
CHS	8	37	149.460	NTC-3-1
CHS	8	43	149.460	NTC-3-1
CHS	8	44	149.460	NTC-3-1
CHY	6	29	149.420	NTC-3-1
CHY	6	30	149.420	NTC-3-1
CHY	6	31	149.420	NTC-3-1
CHY	6	32	149.420	NTC-3-1
CHY	6	37	149.420	NTC-3-1
CHY	6	48	149.420	NTC-3-1
CHY	7	26	149.440	MCFT-3KM
CHY	7	29	149.440	NTC-3-1
CHY	7	32	149.440	NTC-3-1
CHY	7	33	149.440	NTC-3-1
CHY	7	36	149.440	NTC-3-1
CHY	7	39	149.440	NTC-3-1
CHY	7	40	149.440	NTC-3-1
CHY	7	46	149.440	NTC-3-1
CHY	7	48	149.440	NTC-3-1
CHY	8	33	149.460	NTC-3-1
CHY	8	41	149.460	NTC-3-1
CHY	8	45	149.460	NTC-3-1
CHY	8	46	149.460	NTC-3-1
COH	6	35	149.420	NTC-3-1
COH	6	43	149.420	NTC-3-1
COH	6	46	149.420	NTC-3-1
COH	6	47	149.420	NTC-3-1
COH	7	30	149.440	NTC-3-1
COH	7	31	149.440	NTC-3-1
COH	7	34	149.440	NTC-3-1
COH	7	38	149.440	NTC-3-1
COH	7	44	149.440	NTC-3-1
COH	7	45	149.440	NTC-3-1
COH	8	21	149.460	MCFT-3KM

Table 9 (continued). Summary of radio transmitters implanted in Steelhead (STH), Coho (COH), yearling chinook (CHY), and sub-yearling chinook (CHS) in the lower Willamette River, April-June 2001.

COH	8	22	149.460	MCFT-3KM
COH	8	24	149.460	MCFT-3KM
COH	8	27	149.460	MCFT-3KM
COH	8	30	149.460	NTC-3-1
COH	8	38	149.460	NTC-3-1
COH	8	39	149.460	NTC-3-1
COH	8	47	149.460	NTC-3-1
STH	6	21	149.420	MCFT-3KM
STH	6	22	149.420	MCFT-3KM
STH	6	23	149.420	MCFT-3KM
STH	6	24	149.420	MCFT-3KM
STH	6	25	149.420	MCFT-3KM
STH	6	26	149.420	MCFT-3KM
STH	6	27	149.420	MCFT-3KM
STH	7	21	149.440	MCFT-3KM
STH	7	22	149.440	MCFT-3KM
STH	7	23	149.440	MCFT-3KM
STH	7	24	149.440	MCFT-3KM
STH	7	25	149.440	MCFT-3KM
STH	7	27	149.440	MCFT-3KM
STH	8	23	149.460	MCFT-3KM
STH	8	25	149.460	MCFT-3KM
STH	8	26	149.460	MCFT-3KM

^a All tags programmed for 4 s burst rate. Minimum battery life is 12 d (MCFT-3KM) and 15 d (NTC-3-1). Air weight is 1.4 g (MCFT-3KM) and 0.85 g (NTC-3-1).

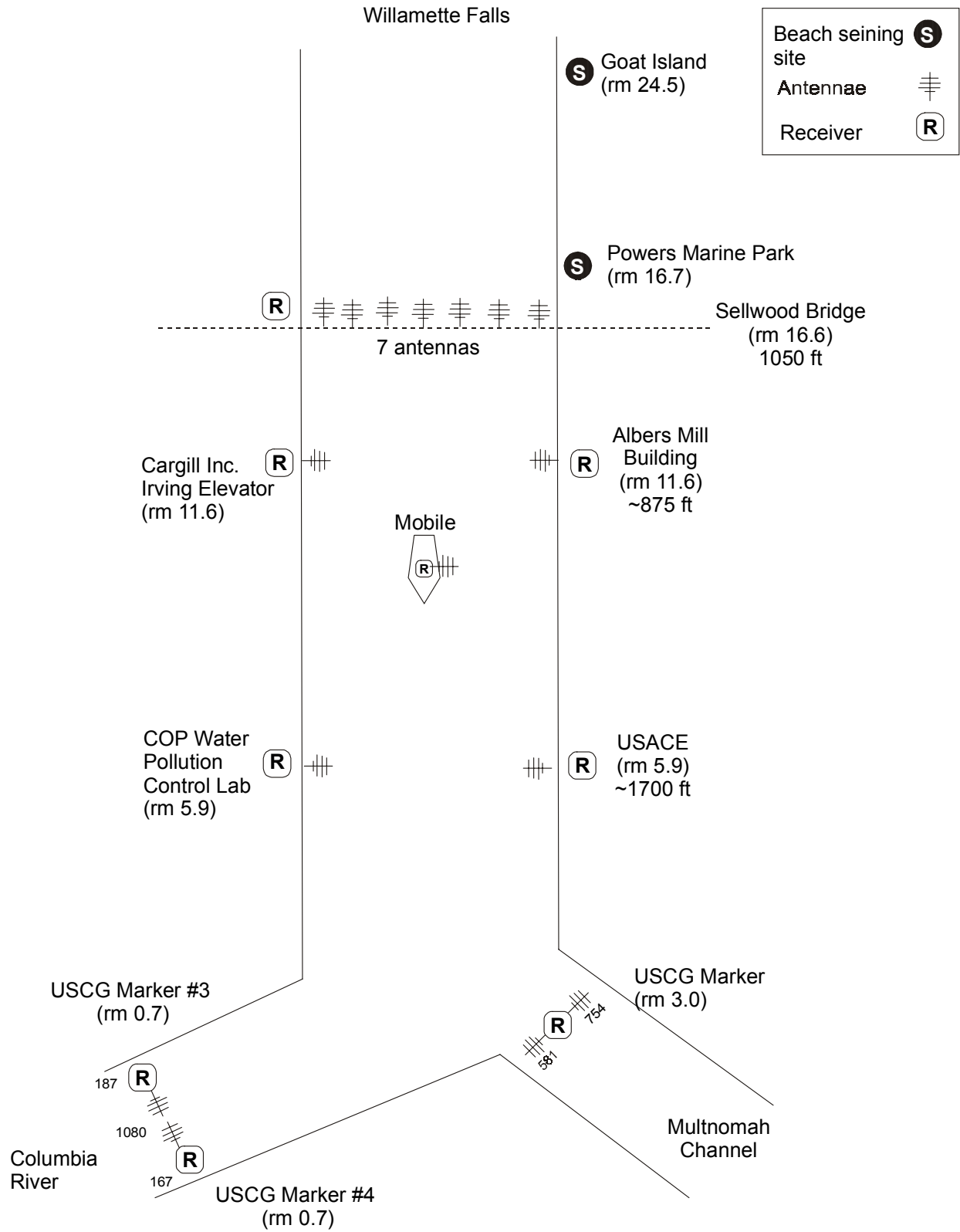


Figure 2. Locations of fixed-site receivers used to monitor migration of juvenile salmonids in the lower Willamette River, April through June, 2001.

P150VDG) to boost signal strength, and attenuators to control variable signal strength. Receivers were protected onsite within metal or wooden containers.

Fixed site receivers (W7 and W16 software) were programmed to scan and record the three juvenile salmonid tag frequencies in addition to tag code, date, time, and signal strength. Scan time was six seconds per frequency. We downloaded data 1-2 times each week to a computer (Gateway Solo Pro 9300) and replaced the receiver batteries.

Mobile Tracking

We conducted five releases of 10-18 tagged salmonids each between April 25 and June 6, 2001. A sixth release scheduled for June 11 failed due to an accident or vandalism, resulting in the death of all but one fish that was released. Fish were released pre-dawn at mid-channel in the Willamette River between rkm 16.8 and 24.3 (rkm 27.0-39.1). We initially attempted to tow the holding pens from Clackamas Cove to the mainstem Willamette, but this method proved unsuccessful. Subsequent releases were conducted by simply loading holding containers onboard a boat and quickly traveling to the site, where the fish were released directly into the river.

We began searching for tagged fish approximately one hour after release, beginning about 1.6 km above the release point and traveling downstream at approximately 5-10 km/h. Mobile tracking was conducted from 5.5-6.7 m boats equipped with a Lotek receiver (W5 software) and a six-element, yagi-style antenna. To ensure random recoveries of fish in both nearshore (0-10% and 91-100% of the river width) and offshore (11-90% of river width) habitat, we initially utilized a zigzag search pattern throughout the study area. Maximum effort per tracking leg was limited to 15 minutes. Using this pattern, the tracking crew could not focus on specific habitat because they were required to cross from one bank to another twice each hour resulting in approximately 25% tracking effort along the east river bank, 25% along the west river bank, and 50% offshore. The total time of tracking conducted in offshore and nearshore areas was recorded for each shift to maintain an approximate 50:50 ratio. Following the first release, we abandoned this zigzag approach above the Sellwood Bridge after it became apparent that tags could be detected on either bank from mid-channel. This allowed us to rapidly cover this area and devote more tracking time below the Sellwood Bridge, where fish were more difficult to relocate. Tracking effort within Multnomah Channel and east of Ross Island was considered low priority.

Once an audible signal was detected, we progressively decreased gain and monitored signal power levels to guide the boat to the approximate location of the fish. This process was then repeated with a coaxial antenna lowered 2 m underwater to pinpoint the location of the fish. Tag channel (frequency) and code, date, time, river mile, GPS waypoint (latitude and longitude), depth, surface temperature, and signal strength were recorded each time a tagged fish was located. We used a laser rangefinder to measure distance to shore and classified the bank habitat type based on criteria in Table 4 for fish relocated within 20% of the river width from either shore. This process of random searching and locating tagged individuals was repeated as the tracking crew progressed downstream with a release group. In order to maximize recoveries, the tracking crew would return to the midpoint of previously relocated fish if ≥ 2 hours elapsed without locating a fish.

Tracking efforts were generally conducted during one or two eight-hour shifts daily from about 0300-1100 and/or 1500-2300. For non-release day tracking, the starting point was determined as the midpoint of fish relocations from the previous shift(s) adjusted for migration rate. If no fish could be located during two hours of tracking in the primary area, the crew would proceed to an alternate site and repeat the process. The total distance covered each day was highly variable depending on fish densities, river width, and ease of locating fish. Any recoveries of fish from previous releases were treated the same as fish from the current release.

To determine species and/or life stage-specific migration rates, mobile telemetry data was combined with the primary record for each unique fixed-site recovery and sorted by tag channel and code. We reviewed the data for peculiarities and edited it to remove suspected mortalities. Rates (distance/time) were calculated for all consecutive relocations of each fish and then averaged by species and geographic area. Criteria used to edit data included:

- 1) Multiple recoveries of an individual fish at the same location may indicate mortality. Most recoveries of fish downstream of the previous relocation are included. Fish relocated multiple times at the same position (± 0.1 mile) for ≥ 24 h are presumed dead. Only the initial data point at this location is included in calculation of migration rate. Fish found multiple times at the same river mile for < 24 h are included.
- 2) Recoveries of fish upstream of release location may be indicative of predation. Upstream movement with no subsequent downstream movement is not included. Relocations of fish upstream of release sites are included if followed by some (> 0.2 miles) downstream movement.

Waypoints of relocated fish were compiled by species and layered onto an Oregon Lambert-projected ortho-photo (2' resolution) with ArcView 3.2a (ESRI) software for visual presentation of data.

TASK 2.2: STANDARDIZED SAMPLING FOR JUVENILE SALMONIDS

Beach seining and electrofishing (concurrent with Task 3.2; see methods below) were used to determine relative abundance, species composition, timing, origin, and size of juvenile salmonids using the study area. The majority of sampling was conducted during a 4-6 week period each season. Seasons were winter (January-March), spring (April-June), summer (July-September), and autumn (October-December) (Table 6). Although we adjusted the timing of sampling periods annually to distribute sampling throughout most months, little or no sampling occurred in July and October.

We identified juvenile salmonids to species whenever possible. Small individuals could not always be identified to species; these were recorded as unidentified salmonids. All fish were measured (fork length in mm) and examined for marks to determine origin. Most fish were weighed (g) with either a 300-g Pesola spring scale equipped with a mesh bag or plastic weighing chamber, or a Tanita (model 1144-110) electronic scale. We noted the disposition of each fish prior to release, and recorded water temperature, depth, and effort duration.

Beach Seining

We conducted daytime beach seining at five sites (006E, 040W, 097E, 167W, and 243W) 1-2 times weekly throughout each seasonal sampling period. Intermittent seining was conducted between these periods as time allowed. In general, we gradually reduced effort after mid-March 2001 as we addressed additional tasks. Seining sites consisted of shallow sandy beaches void of pilings and other obstacles that could snag or tear the net. The seine was a 2.4 x 45.7 m straight-wall, bunt-less net constructed of 4.8 mm Delta-style nylon mesh with a weighted line at the bottom and a floating line at the top. Seines were deployed from a boat and set in a semi-circular pattern.

Electrofishing

Although the primary use of electrofishing was to capture resident fish (Task 3.2; see below), juvenile salmonids were also incidentally collected. Because of the documented potential for injury (Ainslie et al. 1998; Reynolds 1996), many additional procedures were incorporated to reduce impacts on juvenile salmonids (Appendix 1). Because of these limitations we were occasionally unable to collect and sample all observed juvenile salmonids when densities were highest. Therefore, a sub-sample of ≤ 30 unmarked and ≤ 30 hatchery salmonids of each species were measured and weighed after each electrofishing run. We counted juvenile salmonids not collected (± 10 fish) and identified individuals to species when possible.

TASK 3.1: RESIDENT FISH RADIO TELEMTRY

Tags and Tagging

To determine habitat use of resident predator fishes, we fitted smallmouth bass *Micropterus dolomieu*, northern pikeminnow *Ptychocheilus oregonensis*, and walleye *Stizostedion vitreum* with radio tags and monitored habitat association thereafter. Fish were collected during electrofishing and gillnetting activities at 13 sampling sites concurrent with Task 3.2 from late May 2000 through late January 2001. Fish selected for tagging were in good condition with a minimum weight of 340 g. We tagged and released some fish immediately on site following recovery. Most fish were held overnight (12-18 h) in 1.8 m³ floating pens located at rm 10.0 (rkm 16.1) and 20.3 (rkm 32.7) prior to being tagged. We released all fish at their original capture site (rm 1.0-21.9; rkm 1.6-35.2).

Tags were surgically implanted according to methods described in Appendix 2. We used two models (MCFT-3B and MCFT-3EM) of 3.0-volt coded microprocessor transmitters manufactured by Lotek Engineering Incorporated. The MCFT-3B tags were 14 x 43 mm and weighed 10.5 gram (air weight). The MCFT-3EM tags were 11 x 49 mm and weighed 8.9 g. Both tags were programmed with a continuous 4-s burst rate. Minimum estimated battery life was 238 d for the MCFT-3B tags and 439 d for the MCFT-3EM tags. A summary of transmitting frequencies used is provided in Table 10.

Table 10. Summary of radio transmitters implanted in northern pikeminnow (NPM), smallmouth bass (SMB), and walleye (WAL) in the lower Willamette River, May 2000 through January 2001.

Species	Channel	Code	Frequency	Tag type ^a
NPM	26	50	149.820	MCFT-3B
NPM	26	52	149.820	MCFT-3B
NPM	26	56	149.820	MCFT-3B
NPM	26	57	149.820	MCFT-3B
NPM	27	51	149.840	MCFT-3B
NPM	27	56	149.840	MCFT-3B
NPM	28	50	149.860	MCFT-3B
NPM	28	51	149.860	MCFT-3B
NPM	28	52	149.860	MCFT-3B
NPM	28	54	149.860	MCFT-3B
NPM	28	55	149.860	MCFT-3B
NPM	28	56	149.860	MCFT-3B
NPM	30	75	149.900	MCFT-3EM
NPM	30	77	149.900	MCFT-3EM
NPM	30	78	149.900	MCFT-3EM
NPM	30	79	149.900	MCFT-3EM
NPM	30	80	149.900	MCFT-3EM
NPM	30	82	149.900	MCFT-3EM
NPM	30	83	149.900	MCFT-3EM
NPM	30	84	149.900	MCFT-3EM
NPM	31	66	149.900	MCFT-3EM
NPM	31	68	149.900	MCFT-3EM
NPM	31	72	149.900	MCFT-3EM
NPM	31	73	149.900	MCFT-3EM
NPM	31	74	149.900	MCFT-3EM
NPM	33	53	149.960	MCFT-3B
NPM	36	51	150.020	MCFT-3B
NPM	36	52	150.020	MCFT-3B
NPM	36	55	150.020	MCFT-3B
NPM	37	53	150.040	MCFT-3B
SMB	28	57	149.860	MCFT-3B
SMB	28	58	149.860	MCFT-3B
SMB	28	59	149.860	MCFT-3B
SMB	28	60	149.860	MCFT-3B
SMB	29	56	149.880	MCFT-3B
SMB	31	65	149.900	MCFT-3EM
SMB	31	69	149.900	MCFT-3EM
SMB	31	70	149.900	MCFT-3EM
SMB	36	53	150.020	MCFT-3B
SMB	36	56	150.020	MCFT-3B
SMB	36	59	150.020	MCFT-3B
WAL	30	76	149.900	MCFT-3EM
WAL	30	81	149.900	MCFT-3EM
WAL	31	67	149.900	MCFT-3EM
WAL	31	71	149.900	MCFT-3EM

^a All tags programmed for 5 s burst rate. Minimum battery life is 238 d (MCFT-3B) and 439 d (MCFT-3EM). Air weight is 10.5 g (MCFT-3B) and 8.9 g (MCFT-3EM).

Mobile Tracking

Efforts to relocate tagged resident fish began in early June 2000 and continued intermittently through June 2001. We conducted tracking 1-2 times each week from June 2000 through March 2001 and irregularly thereafter. Due to difficulties encountered in relocating tagged fish, several methods were used. During June and July 2000, tracking efforts consisted of returning to known release points of fish and initiating a search. To impart greater randomness to relocations, this approach was abandoned and tracking consisted of single-pass coverage in either the upper or lower half of the study area (12-14 mile sections). Beginning in mid-August 2000, tracking efforts were distributed randomly among five, 5-6 mile sections of the study area. We randomly selected the section and starting point therein to ensure representative fish relocations. The tracking pattern consisted of one pass along each riverbank, with an additional pass mid-channel if time permitted. Typically, we completed only one section per shift. Throughout the recovery period, tracking was conducted primarily during daylight hours although limited tracking was also conducted at night. Methods for pinpointing fish and data collected were identical to those described for juvenile salmonids (Task 2.1).

TASK 3.2: STANDARDIZED SAMPLING FOR RESIDENT FISH

To index fish communities utilizing various habitat types by season, we conducted nighttime sampling with boat electrofishing and gillnetting at 19 sampling sites during each seasonal sampling period (Table 6). We attempted to conduct one electrofishing run and one or two gillnet sets per site each week. Therefore, our target effort level for electrofishing was 16-24 electrofishing runs/site/year. The target effort level for gillnetting was 16-48 net sets/site/year dependent on whether one or two gillnets were deployed at a site (see below). No electrofishing was conducted from 9 March through 19 June 2001 due to lack of a NMFS Section 10(a) permit and because of juvenile telemetry work (Task 2.1).

We measured (fork length in mm) and weighed (g) up to 30 fish of each species on site for each unique sampling effort. Adult shad *Alosa sapidissima*, carp *Cyprinus carpio*, and suckers *Catostomus* spp. were enumerated only. A maximum of 30 juvenile shad and three-spine stickleback *Gasterosteus aculeatus* were weighed and measured each night. We weighed small fish (<300 g) with either a 300-g Pesola spring scale equipped with a mesh bag or a plastic weighing chamber, or a Tanita (model 1144-110) electronic scale. Larger fish were weighed to the nearest 5 g with an Accu-weigh 4000 x 10 g platform scale. The disposition of each fish was noted prior to release. Since we did not attempt to collect and sample adult salmonids due to ESA listings, these fish were only counted and identified to species and life stage (when possible). Additional information recorded for every sampling effort included date, time, site code, surface temperature (°C), and minimum and maximum sampling depth (feet).

Electrofishing

We conducted electrofishing after sunset in the littoral zone to evaluate nearshore resident fish use. Target water depth was 1-3 m along consistent bank habitat whenever possible, although some sites were much deeper (048E; 121W; 200E; 219W) or had mixed bank habitat (112E; 203W). The specific location of electrofishing runs at each of the sites was relatively consistent throughout the study because factors such as site length, depth, and obstacles often limited the area that could be sampled. Target effort was 900 s of continuous

energized direct current (DC) output, but actual effort varied substantially due to varied site lengths.

Boats (5.5 m) were equipped with a 5.0 GPP generator and voltage regulator, and six-element anodes. From May 2000 through November 2000, voltage regulator settings were adjusted to produce an output of 2.0-4.0 amperes. Both 30 and 60 pulses/s, at high and low range settings were used with output regulated by adjusting pulse width. In an effort to reduce potential harm to juvenile salmonids, we evaluated alternative voltage regulator settings to identify a combination that maximized taxis (involuntary attraction) of juvenile salmonids and resident fish and minimized tetany (immobilization) of juvenile salmonids. The setting that best met these criteria was 30 pulses/s at 100% pulse width of the low range. Beginning in December 2000, this setting was used almost exclusively with sufficient results. Output averaged 2.0-2.4 amperes (range 1.0-3.9 amperes) depending on conductivity.

Gillnetting

We employed gill nets as an alternate method of collecting resident fish to evaluate habitat associations. Gill nets were 2.4 x 45.7 m and constructed of six alternating 7.6 m panels of monofilament nylon mesh. Stretched mesh sizes were 3.2, 4.4, and 5.1 cm (two panels each) from May through September 2000 and 3.2 and 5.1 cm (three panels each) thereafter. Nets were constructed with a foam-core floating line at the top and a 3.4-kg/net sinking line at the bottom. We used 3.6-7.3 kg anchors on both ends to keep the net on the river bottom and eliminate drifting. Target effort was 40 minutes, but varied from 10-141 minutes depending on conditions. We deployed nets close to shore at all sites, either parallel or diagonal ($\leq 45^\circ$), and adjacent to a specific bank habitat type. At six sites, an additional "mid-shore" net was set parallel to, or within a structure (four sites) or, when a structure was not present (two control sites), nets were set in similar depths and away from the shoreline.

SAMPLING PERMITS AND REPORTING PROCEDURES

Due to potential take of federal- and state-listed salmonids, a variety of permits and reporting procedures were required to conduct sampling in the lower Willamette River during the reporting period. Beach seining and gillnetting activities were authorized under the 4(d) Research Limit prescribed by section 10(a)(1)(A) of the Endangered Species Act. We filed an application with NMFS in November 2000 and received authorization for these activities on 5 March 2001. No break in sampling occurred because all activities were previously authorized through 7 March 2001. A request for additional 4(d) take was submitted 29 May 2001 and authorized 1 June 2001. We submitted monthly reports of ESU-specific take to NMFS.

In October-November 2000, the NMFS determined that boat electrofishing is not authorized under the 4(d) Research Limit on take of listed salmonids. A Section 10(a) application for take authorization of juvenile salmonids by boat electrofishing was initiated in December 2000 and a final draft was submitted to NMFS 6 February 2001. Because NMFS had not yet reviewed the application or issued authorization, boat electrofishing was discontinued after 8 March 2001. As of December 2001, the application was still pending approval, although NMFS had reviewed the application and indicated authorization was likely. Based on this review, ODFW authorized resumption of boat electrofishing activities after 19 June 2001. We

will submit annual reports summarizing activities authorized under Sections 4(d) and 10(a) each calendar year.

A State of Oregon ESA incidental take permit was also required to conduct sampling because naturally produced coho salmon in the lower Columbia River are listed as endangered by the State of Oregon. Authorization for seining, gillnetting, and boat electrofishing was received from ODFW on 23 March 2001 (Permit 2001-INC-15).

DATA ANALYSES

We used mean catch per unit effort (CPUE) to compare relative abundance of fish among sites and habitat types. To adjust for unequal electrofishing effort expended at each site, we standardized all efforts to the overall mean of all electrofishing runs (748 s). Beach seining and gillnetting efforts were not standardized since sampling effort was relatively consistent. We compared catch rates of electrofishing with beach seining and gillnets before and after November 2000 to determine if reduced electrical output affected CPUE comparisons throughout the reporting period.

To simplify analyses and presentation of results, comparisons were limited to several groupings of fish based on taxonomic, behavioral, and size similarities. Groupings included:

Juvenile salmonids	Coho salmon	<i>Oncorhynchus kisutch</i>
	Chinook salmon	<i>Oncorhynchus tshawytscha</i>
	Steelhead	<i>Oncorhynchus mykiss</i>
	Unidentified salmonids	<i>Oncorhynchus</i> spp.
Sunfish	White crappie	<i>Pomoxis annularis</i>
	Black crappie	<i>Pomoxis nigromaculatus</i>
	Smallmouth bass (<250 mm)	<i>Micropterus dolomieu</i>
	Largemouth bass (<250 mm)	<i>Micropterus salmoides</i>
	Bluegill	<i>Lepomis macrochirus</i>
	Pumkinseed	<i>Lepomis gibbosus</i>
	Yellow perch	<i>Perca flavescens</i>
Minnows and Suckers	Northern pikeminnow (<250 mm)	<i>Ptychocheilus oregonensis</i>
	Peamouth	<i>Mylocheilus caurinus</i>
	Largescale sucker	<i>Catostomus macrocheilus</i>
	Unidentified sucker	<i>Catostomus</i> spp.
Predators	Northern pikeminnow (≥250 mm)	<i>Ptychocheilus oregonensis</i>
	Smallmouth bass (≥250 mm)	<i>Micropterus dolomieu</i>
	Largemouth bass (≥250 mm)	<i>Micropterus salmoides</i>
	Walleye (≥250 mm)	<i>Stizostedion vitreum</i>

Predators included those species known to prey on juvenile salmonids. Only fish ≥ 250 mm were classified as predators, as smaller individuals are not likely to consume large numbers of salmonids (Vigg et al. 1991). Chinook salmon were classified as sub-yearling based on length-frequencies of the seasonal catch whenever possible. Most comparisons are limited to chinook salmon because coho salmon and steelhead were not collected in sufficient numbers.

We combined CPUE data for some bank habitat types (e.g. beach and rock; and vegetated and non-vegetated riprap) to increase sample size and reduce comparisons. Site-specific CPUE data was pooled by classification regardless of whether a nearshore structure was present. For comparisons of different nearshore structures, we limited data to sites where bank types were classified alike and used mid-shore gillnet CPUE. No comparisons involving alcove and refugia sites were attempted due to limited sampling in these areas.

Statistical differences in pooled electrofishing CPUE of the four fish groups among general and bank habitat types were evaluated on transformed [$\log_{10}(\text{catch}+1)$] catch-per-set data with Statistical Analysis System (SAS 1988; 1990). We used a general linear models procedure (GLM) followed by a Tukey's studentized range test to determine pairwise differences. Comparisons were made at both $\alpha=0.05$ and $\alpha=0.10$. Migration rates among salmonid cohorts and section of the study area were evaluated for significant differences ($P\leq 0.05$) with GLM and by individual *t*-test of the least-square means within the GLM analysis. We used identical methods to evaluate differences in size and CPUE of salmonids captured in day and night beach seines. Simple linear regression was used to determine correlations between electrofishing catch rates and mean site values or scores of 12 habitat parameters, using August-November catch data for seasonally-affected parameters and all data for fixed parameters. Most nearshore habitat parameter data was subset to more closely represent the area sampled by electrofishing.

Statistical tests were only conducted on a few select comparisons to investigate if specific observed differences were significantly different. Single-year sampling is probably insufficient for meaningful analyses of some comparisons. Detailed statistical analyses addressing hypotheses will be conducted in future years as sample sizes increase.

RESULTS

TASK 1.2: HABITAT EVALUATION

Habitat Inventory of Study Area

The majority (59.2%) of the riverbank habitat available in the study area was classified as undeveloped, and had not been modified by an obvious bank treatment or nearshore development (Table 11; Figure 3; Appendix 3). Beach was the most abundant habitat type in both the upper (above Ross Island Bridge) and lower (below Ross Island Bridge) sections of the study area, but distribution of other bank habitat types was quite different (Table 11; Figure 4). Undeveloped or "natural" bank habitat occurred throughout 81.1% of the upper section but only 32.8 % of the lower section. Riprap and unclassified fill were two and four times more abundant, respectively, in the lower section than above Ross Island Bridge. Nearshore structures were found adjacent to 18.7% of the study area shoreline. Approximately 75% of these structures were classified as allowing light and 25% limited light penetration.

Transition of Bank Habitat at Sampling Sites

Based on our criteria, only two sites (064W and 079W) transitioned from one bank substrate (riprap) to another (sand) during the reporting period. Two additional sites (112E and

Table 11. Summary of bank habitat types and nearshore structures by area in the lower Willamette River, January-August 2001.

Bank habitat and nearshore structure type	Bank habitat below Ross Island Bridge (rm 0.0-13.9)		Bank habitat above Ross Island Bridge (rm 14.0-26.5)		Total bank habitat (rm 0.0-26.5)		Total nearshore structures (rm 0.0-26.5)		Total bank habitat and nearshore structures (rm 0.0-26.5)	
	Length (m)	% of total	Length (m)	% of total	Length (m)	% of total	Length (m)	% of total	Length (m)	% of total
Beach	13,471	29.1	21,826	38.8	35,297	34.4	0	0.0	35,297	29.0
Rock outcrop	0	0.0	14,763	26.3	14,763	14.4	0	0.0	14,763	12.1
Rock	1,687	3.7	8,974	16.0	10,661	10.4	0	0.0	10,661	8.7
Seawall	3,036	6.6	467	0.8	3,503	3.4	0	0.0	3,503	2.9
Vegetated riprap	11,358	24.5	6,773	12.0	18,131	17.7	0	0.0	18,131	14.9
Non-vegetated riprap	3,482	7.5	445	0.8	3,927	3.8	0	0.0	3,927	3.2
Bio-engineered	389	0.8	0	0.0	389	0.4	0	0.0	389	0.3
Unclassified fill	9,421	20.4	2,980	5.3	12,401	12.1	0	0.0	12,401	10.2
Pilings-allowing light ^a	1,315	2.8	0	0.0	1,315	1.3	6,793	35.0	8,108	6.6
Pilings-limiting light ^a	2,127	4.6	0	0.0	2,127	2.1	2,734	14.1	4,861	4.0
Floating-allowing light	0	0.0	0	0.0	0	0.0	7,659	39.5	7,659	6.3
Floating- limiting light	0	0.0	0	0.0	0	0.0	2,202	11.4	2,202	1.8
Total	46,286	100	56,228	100	102,514	100	19,388	100	121,902	100

^a Classified as bank habitat instead of a nearshore structure type when highly incorporated into the bank and no separate bank habitat classification could be determined.

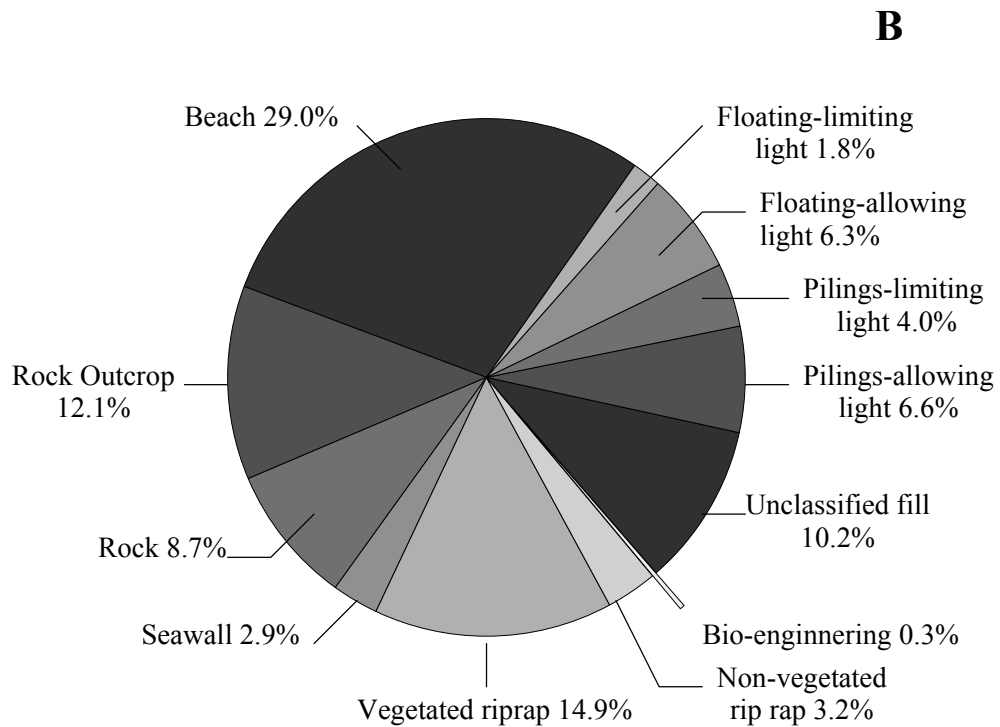
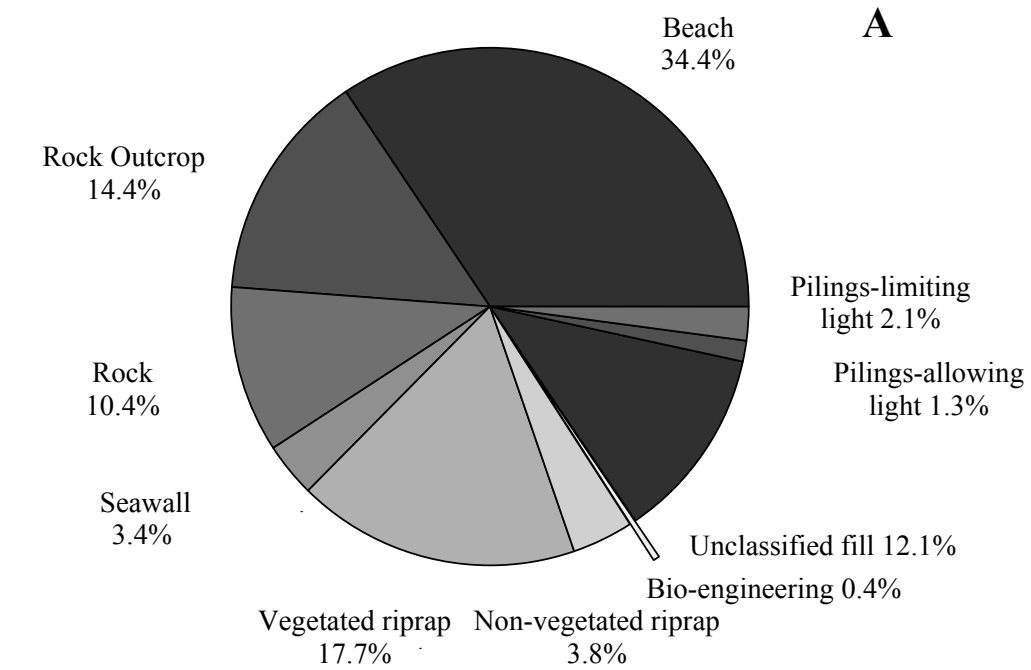


Figure 3. Percent of available A) bank habitat types and B) bank habitat and nearshore structure types in the lower Willamette River, January-August 2001. Piling structures in chart A were classified as bank habitat instead of a nearshore structure type because they were highly incorporated into the bank and no separate bank habitat classification could be determined.

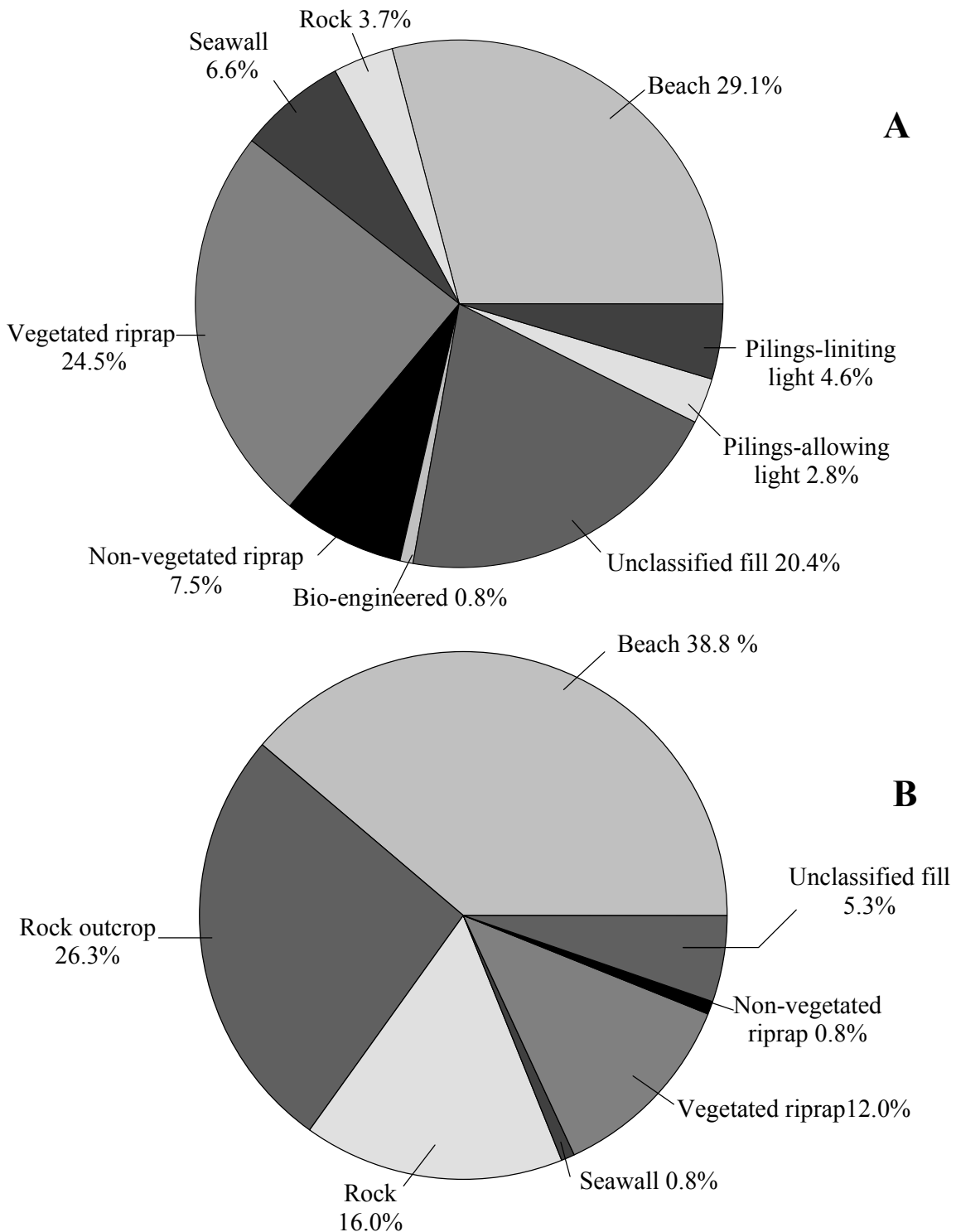


Figure 4. Percent of available bank habitat types A) below and B) above Ross Island Bridge in the lower Willamette River, January-August 2001. Piling structures were classified as bank habitat instead of a nearshore structure type when highly incorporated into the bank and no separate bank habitat classification could be determined.

3W) had mixed habitat (no predominant bank habitat) throughout all sampling seasons and were not included in bank habitat analyses. A summary of seasonal bank habitat types for the 22 sampling sites is provided in Table 12.

Habitat Characteristics of Sampling Sites

We found substantial differences in mean values of some habitat measures at sampling sites but confounding factors may affect results (e.g. tidal effect on velocity). Other parameters including temperature, dissolved oxygen, and conductivity were very similar at all sites, possibly indicating near-complete mixing of the water column. A detailed summary of habitat characteristics at each of the sampling sites is provided in Appendix 4.

TASK 2.1: JUVENILE SALMONID RADIO TELEMETRY

Tagging Summary

A total of 66 juvenile salmonids were released including 13 sub-yearling chinook salmon, 19 yearling chinook salmon, 18 coho salmon, and 16 steelhead (Table 13). Most fish (70%) were of hatchery origin with the remainder unmarked. The size of fish tagged ranged from a 108 mm (13 g) sub-yearling chinook salmon to a 227 mm (97 g) steelhead. Mean length of steelhead was the greatest (202 mm), followed by coho salmon (143 mm), yearling chinook salmon (139 mm), and sub-yearling chinook salmon (114 mm) (Table 14).

Recovery of Tagged Fish

We expended 169 h of on-the-water mobile tracking effort (63% offshore and 37% nearshore) and relocated 57 (86%) of the 66 fish released for 330 independent recoveries. The average number of relocations per tagged fish was 5.8. Group-specific recovery rates were 100% for steelhead, 95% for yearling chinook salmon, 85% for sub-yearling chinook salmon, and 50% for coho salmon. Of all fish relocated, mobile tracking efforts accounted for 77% (255) of the relocations and 83% (55) of all fish released. Fixed sites logged 75 unique tag recoveries representing 55% (36) of all fish released. Twenty-one fish were relocated by mobile tracking only, two by fixed-sites only, and 34 fish were relocated by both methods. Relocation rates per released fish were 1.1 for fixed sites and 3.9 for mobile tracking. The ratio of relocations to fish released was higher for nano tags (4.1:1) than for MCFT-3K tags (3.0:1).

Migration Rates

Migration rates varied within and between cohorts based on 291 unique relocations that met our conservative criteria. Steelhead exhibited the fastest rate (15.5 km/d), followed by coho salmon (13.8 km/d), yearling chinook salmon (11.0 km/d), and sub-yearling chinook salmon (7.2 km/d) (Table 15). Although migration rates of individual fish increased only slightly with length (Figure 5; $r^2=0.08$), mean rates for steelhead and sub-yearling chinook salmon were significantly different ($P=0.0008$; $F=5.70$). Mean duration of residency in the study area based on migration rates ranged from 2.7 d for steelhead to 5.9 d for sub-yearling chinook salmon. Absolute periods of residency for individual fish ranged from 31 h to almost 2 months.

Table 12. Bank substrate of sampling sites in the lower Willamette River by season and year, May 2000 through June 2001. Classifications are based on a minimum of 80% similar substrate existing within -3' of the sampling period mean river stage (MRS).

Site	Sampling season and mean river stage				
	Spring 2000 MRS 6.2	Summer 2000 MRS 3.1	Autumn 2000 MRS 3.2	Winter 2001 MRS 3.4	Spring 2001 MRS 3.5
006E		Beach	Beach	Beach	Beach
010E	Beach	Beach	Beach	Beach	Beach
012W		Beach	Beach	Beach	Beach
031W	Beach	Beach	Beach	Beach	Beach
040W	Beach	Beach	Beach	Beach	Beach
048E	Vertical Wall	Vertical Wall	Vertical Wall	Vertical Wall	Vertical Wall
051E	Riprap	Riprap	Riprap	Riprap	Riprap
064W	Riprap	Beach	Beach	Beach	Beach
079W	Riprap	Beach	Beach	Beach	Beach
097E	Beach	Beach	Beach	Beach	Beach
100W ^a	Riprap	Riprap	Riprap	Riprap	Riprap
112E ^b	Mix (Riprap/ unclassified fill)	Mix (Riprap/ unclassified fill)	Mix (Riprap/ unclassified fill)	Mix (Riprap/ unclassified fill)	Mix (Riprap/ unclassified fill)
118W	Riprap	Riprap	Riprap	Riprap	Riprap
121W	Vertical Wall	Vertical Wall	Vertical Wall	Vertical Wall	Vertical Wall
133W			Beach	Beach	Beach
136E	Riprap	Riprap	Riprap	Riprap	Riprap
148E	Beach	Beach	Beach	Beach	Beach
167W	Beach	Beach	Beach	Beach	Beach
200E	Rock outcrop	Rock outcrop	Rock outcrop	Rock outcrop	Rock outcrop
203W ^b	Mix (beach/rock outcrop)	Mix (beach/rock outcrop)	Mix (beach/rock outcrop)	Mix (beach/rock outcrop)	Mix (beach/rock outcrop)
219W	Rock outcrop	Rock outcrop	Rock outcrop	Rock outcrop	Rock outcrop
243W	Beach	Beach	Beach	Beach	Beach

^a Site classified as riprap although bank substrate was not positively identified below MRS 3.0. Likely riprap or cement.

^b No predominant bank substrate existed at any river stage. Catch rate data for these sites was not used for bank habitat analyses.

Table 13. Summary of releases of radio-tagged juvenile salmonids in the lower Willamette River, April-June, 2001.

Release information		Species ^a released				
Date	Location (rm; rkm)	CHS	CHY	STH	COH	Total
April 25	24.3; 39.1	0	6	3	1	10
May 1	24.2; 38.9	0	6	6	4	16
May 9	17.3; 27.8	0	7	6	3	16
May 16	18.0; 29.0	0	0	1	10	11
June 6	24.4; 39.3	12	0	0	0	12
June 11	16.8; 27.0	1	0	0	0	1
Total		13	19	16	18	66

^a CHS (sub-yearling chinook); CHY (yearling chinook); STH (yearling steelhead); and COH (yearling coho).

Table 14. Lengths and weights of juvenile salmonids (hatchery and unmarked) fitted with radio transmitters in the lower Willamette River, April-June 2001.

Species ^a	N	Fork length (mm)			Weight (g)		
		Min	Max	Mean	Min	Max	Mean
Chinook yearling (all)	19	118	150	139	17	32	25
Chinook yearling (W)	1	125	125	125	19	19	19
Chinook yearling (H)	18	118	150	140	17	32	25
Chinook sub-yearling (all)	13	108	118	114	13	17	15
Chinook sub-yearling (W)	13	108	118	114	13	17	15
Chinook sub-yearling (H)	0	0	0	0	0	0	0
Coho yearling (all)	18	129	153	143	21	34	28
Coho yearling (W)	1	129	129	129	21	21	21
Coho yearling (H)	17	132	153	144	21	34	28
Steelhead yearling (all)	16	157	227	202	38	97	71
Steelhead yearling (W)	5	157	215	182	38	85	55
Steelhead yearling (H)	11	186	227	210	56	97	79

^a W=unmarked fish; H=fin-clipped

Table 15. Summary of migration rates of radio-tagged juvenile salmonids in the lower Willamette River and Multnomah Channel, April-June 2001.

Species	N	Number relocations	Mean fork length (mm)	Mean weight (g)	Mean km/d	Range km	Mean d	Range d
Mouth to Willamette Falls (river kilometer 0.0-42.6) and Multnomah Channel (see below)								
Chinook sub-yearling	11	72	114	14	7.2	0.8-16.4	5.9	2.6-55.9
Chinook yearling	18	93	139	24	11.0	2.4-29.7	3.9	1.4-17.7
Coho yearling	9	44	143	24	13.8	4.7-23.3	3.1	1.8-9.0
Steelhead yearling	16	82	202	71	15.5	1.4-33.8	2.7	1.3-31.3
Mouth to Ross Island Bridge (river kilometer 0.0-22.5)								
Chinook sub-yearling	3	6	113	15	8.6	0.4-14.1	4.9	3.0-122.80
Chinook yearling	12	41	140	25	11.3	3.7-53.1	3.8	0.8-11.5
Coho yearling	8	15	140	27	16.8	13.3-24.3	2.5	1.8-3.2
Steelhead yearling	13	29	202	72	20.5	9.2-36.9	2.1	1.2-4.6
Ross Island Bridge to Willamette Falls (river kilometer 22.6-42.6)								
Chinook sub-yearling	10	55	114	14	7.5	1.0-16.4	5.7	2.6-44.8
Chinook yearling	17	42	137	24	11.0	0.3-30.7	3.9	1.4-147.2
Coho yearling	3	10	140	27	12.3	5.6-27.7	3.5	1.5-7.6
Steelhead yearling	14	40	202	72	9.0	1.4-22.0	4.7	1.9-31.3
Multnomah Channel (river kilometer 0.0-35.1; Warrior Point-upper Sauvie Island)								
Chinook yearling	1	2	144	23	-5.7	-5.7	^a	^a
Coho yearling	1	2	129	21	0.1	1.0	44.0	44.0

^a Second relocation occurred upstream of initial relocation resulting in negative migration.

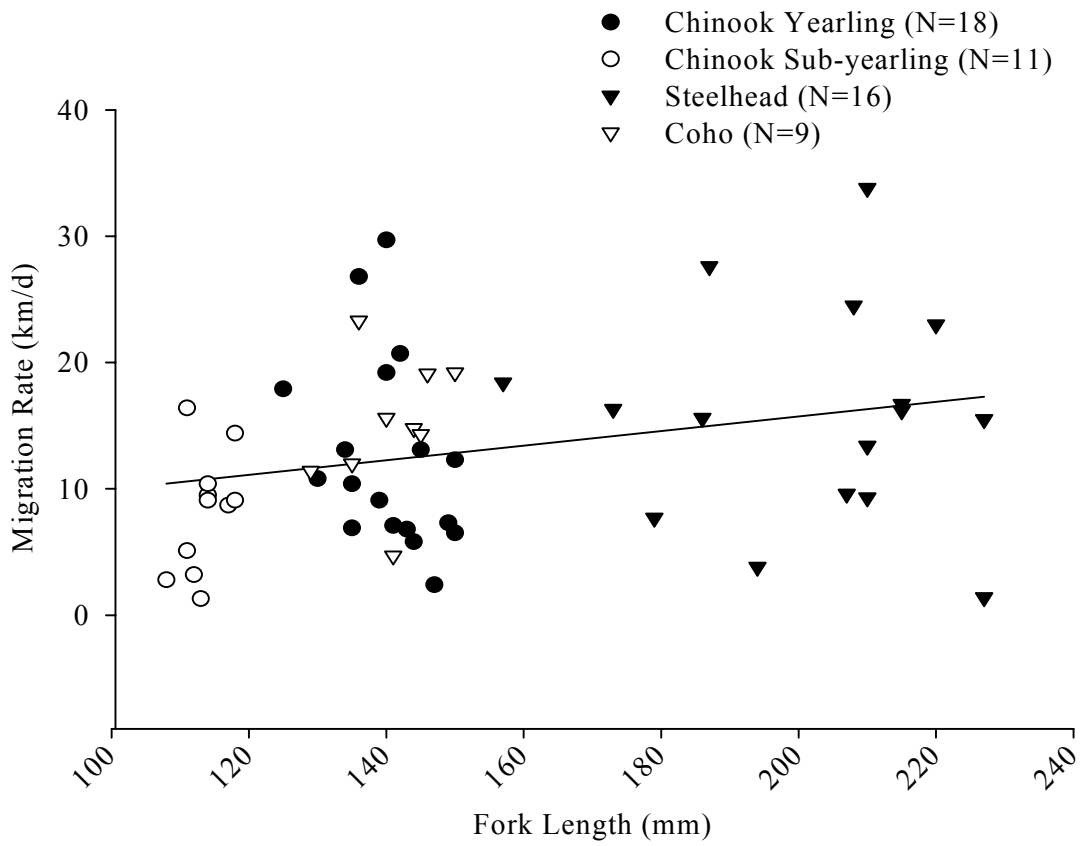


Figure 5. Mean migration rates (km/d) by fork length (mm) of juvenile salmonids in the lower Willamette River, April-June 2001.

Rates of migration also differed between upper (above Ross Island Bridge) and lower sections of the study area. All cohorts tended to migrate faster in the lower section, although only rates for steelhead were significantly different ($P < 0.0001$; $F = 20.38$). However, the mean migration rate for all juvenile salmonids combined in the lower section (14.4 km/d) was significantly faster than in the upper section (9.2 km/d) ($P = 0.0008$; $F = 11.5$).

Habitat Association

Cohort-specific relocations of juvenile salmonids by river width and section yielded no distinct pattern of distribution across the water column (Figure 6). Actual percentages of relocations in the nearshore zone (within 10% of either shore) of the entire study area were 29% for sub-yearling chinook salmon, 26% for yearling chinook salmon, 13% for coho salmon, and 14% for steelhead, indicating chinook salmon are more likely to be found close to shore. Above Ross Island Bridge, 25% of all salmonids were relocated in the nearshore area. In the lower section, 18% of relocations occurred in this zone.

Relocations of radio-tagged salmonids adjacent to different bank habitat types were relatively consistent with availability of each (Figure 7; Appendix 3). Frequencies of recoveries for individual cohorts adjacent to each bank type varied considerably. Relocations of all cohorts except coho were disproportionately high adjacent to rock outcrops. Overall, we found 69.6% of all tagged salmonids adjacent to "natural" bank habitat types (59.2% of study area). Frequencies of individual cohorts adjacent to "natural" bank types were 80.9% for sub-yearling chinook salmon, 72.7% for yearling chinook salmon, 75% for steelhead, and 0.0% for coho salmon. A chi-square comparison was postponed until additional sample sizes can be collected.

TASK 2.2: STANDARDIZED SAMPLING FOR JUVENILE SALMONIDS

Catch and Effort

We caught 993 juvenile salmonids in 256 beach seine efforts (3.9 fish/effort) and 2,457 salmonids in 397 electrofishing runs (6.6 fish/effort). Distribution of sampling efforts varied among sampling sites (Table 16). Each of the five beach seine sites was sampled approximately 50 times (range 46-57). Between 10 and 25 electrofishing runs were conducted at each of the 19 sampling sites. For both gear types, effort was lowest during the autumn sampling period (Table 17). Due to other tasks, limited sampling was conducted in April and no sampling occurred in October. Distribution of electrofishing effort among months was unequal. No sampling was conducted in April, July, or October.

Seasonal Catch Rates and Abundance

Catch rates (CPUE) by month were considerably different for beach seining and electrofishing. Beach seining CPUE was highest from February through June and peaked in May (27.9 fish/effort). From July through January, CPUE was less than 0.8 fish/set (Figure 8). Electrofishing CPUE was highest from November through January, with moderate catches continuing through July, although April-May catches may be an artifact of limited effort. Most notable was the extremely high CPUE (45.2 fish/effort) in December. Salmonids were captured

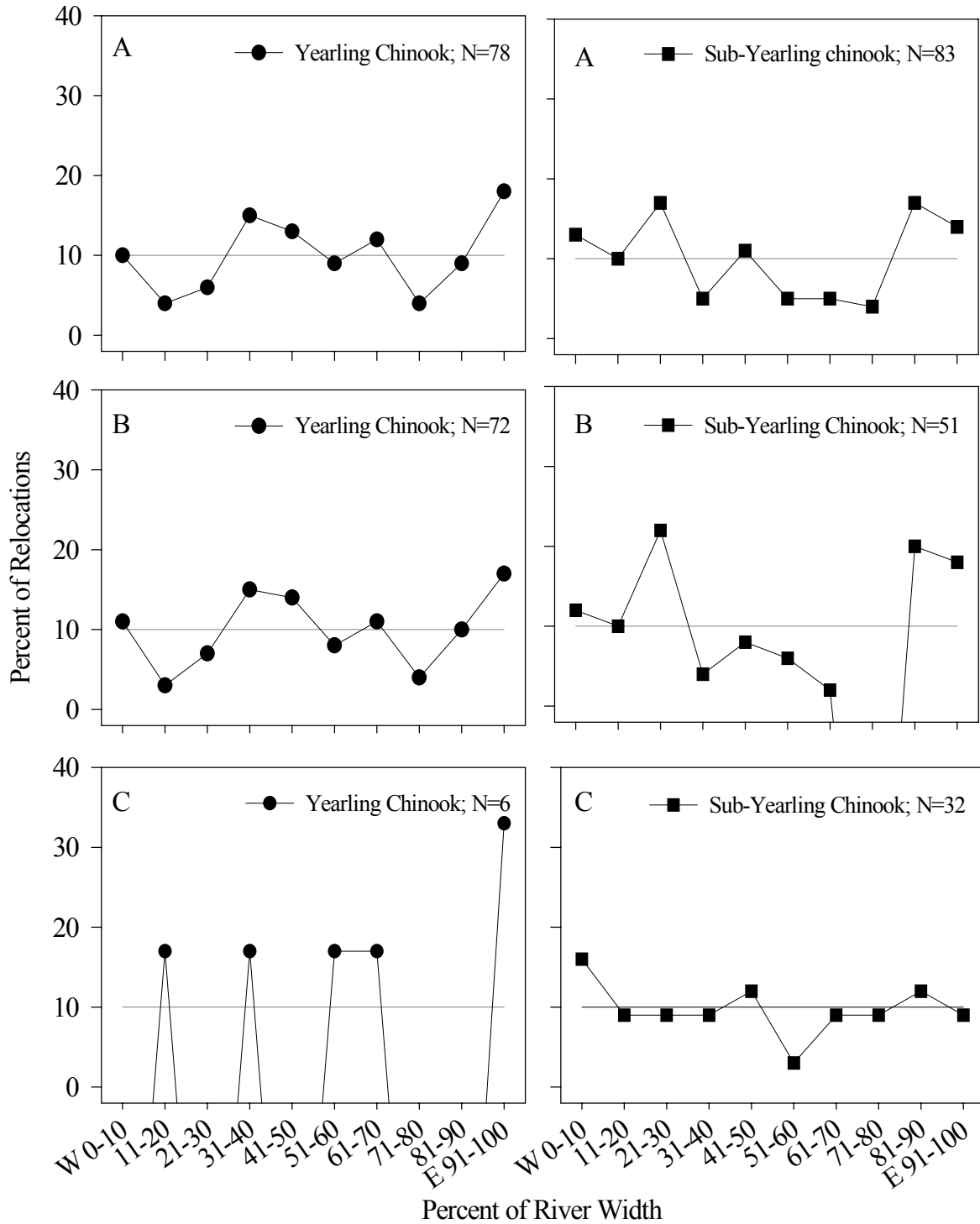


Figure 6. Frequency of recoveries of radio-tagged juvenile salmonids by percent of river width for A) Willamette Falls to Columbia River, B) Willamette Falls to Ross Island Bridge, and C) Ross Island Bridge to Columbia River, May 2000 through June 2001. West bank of river = 0%, East bank of river = 100%.

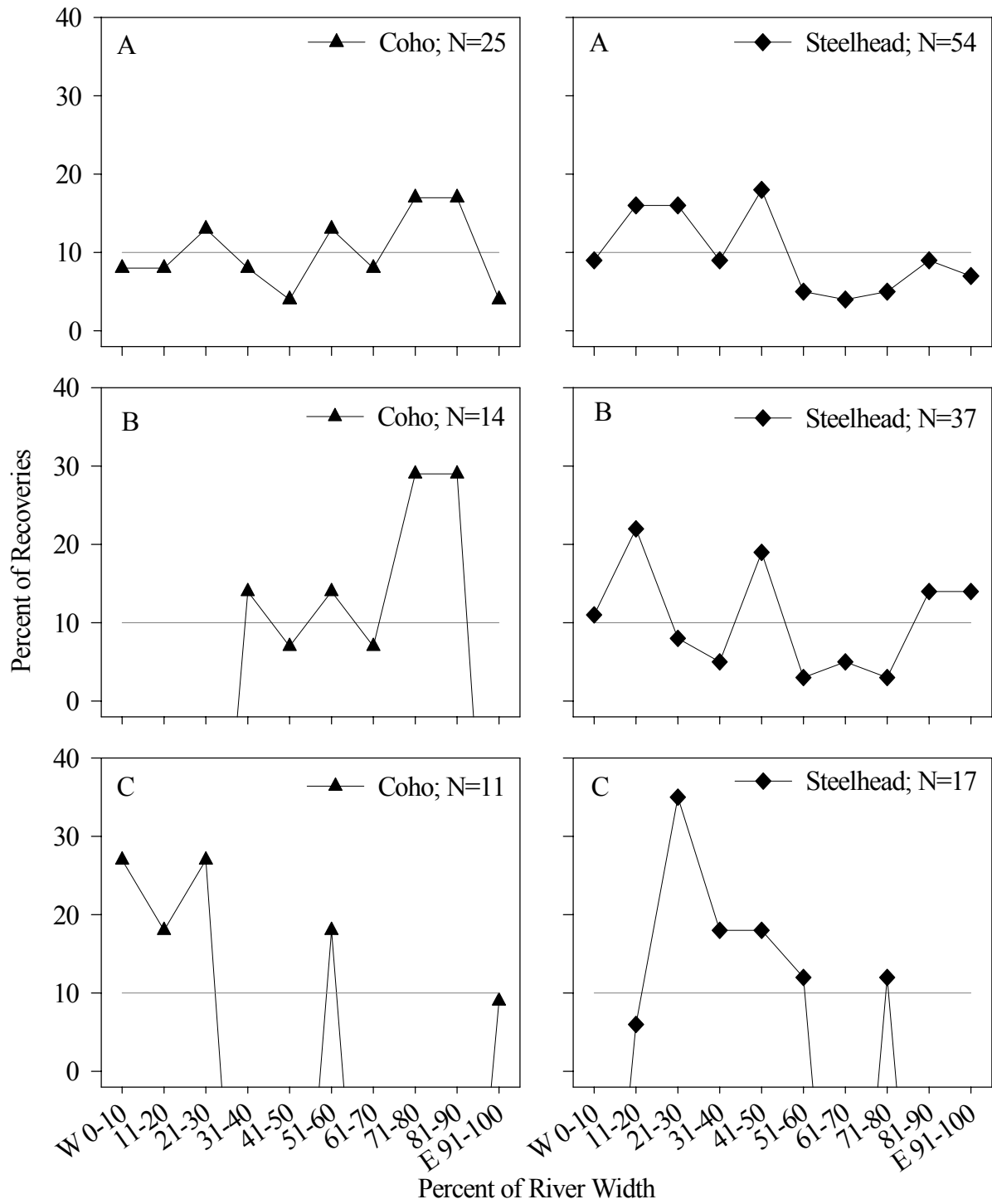


Figure 6. (continued)

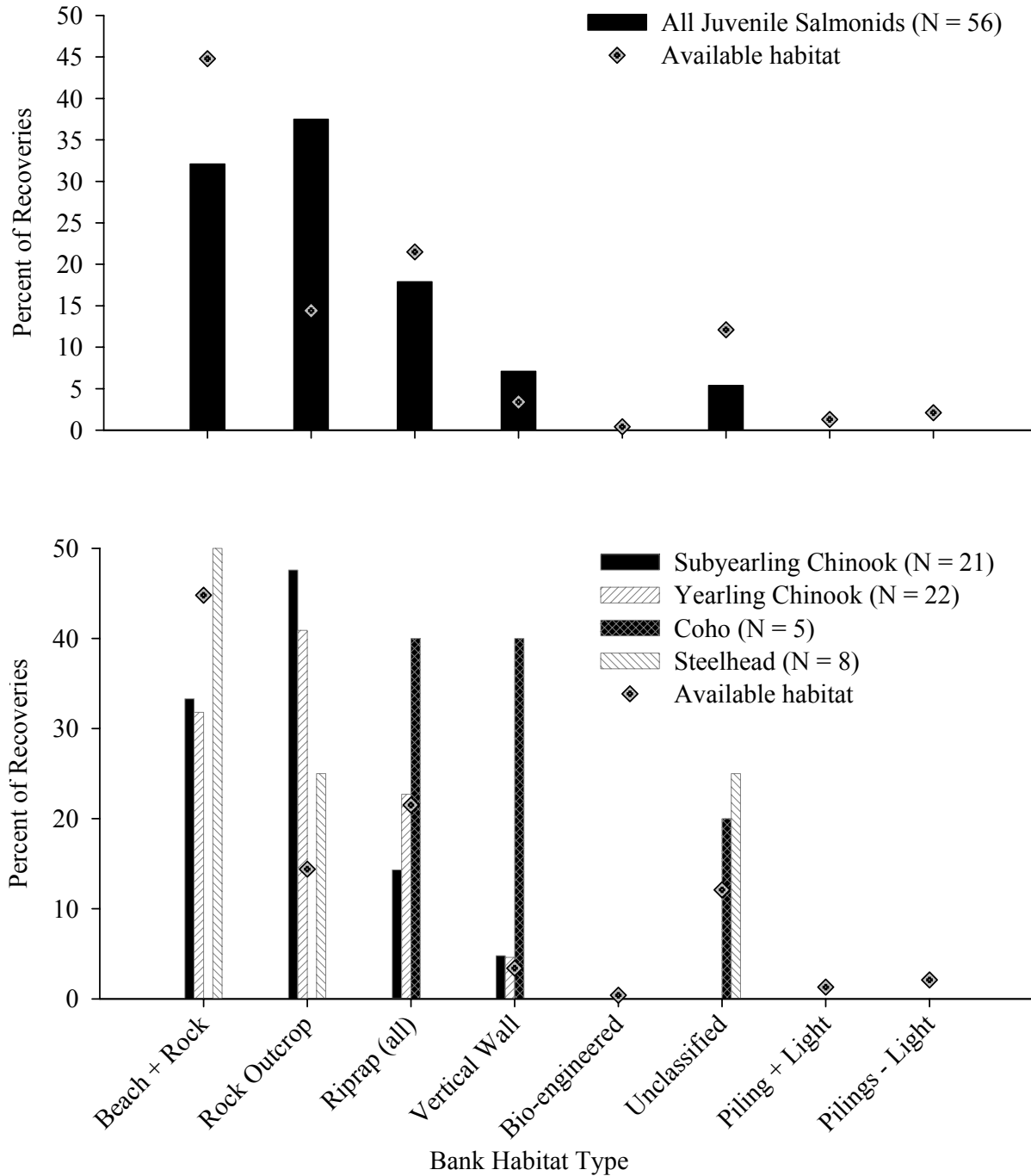


Figure 7. Frequency of relocations of radio-tagged juvenile salmonids by bank habitat type in the lower Willamette River, May 2000 through June 2001. Data limited to relocations in the nearshore zone equal to 10% of the river width.

Table 16. Mean sampling effort (seconds) by gear type for sampling sites in the lower Willamette River, May 2000 through June 2001.

Sampling sites	Beach Seining		Gillnetting		Electrofishing	
	N	Effort s (range)	N	Effort s (range)	N	Effort s (range)
006E	48	406 (180-960)	21	2,583 (2,400-4,380)	22	792 (600-902)
010E ^a			38	2,478 (2,160-3,540)	24	819 (609-914)
012W			17	2,714 (2,400-4,860)	19	699 (420-900)
031W	2	240(180-300)	20	2,538 (2,400-3,780)	24	675 (364-907)
040W	46	425 (240-900)				
048E			20	2,754 (2,280-6,420)	25	735 (500-902)
051E ^a			36	2,825 (1,800-6,960)	23	769 (436-914)
058E					3	901 (900-901)
060E			5	2,484 (2,400-2,700)	6	902 (900-905)
061W					1	900 (900-900)
064W ^a			40	2,691 (2,400-4,920)	24	841 (600-920)
079W ^a			41	2,938 (2,040-9,660)	24	665 (364-903)
097E	49	456 (240-1,020)				
100W ^a			26	2454 (2,160-3,600)	10	188 (81-200)
112E			16	2,595 (2,400-3,300)	16	660 (142-900)
117E			1	2,400 (2,400-2,400)	1	900 (900-900)
118W			23	2,645 (900-6,240)	22	739 (526-906)
121W			21	2,640 (1,740-5,280)	21	882 (611-904)
133W			13	2,488 (1,800-3,240)	11	509 (321-866)
136E ^a			37	2429 (1,080-3,240)	20	635 (310-902)
148E			21	2,594 (2,400-3,660)	19	886 (764-901)
167W	57	455 (240-1,080)	22	2,643 (2,400-3,600)	20	843 (300-900)
200E			20	2,394 (600-3,960)	18	787 (540-925)
203W			21	2,694 (2,400-6,000)	18	612 (342-905)
219W			21	2,623 (2,400-4,560)	19	771 (333-914)
243W	55	421 (180-1,260)				
Alcoves						
067EA					2	700 (499-900)
076wA					2	597 (593-600)
148WA					1	360 (360-360)
232WA					1	902 (902-902)
239EA					1	901 (901-901)

^a Includes near shore and mid-shore gill net efforts.

Preliminary sites that were eliminated due to adverse conditions.

Table 17. Monthly effort by gear type for sampling sites in the lower Willamette River, May 2000 through June 2001.

Season; month	Beach Seining (sets)	Electrofishing (runs)	Gillnetting (sets)
Winter			
January	30	8	25
February	30	66	58
March	12	24	13
	72	98	96
Spring			
April	6	0	0
May	14	15	50
June	49	109	118
	69	124	168
Summer			
July	29	0	0
August	41	64	78
September	14	33	35
	84	97	113
Autumn			
October	0	0	20
November	11	62	56
December	20	16	21
	31	78	97
	256	397	474

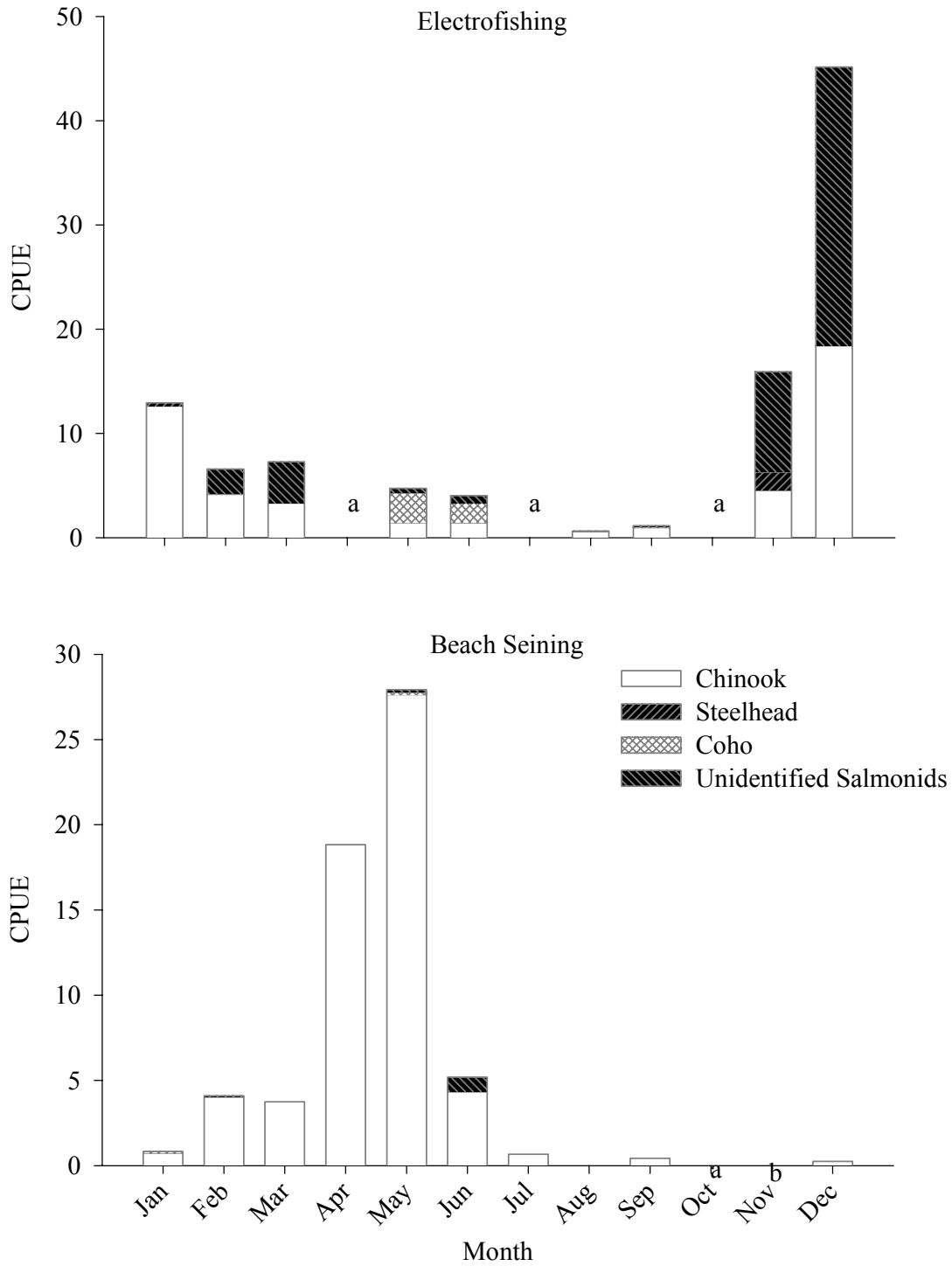


Figure 8. Catch-per-unit-effort (CPUE) of juvenile salmonids captured by electrofishing and beach seining in the lower Willamette River, May 2000 through June 2001. a = no sampling conducted; b = three days of sampling.

with both gears during every month sampling was conducted except for a zero catch by beach seining in November.

Chinook salmon was the most prevalent salmonid species captured throughout the year with either gear, except coho salmon comprised the majority of the electrofishing catch in May and June (Figure 8). Beach seining species composition was 94.7% chinook, 0.6% coho, 0.0% steelhead, and 4.7% unidentified salmonids. The electrofishing catch was comprised of 47.1% chinook, 11.5% coho, 3.0% steelhead, and 38.4% unidentified salmonids (fish that were counted but not handled).

Of the salmonid beach seine catch, unmarked sub-yearling chinook were the most prevalent cohort followed by fish of unknown origin for which a mark code was not recorded (Figure 9). Because mean lengths of unmarked (64 mm) and unidentified (71 mm) chinook were similar and considerably different from known hatchery fish (127mm), we assumed most unidentified chinook were naturally produced. Among the electrofishing catch, larger yearling fish, both unmarked and hatchery, were more prevalent with catches distributed throughout the year. Additional fish species collected are listed in Table 18.

Season-specific length-frequencies based on all data indicate multiple age classes of unmarked chinook salmon juveniles are present within the study area during the winter (January-March) but fish remaining thereafter are probably sub-yearling chinook (Figure 10). Monthly length-frequencies show a clear pattern of growth by age 0+ fish from February through June (Figure 11). Juvenile hatchery chinook were most abundant during the winter and autumn sampling periods (Figure 12) and consisted of a fairly uniform size class present from November through March (Figure 13). Length-weight relationships were calculated for all salmonid species for which paired length and weight data were collected (Table 19).

Rearing Potential

We compared mean fork length of all unmarked sub-yearling chinook salmon caught each month at the upper two seine sites (167W and 243W) with the lowest two sites (006E and 040W) to evaluate the extent of growth and rearing in the study area (Figure 14). Sample sizes were very small in the lower section but means were significantly different in February and April ($P=0.0490$ and $P=0.0150$, respectively).

We attempted to compare mean monthly weights of hatchery chinook at time of release and recapture to see if growth occurred (Figure 15). Unfortunately, inconsistencies in releases and sampling efforts, and too few fish weights by month limited the number of data pairs available for interpretation. The same problems hampered a comparison of CPUE and hatchery releases (Figure 16).

Gear Efficiencies and Selectivity

A comparison of mean monthly catch rates of salmonids by beach seining and electrofishing over time indicates that reducing amperage output of the electrofisher in November 2000 did not reduce catch rates (Figure 17). Juvenile chinook salmon caught by electrofishing were consistently larger than fish caught by beach seining (Figure 18). A comparison of mean catch rates by month of juvenile chinook salmon indicates electrofishing

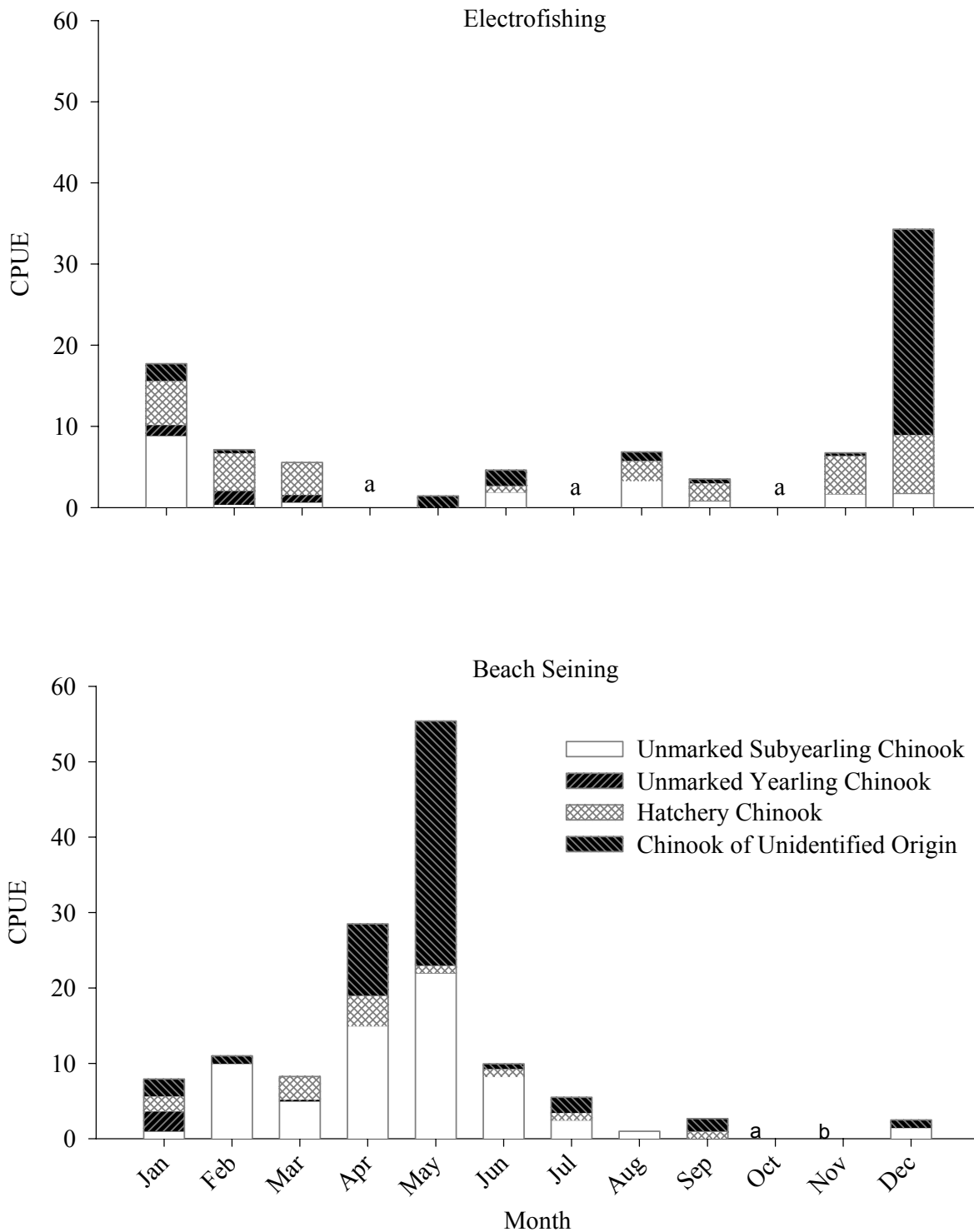


Figure 9. Electrofishing and beach seining catch-per-unit-effort (CPUE) of juvenile chinook salmon by month in the lower Willamette River, May 2000 through June 2001. a = no sampling conducted; b = three days of sampling.

Table 18. Fish species collected in the lower Willamette River, May 2000-June 2001. An asterisk denotes introduced species.

Family, species	Common name	Collection method		
		ES	GN	BS
Petromyzontidae				
<i>Lampetra tridentata</i>	Pacific lamprey	X		
Acipenseridae				
<i>Acipenser transmontanus</i>	white sturgeon	X	X	
Clupeidae				
<i>Alosa sapidissima</i>	*American shad	X	X	X
Salmonidae				
<i>Oncorhynchus kisutch</i>	coho salmon	X	X	X
<i>Oncorhynchus tshawytscha</i>	chinook salmon	X	X	X
<i>Oncorhynchus mykiss</i>	steelhead / rainbow	X		
<i>Oncorhynchus clarki</i>	cutthroat trout	X	X	
<i>Prosopium williamsoni</i>	mountain whitefish	X		X
Cyprinidae				
<i>Ptychocheilus oregonensis</i>	northern pikeminnow	X	X	X
<i>Mylocheilus caurinus</i>	peamouth	X	X	X
<i>Acrocheilus alutaceus</i>	chiselmouth	X	X	X
<i>Cyprinus carpio</i>	*common carp	X	X	X
<i>Carassius auratus</i>	*goldfish	X	X	
<i>Richardsonius balteatus</i>	redside shiner	X	X	X
<i>Rhinichthys cataractae</i>	longnose dace			X
Catastomidae				
<i>Catostomus macrocheilus</i>	largescale sucker	X	X	X
<i>Catostomus platyrhynchus</i>	mountain sucker			X
Ictaluridae				
<i>Amerius natalis</i>	*yellow bullhead	X	X	
<i>Amerius nebulosus</i>	*brown bullhead	X	X	X
Gasterosteidae				
<i>Gasterosteus aculeatus</i>	threespine stickleback	X		X
Percopsidae				
<i>Percopsis transmontana</i>	sand roller	X		
Cyprinodontidae				
<i>Fundulus diaphanus</i>	*banded killifish	X		X
Centrarchidae				
<i>Pomoxis annularis</i>	*white crappie	X	X	
<i>Pomoxis nigromaculatus</i>	*black crappie	X	X	
<i>Micropterus dolomieu</i>	*smallmouth bass	X	X	X
<i>Micropterus salmoides</i>	*largemouth bass	X		X
<i>Lepomis macrochirus</i>	*bluegill	X		
<i>Lepomis gibbosus</i>	*pumpkinseed	X		X
<i>Lepomis gulosus</i>	*warmouth		X	
Percidae				
<i>Stizostedion vitreum</i>	*walleye	X	X	X
<i>Perca flavescens</i>	*yellow perch	X		X
Cottidae				
<i>Cottus asper</i>	prickly sculpin	X	X	X
Pleuronectidae				
<i>Platichthys stellatus</i>	starry flounder	X	X	X

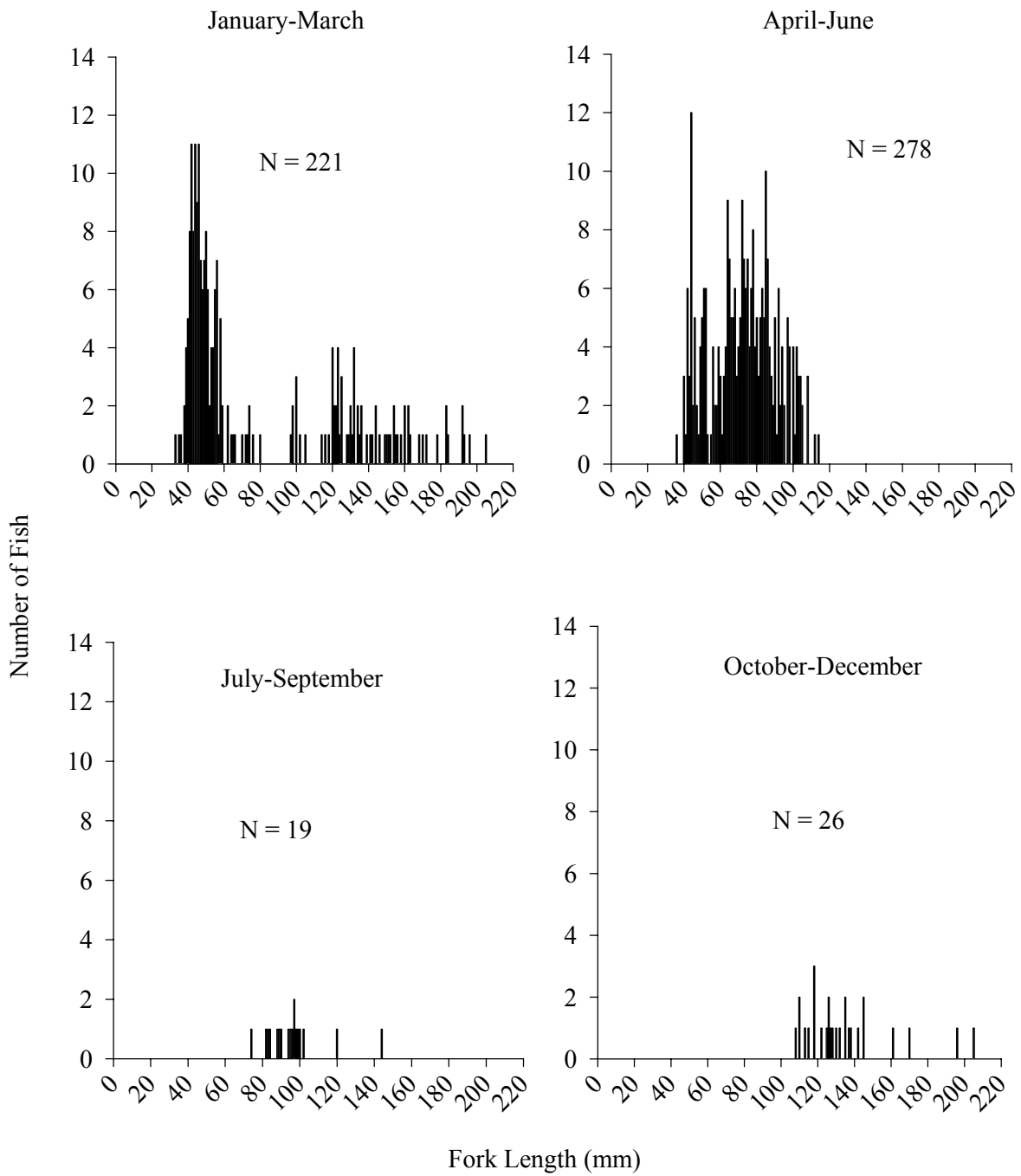


Figure 10. Length-frequency by season of unmarked juvenile chinook salmon captured by electrofishing and beach seining in the lower Willamette River, May 2000 through June 2001.

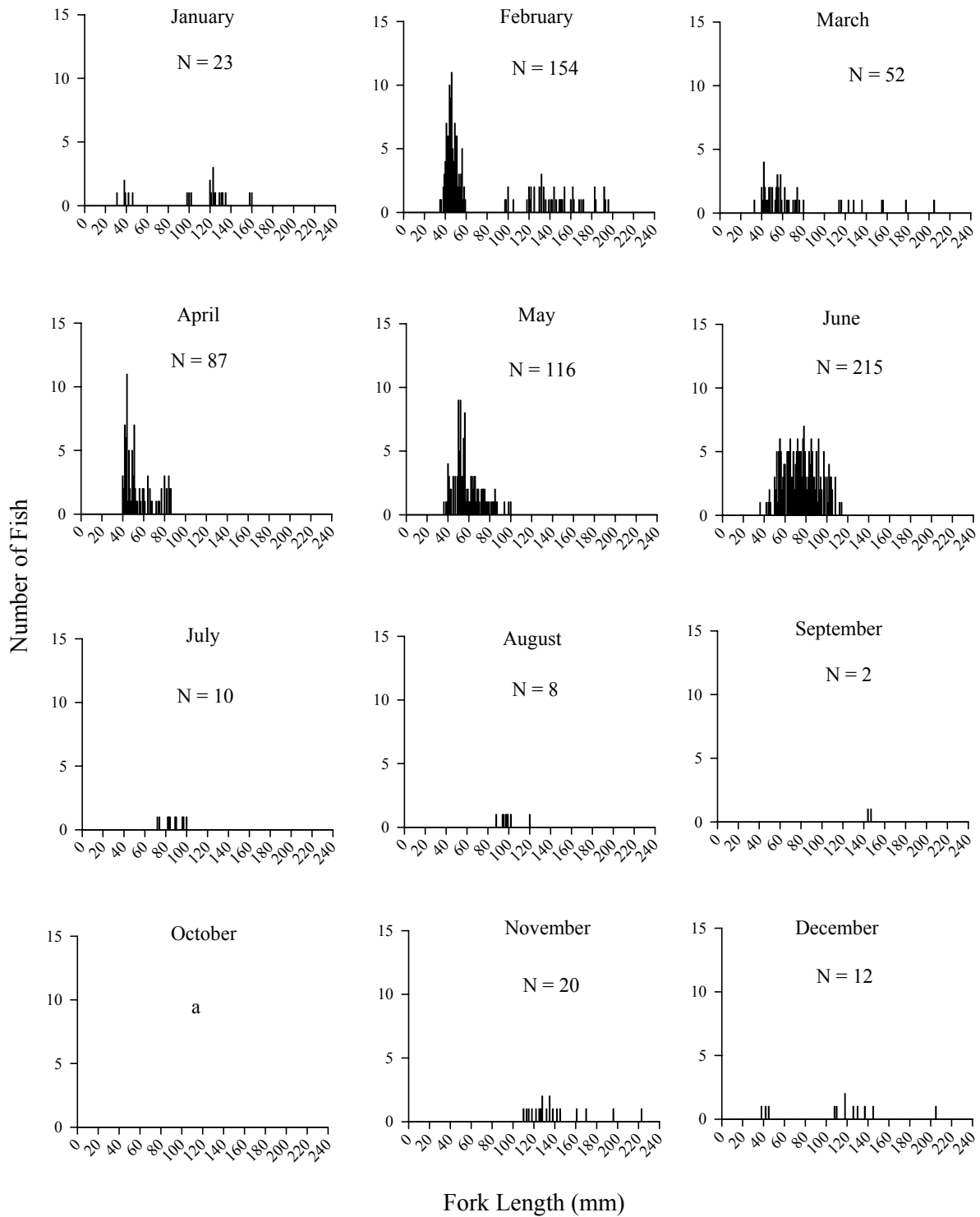


Figure 11. Length-frequency by month of unmarked juvenile chinook salmon captured by electrofishing and beach seining in the lower Willamette River, May 2000 through June 2001. a = no sampling conducted.

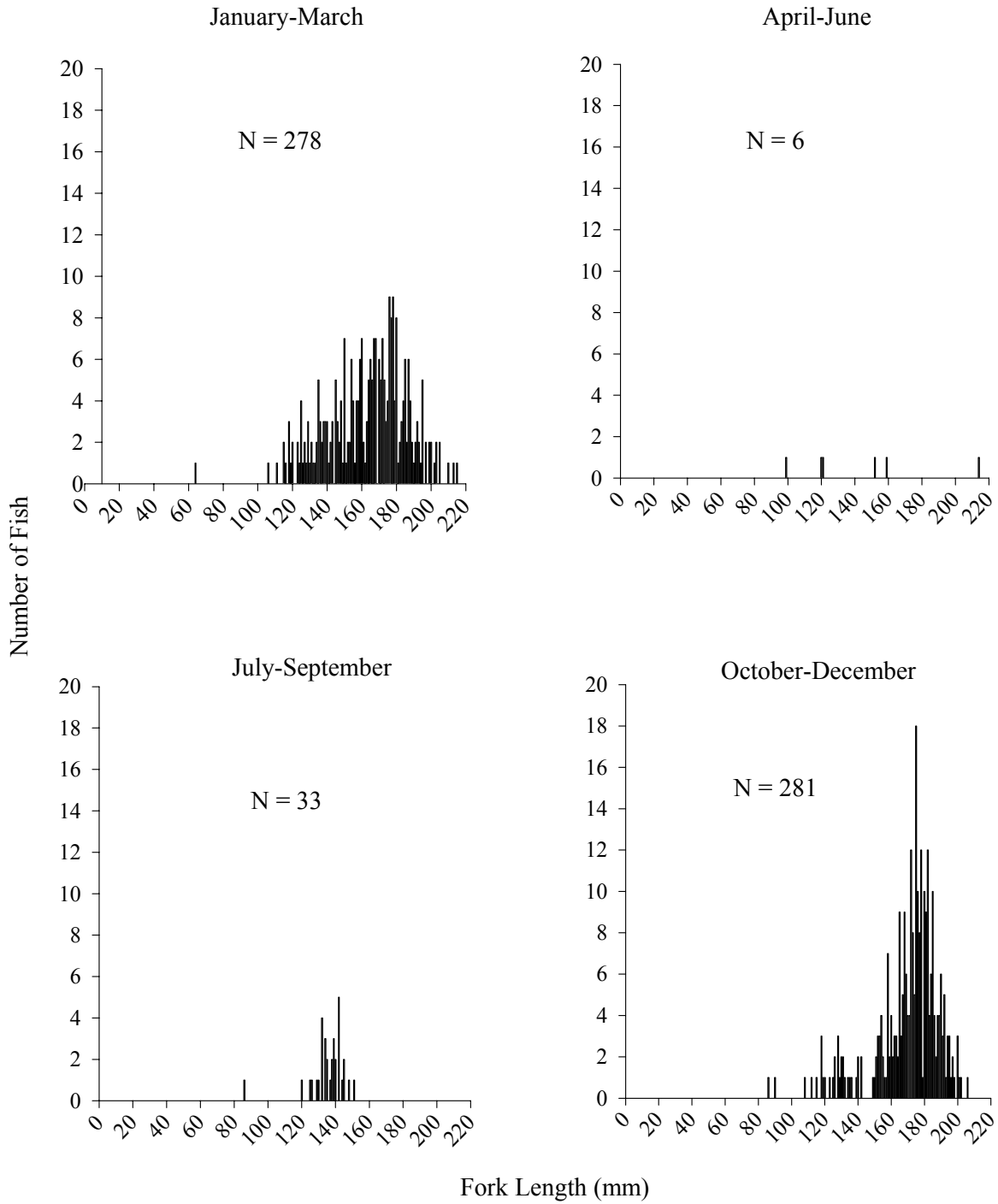


Figure 12. Length-frequency by season of hatchery juvenile chinook salmon captured by electrofishing and beach seining in the lower Willamette River, May 2000 through June 2001.

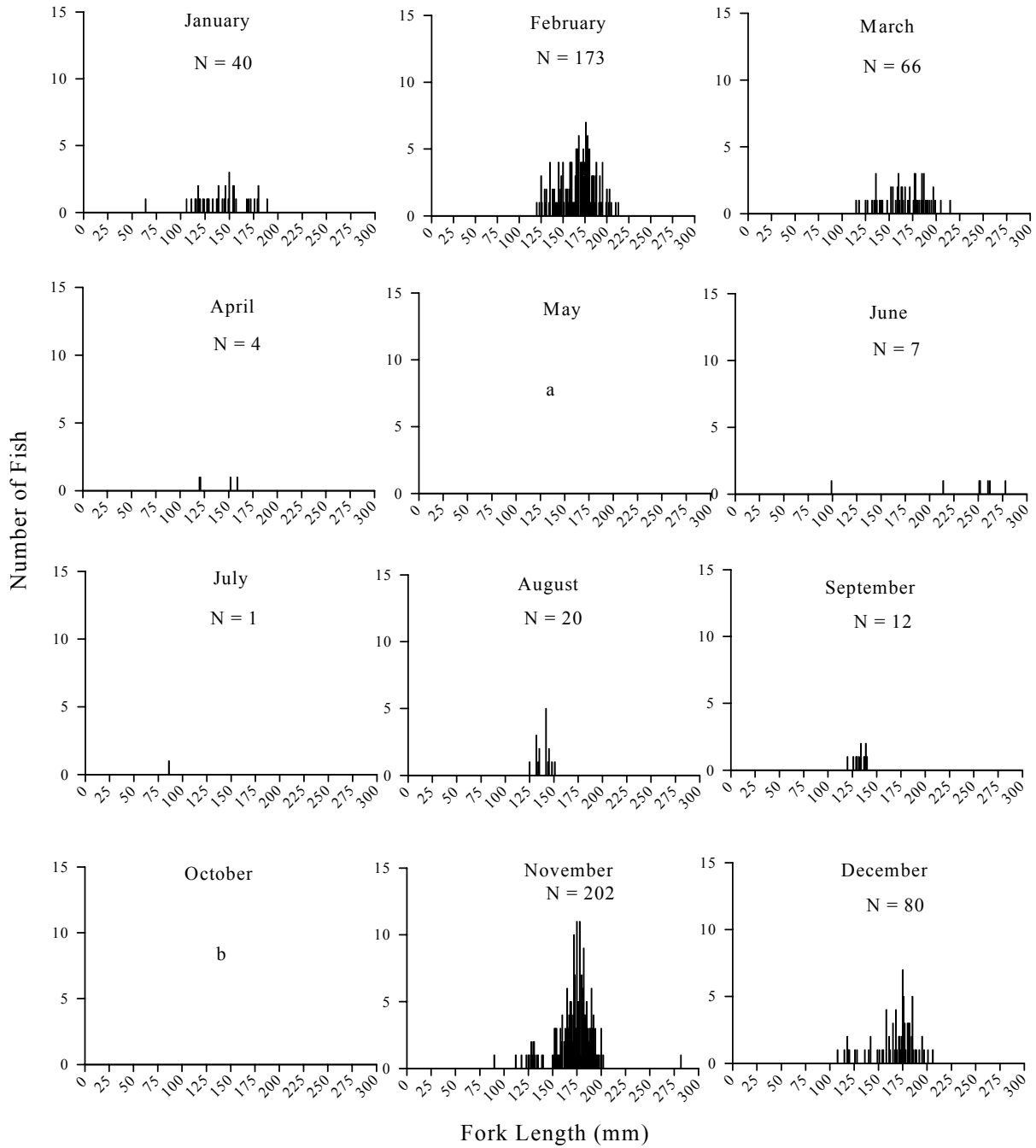


Figure 13. Length-frequency by month of hatchery juvenile chinook salmon captured by electrofishing and beach seining in the lower Willamette River, May 2000 through June 2001. a = no hatchery chinook sampled; b = no sampling conducted.

Table 19. Length-weight relationships of juvenile salmonids collected at sampling sites in the lower Willamette River, May 2000 through June 2001.

Species	Length-weight equation	r^2	N
Chinook salmon (unmarked)	$W = 1.83 \times 10^{-5} FL^{2.88}$	0.93	449
Chinook salmon (hatchery)	$W = 1.07 \times 10^{-5} FL^{2.99}$	0.87	431
Coho salmon (unmarked)	$W = 9.72 \times 10^{-7} FL^{3.55}$	0.96	18
Coho salmon (hatchery)	$W = 9.43 \times 10^{-4} FL^{2.09}$	0.99	3
Steelhead (unmarked)	$W = 1.56 \times 10^{-5} FL^{2.91}$	0.99	4
Steelhead (hatchery)	$W = 1.26 \times 10^{-4} FL^{2.53}$	0.58	50

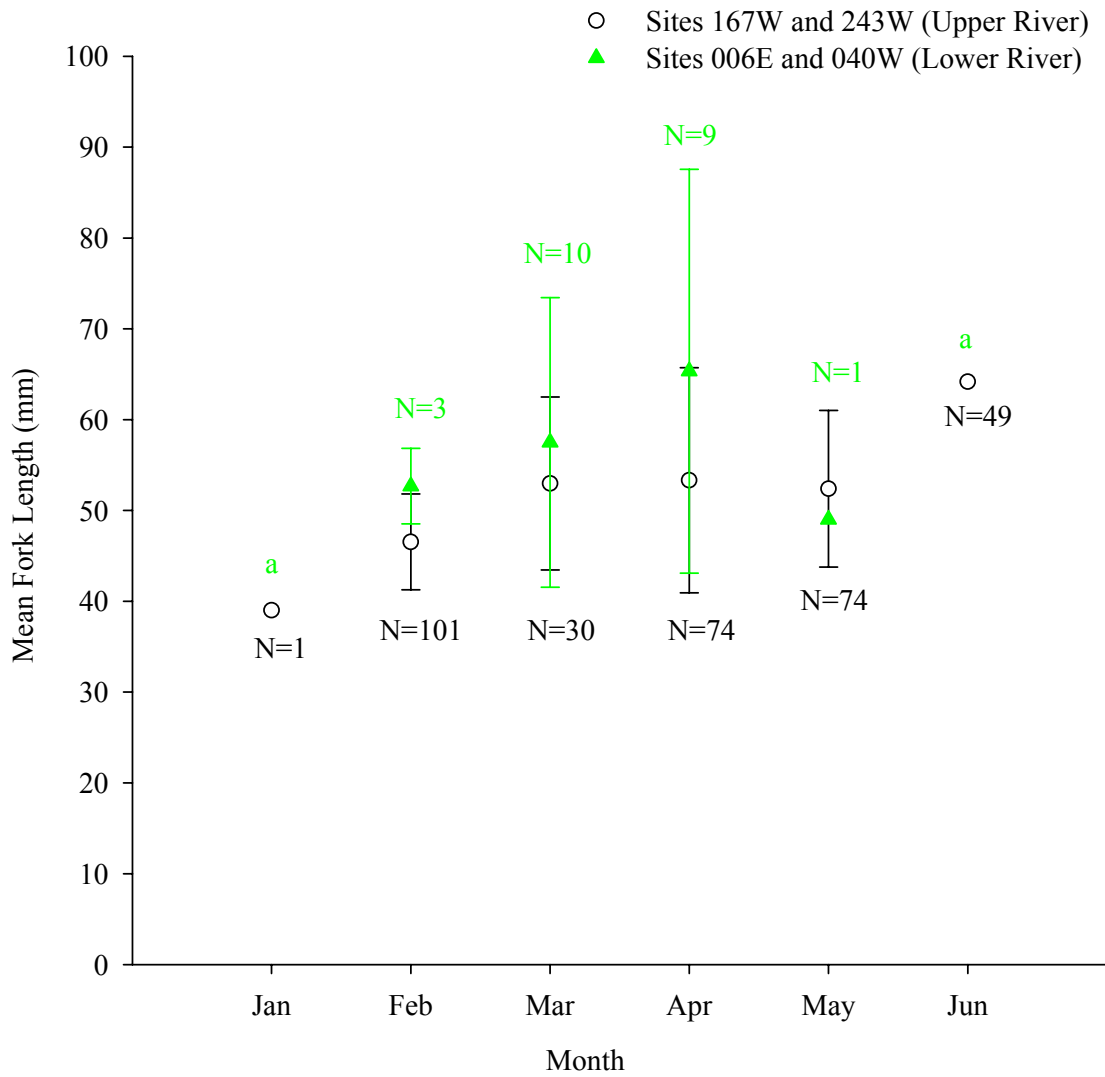


Figure 14. Mean fork length (mm) and standard deviations of unmarked sub-yearling chinook at upper and lower beach seining sites in the lower Willamette River, January 2001 through June 2001. a = No unmarked sub-yearly chinook captured at lower sites in January or June.

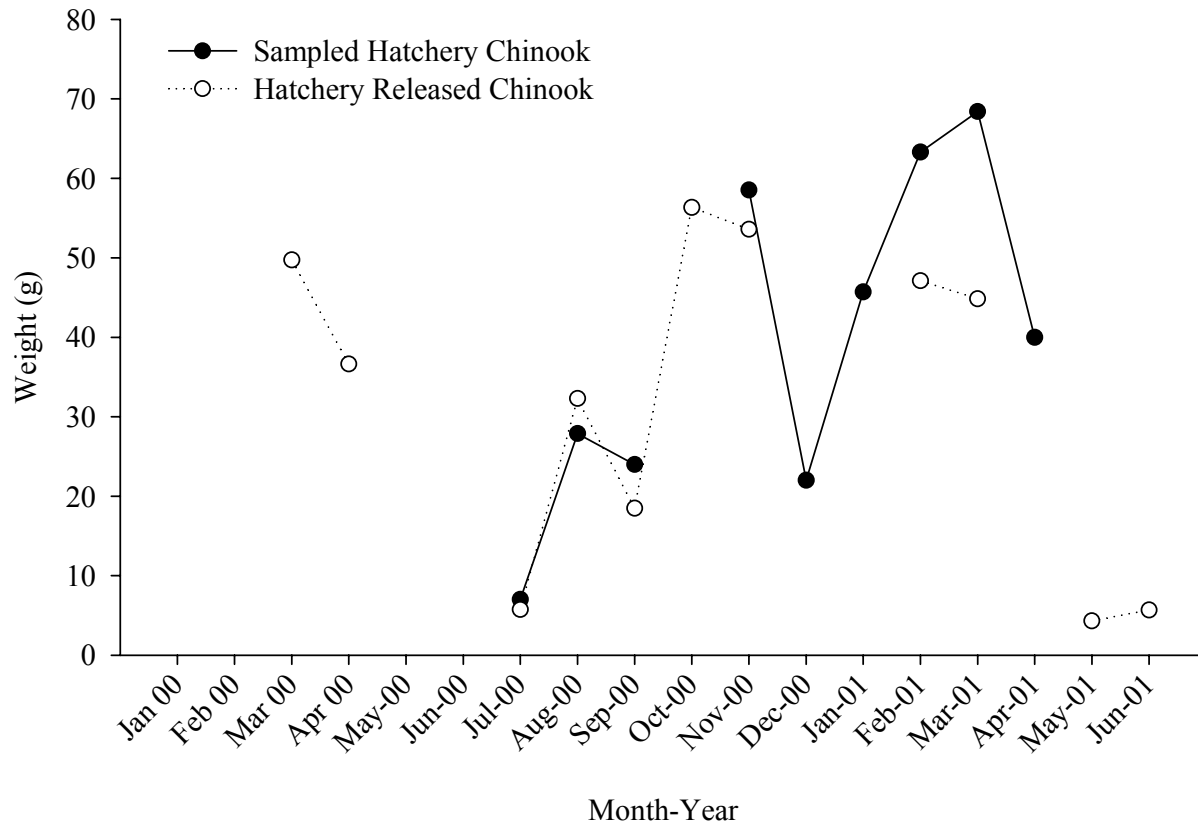


Figure 15. Mean weight (g) of hatchery juvenile chinook salmon captured by electrofishing and beach seining in the lower Willamette River and mean weight of juvenile chinook salmon at time of release into the Willamette River Basin, May 2000 through June 2001.

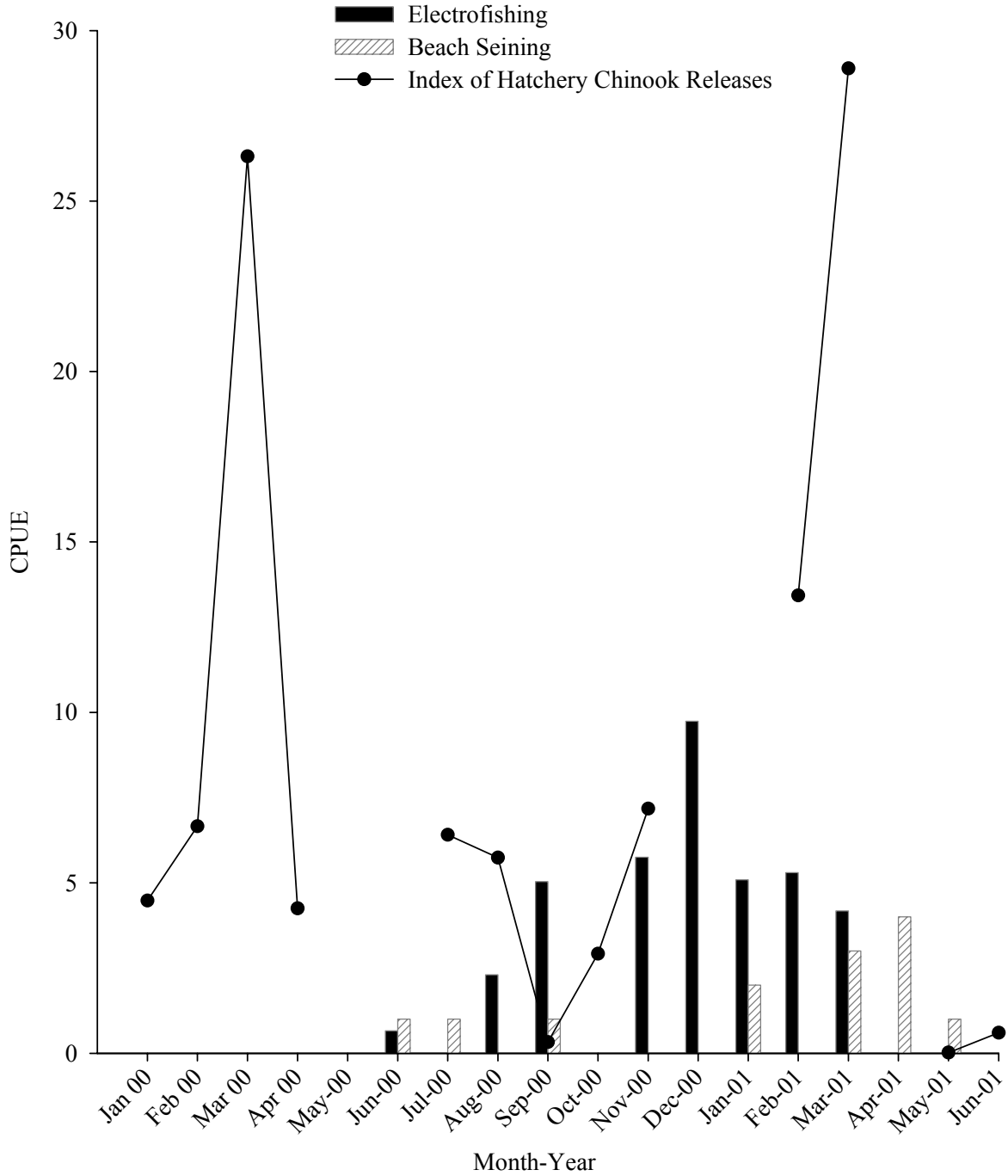


Figure 16. Electrofishing and beach seining catch-per-unit-effort (CPUE) of hatchery juvenile chinook salmon by month in the lower Willamette River compared to an index of hatchery releases for juvenile chinook salmon into the Willamette River Basin, May 2000 through June 2001.

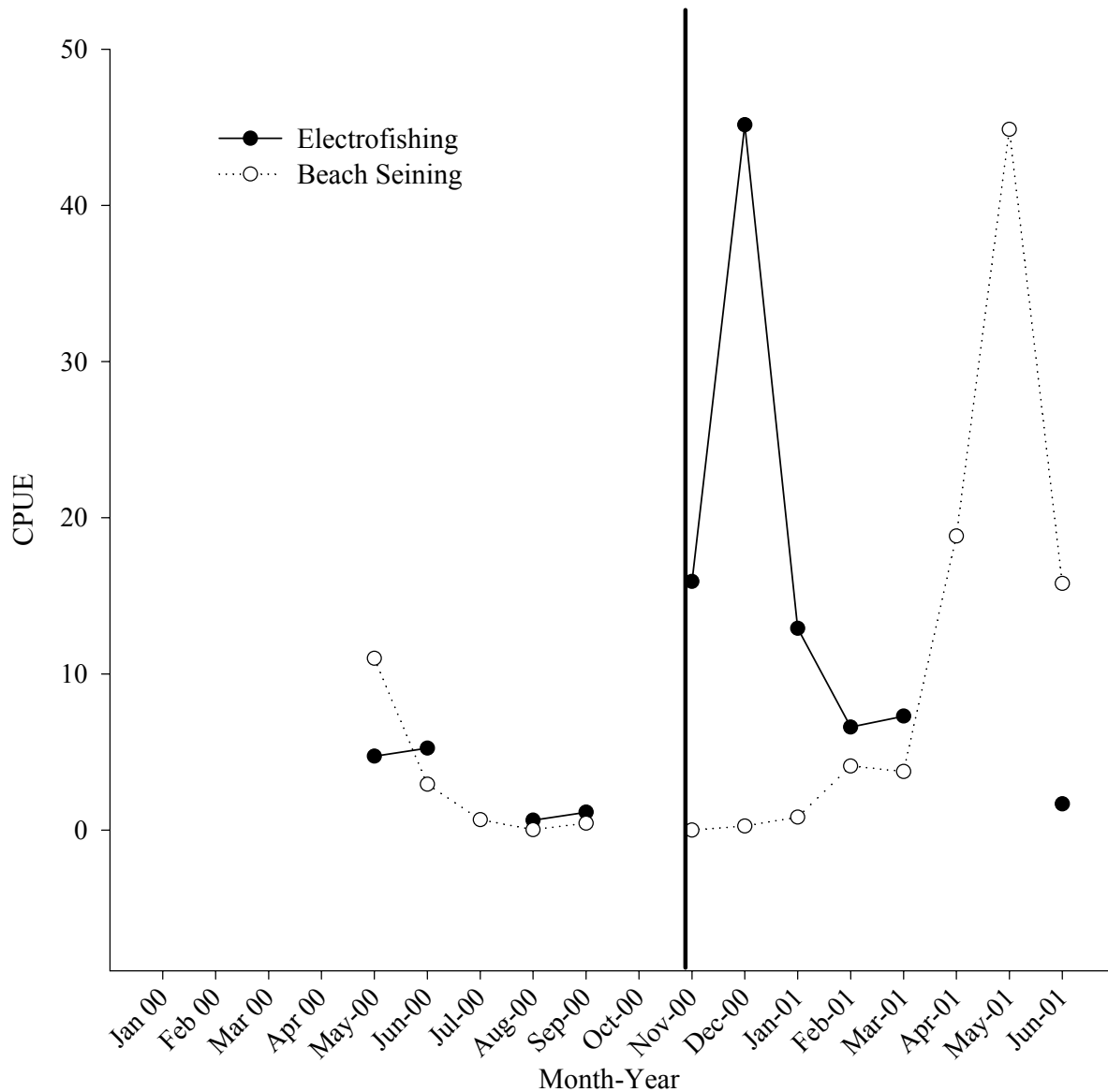


Figure 17. Electrofishing and beach seining catch-per-unit-effort (CPUE) of juvenile salmonids by month in the lower Willamette River, May 2000 through June 2001. Gaps in trend lines indicate non-sampling periods. Vertical line indicates change in electrofisher settings.

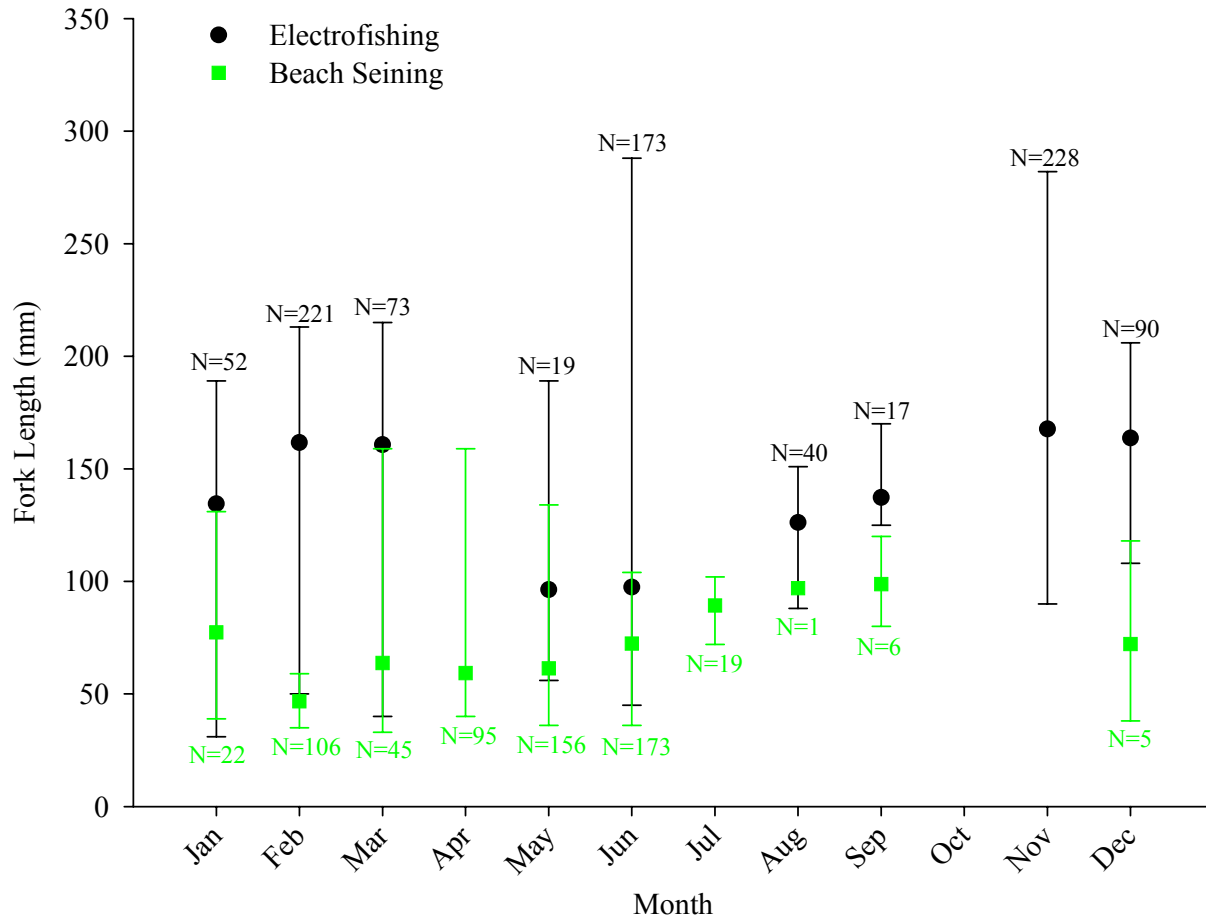


Figure 18. Mean, minimum, and maximum fork lengths (mm) by month of juvenile chinook salmon captured by electrofishing and beach seining in the lower Willamette River, May 2000 through June 2001. No sampling occurred in October.

CPUE increases with increasing fish size while beach seining CPUE responded oppositely (Figure 19).

Habitat Use

Mean electrofishing catch rates of salmonids varied widely among sampling sites (Table 20). The highest CPUE of chinook, steelhead, and unidentified salmonids occurred at sites 133W and 167W. Catch rates of all salmonids combined at these two sites were over 700% higher than any other site. Catch rates for coho were highest at sites 200E and 219W. Of the sampled catch, chinook salmon were most abundant (3.2 fish/effort) followed by coho salmon (0.6 fish/effort) and steelhead (0.3 fish/effort). Steelhead were not found at 32% of the sampling sites.

Mean CPUE of juvenile salmonids was 300% higher at sites with no riprap and no shoreline structures (Figure 20) than at other habitat types but results were not statistically significant ($P=0.0505$; Table 21). This same comparison at $\alpha=0.10$ resulted in a significant difference between habitat types lacking both riprap and nearshore structures and vertical walls. Catch rates of juvenile salmonids among bank habitat types were not significantly different ($P=0.1174$; Table 21) even though beach and rock sites produced noticeably more fish (Figure 21). We found no apparent difference in electrofishing CPUE of salmonids between site 079W, a piling site allowing light and 100W where light is limited (Figure 22). No meaningful correlations were identified between electrofishing CPUE of all salmonids or sub-yearling chinook salmon and 12 onshore and nearshore habitat parameters (Table 22).

Diel Differences

We compared catch rates and mean size of juvenile salmonids collected by day and night beach seining to determine if any or all of the salmonid species exhibit diel movements (Figure 23). The mean catch rate of all juvenile salmonids combined increased about 50% at night but results were not significant ($P=0.2750$, $F=1.23$); however, coho salmon alone did exhibit a significant relationship ($P<0.0001$; $F=30.02$). Mean length of the salmonid catch increased from 58 to 111 mm at night, but these results were not statistically significant ($P=0.1340$; $F=2.36$).

TASK 3.1: RESIDENT FISH RADIO TELEMETRY

Recovery and Movements of Tagged Fish

We tagged and released 30 northern pikeminnow, 11 smallmouth bass, and 4 walleye (Table 23). Average size ranged widely within species but all fish were large enough to be predaceous on juvenile salmonids. We conducted 58 d (11 nights) of tracking effort and recovered 29 (64%) of the 45 tagged fish for 118 relocations (Table 24). The average number of relocations per fish was 4.1 (range 0-12). Species-specific recovery rates were 100% for smallmouth bass, 57% for northern pikeminnow, and 20% for walleye.

Fish were relocated from 0.8 to 276 d following release. The average distance traveled between recoveries was least for smallmouth bass (1.3 km) and greatest for walleye (3.9 km). Approximately 80% of smallmouth bass and northern pikeminnow remained within 1 mile (1.6

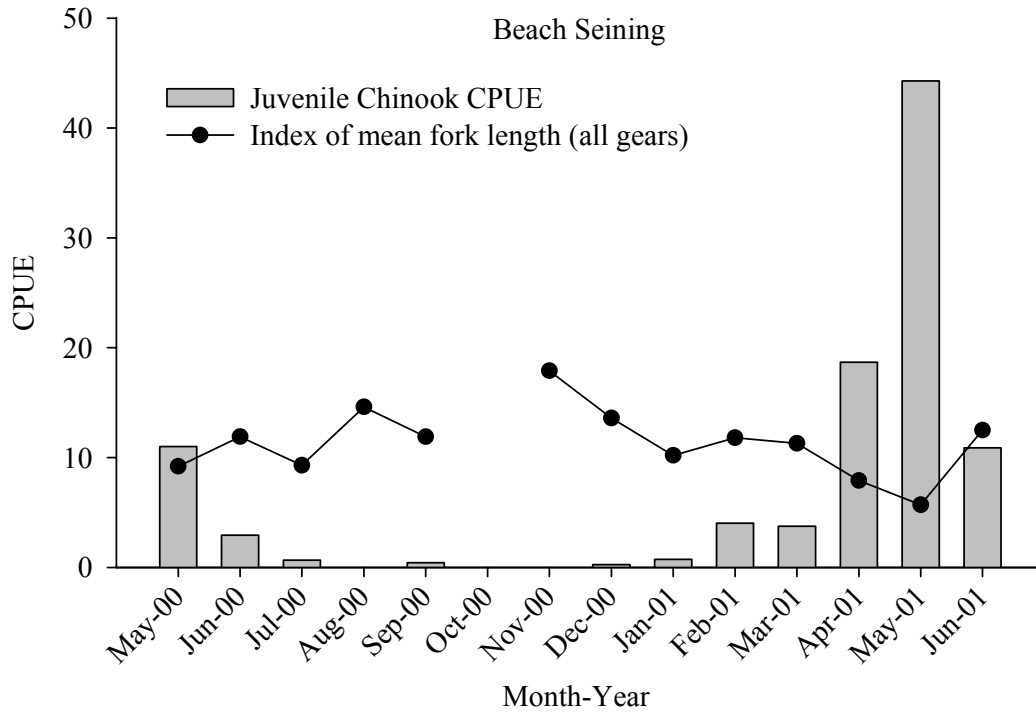
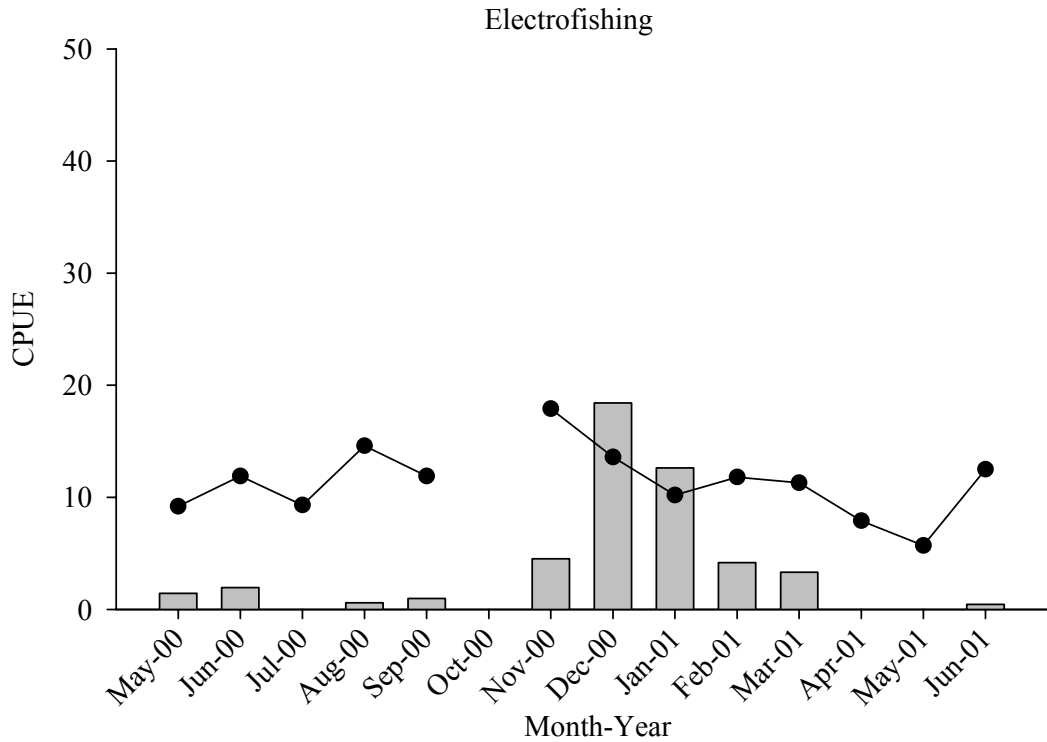


Figure 19. Catch-per-unit-effort (CPUE) of juvenile chinook salmon captured by electrofishing and beach seining in the lower Willamette River compared to an index of mean fork length of all juvenile chinook, May 2000 through June 2001. Gaps in trend lines indicate non-sampling periods.

Table 20. Mean standardized electrofishing catch rate of juvenile salmonids at sampling sites in the lower Willamette River, May 2000 through June 2001.

Site	Effort	Chinook	Coho	Steelhead	Salmon unidentified	All
Standard sites						
006E		1.62	0.23	0.00	1.20	3.04
010E		1.76	0.48	0.00	0.88	3.12
012W		0.84	0.00	0.00	1.05	1.89
031W		0.52	0.14	0.08	1.01	1.75
048E		0.96	0.27	0.00	0.10	1.32
051E		1.67	0.25	0.10	0.52	2.55
064W		1.00	0.45	0.14	0.73	2.32
079W		2.33	0.45	0.00	0.99	3.77
100W		4.49	0.37	0.00	0.75	5.61
112E		5.27	1.09	0.10	0.81	7.27
118W		2.62	1.09	0.11	1.08	4.90
121W		1.05	0.51	0.35	0.41	2.33
133W		13.32	0.00	0.59	41.07	54.98
136E		2.23	0.29	0.18	0.60	3.30
148E		4.24	0.13	0.22	1.36	5.95
167W		21.33	0.04	3.49	30.21	55.07
200E		1.35	3.46	0.14	0.69	5.65
203W		2.20	0.14	0.28	0.18	2.79
219W		2.36	2.59	0.34	2.20	7.49
		3.20	0.63	0.30	3.44	7.58
Alcoves and Refugia						
067EA		0.75	0.00	0.00	3.00	3.75
076WA		0.00	0.00	0.00	1.26	1.26
107WA		0.00	0.00	0.00	0.00	0.00
148WA		0.00	0.00	0.00	0.00	0.00
232WA		0.83	0.00	0.00	0.00	0.83
239EA		3.32	0.00	0.00	0.00	3.32

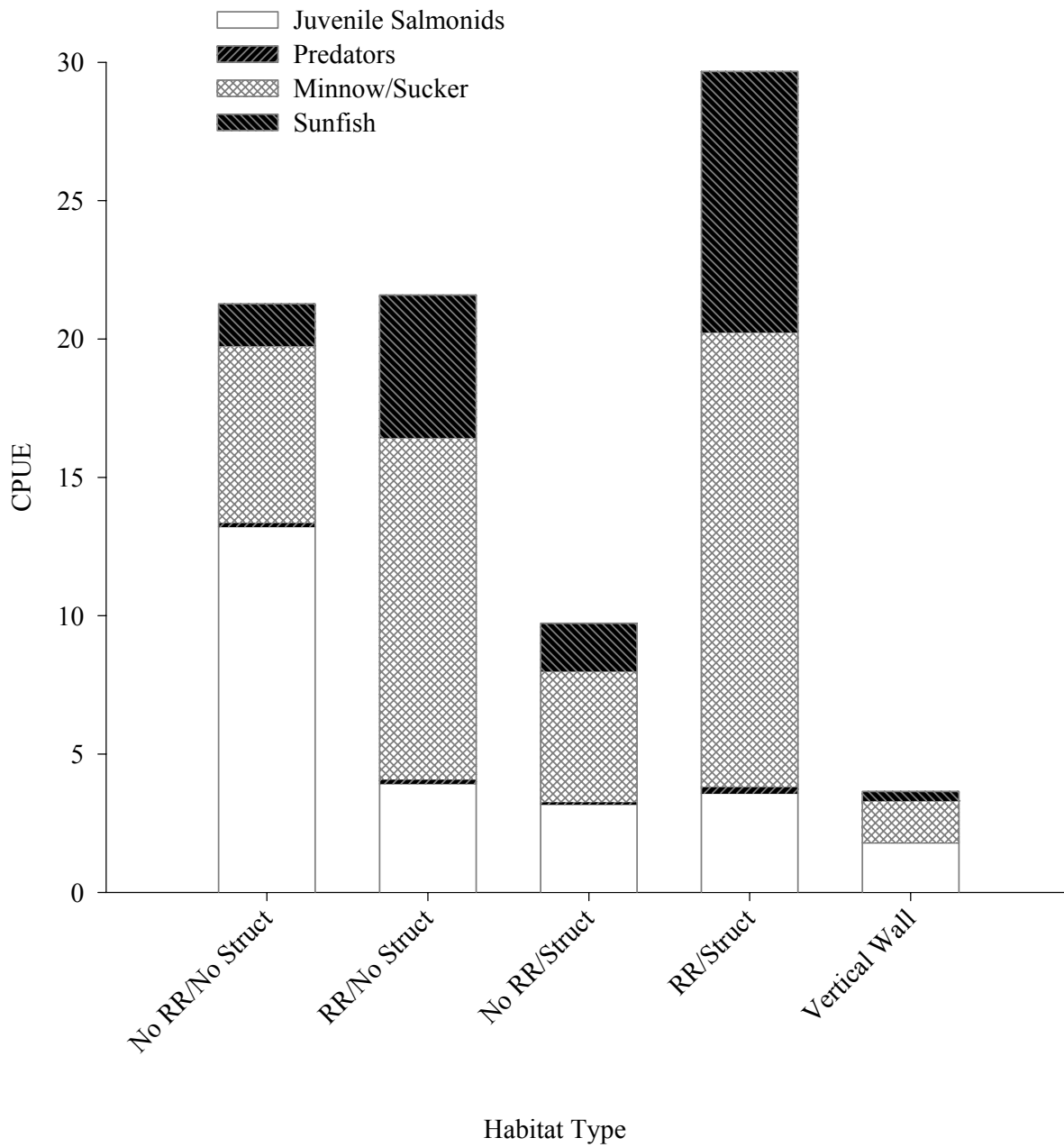


Figure 20. Electrofishing catch-per-unit-effort (CPUE) of juvenile salmonids, potential predator fishes, and other resident family groups by habitat type in the lower Willamette River, May 2000 through June 2001.

Table 21. Probability (P) and significance of mean electrofishing catch-per-unit-effort (CPUE) and habitat categories at sampling sites in the lower Willamette River, May 2000 through June 2001. Variables without a letter in common are significantly different at the indicated level.

Independent Variable	CPUE (Dependent variable)							
	All Juvenile Salmonids		Predator Fishes		Minnow/Sucker		Sunfish	
	$\alpha=0.05$	$\alpha=0.10$	$\alpha=0.05$	$\alpha=0.10$	$\alpha=0.05$	$\alpha=0.10$	$\alpha=0.05$	$\alpha=0.10$
Habitat Type	$P=0.0505$		$P=0.1025$		$P=0.4233$		$P=0.6301$	
No Riprap/No Structure	a	a	a	ab	a	a	a	a
Riprap/No Structure	a	ab	a	ab	a	a	a	a
No Riprap/Structure	a	ab	a	ab	a	a	a	a
Riprap/Structure	a	ab	a	a	a	a	a	a
Vertical Wall	a	b	a	b	a	a	a	a
Bank Treatment Type	$P=0.1174$		$P=0.0254$		$P=0.6170$		$P=0.2015$	
Beach + Rock	a	a	ab	abc	a	a	a	a
Rock Outcrop	a	a	a	a	a	a	a	a
Riprap (all)	a	a	ab	ab	a	a	a	a
Seawall	a	a	b	c	a	a	a	a
Unclassified Fill	a	a	ab	abc	a	a	a	a

Table 22. Correlations (r^2) between electrofishing catch-per-unit-effort (CPUE) and nearshore habitat parameters at 19 sampling sites in the lower Willamette River, May 2000 through June 2001. For all correlations, $P \leq 0.05$.

Habitat Parameter	CPUE				
	All Juvenile Salmonids	Wild Sub-yearling Chinook	Predator Fishes	Minnow/Sucker	Sunfish
Depth	0.01	0.18	0.02	0.03	0.16
Overhead cover	0.02	0.00	0.02	0.01	0.00
Distance to nearest impervious surface	0.00	0.04	0.24	0.01	0.02
Number of pilings	0.06	0.02	0.05	0.03	0.02
October vegetation index	0.04 ^a	0.01 ^a	0.01 ^a	0.03 ^a	^b
Transparency	0.04	0.09	0.04	0.04	0.02
Water temperature	0.11 ^a	0.01 ^a	0.04 ^a	0.09 ^a	^b
Dissolved oxygen	0.06 ^a	0.06 ^a	0.05 ^a	0.05 ^a	^b
Conductivity	0.05 ^a	0.03 ^a	0.03 ^a	0.05 ^a	^b
Bank slope	0.06	0.01	0.06	0.05	0.06
Shoreline substrate type					
Sand/Gravel	0.06	0.00	0.05	0.08	0.12
Natural rock	^c	^c	^c	^c	^c
Boulders	^c	^c	^c	^c	^c
Bedrock	^c	^c	^c	^c	^c
All riprap	0.02	0.04	0.14	0.01	0.00
Artificial fill	^c	^c	^c	^c	^c
Vertical wall	^c	^c	^c	^c	^c
Percent natural substrate	0.09	0.02	0.04	0.05	0.01

^a CPUE data from August-November, 2000.

^b No sunfish captured in August-November, 2000.

^c Insufficient spread in habitat data among transects to conduct a meaningful regression analysis.

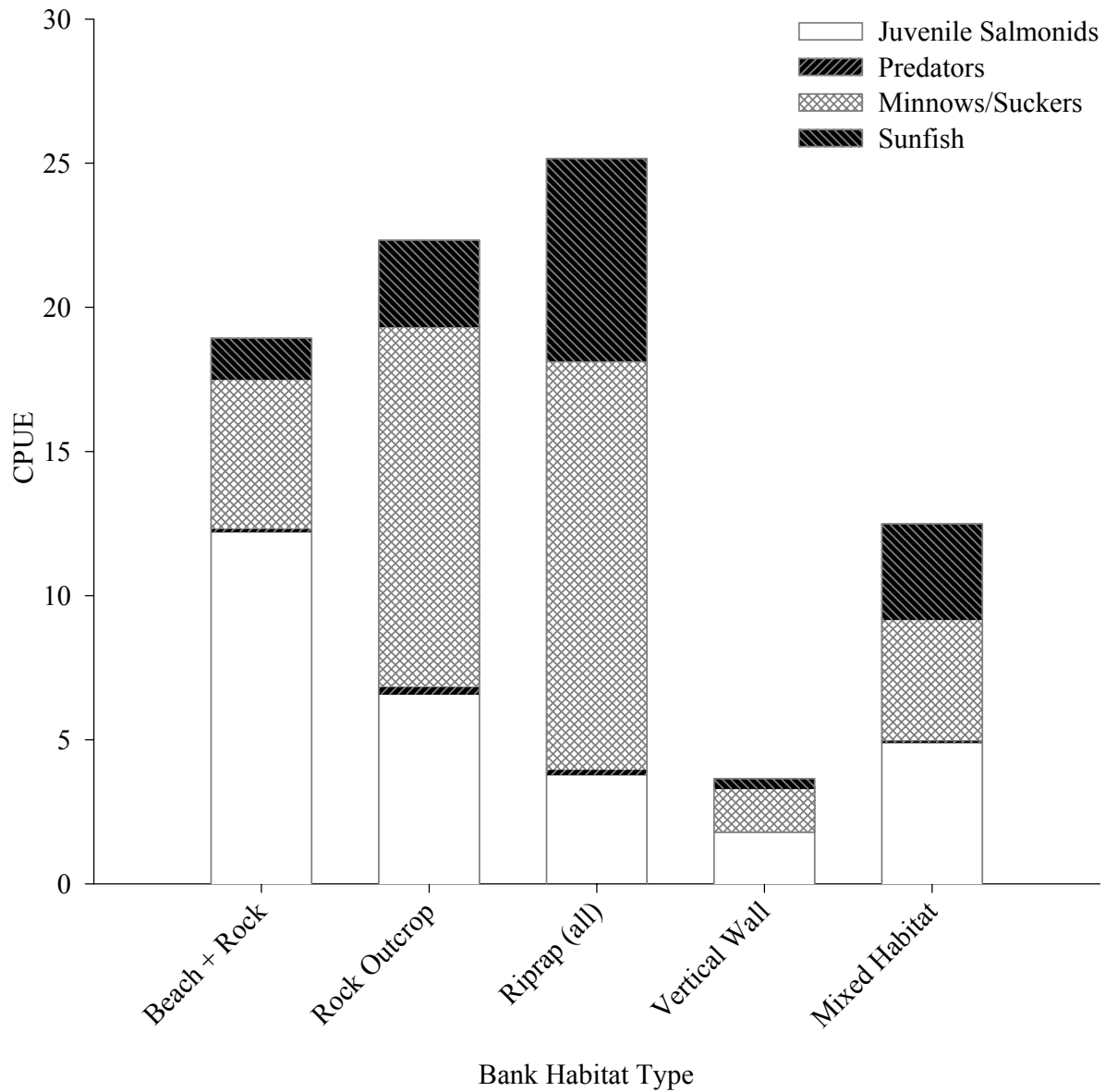


Figure 21. Electrofishing catch-per-unit-effort (CPUE) of juvenile salmonids, potential predator fishes, and other resident family groups by bank habitat type in the lower Willamette River, May 2000 through June 2001.

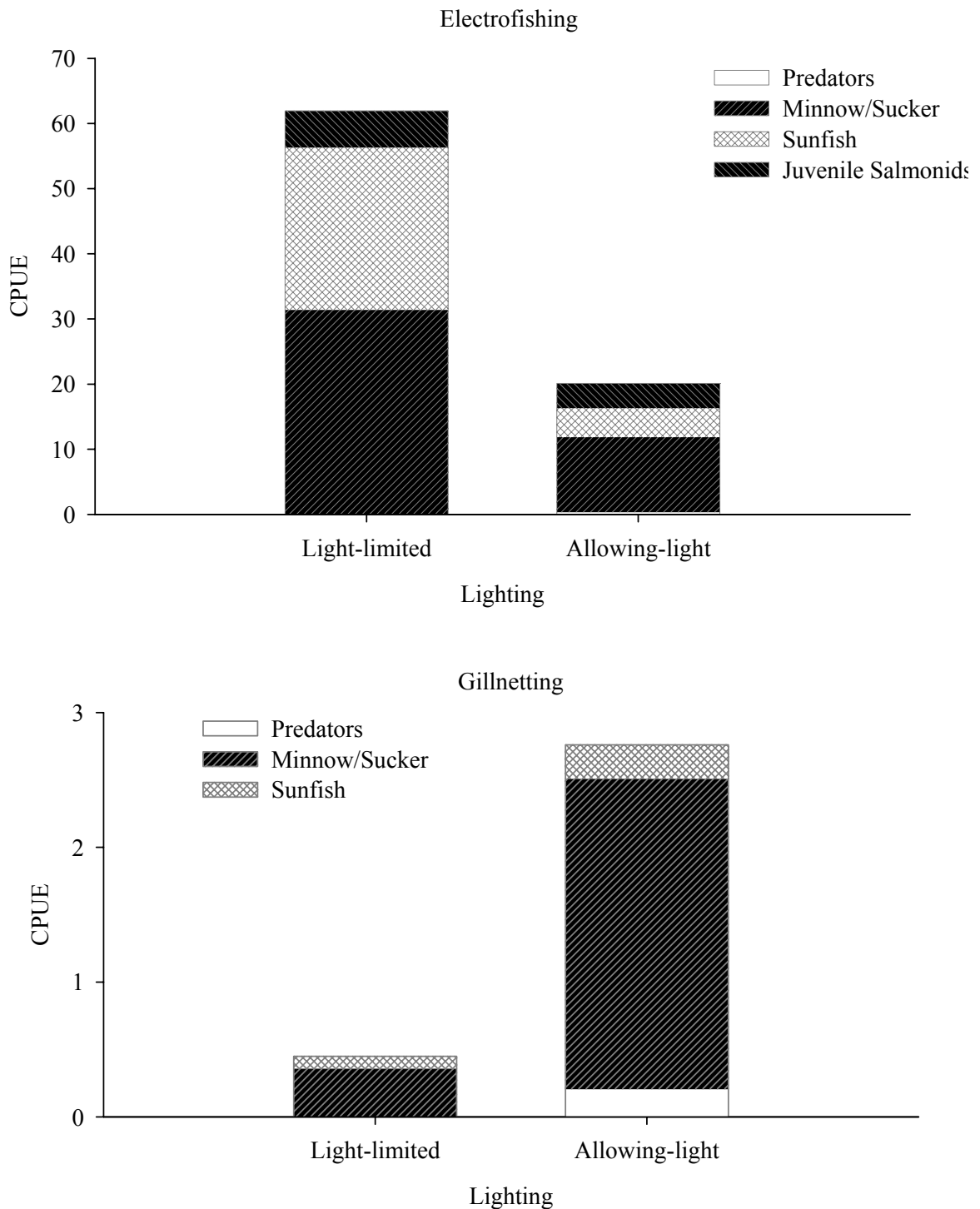


Figure 22. Electrofishing and gillnetting catch-per-unit-effort (CPUE) of juvenile salmonids, potential predator fishes, and other resident family groups by nearshore piling-structure type in the lower Willamette River, May 2000 through June 2001. Data for light-limited from site 100W; data for allowing light from 179W.

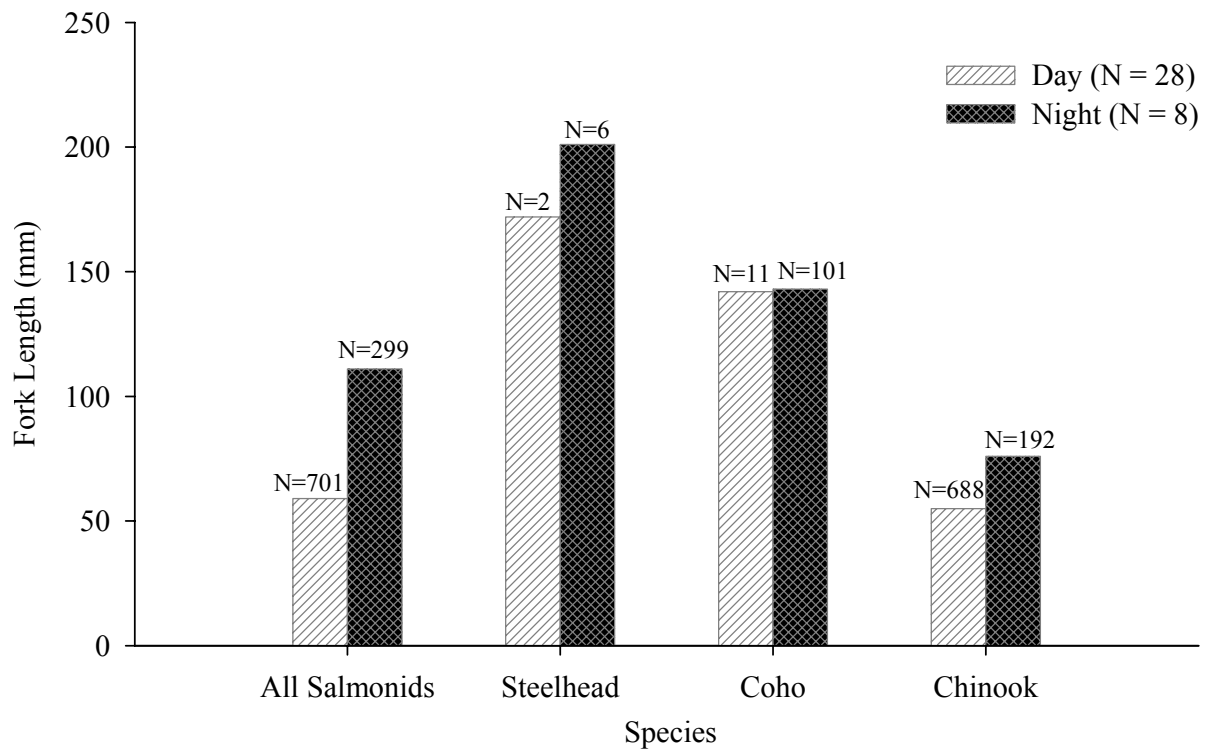
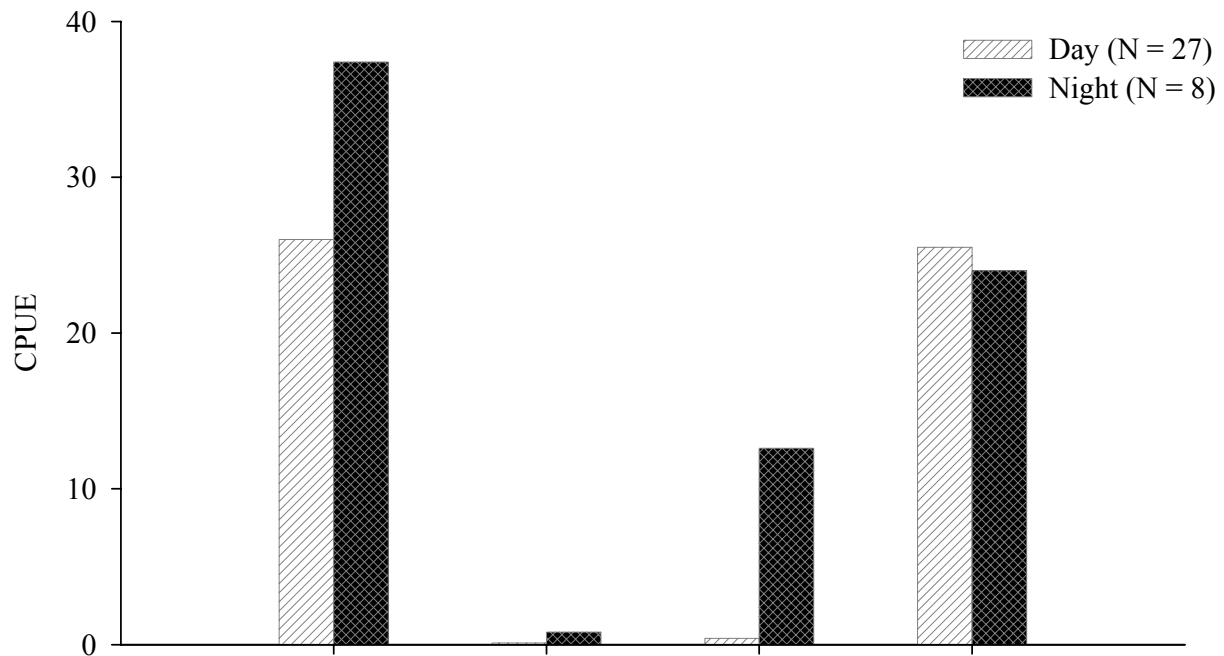


Figure 23. Catch-per-unit-effort (CPUE) and mean fork length (mm) of juvenile salmonids captured by day and night beach seining in the lower Willamette River, May 2000 through June 2001.

Table 23. Lengths and weights of 45 resident fish fitted with radio transmitters in the lower Willamette River, May 2000 through June 2001.

Species	N	Fork length (mm)		Weight (g)	
		Mean	Range	Mean	Range
NPM	30	397	253-492	852	340-1,650
SMB	11	364	298-398	747	440-1,040
WAL	4	361	328-396	548	405-750

^a NPM=Northern pikeminnow; SMB=Smallmouth bass; WAL=Walleye

Table 24. Summary of movements by radio-tagged resident fish in the lower Willamette River, May 2000 through June 2001.

Species ^a	Days-at-large			Distance moved (km)		
	N (fish)	N (recoveries)	Mean	Minimum	Maximum	Mean
NPM	17	39	38.0	1	193	21.6
SMB	11	74	21.7	0.8	276	10.8
WAL	1	5	40.6	4	122	9.7

^a NPM=Northern pikeminnow; SMB=Smallmouth bass; WAL=Walleye

km) of the release site, but smallmouth bass were the most sedentary predator. Over 65% of recoveries for this species occurred within 0.2 km of the release site (Figure 24). The largest confirmed movement was 21.6 km by a northern pikeminnow. The only walleye recovered was relocated 5 times prior to entering the Columbia River 203 d after release. Time-series movements of smallmouth bass and northern pikeminnow are provided in Figures 25 and 26.

Habitat Association

Relocations of radio-tagged northern pikeminnow and smallmouth bass indicate these fish utilize offshore habitat but are most likely to be found nearshore (Figure 27). Walleye were recovered infrequently and only offshore. Percentages of relocations in the nearshore zone (within 10% of either shore) of the entire study area were 42% for northern pikeminnow, 53% for smallmouth bass, and 0% for walleye. Nearshore relocations of northern pikeminnow were more frequent during the day (47%) than at night (27%). Smallmouth bass were equally likely to be relocated near shore regardless of time of day (53%) (Figures 28 and 29).

Frequencies of tagged-fish relocations in the nearshore zone adjacent to available bank habitat types differed somewhat from the percentages of bank type available (Figure 30). The greatest discrepancy occurred at piling structures allowing light where northern pikeminnow and smallmouth bass were recovered at rates three and six times expected. Overall, 40% of all tagged predator relocations occurred near or under structures that represented 19% of the combined bank and nearshore structure habitat area.

TASK 3.2: STANDARDIZED SAMPLING FOR RESIDENT FISH

Catch and Effort

We caught 2,786 minnows and suckers, 1,001 sunfish, and 64 predators in 397 electrofishing runs at 19 sites. We set 377 nearshore and 97 mid-shore gillnets and caught 983 minnows and suckers, 63 sunfish, and 119 predators. An additional 732 suckers and minnows and 156 sunfish were collected incidentally while beach seining for juvenile salmonids. Distribution of sampling effort varied from 13 to 41 gillnet sets and 10 to 25 electrofishing runs per site (Table 16). No sampling was conducted with gillnets in April or July, and electrofishing was not conducted in April, July, or October (Table 17). We collected 33 fish species from 14 families with all gears combined. Eighteen species from nine families were native to the Willamette Basin (Table 18).

Seasonal Catch Rates and Abundance

Resident fish were captured with both gears during all months sampled, with few trends apparent (Figure 31). Minnows and suckers predominated the catch of both gear types. Electrofishing CPUE for minnows, suckers, and sunfish was generally several fold higher for electrofishing than for gillnetting, but more predators were caught with gill nets. Overall, more resident fish, and especially sunfish, were caught during spring and summer months. Predator fish were not abundant during any season. The frequency of predator species at sampling sites was 95% for northern pikeminnow, 53% for smallmouth bass, 37% for walleye, and 10% for largemouth bass (Tables 25 and 26).

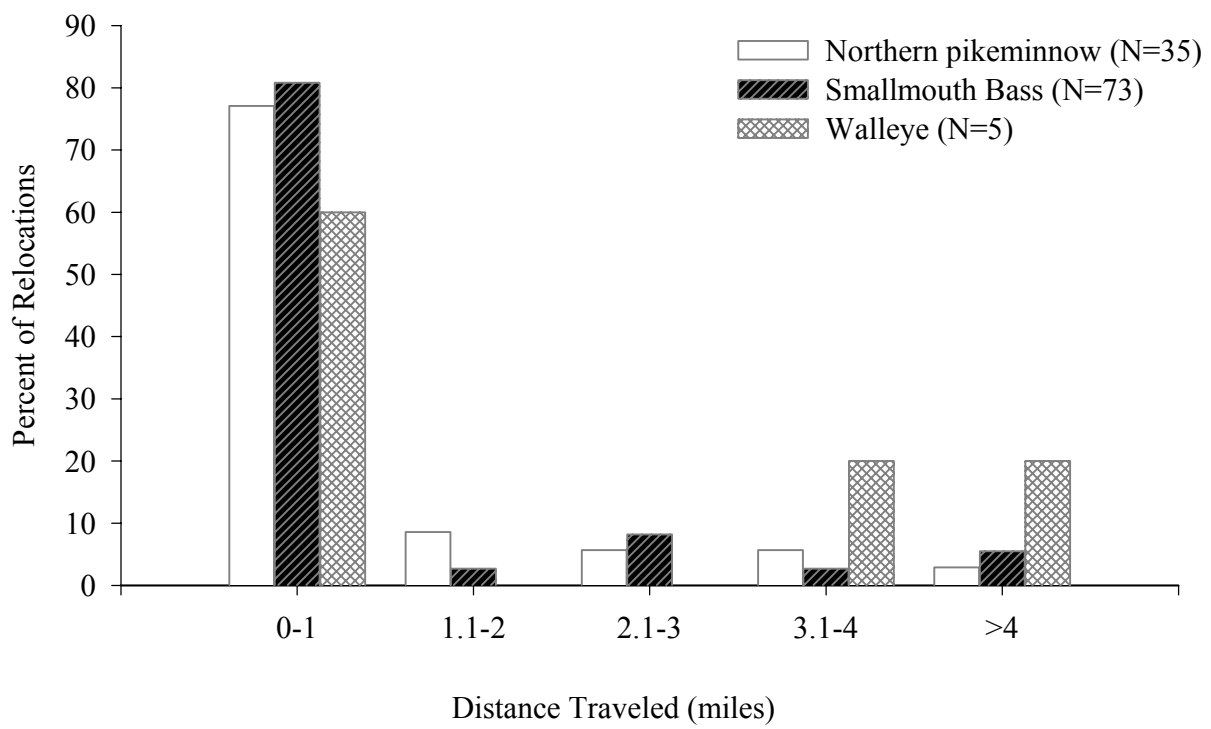


Figure 24. Frequency of movements of radio-tagged predator species from capture sites in the lower Willamette River, May 2000 through June 2001.

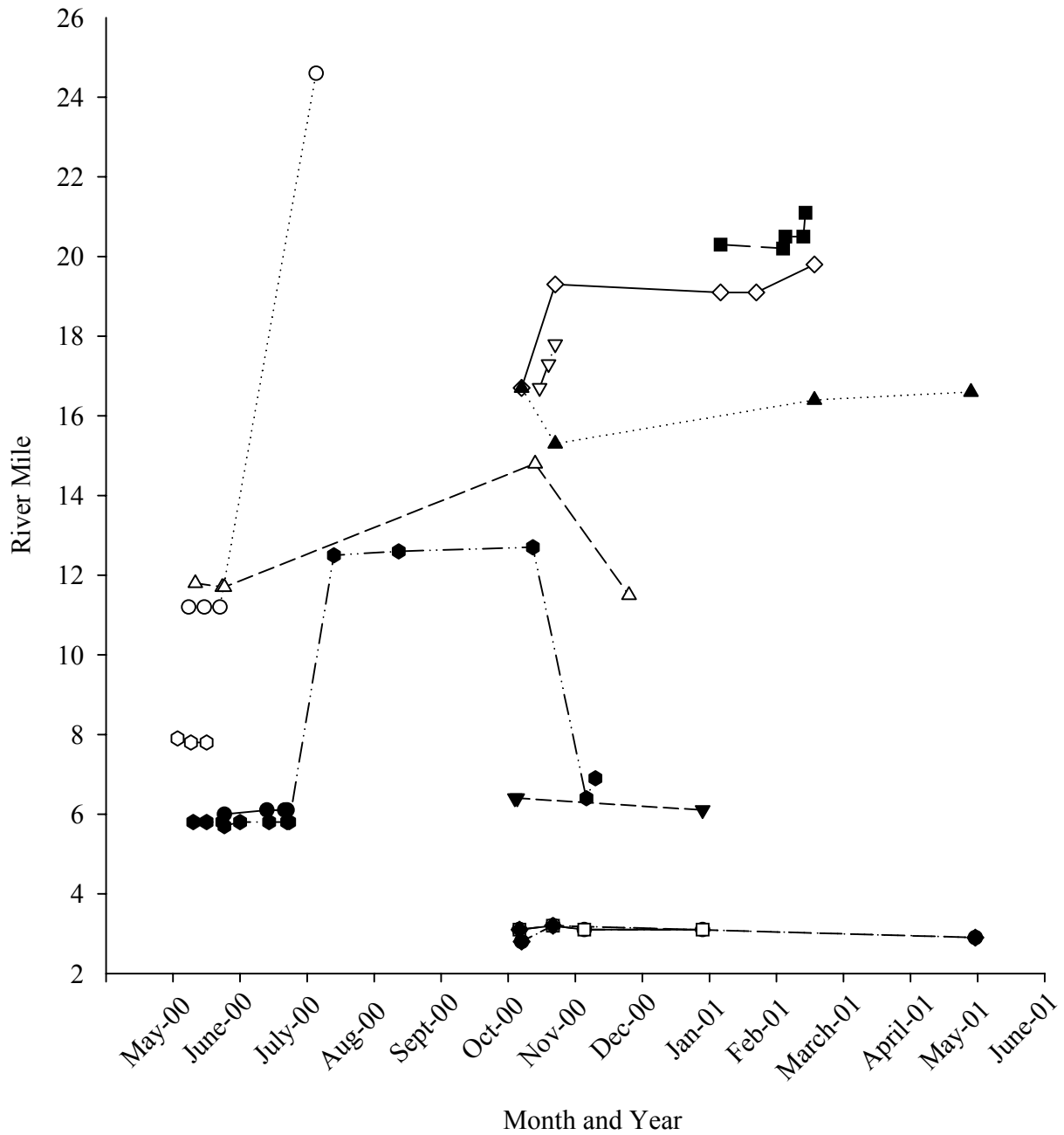


Figure 25. Movements of individual radio-tagged northern pikeminnow in the lower Willamette River, May 2000 through June 2001. Includes data for fish with three or more relocations.

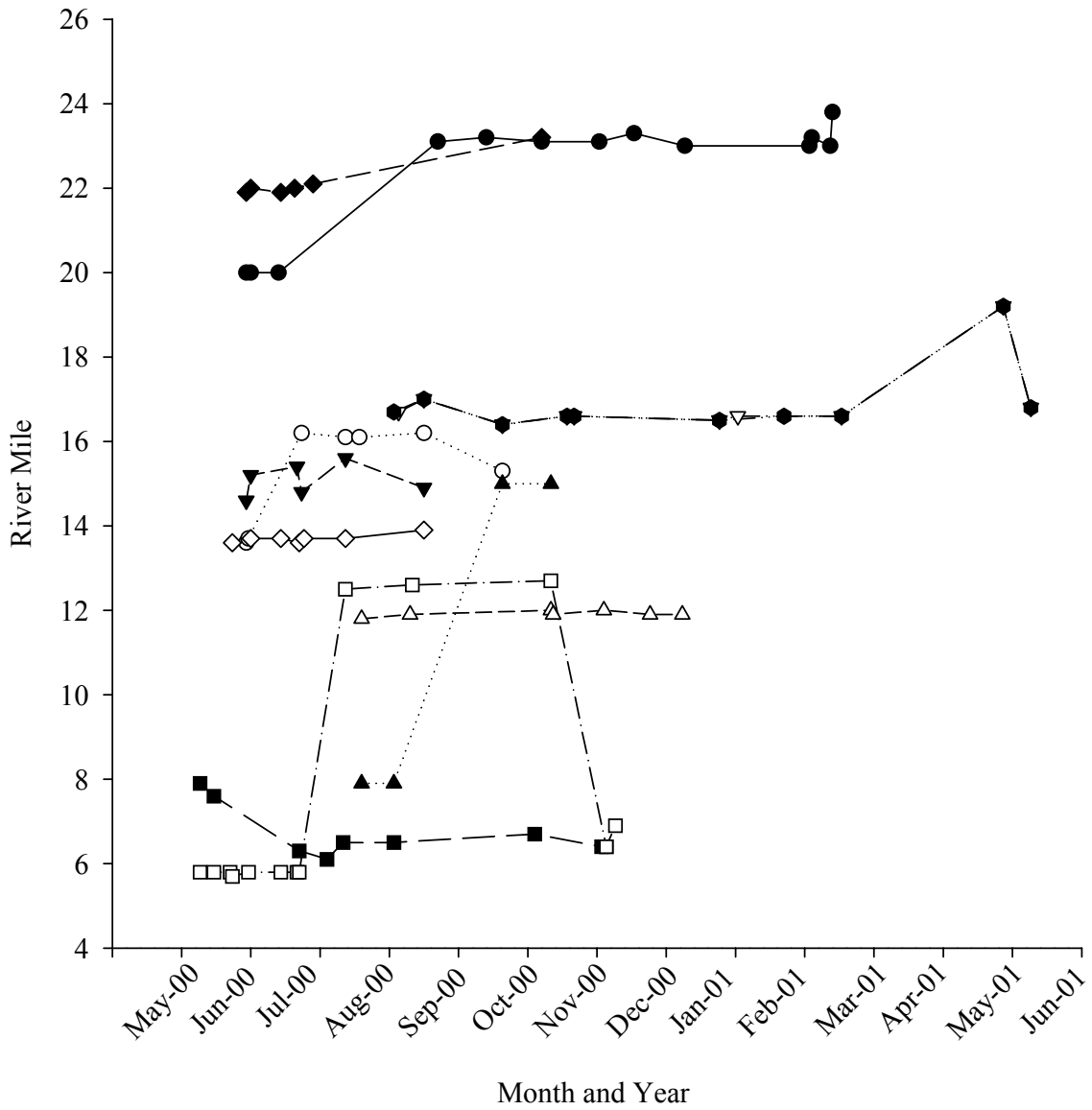


Figure 26. Movements of individual radio-tagged smallmouth bass in the lower Willamette River, May 2000 through June 2001. Includes data for fish with three or more relocations.

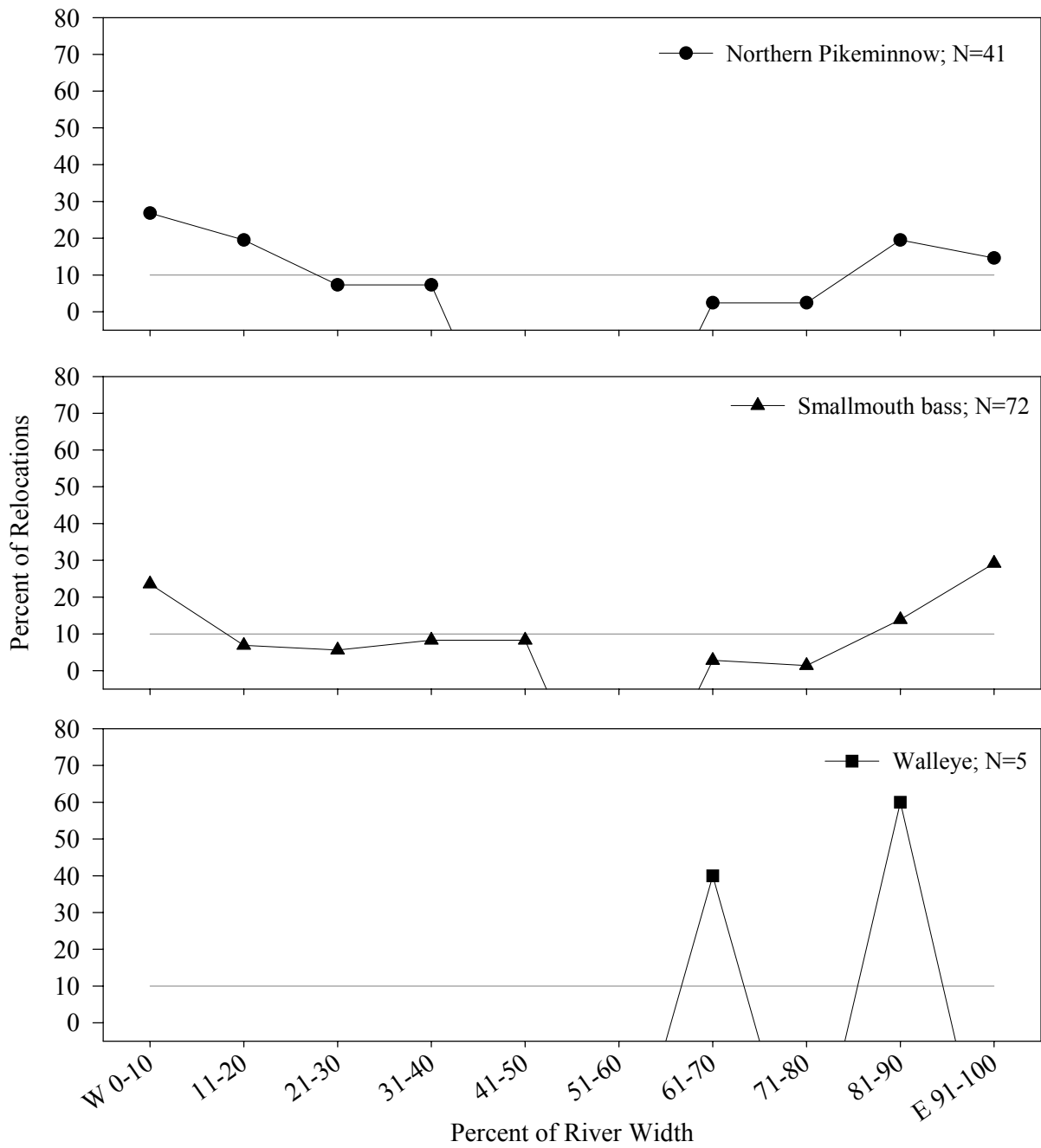


Figure 27. Frequency of relocations of radio-tagged predator species by percent of river width in the lower Willamette River, May 2000 through June 2001. West bank of river = 0%, East bank of river = 100%.

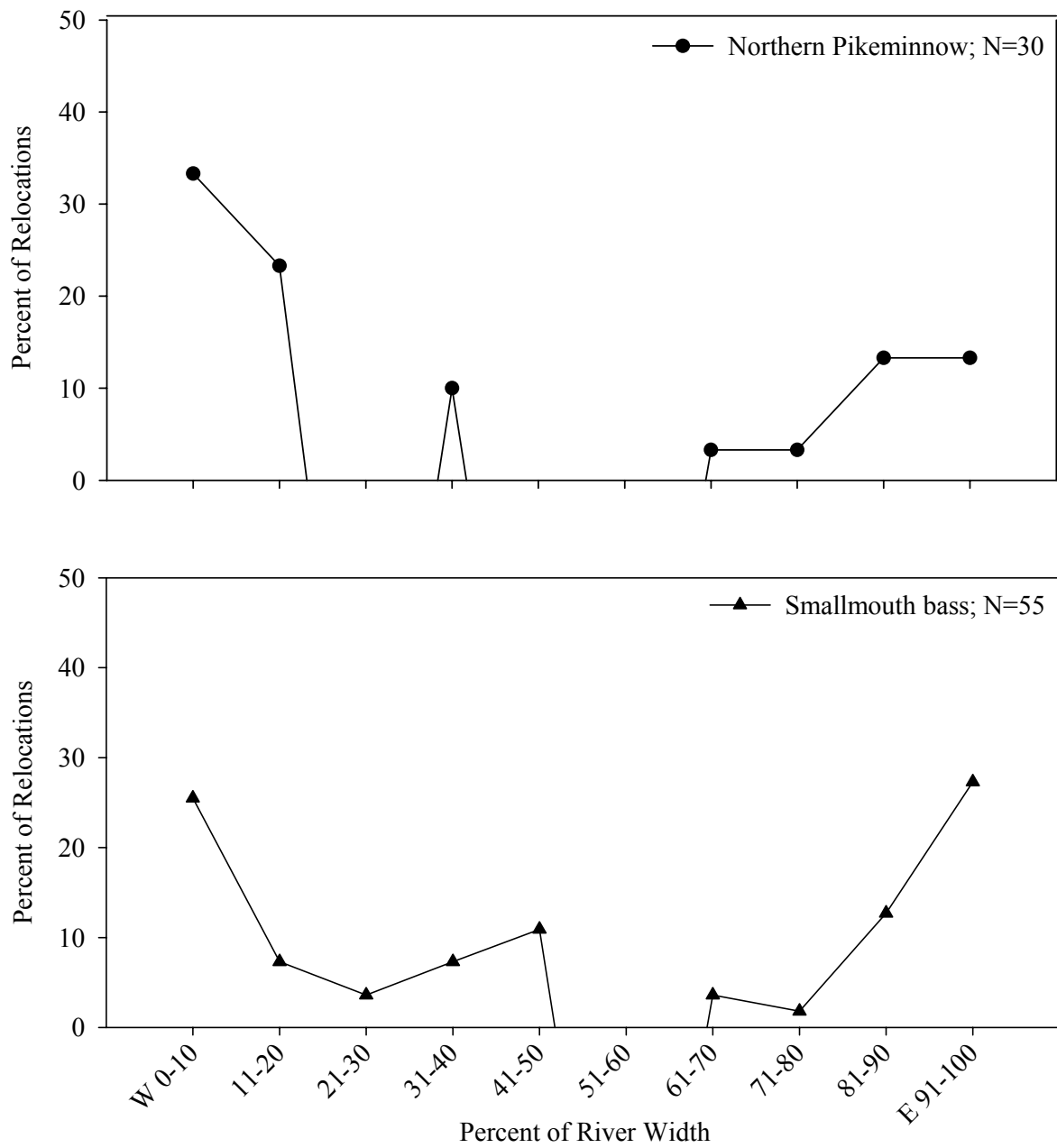


Figure 28. Frequency of daytime relocations of radio-tagged predator species by percent of river width in the lower Willamette River, May 2000 through June 2001. West bank of river = 0%, East bank= 100%

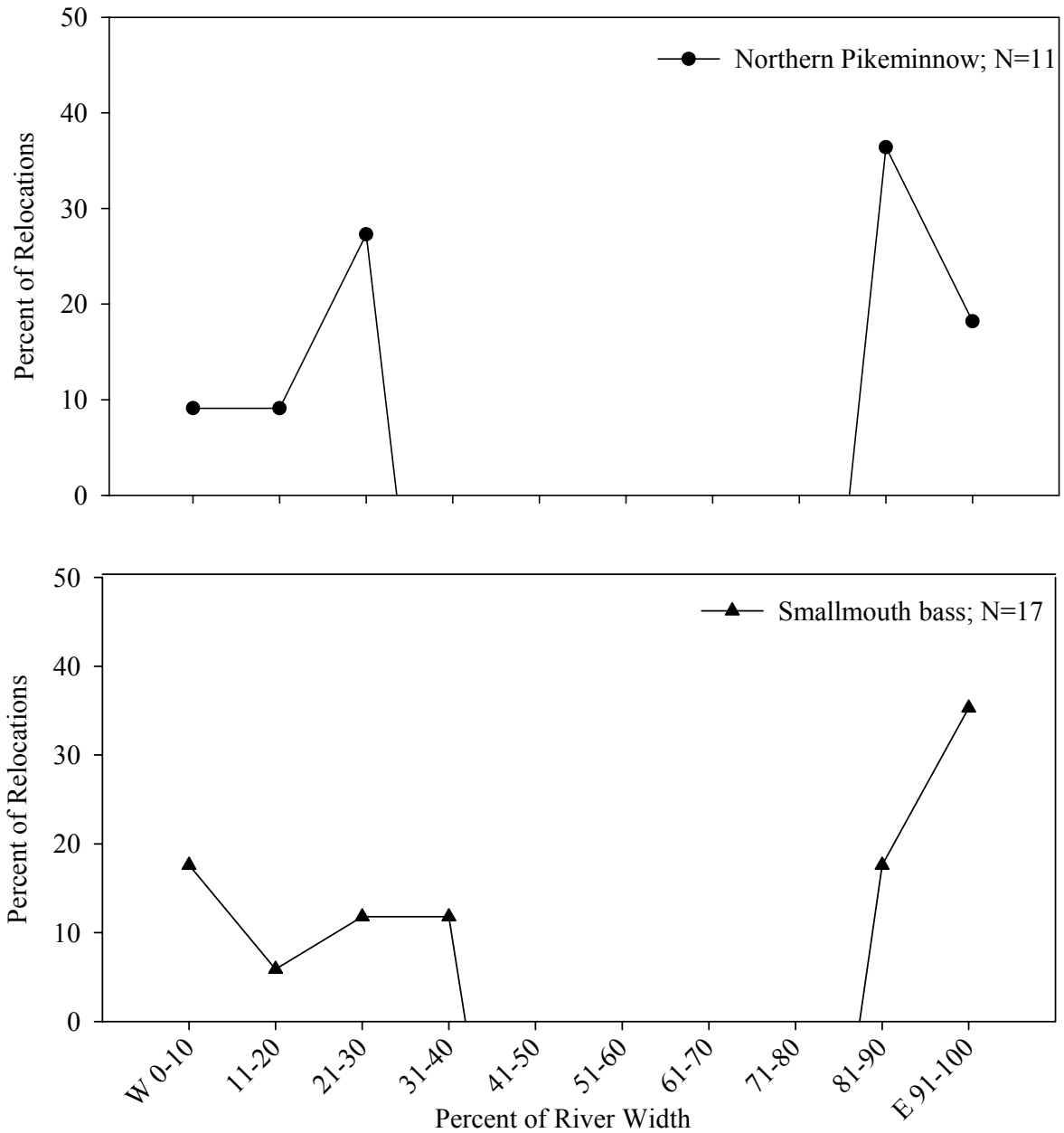


Figure 29. Frequency of nighttime relocations of radio-tagged predator species by percent of river width in the lower Willamette River, May 2000 through June 2001. West bank of river = 0%, East bank = 100%.

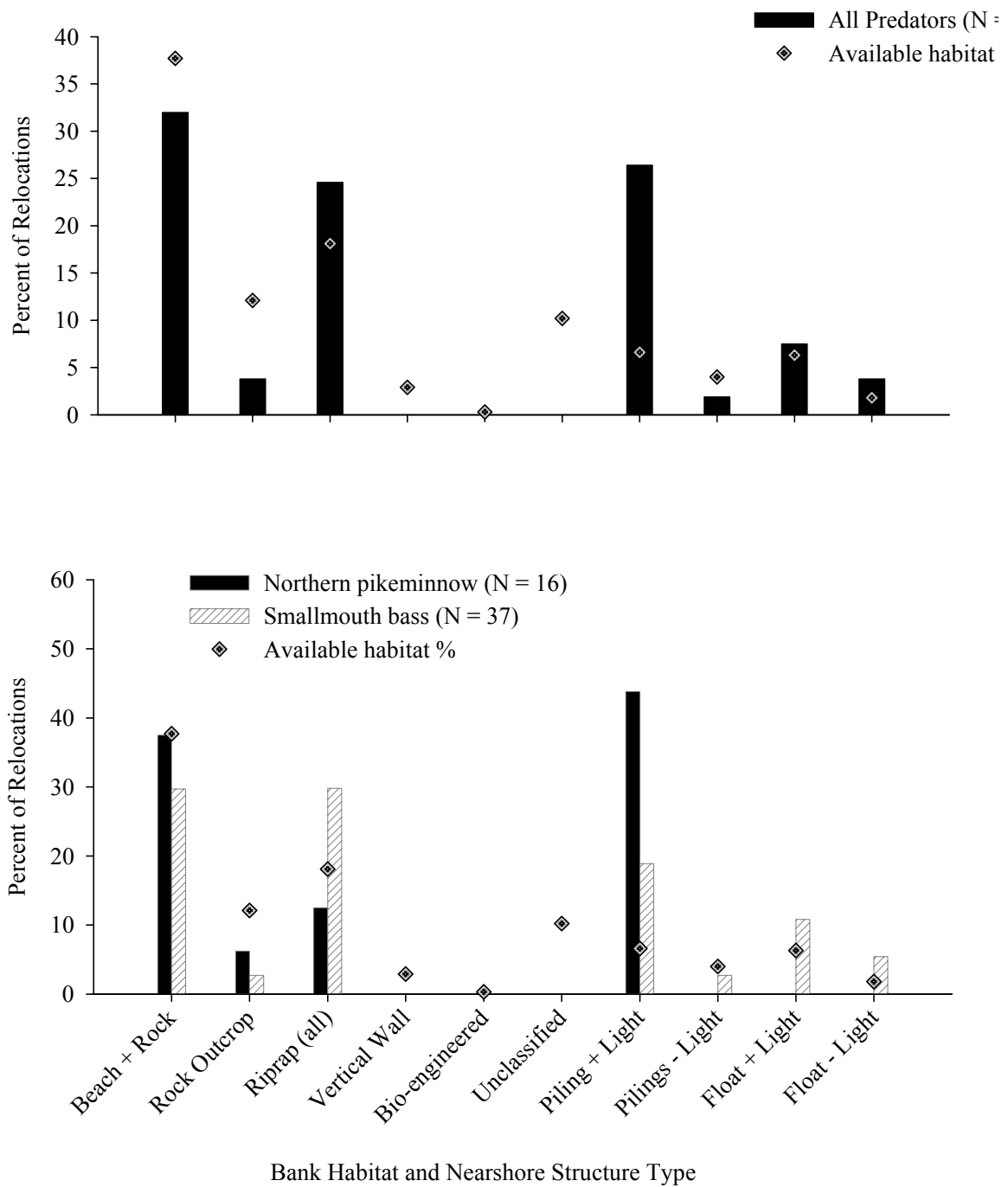


Figure 30. Frequency of relocations of radio-tagged predator fishes by bank habitat and nearshore structure type in the lower Willamette River, May 2000 through June 2001. Data limited to fishes relocated in the nearshore zone equivalent to 10% of the river width.

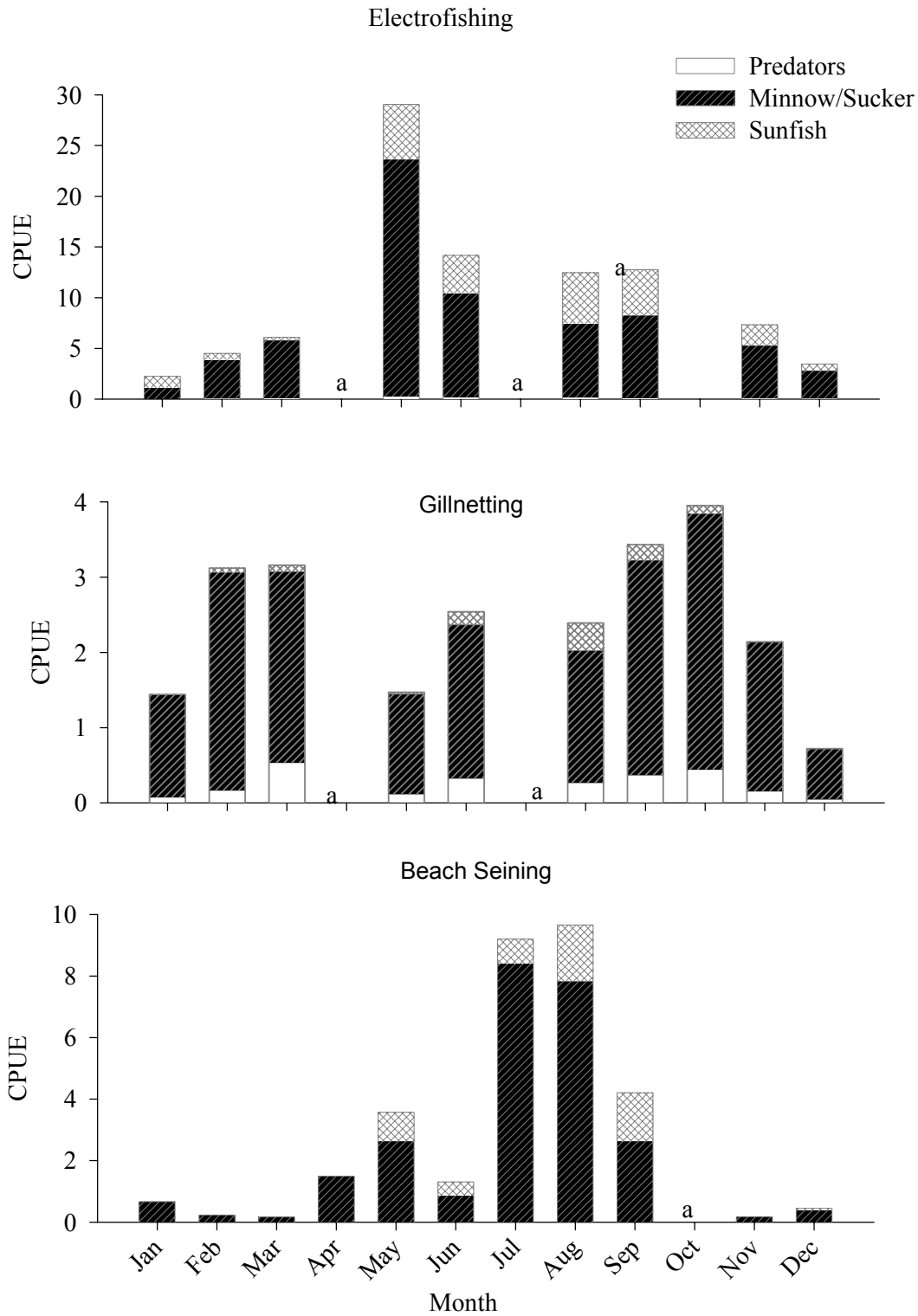


Figure 31. Monthly catch-per-unit-effort (CPUE) of potential predator fishes and other resident family groups captured by electrofishing, gillnetting, and beach seining in the lower Willamette River, May 2000 through June 2001. a = no sampling conducted.

Table 25. Mean standardized electrofishing catch rate of select species^a at sampling sites in the lower Willamette River, May 2000 through June 2001.

Site	≥250 mm				<250 mm				All sizes								
	NPM	SMB	LMB	WAL	NPM	SMB	LMB	WAL	YLP	PMC	BLG	BCP	WCP	PMK	TSS	RSS	SUC
Standard sampling sites																	
006E	0.00	0.00	0.00	0.08	0.09	0.04	0.00	0.08	0.73	1.51	0.00	0.00	0.13	0.00	0.94	0.00	1.95
010E	0.00	0.08	0.05	0.00	0.15	0.09	0.04	0.07	1.74	1.23	0.00	0.14	0.14	0.07	49.1	0.04	3.69
012W	0.11	0.00	0.00	0.00	0.50	0.05	0.04	0.00	1.04	1.05	0.00	0.22	0.09	0.00	0.62	0.00	2.81
031W	0.05	0.04	0.00	0.08	0.00	0.04	0.00	0.07	0.10	0.43	0.00	0.16	0.08	0.00	0.00	0.00	5.54
048E	0.00	0.00	0.00	0.00	0.09	0.03	0.00	0.03	0.43	0.11	0.00	0.03	0.07	0.00	7.08	0.00	0.89
051E	0.09	0.08	0.00	0.00	0.09	0.43	0.04	0.00	1.57	1.01	0.05	0.24	0.00	0.00	0.62	0.00	7.47
064W	0.03	0.00	0.00	0.08	0.04	0.28	0.00	0.04	0.94	0.33	0.00	0.59	0.28	0.10	0.19	0.00	6.82
079W	0.15	0.22	0.00	0.00	0.00	0.69	0.08	0.00	2.84	0.72	0.08	0.26	0.16	0.32	2.72	0.04	10.83
100W	0.00	0.00	0.00	0.00	0.75	4.47	0.75	0.00	1.87	24.68	4.49	1.87	1.87	9.61	0.37	0.00	5.98
112E	0.16	0.00	0.00	0.00	0.00	1.93	0.00	0.00	4.81	1.16	0.00	0.05	0.00	0.12	0.00	0.00	7.70
118W	0.05	0.06	0.00	0.00	0.00	2.13	0.00	0.00	2.95	0.57	0.00	0.00	0.11	0.05	0.05	0.00	12.25
121W	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.20	0.00	0.00	0.00	0.00	3.31	0.00	1.80
133W	0.10	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.47	0.82	0.00	0.00	0.00	0.00	0.53	0.00	4.45
136E	0.00	0.15	0.00	0.11	0.08	1.45	0.00	0.06	2.96	1.00	0.00	0.00	0.08	0.17	0.35	0.00	10.82
148E	0.04	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.70	0.44	0.04	0.88	0.80	0.13	2.32	0.00	3.29
167W	0.10	0.04	0.00	0.00	0.08	0.04	0.00	0.00	0.58	1.04	0.00	0.08	0.29	0.04	0.06	0.00	3.89
200E	0.05	0.10	0.00	0.00	0.33	2.24	0.00	0.00	0.07	0.75	0.00	0.00	0.09	0.07	0.00	0.00	10.01
203W	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
219W	0.04	0.26	0.07	0.00	0.28	2.89	0.00	0.00	0.05	0.83	0.21	0.00	0.07	0.30	0.00	0.00	12.68
Alcoves and refugia																	
067EA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25
076W	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
148W	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
232W	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	5.81	7.46	0.00	0.00	0.00	0.00	0.00	0.83	4.98
239EA	0.00	3.32	0.00	0.00	0.83	6.64	0.00	0.00	4.15	0.00	0.00	0.00	0.00	0.83	0.00	4.98	19.09

^a BCP=black crappie, BLG=bluegill, LMB=largemouth bass, NPM=northern pikeminnow, PMC=peamouth chub, PMK=pumpkinseed, RSS=redside shiner, SMB=smallmouth bass, SUC=sucker spp., TSS=threespine stickleback, WAL=walleye, WCP=white crappie, YLP=yellow perch.

Table 26. Mean gillnetting catch rate of select species^a by sampling site in the lower Willamette River, May 2000 through June 2001.

Site	≥250mm				<250mm				All sizes								
	NPM	SMB	LMB	WAL	NPM	SMB	LMB	WAL	YLP	PMC	BLG	BCP	WCP	PMK	TSS	RSS	SUC
006EN	0.33	0.00	0.00	0.05	0.10	0.00	0.00	0.05	0.00	3.43	0.00	0.05	0.00	0.00	0.00	0.00	3.91
010EN	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.05	0.14	0.00	0.00	0.00	0.00	1.38
010EO	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.53	0.00	0.06	0.06	0.00	0.00	0.00	0.24
012WN	0.24	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.18	0.00	0.29	0.00	0.00	0.00	0.00	2.65
031WN	0.40	0.05	0.00	0.30	0.05	0.00	0.00	0.00	0.00	0.15	0.05	0.00	0.05	0.00	0.00	0.00	2.45
048EN	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.20
051EN	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.05	0.00	0.10	0.10	0.00	0.00	0.00	1.05
051EO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.07	0.20	0.00	0.00	0.00	0.40
064WN	0.27	0.00	0.00	0.05	0.14	0.00	0.00	0.00	0.00	0.14	0.00	0.09	0.05	0.00	0.00	0.00	0.77
064WO	0.22	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.22
079WN	0.17	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.21	0.00	0.00	0.63	2.26
079WO	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.35
100WN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.36
100WO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.07	0.00	0.00	0.00	0.20
112EN	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.19	0.00	0.00	0.06	0.00	0.00	0.00	1.25
118WN	0.22	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.39	0.04	0.30	0.00	0.00	0.00	0.00	1.26
121WN	0.19	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	2.52	0.00	0.05	0.05	0.00	0.00	0.00	2.05
133WN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	1.62
136EN	0.27	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.05	0.00	0.00	0.00	2.73
136EO	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.13	0.07	0.00	0.00	0.00	1.87
148EN	0.10	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.14	0.00	0.00	0.00	1.81
167WN	0.59	0.00	0.00	0.09	0.05	0.00	0.00	0.05	0.00	0.50	0.00	0.05	0.14	0.00	0.00	0.00	1.41
200EN	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.70
203WN	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.24	0.10	0.00	0.00	0.00	0.33
219WN	0.33	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.05	0.00	0.00	0.00	0.95

^a BCP=black crappie, BLG=bluegill, LMB=largemouth bass, NPM=northern pikeminnow, PMC=peamouth chub, PMK=pumpkinseed, RSS=redside shiner, SMB=smallmouth bass, SUC=sucker, TSS=threespine stickleback, WAL=Walleye, WCP=white crappie, YLP=yellow perch.

Gear Efficiencies and Selectivity

A comparison of mean monthly catch rates of resident fish groups by gillnetting and electrofishing over time indicates that reducing amperage output of the electrofisher in November 2000 did not reduce catch rates of predators and minnows and suckers (Figure 32 and 33). This change may have affected our ability to collect sunfish by electrofishing (Figure 34), but additional sampling is needed to better assess these results.

Habitat Use

Mean CPUE of resident fish groups for both electrofishing and gillnetting varied widely among sampling sites with no apparent pattern (Tables 27 and 28). Only site 100W had substantially higher catch rates of multiple fish groups but this may be an artifact of standardization. Electrofishing catch rates of resident fish groups by habitat type were dissimilar (Figure 20) but not significantly different (Table 21). The same comparison using gillnet CPUE indicated resident fish communities within different habitat types were homogeneous (Figure 35). We found a significant difference in electrofishing CPUE between rock outcrop and vertical wall bank treatment types ($P=0.0254$) for predators but no difference for other resident fish groups (Table 21; Figure 21). Differences in gillnet CPUE among bank treatment types were not tested for significance but appeared less distinct than electrofishing (Figure 36).

The mean catch rate of predators and minnow/suckers in nearshore gill nets was nearly twice that of mid-shore gill nets (Figure 37). Gillnet catch rates of predators were also higher at sites where no structure was present (Figure 38), particularly mid-shore (Figure 39). When a structure was present, gillnet CPUE of predators and sunfish was higher at sites with floating structures while minnows/suckers were more abundant at piling sites (Figure 40). No meaningful correlations were identified between electrofishing CPUE of any resident fish group and 12 habitat parameters measured at the sampling sites (Table 22).

DISCUSSION

The goal of this project is to determine what relationships may exist between fish communities and available habitat in the lower Willamette River. This is a complex issue due to the variety of species, habitat conditions, and potential confounding factors involved. In this first year, we have made significant progress toward developing an understanding of potential relationships. Although many trends were observed, several years of sampling will be required before the hypotheses of the study can be addressed with certainty. Several preliminary findings merit further discussion.

One interesting result was the occurrence of unmarked juvenile salmonids in the study area throughout much of the year. We are unsure if this is the result of a continual influx of new fish or if juvenile salmonids are rearing in this area. It is likely a product of both. Most sub-yearling chinook were present from February through June, after which time we collected few individuals, indicating possible departure of this cohort. However, in November and December, and continuing through the following spring, we resumed catches of what we presume to be larger sub-yearling fish (1+ in January). A few extremely small individuals were also collected in December and January indicating the cycle may begin earlier, although these fish may be an

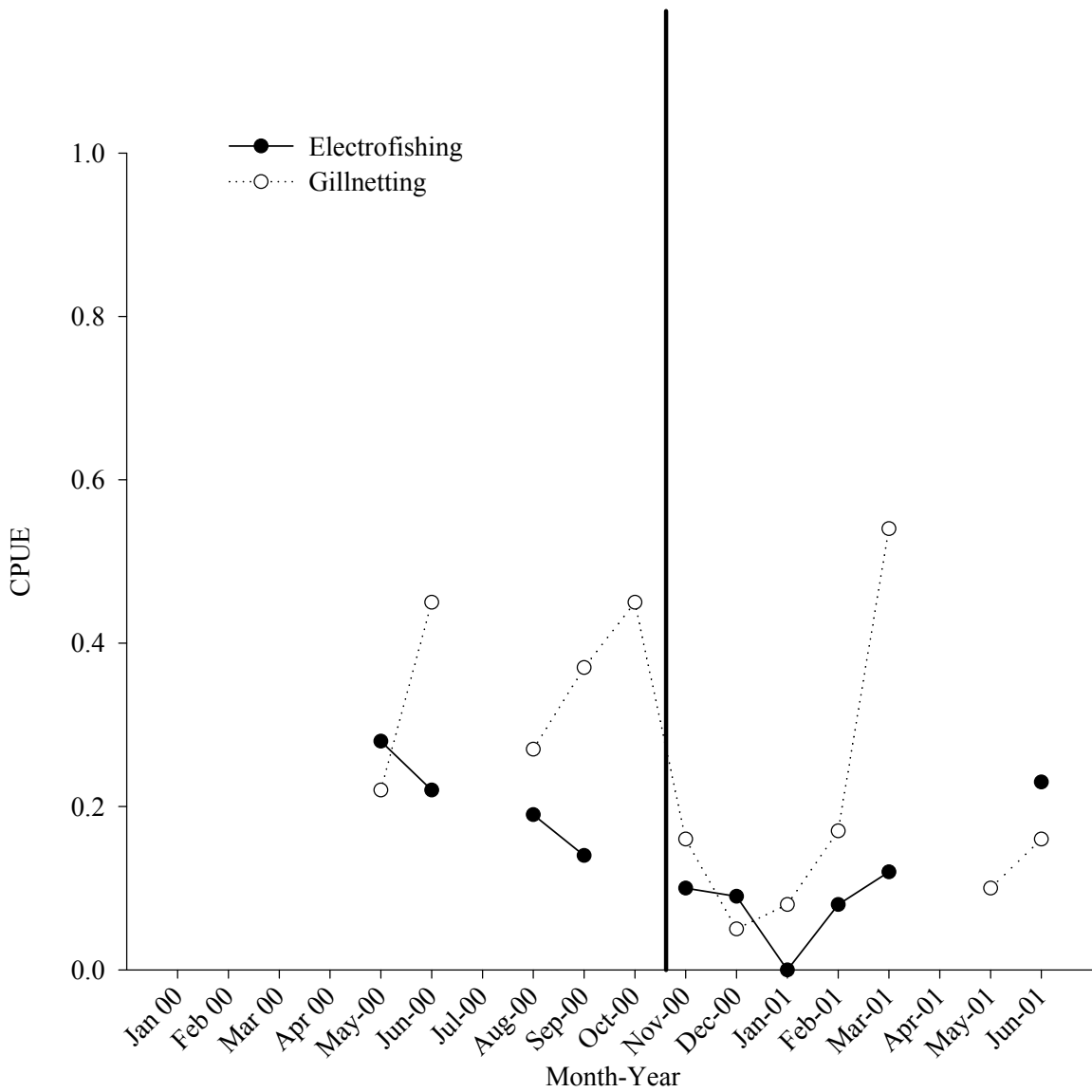


Figure 32. Electrofishing and gillnetting catch-per-unit-effort (CPUE) of potential predator fish by month and year in the lower Willamette River, May 2000 through June 2001. Gaps in trend lines indicate non-sampling periods. Vertical line indicates change in electrofisher settings.

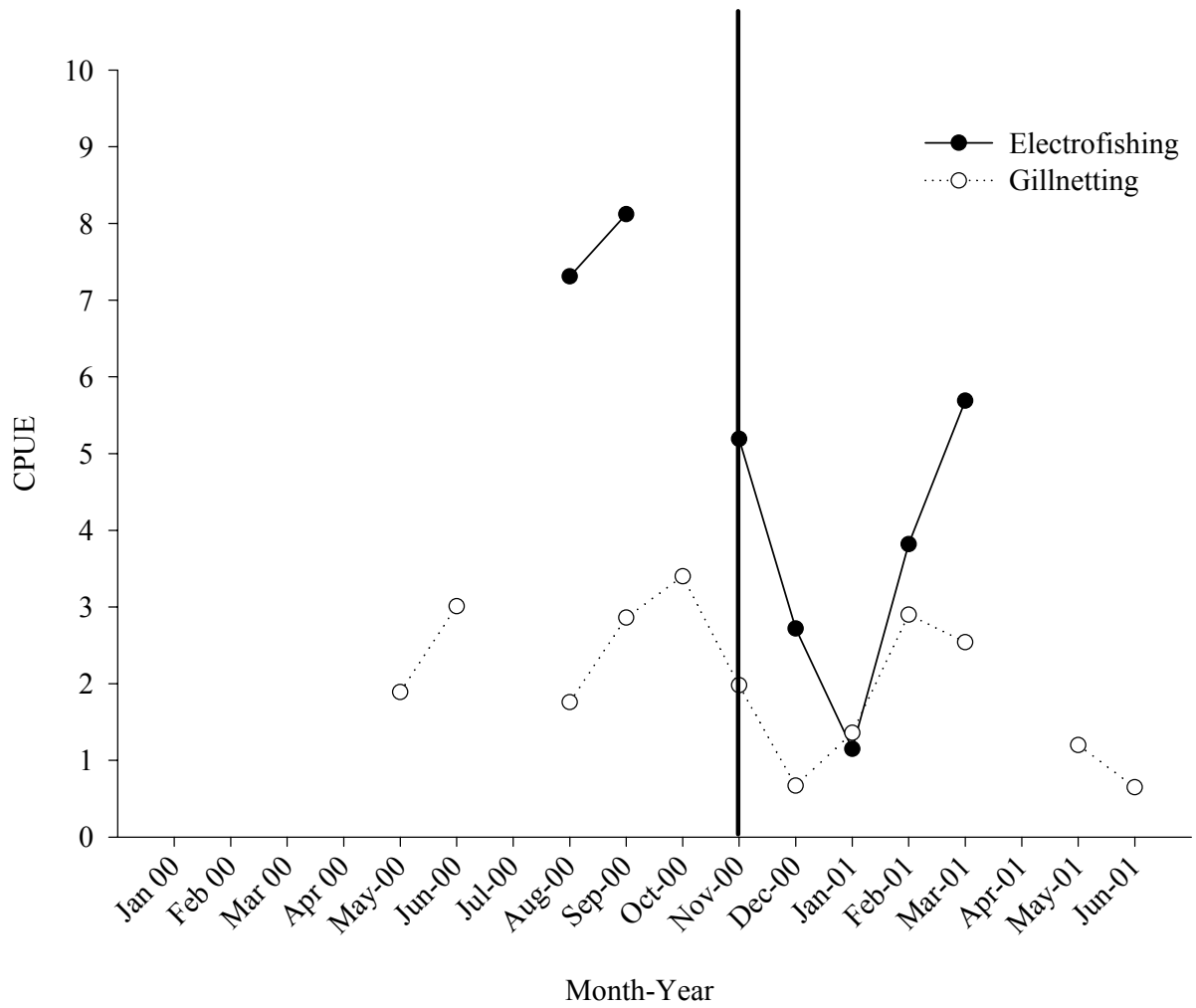


Figure 33. Electrofishing and gillnetting catch-per-unit-effort (CPUE) of minnows and suckers by month and year in the lower Willamette River, May 2000 through June 2001. Gaps in trend lines indicate non-sampling periods. Vertical line indicates change in electrofisher settings.

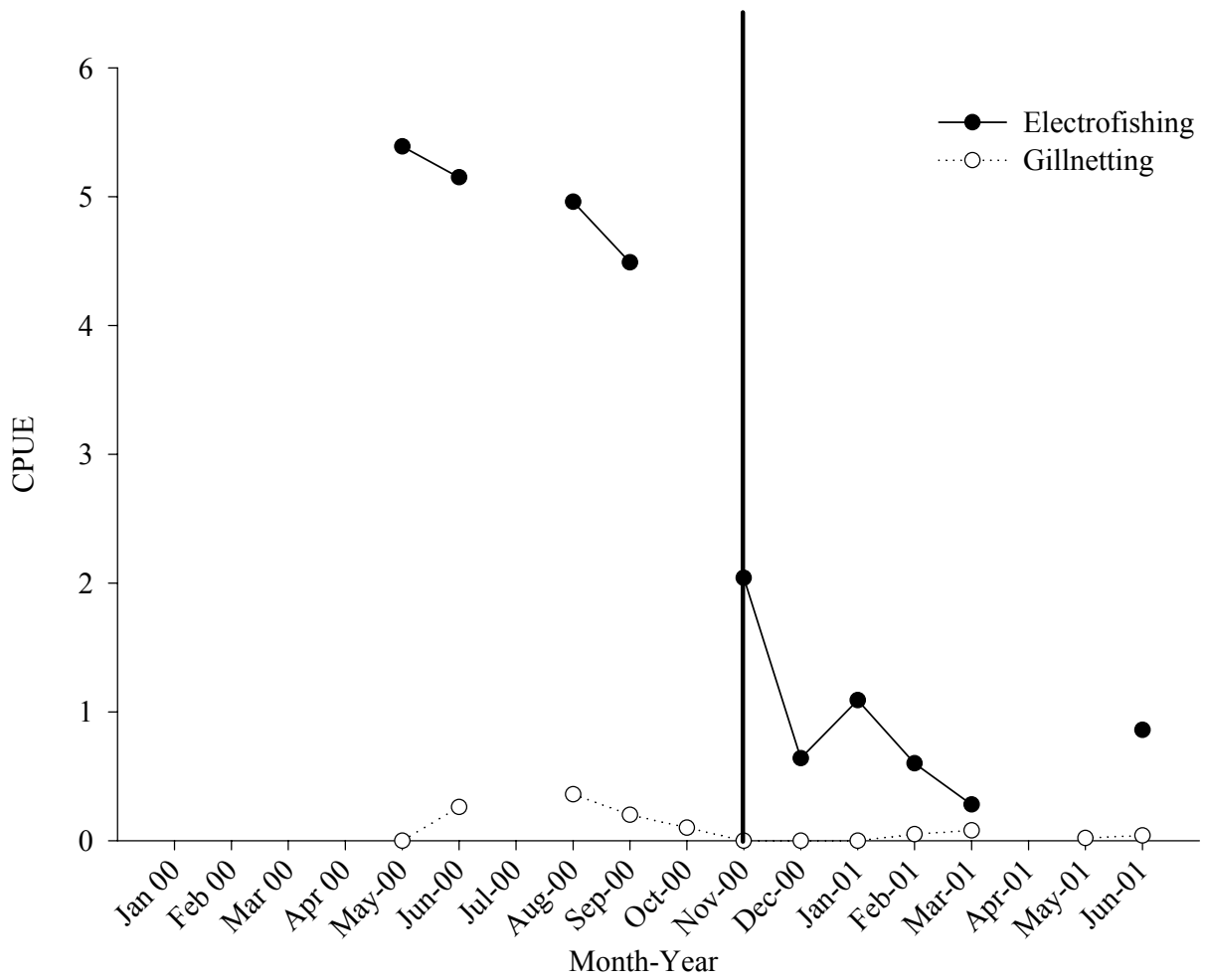


Figure 34. Electrofishing and gillnetting catch-per-unit-effort (CPUE) of sunfish by month and year in the lower Willamette River, May 2000 through June 2001. Gaps in trend lines indicate non-sampling periods. Vertical line indicates changes in electrofisher settings.

Table 27. Mean standardized electrofishing catch rates of predator^a, minnow/sucker^b, and sunfish^c species by sampling site in the lower Willamette River, May 2000 - June 2001.

Site	Predator	Minnow/Sucker	Sunfish
006E	0.08	3.56	0.90
010E	0.13	5.06	2.21
012W	0.11	3.91	1.44
031W	0.17	5.97	0.37
048E	0.00	1.08	0.57
051E	0.17	8.57	2.32
064W	0.12	7.07	2.18
079W	0.36	11.55	4.42
100W	0.00	31.42	24.92
112E	0.16	8.86	6.92
118W	0.10	12.83	5.24
121W	0.04	2.00	0.08
133W	0.10	5.27	0.66
136E	0.26	11.90	4.67
148E	0.09	3.77	2.59
167W	0.14	5.01	1.04
200E	0.14	11.09	2.47
203W	0.00	0.05	0.12
219W	0.37	13.78	3.52
Alcoves			
067EA	0.00	1.25	0.00
076WA	0.00	0.00	0.00
107WA	0.00	0.00	0.00
148WA	0.00	0.00	0.00
232WA	0.83	12.44	5.80
239EA	3.32	19.92	11.62

^a Smallmouth bass, largemouth bass, northern pikeminnow and walleye \geq 250mm.

^b Peamouth chub and suckers of all sizes and northern pikeminnow <250mm.

^c Black crappie, bluegill, pumpkinseed, white crappie, and yellow perch of all sizes. Smallmouth and largemouth bass <250mm.

Table 28. Mean gillnet catch rates of predator^a, sucker/minnow^b, and sunfish^c species by sampling site in the lower Willamette River, May 2000 through June 2001.

Site	Predator	Sucker/Minnow	Sunfish
006EN	0.38	7.43	0.05
010EN	0.19	1.62	0.19
010EO	0.06	1.76	0.12
012WN	0.24	2.88	0.29
031WN	0.75	2.65	0.10
048EN	0.15	0.40	0.00
051EN	0.10	1.14	0.19
051EO	0.00	0.67	0.27
064WN	0.32	1.05	0.14
064WO	0.28	0.39	0.00
079WN	0.21	2.30	0.25
079WO	0.06	1.18	0.00
100WN	0.00	0.36	0.09
100WO	0.00	0.73	0.07
112EN	0.19	3.44	0.06
118WN	0.22	1.70	0.35
121WN	0.19	4.67	0.10
133WN	0.00	1.69	0.00
136EN	0.27	3.59	0.05
136EO	0.27	3.07	0.20
148EN	0.14	2.10	0.14
167WN	0.68	1.95	0.18
200EN	0.35	1.30	0.00
203WN	0.38	0.48	0.33
219WN	0.33	1.81	0.05

^a Smallmouth bass, largemouth bass, northern pikeminnow, and walleye \square 250mm.

^b Peamouth chub and suckers of all sizes and northern pikeminnow <250mm.

^c Black crappie, bluegill, pumpkinseed, white crappie, yellow perch of all sizes. Smallmouth and largemouth bass <250mm.

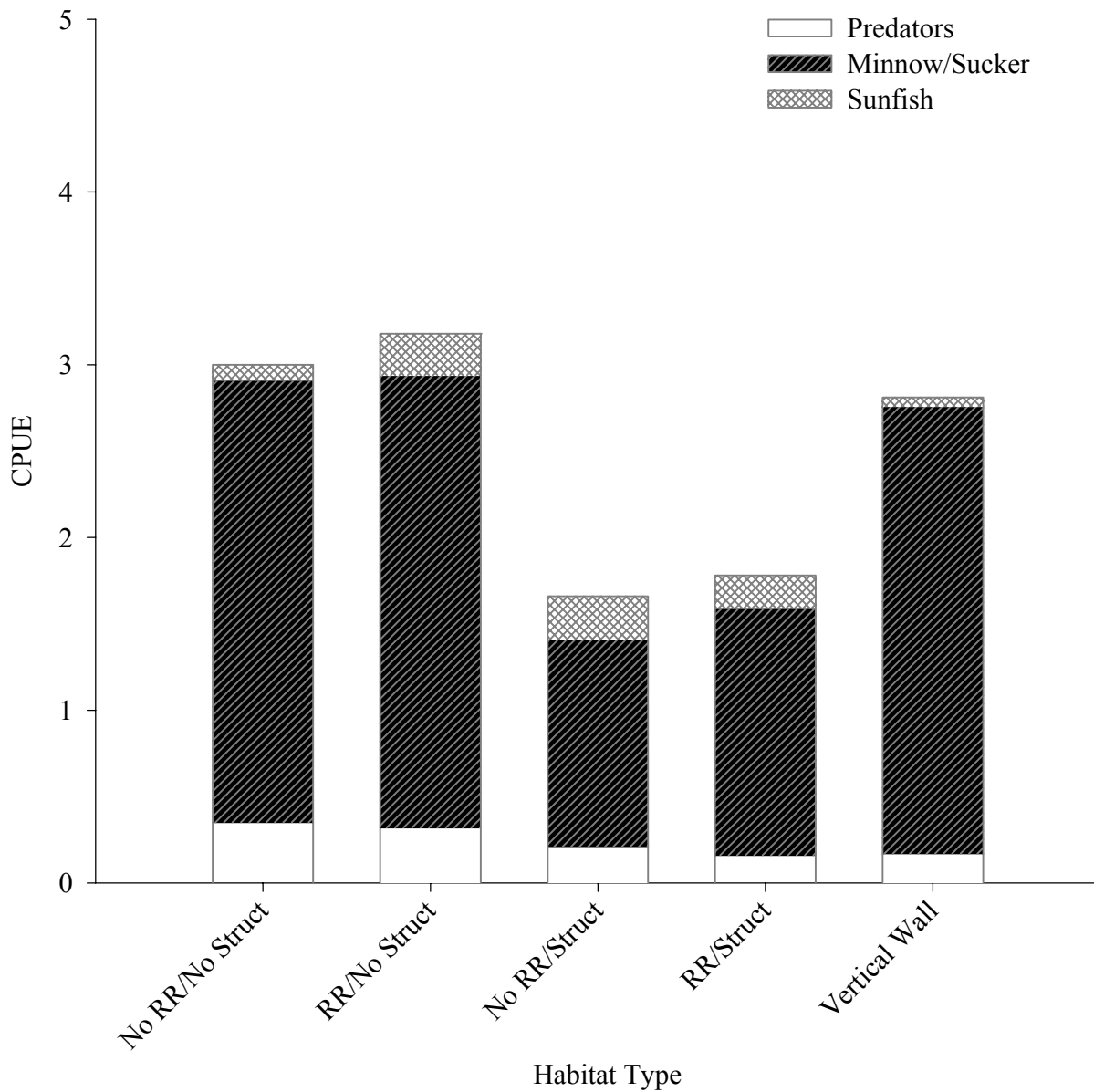


Figure 35. Gillnetting catch-per-unit-effort (CPUE) of potential predator fishes and other resident family groups by habitat type in the lower Willamette River, May 2000 through June 2001. RR = riprap.

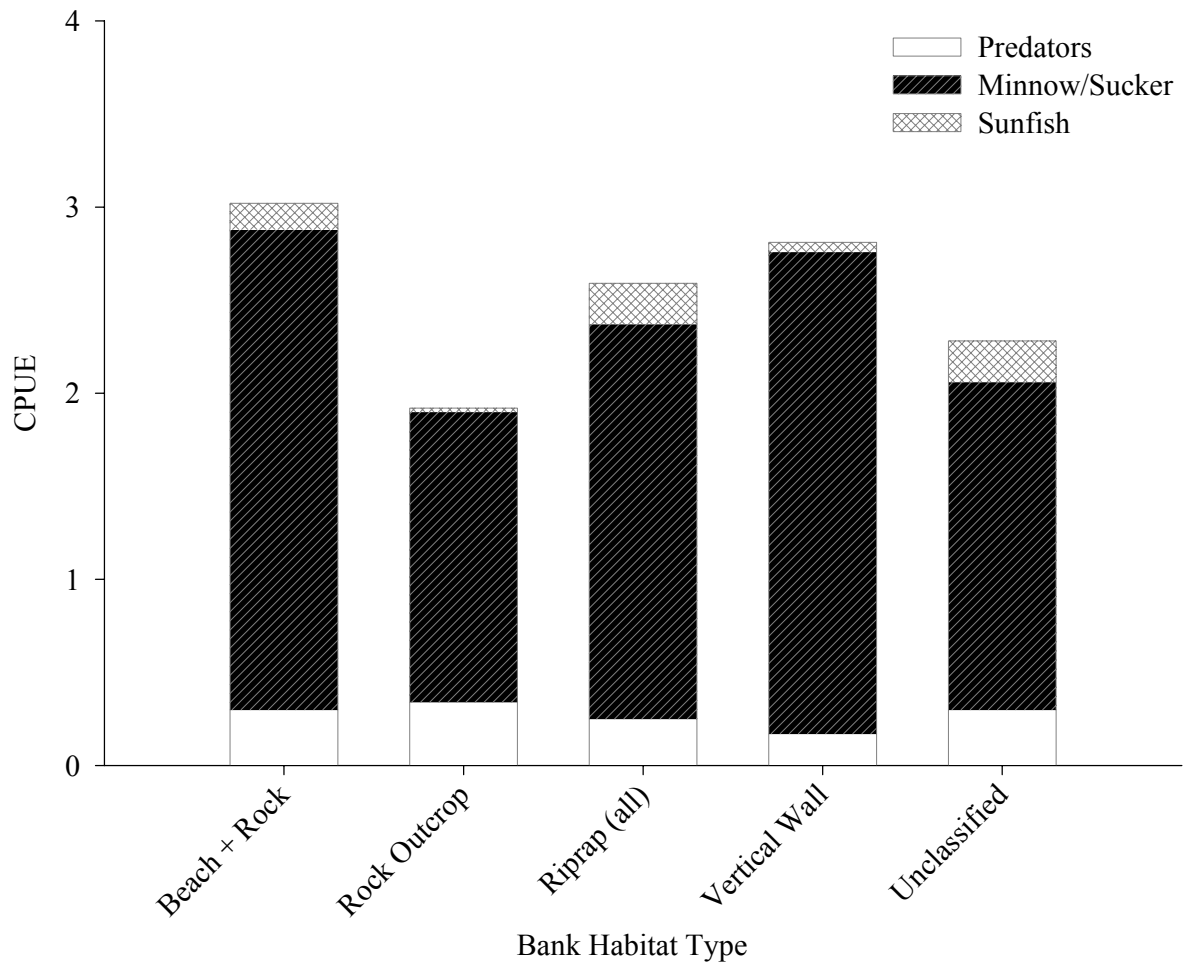


Figure 36. Gillnetting catch-per-unit-effort (CPUE) of potential predator fishes and other resident family groups by bank habitat type in the lower Willamette River, May 2000 through June 2001.

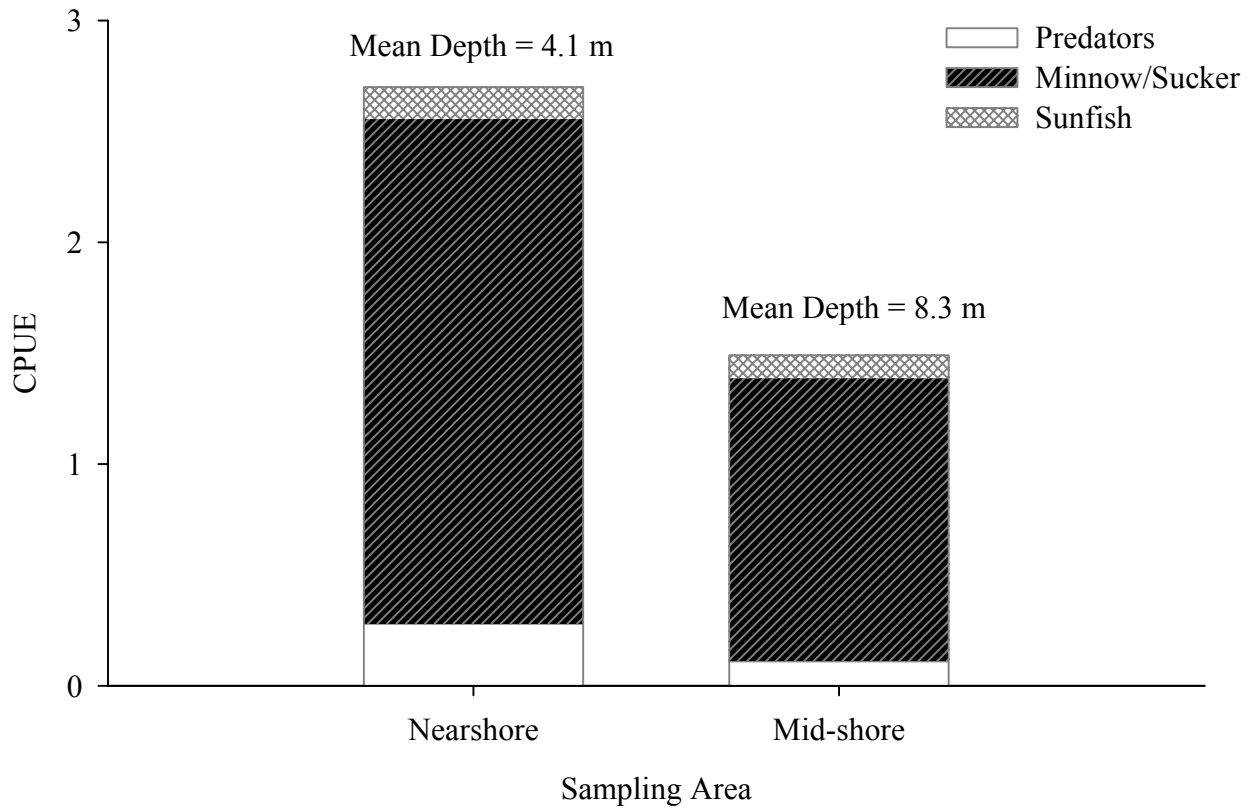


Figure 37. Gillnetting catch-per-unit-effort (CPUE) of potential predator fishes and other resident family groups by proximity to shore in the lower Willamette River, May 2000 through June 2001.

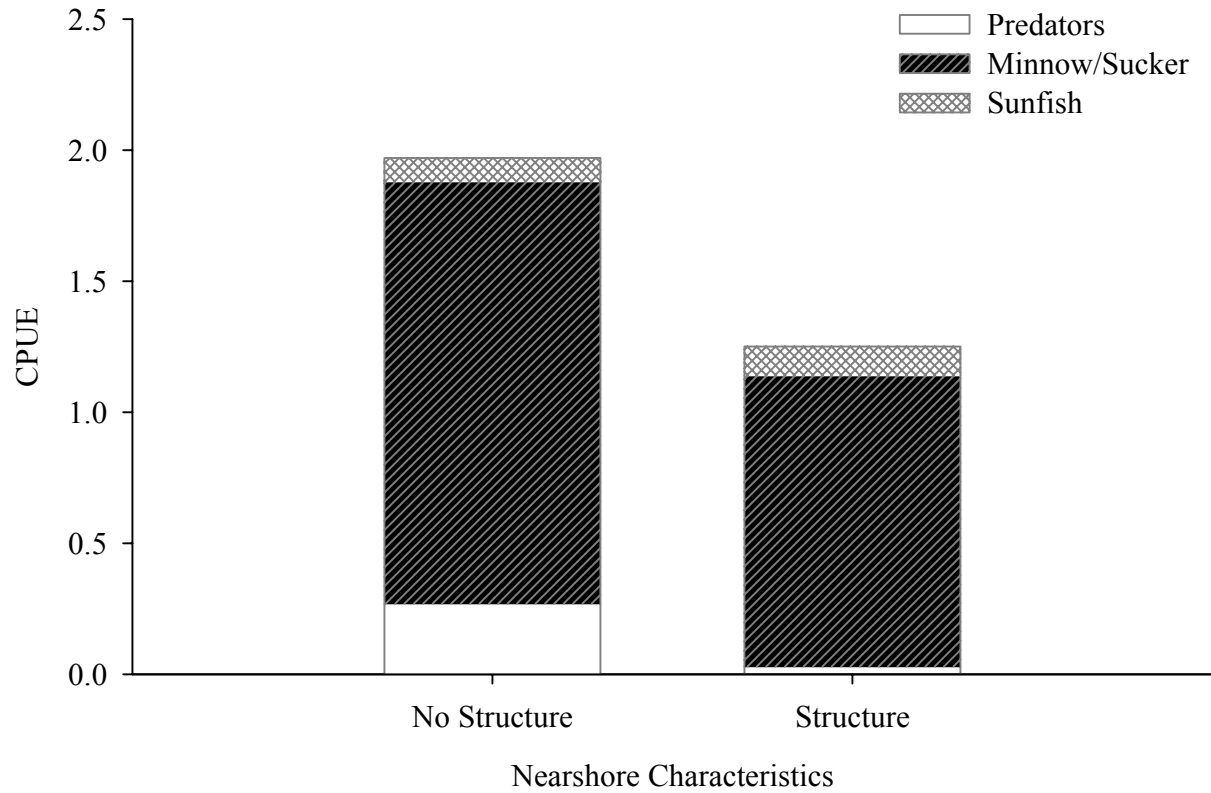


Figure 38. Gillnetting catch-per-unit-effort (CPUE) of potential predator fishes and other resident family groups by presence/absence of nearshore structure in the lower Willamette River, May 2000 through June 2001.

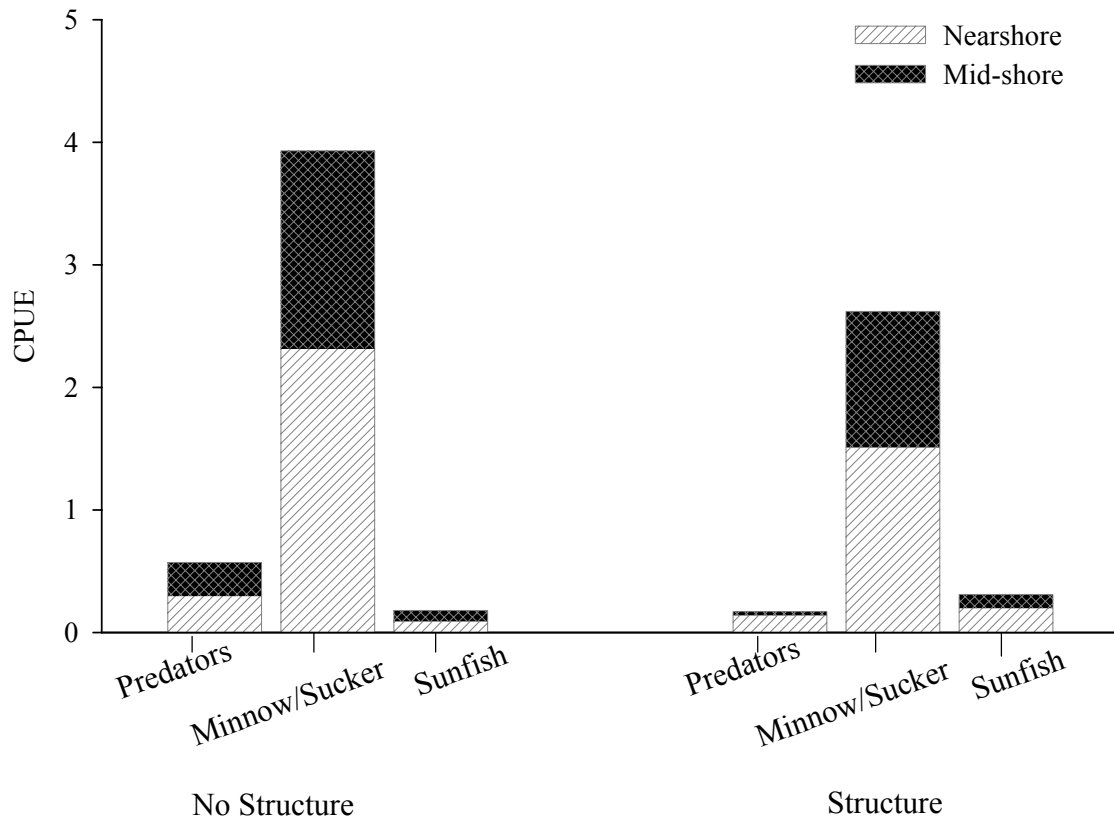


Figure 39. Gillnetting catch-per-unit-effort (CPUE) of potential predator fishes and other resident family groups by presence/absence of nearshore structure in the Willamette River, May 2000 through June 2001.

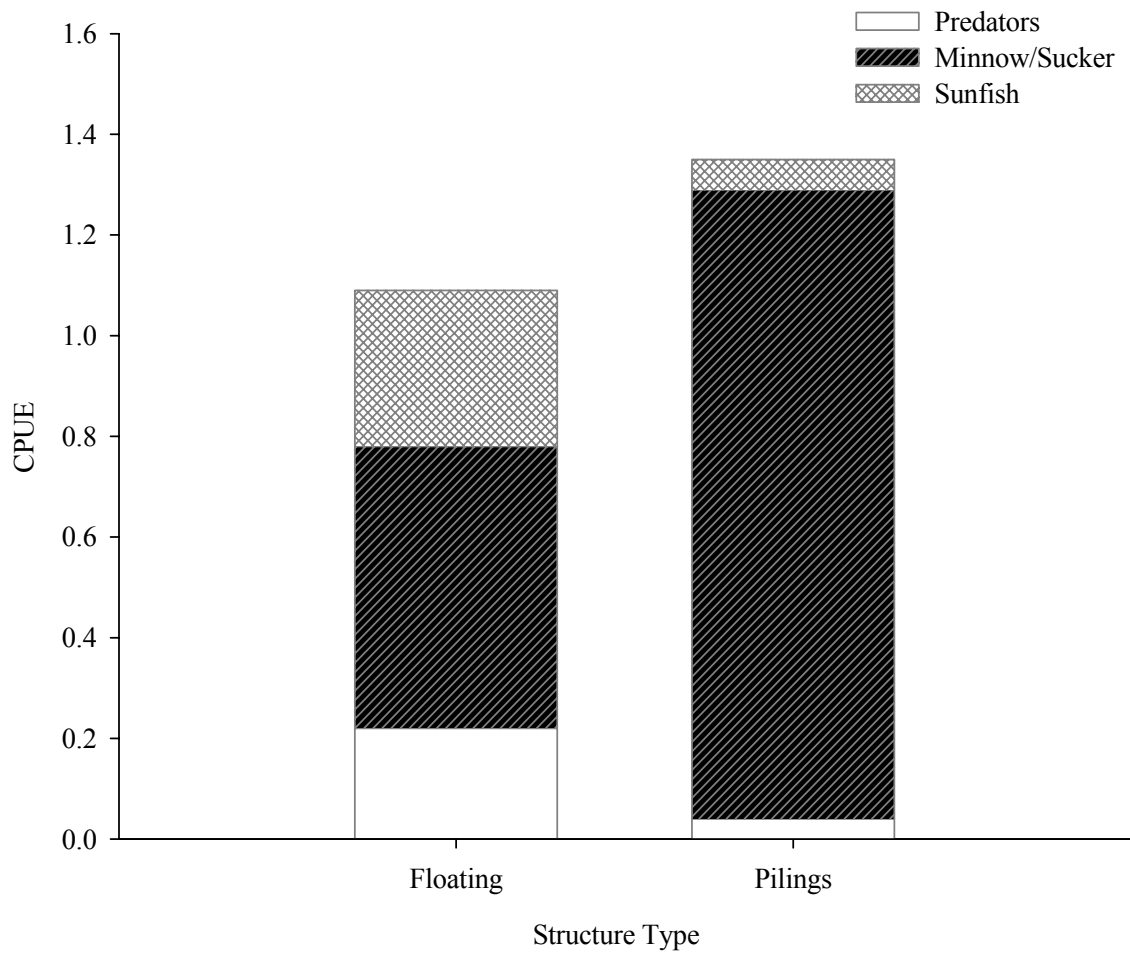


Figure 40. Gillnetting catch-per-unit-effort (CPUE) of potential predator fishes and other resident family groups by nearshore structure type in the Willamette River, May 2000 through June 2001.

artifact of winter freshets. Low catches from July through September may reflect out-migration of age 0+ fish or an ontogenetic response to increasing temperatures in the littoral zone documented in other salmonid studies (Kahler et al. 2000). Because we did not sample offshore, and did not conduct any radio telemetry during this season, we can only speculate.

We were initially surprised by the substantial difference in size, species composition, and peak timing of the juvenile salmonid catch by seining and electrofishing. However, it appears behavioral differences between sub-yearling and yearling fish may explain the difference in size. Based on our day and night beach seining results, it appears yearling fish move inshore at night, making them much more susceptible to electrofishing, and therefore increasing the average size of the catch. We considered that these larger fish were simply escaping the beach seine during the day, but few yearling fish were collected when we attempted electrofishing during daylight hours. Our telemetry results, and findings of other researchers (Reimers 1971; Ward et al. 1994), indicate sub-yearling fish tend to remain close to shore, which should make them susceptible to both gears; however, these small fish may not be as easy to see and capture at night, particularly if larger fish are more abundant. It is also possible that sub-yearling fish are somewhat displaced away from shore at night. We observed a substantial increase in mean size of chinook caught at night, potentially due to our speculated influx of yearling fish, yet CPUE was actually higher during the day. Peak timing of the catch was most likely a result of when we were able to conduct electrofishing. Since sampling did not begin until late May in 2000 and very little sampling was conducted mid-March through mid-June in 2001, we likely missed the peak out-migration of yearling hatchery chinook, resulting in peak catches in the November-December period rather than the spring. Had we conducted sampling during this period, we anticipate distribution of the electrofishing catch would have been different.

We found juvenile salmonids migrated through the lower Willamette River more slowly than reported by Ward et al. (1994). Differences can likely be attributed to a smaller mean size of tagged fish in this study. Both studies found larger fish generally migrated through the study area faster than smaller fish. We also released fish farther upriver where migration rates were significantly slower than downstream. The conservative criteria we applied to migration data would favor actively migrating fish. Migration may actually be slower than we estimated because we discounted sedentary fish to avoid bias resulting from death or predation.

Our estimates of migration rates within Multnomah Channel were limited because only two fish were recovered multiple times within the channel. However, it appears that juvenile salmonids may linger in this area. One coho was traveling at 0.1 km/d and a yearling chinook was recovered 5.7 km upstream of the original relocation. We expended 5% of our mobile tracking in this area and found seven (12%) of all relocated fish. Further evidence that fish slow down in this area is due to our recovery of several fish within the channel that were released weeks earlier.

The extremely high catch rates of juvenile salmonids at sites 133W and 167W are not easily explained. Although site 133W is generally classified as a bio-engineered site, the bank treatment stops relatively high on the bank. Because of this, we classified it as a beach site during much of the reporting period. Similarities do exist between these two sites. Both have a shallow gradient sand bottom extending well out from the lower shore zone; water column velocities were also quite low. Conversely, they were not dissimilar from several other sites. We will investigate riverbed gradient, rather than nearshore mean depth as a possible effect in analyses.

The extent that juvenile salmonids rear in the study area is unclear. Significant differences in mean length of sub-yearling chinook between upper and lower beach seine sites may indicate these fish potentially remain in the study area for extended periods but sample sizes were very small. Although technological advances in radio telemetry continue to provide smaller radio transmitters, it is unlikely that a product will be available soon to allow tagging of abundant 40-60 mm sub-yearling chinook. To address this question, we will focus additional effort on this task during the coming year, particularly during spring. We will also examine differences in timing of peak catch between upper and lower sections and compare catch percentages at lower sites with passage rates at Willamette Falls. Genetic analysis may be a worthwhile pursuit to identify race and potential origin of unmarked juvenile chinook salmon and improve our ability to describe rearing patterns in the study area.

The task of determining why fish communities and abundances differ among seasons and habitat types is especially challenging. Our initial attempt enlightened us to the difficulty of collecting accurate habitat data. Multivariate analysis may be sufficient to isolate significant effects between our point samples of habitat conditions and relative abundance of fish at each of the sampling sites. It may be necessary to reduce the number of variables investigated and increase the frequency and detail of effort devoted to habitat sampling to more accurately represent the entire period of fish collection.

We will likely make several changes to our sampling methodologies in the coming year. Our initial goal was to balance electrofishing and gillnet sampling among seasons with less concern for dispersion among months. Unfortunately, we have found this caused "gaps" in the data that are problematic. Rather than sample in 4-6 week blocks each season, we will likely sample 1-2 weeks each month to better represent potential changes in fish communities and abundances.

PLANS FOR 2002

Task 1.1: Selection of Sampling Sites

We discontinued sampling at site 112E due to commercial traffic and because it is difficult to navigate during low water. Site 031W was dropped due to extremely shallow water, navigation hazards, and an abundance of beach sites. Site 118W was replaced with 116E.

Task 1.2: Habitat Evaluation

We have completed the task of mapping and inventorying available bank habitat types and nearshore structures above mean low water. As previously mentioned, we may re-evaluate collection of habitat parameters at each of the sampling sites.

Task 2.1: Juvenile Salmonid Radio Telemetry

We intend to replicate the spring 2001 juvenile salmonid telemetry study in 2002. An additional effort is being considered for the autumn of 2002. Methods will be similar to those reported herein except the number of fixed sites may be reduced.

Task 2.2: Standardized Sampling for Juvenile Salmonids

We plan to continue beach seining weekly during a portion of 2002 to address whether juvenile salmonids rear in the study area.

Assuming the appropriate permits are obtained, we will continue collecting length and weight information on juvenile salmonids caught incidentally while boat electrofishing. This is a valuable tool for several tasks because of the number and variety of salmonids that can be collected.

Task 2.3: Juvenile Salmonid Diets

Beginning in autumn 2002, we will begin to sample the diet of juvenile salmonids by using non-lethal techniques (levage). Prey will be classified to taxa and compared with availability and prey consumed by select resident fish.

Task 3.2: Standardized Sampling for Resident Fish

We plan to continue standardized sampling of resident fish. Gillnet effort may be reduced to facilitate new tasks. Indices of community structure will be developed. We will also apply more robust statistical tests to determine if differences in fish communities among habitat types exist.

Task 3.3: Resident Fish Diets

We intend to analyze the diet of smallmouth bass and northern pikeminnow to evaluate predation on salmonids in relation to habitat types. Diets of other select resident fish will be analyzed to determine the dietary overlap of introduced species with juvenile salmonids.

Task 4.1: Benthic Invertebrate Sampling

Beginning in autumn 2002, we will begin to collect benthic invertebrate samples with substrate grabs and artificial substrates deployed along bank treatments to classify community structures among habitat types. We intend to collect eight grab samples and deploy four substrates per site per season.

Task 4.2: Sediment Sampling

Sediment samples will be collected concurrent with Task 4.1 to describe riverbed composition among habitat types and seasons.

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The use of trade names does not imply endorsement by the Oregon Department of Fish and Wildlife.

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APPENDIX 1

Electrofishing Protocols

Electrofishing protocols incorporated to reduce impacts on juvenile salmonids in the lower Willamette River, May 2000 through June 2001.

- Reduced average range of electrical output from 3.0-3.5 to 2.0-2.4 amperes.
- Electrofishing procedures followed the National Marine Fisheries Service protocols (Guidelines for electrofishing waters containing salmonids listed under the endangered species act, June 2000).
- Project personnel obtained and reviewed “Principles and techniques of electrofishing” training course offered by the U. S. Fish and Wildlife Service-National Conservation Training Center.
- Obtained personal on-the-water training by staff of Smith-Root.
- Reduced voltage output to minimize injury to adult and juvenile salmonids.
- Changed pulse width and wave form to maximize taxis of juvenile salmonids.
- Eliminated sampling at a few areas where juvenile salmonid densities were highest.
- Adult salmonids were not handled.
- Limited electrical-field exposure of juvenile salmonids to 10 seconds.
- Collection of juvenile salmonids for length and weight measurements was limited to fish that could be collected within the 10-second exposure time limit and any remaining stunned fish. Remaining individuals were enumerated rather than handled.
- Avoided reintroduction of dipped fish to the energized field.
- Large concentrations of juvenile salmonids were bypassed after initial detection to avoid repeated exposure to the energized field.
- Stunned fish nearest the anodes were dipped first to avoid contact.
- Used a designated boom configuration for even distribution of the energized field.

APPENDIX 2

Radio Telemetry Surgical Procedures

Procedures used for surgical implantation of radio transmitters in resident fish in the lower Willamette River, May 2000 through January 2001.

Surgical Supplies:

Data sheets	Speculum	Forceps
Scalpel handle and blades	Hemostatic scissors	Kimwipes
Cannula for antenna exit	Sutures	Bucket
Razor blades	Basting bulb	Q-tips
Nexaband or Vetbond (adhesive)	Iodine	Radio tags
Telemetry receiver	Sterile gauze pads	MS-222 (anesthetic)
Surgical platform (blue tote)	Polyaqua stress coat	MSDS sheets
Nolvasan (Chlorhexidine diacetate)	Saline solution	Latex gloves
Cooler modified with trough	30 ml syringe	Sharps container
Surgical instrument trays (tupperware)	Probe	

Surgical Preparations:

Ensure fish meet the minimum tagging criteria of 400 g.

Find a stable site to perform the surgery such as a boat ramp or on the river shore. A shaded site is preferred on warm sunny days to minimize the stress on the fish.

Test the radio tag before implantation to ensure it is functioning. Record the channel and code of the tag on the data sheet.

Pour Nolvasan in one instrument tray and saline in the other tray. Place surgical tools (scalpel, forceps, cannula, speculum, hemostatic scissors, razor blade) in Nolvasan first to disinfect and then rinse in saline before each surgical use. This should be done for each fish when performing consecutive surgeries.

Prepare the anesthetic bath by placing 15 L of river water into the blue cooler. This volume is achieved by filling the cooler with water up to the black line drawn on the inside wall of the cooler. Using a syringe to measure 20 ml of the stock solution of MS-222 and add to the water in the cooler. Avoid excessive sun exposure of the MS-222 as it is photosensitive. Add a splash of Polyaqua to the anesthetic bath to help offset loss of mucous by the fish.

Have the following supplies readily available during the surgical procedure: basting bulb, bucket of river water, surgical adhesive, sutures, iodine, and Q-tip gauze swabs.

Surgical Procedure:

Both the surgeon and the assistant should put on latex gloves.

Place the fish into the anesthetic bath. When the fish succumbs to the anesthetic (belly up), place it in the surgical trough with the head oriented down slope.

Throughout the surgery the assistant should continuously administer anesthetic to the gills using the basting bulb. Use the anesthetic bath water in the cooler to irrigate the gills. If the fish stops

gilling, use fresh river water to irrigate the gills until gilling resumes. Care should be taken by the surgeon and the assistant to avoid contacting the surgical incision, tools, or sutures with the MS-222 solution.

Using a razor blade, scrape scales off the surgical incision site. The incision site is located several cm anterior to the pelvic girdle and just off the ventral midline. Scrape toward the head to remove scales. Apply iodine to the de-scaled site using a Q-tip.

Using a scalpel, make an incision approximately 2 cm in length, cutting from head to tail. Stay shallow initially to avoid internal organs and wipe blood as needed. Tissue grabbing forceps help pull the skin away from the body when making the incision.

After the incision is complete, insert the cannula into the fleshy tissue posterior to the pelvic girdle. The pelvic girdle lies between the two pelvic fins. Insert the speculum into the incision and apply slight upward pressure. Insert the cannula anteriorly and use the speculum to guide it out the incision. Once the cannula protrudes from the incision, remove the speculum. Disinfect and rinse the radio tag in the Nolvasan and saline solution respectively. Feed the antenna through the cannula so that the tail exits behind the incision. Remove the cannula and insert the tag into the body cavity, as slack in the antennae is withdrawn from the body cavity. (Note: the cannula technique applies only to northern pikeminnow. When implanting tags into smallmouth bass and walleye, the antenna will exit the same incision wound that the tag is inserted into.)

Apply 3-4 sutures to the incision wound. Tie two knots per suture. The second knot of each suture has a tendency to twist. To ensure the second knot lies flat, the assistant should use a probe to help orient the stitch while the surgeon slowly pulls the ends tight. During the last suture the assistant should switch to irrigating the gills with fresh river water to initiate the recovery process. Apply surgical adhesive sparingly to each stitch and to the antenna exit wound. Place fish into a fresh water recovery bin.

Before releasing the tagged fish at the capture location test the tag again to ensure channel and code can be detected.

If performing multiple surgeries, add 2 ml MS-222 stock solution to the anesthetic bath after each fish. Discard anesthetic bath after the third fish.

APPENDIX 3

Habitat Parameter Data

Appendix 3; Table 1. Water column^a velocities (cm/s) of sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000											March 2001												
	Shore zone (0-25m)					Shore zone (26-50 m)					Site mean	Shore zone (0-25m)					Shore zone (26-50 m)							
	Site Quartile ^b					Site Quartile ^b						Site Quartile ^b					Site Quartile ^b							
	2		4			Mean	1		3			Mean	2		4			Mean	1		3			Mean
S	B	S	B	S	B		S	B	S	B	S		B	S	B	S	B		S	B	S	B		
006E	*	*	0.9	1.2	1.0	6.3	3.1	3.7	13.3	6.6	4.7	*	*	16.9	*	16.9	*	*	19.8	9.0	14.4	15.2		
010E	3.0	6.5	9.7	8.9	7.0	0.8	1.5	10.2	13.0	6.4	6.7													
012W	11.4	3.0	3.0	3.0	5.1	13.0	13.9	1.4	2.2	7.6	6.3													
031W	*	*	*	*	0.0	8.6	*	24.2	*	16.4	16.4													
040W ^c	*	*	*	*	0.0	5.2	2.9	*	*	4.1	4.1													
048E	0.4	0.4	0.8	5.2	1.7	0.4	5.4	5.3	4.9	4.0	2.8	5.5	6.6	4.8	1.0	4.5	20.1	19.3	10.3	23.4	18.2	11.4		
051E	13.1	10.3	1.9	1.3	6.6	*	*	6.7	4.0	5.3	6.2	0.8	*	0.7	*	0.7	*	*	6.7	3.6	5.1	2.9		
064W	2.6	0.9	0.8	1.5	1.5	3.9	3.1	8.3	1.6	4.2	2.8	1.1	*	0.5	0.1	0.6	20.3	16.1	12.4	17.7	16.6	9.7		
079W	3.2	0.8	1.3	*	1.8	0.7	2.9	0.9	2.1	1.6	1.7	0.0	2.0	1.6	0.3	1.0	3.4	*	0.1	1.9	1.8	1.3		
097E	*	*	*	*	0.0	16.1	8.6	10.9	*	11.9	11.9													
100W	2.7	3.1	0.4	0.8	1.7	0.0	0.6	2.2	1.8	1.1	1.4													
112E	0.4	0.1	0.0	0.5	0.2	7.5	4.5	1.5	0.0	3.4	1.8													
118W	0.6	1.7	1.1	9.6	3.2	1.4	11.2	5.5	9.6	6.9	5.1													
121W	18.7	12.1	0.6	1.2	8.1	10.9	7.6	17.2	10.7	11.6	9.9													
133W	*	*	0.2	0.9	0.5	2.0	*	5.9	2.3	3.4	2.3	*	*	*	*	*	*	*	13.2	*	13.2	13.2		
136E	*	*	0.2	0.8	0.5	5.7	5.1	5.8	1.7	4.5	3.2	*	*	*	*	*	8.6	8.6	5.9	1.7	6.2	6.2		
148E	1.7	2.7	4.3	*	2.9	1.8	1.7	7.0	5.5	4.0	3.5													
167W	0.0	*	0.1	0.5	0.2	0.2	0.5	0.2	0.5	0.4	0.3	4.6	*	*	*	4.6	3.0	0.7	7.9	5.8	4.3	4.4		
200E	2.4	1.5	21.0	9.2	8.5	24.1	17.4	28.9	12.0	20.6	14.6													
203W	0.1	1.1	0.1	0.4	0.4	5.7	13.8	1.3	9.7	7.6	4.0	1.8	5.8	3.4	5.9	4.2	20.8	13.9	8.4	2.9	11.5	7.9		
219W	15.4	10.8	6.5	4.5	9.3	20.1	16.4	5.3	10.7	13.1	11.2	10.7	22.9	3.9	26.0	15.9	*	*	88.9	27.7	58.3	30.0		
243W	0.3	0.7	0.2	1.0	0.6	0.1	2.6	0.1	0.2	0.7	0.7													

^a Velocities collected 1 m below surface (S) and 1 m above river bed (B) at random points within each site quartile.

^b Site quartiles are: 1=0-25%; 2=26-50%; 3=51-75%; and 4=76-100% of site length.

^c Short transect; data collected in quartiles 1-2 (0-50% of site length) and quartiles 3-4 (51-100% of site length).

An asterisk (*) indicates velocities could not be measured due to shallow water.

Appendix 3; Table 2. Depth profiles (m) of sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000								March 2001							
	Distance from shore (m)							Site Mean	Distance from shore (m)							Site Mean
	5	10	15	20	30	40	50		5	10	15	20	30	40	50	
006E	0.4	0.8	1.6	3.0	5.2	7.5	10.4	4.1	0.4	0.5	1.2	2.2	3.7	6.1	7.9	3.2
010E	0.4	1.0	2.9	5.1	6.2	7.2	8.7	4.4								
012W	0.6	0.8	1.5	3.9	6.6	8.5	9.2	4.4								
031W	0.4	0.6	0.7	0.9	1.4	2.4	3.2	1.4								
040W ^a	0.5	0.5	0.7	1.1	1.7	3.5	7.7	2.2								
048E	14.8	14.7	15.0	15.6	16.3	18.0	19.6	16.3	13.7	13.7	13.6	13.6	14.4	15.1	16.5	14.4
051E	1.9	2.8	4.0	6.1	8.9	11.1	13.0	6.4	1.1	3.1	4.6	5.9	9.1	11.2	13.1	6.6
064W	0.7	2.5	6.2	9.0	12.1	14.5	15.1	8.6	0.9	1.7	3.3	4.8	7.9	10.9	12.1	5.9
079W	0.6	1.8	3.0	6.2	9.1	11.2	12.8	6.4	0.9	1.8	2.8	4.3	6.4	8.6	9.9	4.7
097E	0.6	0.8	1.3	1.5	2.5	3.8	5.1	2.2								
100W	3.3	4.9	6.3	7.1	7.4	8.3	8.9	6.6								
112E	2.2	4.1	6.4	10.9	12.4	13.4	14.8	9.2								
118W	3.0	6.1	8.9	12.6	15.6	17.3	17.7	12.0								
121W	11.1	11.0	12.3	14.9	16.8	16.9	17.5	14.4								
133W	0.5	1.0	1.3	1.6	2.0	2.3	2.5	1.6	0.8	1.5	1.8	2.0	2.6	2.9	3.2	2.1
136E	0.8	2.6	3.7	4.7	7.7	10.1	10.8	5.7	0.8	3.1	4.0	5.0	7.5	9.3	10.6	5.8
148E	0.5	1.4	2.7	3.7	4.8	6.0	6.9	3.7								
167W	0.2	1.3	3.1	4.9	8.2	9.7	12.9	5.8	0.4	1.1	1.6	3.3	4.9	7.5	9.8	4.1
200E	4.5	9.2	11.8	16.2	19.2	20.9	21.1	14.7								
203W	1.9	5.8	6.6	10.5	13.3	16.1	19.0	13.3	1.2	4.1	9.0	11.3	13.4	16.9	19.6	13.5
219W	12.3	18.5	19.0	21.8	20.0	17.9	21.9	18.8	4.5	8.8	13.4	14.4	18.6	20.2	17.1	13.9
243W	1.2	2.8	5.1	6.2	6.2	6.5	6.5	4.9								

^a Short site; data collected at 0, 50, and 100% of length.

Appendix 3; Table 3. Percent^a overhead cover (natural and artificial) of sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000						March 2001					
	Site Percentile (0=upstream)					Site mean	Site Percentile (0=upstream)					Site mean
0	25	50	75	100	0		25	50	75	100		
006E	0	0	0	0	0	0	0	0	0	0	0	0
010E	0	25	25	12	0	12						
012W	0	0	0	0	0	0						
031W	0	0	0	0	0	0						
040W	0		0		0	0						
048E	0	0	0	0	0	0	0	0	0	0	0	0
051E	50	0	12	25	12	20	25	0	12	12	12	12
064W	0	0	0	0	0	0						
079W	12	12	88	12	0	25						
097E	0	0	0	0	0	0						
100W	75	88	100	25	25	63						
112E	0	12	50	25	12	20						
118W	0	0	25	0	0	5						
121W	0	0	0	0	0	0						
133W	0	0	0	0	0	0						
136E	0	0	0	0	0	0						
148E	0	0	0	0	0	0						
167W	0	0	0	0	0	0						
200E	0	0	0	0	0	0						
203W	12	0	25	12	0	10	0	0	25	0	0	5
219W	0	0	0	0	0	0						
243W	0	0	0	0	0	0						

^a Mean percentage of overhead cover measured at seven points (0, 5, 10, 20, 30, 40, and 50 m from shore) at 0, 25, 50, 75, and 100 percentiles of the site length.

Appendix 3; Table 4. Mean^a temperatures (°C) of sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000											March 2001										
	Shore zone (0-25 m)					Shore zone (26-50 m)					Site mean	Shore zone (0-25 m)					Shore zone (26-50 m)					Site mean
	Site Quartile ^b				Mean	Site Quartile ^b				Mean		Site Quartile ^b				Mean	Site Quartile ^b				Mean	
1	2	3	4	1		2	3	4	1		2	3	4	1	2		3	4	1	2		3
006E	6.9	6.6	6.5	6.8	6.7	6.8	6.6	6.6	6.5	6.6	6.7	7.0		7.0	7.8	7.3	7.0	7.1	7.8	7.5	7.4	7.3
010E	6.6	6.5	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.5	6.5											
012W	6.5	6.5	6.5	6.4	6.5	6.5	6.5	6.5	6.5	6.5	6.5											
031W	6.6	6.6	6.6	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.6											
040W	6.6	6.7	6.5	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6											
048E	6.5	6.6	6.6	6.6	6.5	6.6	6.6	6.6	6.6	6.6	6.6	9.1	9.1	9.1	9.2	9.1	9.1	9.1	9.1	9.1	9.1	9.1
051E	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	9.3	9.3	9.3	9.3	9.3		9.2	9.2	9.2	9.2	9.3
064W	7.4	7.4	7.5	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	10.0	10.0	9.9	10.0	10.0	9.8	9.8	9.9	9.9	9.9	9.9
079W	7.3	7.4	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	9.9	9.8	10.0	10.0	9.9	9.8	9.9	10.0	9.9	9.9	9.9
097E	7.0				7.0	6.9	7.0		7.0	7.0	7.0											
100W	6.8	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9											
112E	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4											
118W	6.8	6.8	6.8	6.7	6.8	6.8	6.8	6.8	6.8	6.8	6.8											
121W	6.8	6.8	6.8	6.8	6.8	6.7	6.8	6.8	6.7	6.7	6.8											
133W				6.9	6.9		6.8	6.8	6.8	6.8	6.8						10.0	10.0	10.0	9.9	10.0	10.0
136E	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	10.3	10.4	10.2	10.2	10.3	10.1	10.1	10.1	10.1	10.1	10.2
148E	7.4	7.4	7.3	7.3	7.4	7.4	7.4	7.3	7.4	7.4	7.4											
167W	7.4	7.4		7.5	7.5	7.4	7.5	7.5	7.5	7.5	7.5	10.2	10.3	10.4		10.3	10.2	10.2	10.2	10.2	10.2	10.2
200E	7.3	7.3	7.3	7.4	7.3	7.3	7.3	7.3	7.3	7.3	7.3											
203W	7.3	7.4	7.4	7.4	7.4	7.3	7.4	7.4	7.4	7.4	7.4	9.3	9.2	9.4	9.4	9.3	9.4	9.3	9.3	9.3	9.3	9.3
219W	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
243W	7.4	7.5	7.5	7.5	7.4	7.4	7.5	7.5	7.5	7.5	7.4											

^a Mean of measurements at 1 m below surface, mid-column, and 1 m above river bed at random points in each site quartile.

^b Site quartiles are: 1=0-25%; 2=26-50%; 3=51-75%; and 4=76-100% of site length.

Appendix 3; Table 5. Mean^a conductivities (micro seimens) of sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000											March 2001										
	Shore zone (0-25 m)					Shore zone (26-50 m)					Site mean	Shore zone (0-25 m)					Shore zone (26-50 m)					Site mean
	Site Quartile ^b					Site Quartile ^b						Site Quartile ^b					Site Quartile ^b					
1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	Mean			
006E	0.12	0.11	0.11	0.12	0.11	0.12	0.11	0.11	0.11	0.11	0.11	0.15	0.14	0.13	0.14	0.14	0.14	0.14	0.12	0.13	0.13	0.14
010E	0.11	0.10	0.10	0.10	0.10	0.11	0.10	0.10	0.10	0.10	0.10											
012W	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10											
031W	0.09	0.10	0.09	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09											
040W	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09											
048E	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09
051E	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
064W	0.11	0.11	0.13	0.12	0.12	0.11	0.11	0.12	0.12	0.12	0.12	0.09	0.08	0.09	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.08
079W	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.07	0.07	0.07
097E	0.07				0.07	0.07	0.08		0.08	0.07	0.07											
100W	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08											
112E	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08											
118W	0.08	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08											
121W	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07											
133W				0.08	0.08		0.08	0.07	0.07	0.07	0.08					0.06	0.06	0.06	0.06	0.06	0.06	0.06
136E	0.07	0.07	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
148E	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08											
167W	0.08	0.08		0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
200E	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08											
203W	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
219W	0.08	0.08	0.07	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
243W	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08											

^a Mean of measurements at 1 m below surface, mid-column, and 1 m above river bed at random points within each site quartile.

^b Site quartiles are: 1=0-25%; 2=26-50%; 3=51-75%; and 4=76-100% of site length.

Appendix 3; Table 6. Mean^a dissolved oxygen (ppm) of sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000											March 2001										
	Shore zone (0-25 m)					Shore zone (26-50 m)					Site mean	Shore zone (0-25 m)					Shore zone (26-50 m)					Site mean
	Site Quartile ^b					Site Quartile ^b						Site Quartile ^b					Site Quartile ^b					
1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	Mean			
006E	13.4	10.7	10.7	11.0	11.5	11.3	11.0	10.9	10.8	11.0	11.2	10.8	10.4	10.2	10.5	10.3	10.8	10.0	10.2	10.3	10.4	
010E	10.7	11.0	11.1	11.0	10.9	10.8	10.9	10.9	11.0	10.9	10.9											
012W	10.9	10.9	11.0	10.9	10.9	10.6	11.0	10.9	10.9	10.8	10.9											
031W	11.2	11.1	11.1	11.5	11.2	11.2	11.2	11.1	11.1	11.1	11.2											
040W	11.1	11.1	11.0	11.0	11.1	11.0	11.1	11.0	11.1	11.0	11.1											
048E	11.1	12.0	11.1	11.0	11.3	11.0	11.1	11.1	11.0	11.1	11.2	9.0	8.9	8.9	8.9	8.9	8.9	8.8	8.9	8.9	8.9	8.9
051E	11.2	11.1	11.1	11.0	11.1	11.1	11.0	11.0	11.1	11.0	11.1	8.9	8.6	8.7	8.7	8.7	9.0	8.8	9.1	9.0	8.8	
064W	11.6	11.4	11.3	11.3	11.4	11.4	11.4	11.3	11.3	11.4	11.4	8.8	8.8	8.8	8.9	8.8	8.8	8.8	9.0	8.9	8.8	
079W	11.0	11.3	11.2	11.1	11.1	11.1	11.2	11.2	11.2	11.2	11.2	9.0	8.8	8.8	8.6	8.8	8.8	8.7	8.8	8.8	8.8	8.8
097E	11.1				11.1	11.0	11.1		11.0	11.0	11.1											
100W	11.0	11.0	11.0	10.9	11.0	11.0	11.0	11.0	11.3	11.0	11.0											
112E	11.5	11.6	11.8	11.3	11.5	11.4	11.5	11.4	11.5	11.4	11.5											
118W	11.2	11.2	11.1	11.1	11.1	11.1	11.2	11.1	11.4	11.2	11.2											
121W	11.4	11.3	11.2	11.4	11.3	11.3	11.2	11.2	11.2	11.2	11.3											
133W				11.2	11.2		13.4	11.2	11.2	11.9	11.8			8.8	8.8	8.8	8.6	8.9	8.8	8.8	8.8	8.8
136E	11.6	11.2	11.5	11.3	11.4	11.6	11.2	11.4	11.3	11.4	11.4	8.7	8.8	8.7	8.6	8.7	9.0	8.9	8.8	8.7	8.9	8.8
148E	10.4	10.3	10.3	10.2	10.3	10.4	10.4	10.2	10.3	10.3	10.3											
167W	10.5	10.4		10.3	10.4	10.5	11.4	11.4	11.3	11.2	10.8	8.7	8.7	9.2		8.9	8.7	8.7	8.7	8.7	8.7	8.8
200E	10.6	10.4	10.5	10.4	10.4	10.5	10.4	10.5	10.5	10.5	10.4											
203W	10.6	10.4	10.4	10.4	10.5	10.5	10.4	10.4	10.4	10.4	10.5	9.3	9.2	9.4	9.4	9.3	9.4	9.3	9.3	9.3	9.3	9.3
219W	10.7	10.5	10.5	10.7	10.6	10.6	10.4	10.6	10.6	10.5	10.6	9.2	9.2	9.0	9.0	9.1	9.0	9.1	9.3	9.0	9.1	9.1
243W	10.9	10.7	10.6	10.6	10.7	10.6	10.6	10.6	10.4	10.5	10.6											

^a Mean of measurements at 1 m below surface, mid-column, and 1 m above river bed at random points within each site quartile.

^b Site quartiles are: 1=0-25%; 2=26-50%; 3=51-75%; and 4=76-100% of site length.

Appendix 3; Table 7. Mean^a water column clarity (cm) of sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000										Site mean	March 2001										Site mean
	Shore zone (<15 m)					Shore zone (>15 m)						Shore zone (<15 m)					Shore zone (>15 m)					
	Site Quartile ^b				Mean	Site Quartile ^b				Mean		Site Quartile ^b				Mean	Site Quartile ^b				Mean	
1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	Mean			
006E	*	*	*	85	85	96	108	115	119	110	105	*	*	*	120	120	125	100	*	114	113	115
010E	*	*	*	*	150	131	142	170	158	150	150											0
012W	*	*	*	*	110	120	107	106	107	110	110											0
031W	*	*	*	*	131	127	137	118	142	131	131											0
040W	*	*			159	161	156			159	159											0
048E	142	147	145	162	149	158	155	148	155	154	151	168	165	148	154	159	153	154	114	150	143	151
051E	*	162	168	141	157		172	175	169	172	165	113	*	117	120	117		156	114	162	144	130
064W	149	150	155	151	151	171	159	175	165	168	159	*	*	*	*		107	120	112	102	110	110
079W	181		151	145	159	154	147	144	178	156	157	*	*	*	*		112	111	95	132	113	113
097E	*	*	*		162	162	160	164	163	162	162											
100W	110	138	178	149	144	185	163	152	187	172	158											
112E	158	152	160	154	156	123	165	144	141	143	150											
118W	169	153	169	131	156	103	143	146	155	137	146											
121W	*	*	*	*	161	174	179	137	152	161	161											
133W	*	*	*	100	100	110	140	115	129	124	119	*	*	*	*		112	119	112	131	119	119
136E	154	146	160	165	156	173	165	156	161	164	160	*	*	*	*		108	111	101	117	109	109
148E	*	173	*	*	173	170	178	166	194	177	176											
167W	188	217	215	180	200	241	276	242	270	257	229	*	*	*	*		97	107	90	*	98	98
200E	173	160	159	174	167	153	165	166	162	162	164											
203W	148	138	154	142	146	170	158	157	157	161	153	116	103	99	*	106	96	97	95	114	101	103
219W	217	201	199	140	189	236	199	210	201	212	200	95	124	125	131	119				127	127	120
243W	181	175	197	201	189	176	172	222	195	191	190											

^a Average depth of a 20.0 cm secchi disk appearance and reappearance measured in shade at random points within each site quartile.

^b Site quartiles are: 1=0-25%; 2=26-50%; 3=51-75%; and 4=76-100% of site length.

* Water clarity exceeded depth; data not recorded.

Appendix 3; Table 8. Mean shoreline substrate composition (%) of sampling sites in the lower Willamette River, November 2001.

Site	Sand and gravel (<64 mm)	Natural rock (>64 mm)	Small riprap (65-256 mm)	Large riprap (257-512 mm)	Boulders (>513 mm)	Bedrock	Seawall	Artificial fill (concrete, etc.)	% "Natural"
006E ^a	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
010E ^a	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
012W ^a	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0
031W	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
040W	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
048E ^a	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0
051E	0.0	0.0	12.5	87.5	0.0	0.0	0.0	0.0	0
064W ^a	37.5	0.0	25.0	37.5	0.0	0.0	0.0	0.0	38
079W ^a	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0
097E	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
100W	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0
112E	0.0	0.0	31.3	56.3	0.0	0.0	0.0	12.5	0
118W	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0
121W ^a	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0
133W ^a	75.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	75
136E ^a	0.0	0.0	25.0	75.0	0.0	0.0	0.0	0.0	0
148E ^a	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
167W ^a	83.3	0.0	8.3	8.5	0.0	0.0	0.0	0.0	83
200E	0.0	12.5	0.0	0.0	0.0	87.5	0.0	0.0	100
203W	25.0	0.0	0.0	0.0	0.0	75.0	0.0	0.0	100
219W ^a	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	100
243W	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100

Appendix 3; Table 9. Estimated percent of shoreline vegetation types of sampling sites in the Lower Willamette River, October 2000.

Site	No vegetation					Grasses					Forbes					Shrubs					Trees					Score ^b
	Site Percentile ^a					Site Percentile ^a					Site Percentile ^a					Site Percentile ^a					Site Percentile ^a					
	0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	0	25	50	75	100	
006E	100	100	100	100	100																				0.0	
010E	100	100	100	100	50								50												2.5	
012W	90	80	85	75	95	5	10	5	10	5	5	10	10		5					5			5		3.8	
031W	100	100	90	90	100				10	10															1.0	
040W	100		100		100																				0.0	
048E	100	100	100	100	100																				0.0	
051E	75	90	100	80	90	5			5	10	10		15		20										3.3	
064W	100	100	100	100	100																				0.0	
079W	94	98	99	100	95						5	1				1	1	1		5					0.7	
097E	70	100	100	100	99										30					1					1.6	
100W	100	100	100	100	100																				0.0	
112E	90	95	90	60	60	5					5	10			5				40	40					5.3	
118W	95	75	100	50	95	5	5					20							50	5					4.3	
121W	100	100	100	100	100																				0.0	
133W	100	100	100	100	100																				0.0	
136E	99	90	80	80	90						1		20	20				10					10		3.1	
148E	100	100	100	100	99																		1		0.1	
167W	99	99	100	100	100	1						1													0.1	
200E	100	90	80	100	95			10	10		5			10											1.8	
203W	75	70	70	90	99	20			10			5	20	20	10	1		10							4.8	
219W	99	99	99	98	99					1		1	1	1	1	1									0.3	
243W	95	100	100	100	100							5													0.3	

^a 0=Upstream, 100=Downstream.

^b Vegetation score is the sum of vegetation percentages (excluding no-vegetation) divided by 20.

Appendix 3; Table 10. Bank slope^a (degrees) of sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000						March 2001					
	Site Percentile (0=upstream)					Site mean	Site Percentile (0=upstream)					Site mean
	0	25	50	75	100		0	25	50	75	100	
006E	4	5	6	6	6	5	3	6	8	7	7	6
010E	7	14	6	6	3	7						
012W	12	10	12	12	2	10						
031W	4	4	4	7	7	5						
040W ^b	6		6		6	6						
048E	90	90	90	90	90	90	90	90	90	90	90	90
051E	23	23	23	23	23	23	21	17	18	26	21	21
064W	15	18	5	8	14	12						
079W	13	15	15	18	22	17						
097E	7	7	7	8	8	7						
100W	28	28	24	24	24	26						
112E	29	31	27	31	37	31						
118W	14	16	22	14	22	18						
121W	90	90	90	90	90	90						
133W	4	13	8	18	22	13						
136E	12	16	22	32	33	23						
148E	5	6	9	5	8	7						
167W	12	6	3	5	3	6						
200E	42	33	9	25	28	27						
203W	32	26	26	23	10	23						
219W	14	14	25	32	18	21						
243W	12	16	9	8	6	10						

^a Angle of river bank measured 10 m upslope from waterline.

^b Short site; data collected at 0, 50, and 100th percentiles.

Appendix 3; Table 11. Number of pilings within sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000										March 2001														
	Shore zone (0-25 m)					Shore zone (26-50 m)					Site Sum	Shore zone (0-25 m)					Shore zone (26-50 m)					Site Sum			
	Site Quartile ^a					Site Quartile ^a						Site Quartile ^a					Site Quartile ^a								
1	2	3	4	Sum	1	2	3	4	Sum	1	2	3	4	Sum	1	2	3	4	Sum	1	2	3	4	Sum	Site Sum
006E	0	0	0	0	0	5	0	0	0	5	5	0	0	0	0	0	5	0	0	0	0	5	5		
010E	0	4	20	263	287	59	49	75	66	249	536														
012W	0	0	4	0	4	0	0	0	0	0	4														
031W	8	5	0	0	13	0	0	0	0	0	13														
040W	0	0	0	0	0	0	7	0	0	7	7														
048E	36	45	36	39	156	0	0	0	0	0	156	35	42	36	39	152	0	0	0	0	0	0	152		
051E	4	6	14	14	38	1	27	20	0	48	86	6	4	15	15	40	0	29	14	0	43	83			
064W	0	0	0	0	0	0	0	0	0	0	0														
079W	19	6	24	0	49	0	53	66	8	127	176														
097E	0	0	0	0	0	0	0	0	0	0	0														
100W	40	17	27	49	133	25	19	46	0	90	223														
112E	0	31	0	25	56	28	10	36	39	113	169														
118W	3	10	12	5	30	0	0	2	0	2	32														
121W	3	0	0	0	3	0	0	0	0	0	3														
133W	0	5	0	0	5	0	0	0	0	0	5														
136E	0	0	0	0	0	0	0	0	0	0	0														
148E	2	22	0	0	24	0	0	0	0	0	24														
167W	0	0	0	0	0	0	0	0	0	0	0														
200E	0	3	0	0	3	0	0	0	0	0	3														
203W	20	16	16	20	72	0	0	0	0	0	72														
219W	0	0	0	0	0	0	0	0	0	0	0														
243W	0	0	0	0	0	0	0	0	0	0	0														

^a Site quartiles are: 1=0-25%; 2=26-50%; 3=51-75%; and 4=76-100% of site length.

Appendix 3; Table 12. Number of outfalls (pipes) entering sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000										March 2001											
	Active					Inactive					Site sum	Active					Inactive					Site sum
	Site Quartile ^a					Site Quartile ^a						Site Quartile ^a					Site Quartile ^a					
1	2	3	4	Sum	1	2	3	4	Sum	1	2	3	4	Sum	1	2	3	4	Sum			
006E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
010E	0	0	0	0	0	0	1	0	2	3	3											
012W	0	0	0	0	0	0	0	0	0	0	0											
031W	0	0	0	0	0	0	0	0	0	0	0											
040W	0	0	0		0	0	0	0		0	0											
048E ^b	0	0	0	0	0	24	27	35	33	119	119	9	9	12	8	38	15	18	23	25	81	119
051E	0	0	0	0	0	0	2	4	7	13	13		0	0	0	0		3	5	5	13	13
064W	0	0	0	0	0	0	0	0	0	0	0											
079W	0	0	0	0	0	0	0	0	0	0	0											
097E	0	0	0	0	0	0	0	0	0	0	0											
100W	0	0	0	1	1	0	0	0	0	0	1											
112E	0	0	0	0	0	1	0	1	0	2	2											
118W	0	0	0	0	0	1	1	0	0	2	2											
121W	0	0	0	1	1	23	28	19	23	93	94											
133W	0	0	0	0	0	0	0	0	0	0	0											
136E	0	0	0	0	0	0	0	0	0	0	0											
148E	0	0	0	0	0	0	0	0	0	0	0											
167W	0	0	0	0	0	0	0	0	0	0	0											
200E	0	0	0	0	0	0	0	1	0	1	1											
203W	0	0	0	0	0	0	0	0	0	0	0											
219W	0	0	0	0	0	0	0	0	0	0	0											
243W	0	0	0	0	0	0	0	0	0	0	0											

^a Site quartiles are: 1=0-25%; 2=26-50%; 3=51-75%; and 4=76-100% of site length.

^b Overhead parking lot drainage pipes.

Appendix 3; Table 13. Minimum distance (m) to nearest impervious surface adjacent to sampling sites in the lower Willamette River, October 2000 and March 2001.

Site	October 2000						March 2001					
	Site Percentile (0=upstream)					Site mean	Site Percentile (0=upstream)					Site mean
	0	25	50	75	100		0	25	50	75	100	
006E	250	250	250	150	131	206	250	250	250	150	60	192
010E	34	28	46	28	28	33						
012W	250	250	250	250	250	250						
031W	250	250	250	250	250	250						
040W ^a	250		250		250	250						
048E	0	0	0	0	0	0	0	0	0	0	0	0
051E	22	18	18	18	19	19	16	16	16	16	16	16
064W	23	23	23	23	23	23						
079W	27	27	24	28	20	25						
097E	22	38	37	29	35	32						
100W	12	12	12	12	12	12						
112E	24	15	15	15	15	17						
118W	20	15	5	10	5	11						
121W	0	0	0	0	0	0						
133W	80	53	24	29	33	44						
136E	45	45	39	30	30	38						
148E	250	250	98	250	250	220						
167W	70	76	68	88	114	83						
200E	65	67	61	86	250	106						
203W	30	10	10	15	27	18						
219W	250	250	250	250	250	250						
243W	250	250	250	250	124	225						

^a Short transect; data collected at 0, 50, and 100th percentiles.

Appendix 3; Table 14. Nighttime artificial light intensities (Lux^a) at sampling sites in the lower Willamette River, October 2000.

Site	Shore zone (0-25 m)					Shore zone (26-50 m)					Site mean
	Site Quartile ^b					Site Quartile ^b					
	1	2	3	4	Mean	1	2	3	4	Mean	
006E	3	2	3	3	2.8	3	3	3	3	3.0	2.9
010E	7	8	7	4	6.5	7	10	5	3	6.3	6.4
012W	3	3	3	3	3.0	3	3	3	3	3.0	3.0
031W				4	4.0	3	3	4	3	3.3	3.4
040W	3				3.0	3		3		3.0	3.0
048E	7	8	7	14	9.0	7	6	7	8	7.0	8.0
051E	4	5	4	25	9.5	3	4			3.5	7.5
064W	3	3	4	4	3.5	3	2	5	3	3.3	3.4
079W	4		10	6	6.7	4	48	6	4	15.5	11.7
097E	2	2	2	2	2.0	3	1	2	1	1.8	1.9
100W	3	3	3	3	3.0	4	3	2	3	3.0	3.0
112E	3	1	2	1	1.8	3	2	2	3	2.5	2.1
118W	3	3	3	5	3.5	2	2	3	3	2.5	3.0
121W	9	4	4	14	7.8	3	4	4	5	4.0	5.9
133W	3	4	3	5	3.8	3	3	2	4	3.0	3.4
136E	3	4	4	3	3.5	2	4	3	3	3.0	3.3
148E	3	3	3	2	2.8	3	3	3	1	2.5	2.6
167W	3	3	3	3	3.0	3	3	3	3	3.0	3.0
200E	3	3	3	3	3.0	3	3	3	3	3.0	3.0
203W	4			4	4.0	3	4	12	4	5.8	5.2
219W	3	3	3	4	3.3	3	3	3	4	3.3	3.3
243W	3	3	3	3	3.0	3	3	3	3	3.0	3.0

^a Lux: equals one lumen/m² or illumination on a surface one meter from a point source of one candle intensity.

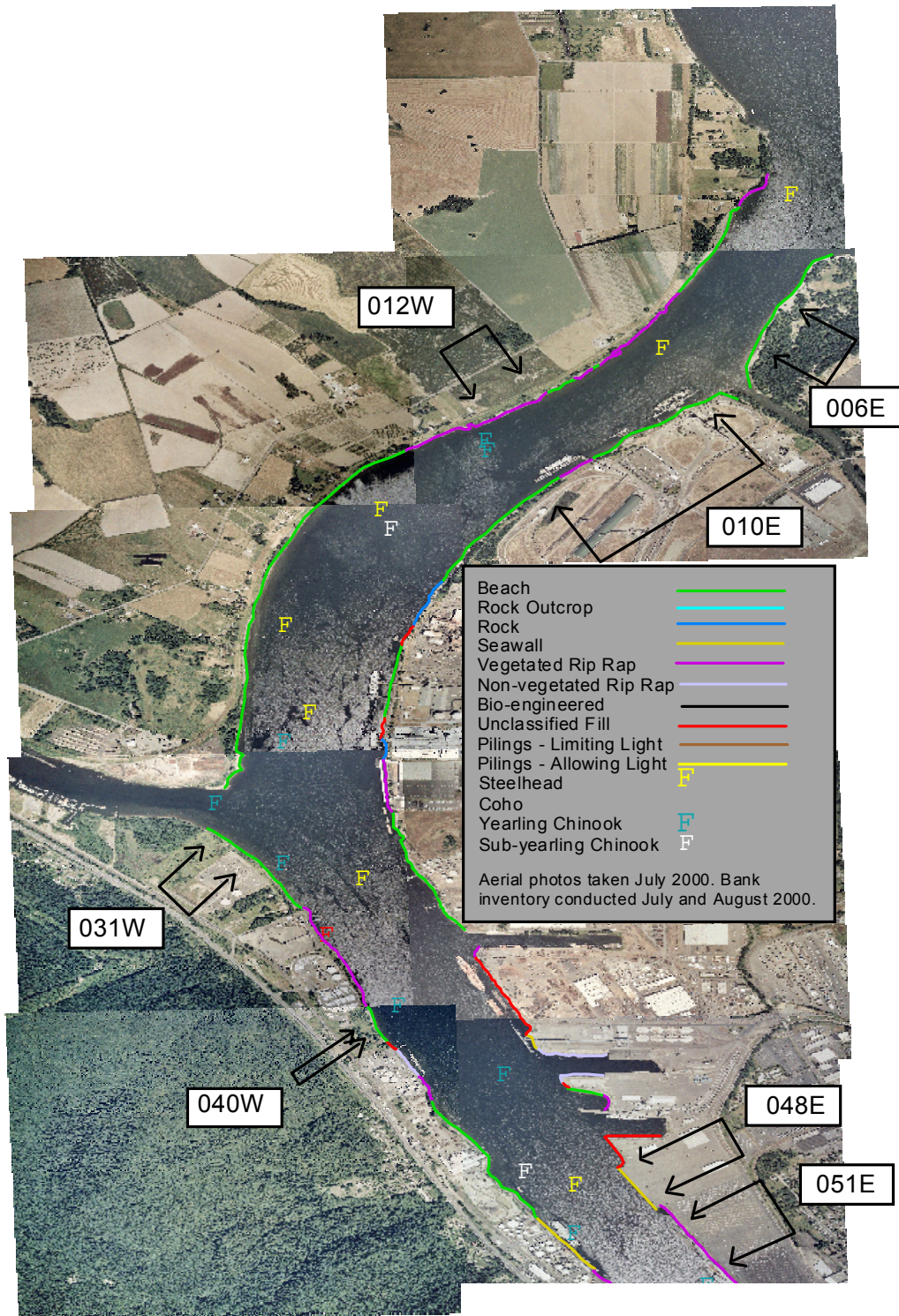
^b Site quartiles are: 1=0-25%; 2=26-50%; 3=51-75%; and 4=76-100% of site length.

Appendix 3; Table 15. Mean habitat parameter values of sampling sites in the lower Willamette River, October-November 2000.

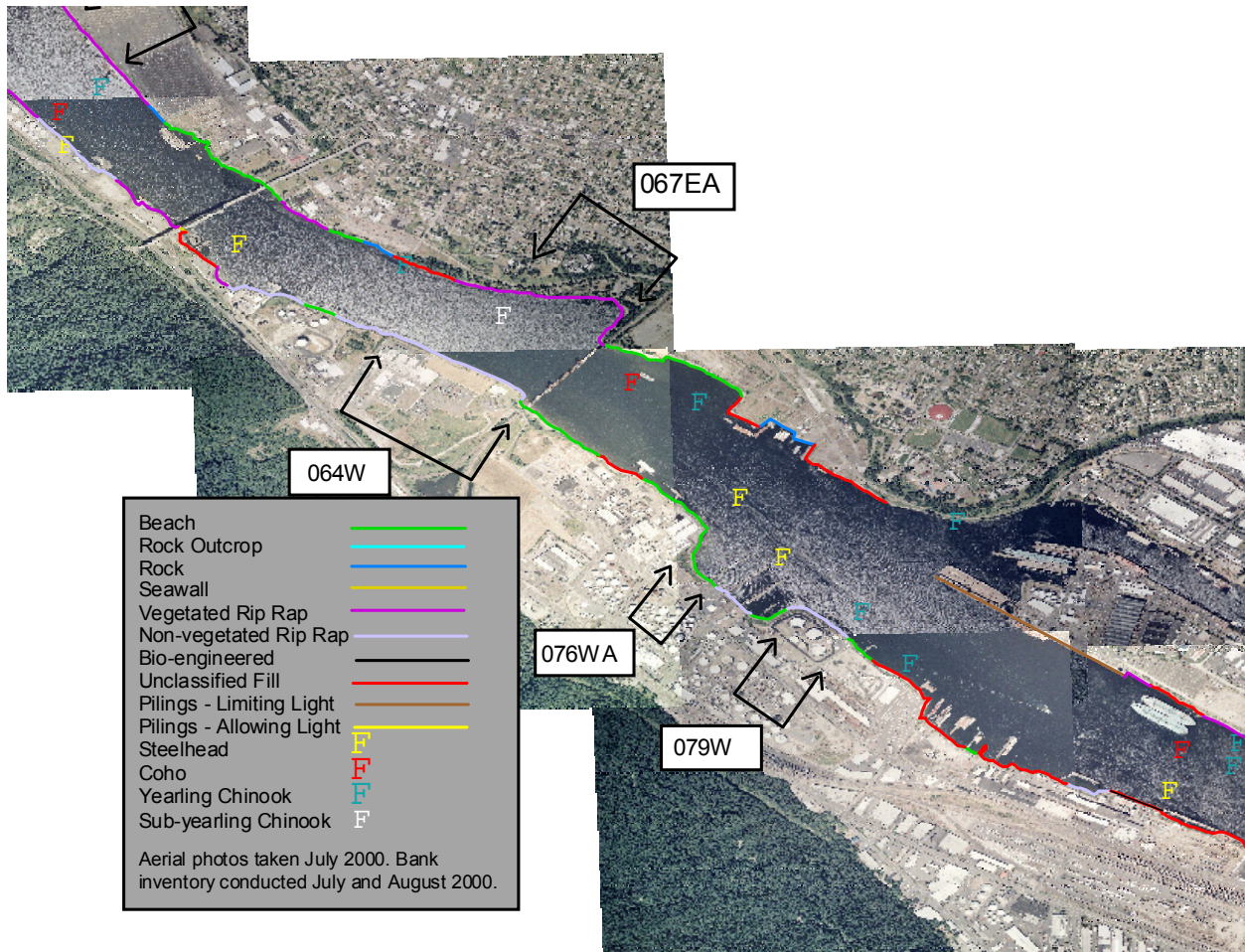
Site	Velocity (cm/s)	Depth (m)	Overhead cover (%)	Temperature (C)	Conductivity (microseimens)	Dissolved oxygen (ppm)	Transparency (cm)	Shoreline substrate (% natural)	Vegetative score	Bank slope (degrees)	Pilings (#)	Outfalls (#)	Buffer width (m)	Artificial light (Lux)
006E	4.7	4.1	0.0	6.7	0.11	11.2	105	100	0.0	5	5	0	206	2.9
010E	6.7	4.4	12.4	6.5	0.10	10.9	150	100	2.5	7	536	3	33	6.4
012W	6.3	4.4	0.0	6.5	0.10	10.9	110	0	3.8	10	4	0	250	3.0
031W	16.4	1.4	0.0	6.6	0.09	11.2	131	100	1.0	5	13	0	250	3.4
048E	2.8	16.3	0.0	6.6	0.09	11.2	151	0	0.0	90	156	119	0	8.0
051E	6.2	6.4	19.8	6.6	0.09	11.1	165	0	3.3	23	86	13	19	7.5
064W	2.8	8.6	0.0	7.4	0.12	11.4	159	38	0.0	12	0	0	23	3.4
079W	1.7	6.4	24.7	7.3	0.10	11.2	157	0	0.7	17	176	0	25	11.7
100W	1.4	6.6	62.5	6.9	0.08	11.0	158	0	0.0	26	223	1	12	3.0
112E	1.8	9.2	19.8	7.4	0.08	11.5	150	0	5.3	31	169	2	17	2.1
118W	5.1	12.0	5.0	6.8	0.08	11.2	146	0	4.3	18	32	2	11	3.0
121W	9.9	14.4	0.0	6.8	0.07	11.3	161	0	0.0	90	3	94	0	5.9
133W	2.3	1.6	0.0	6.8	0.08	11.8	119	75	0.0	13	5	0	44	3.4
136E	3.2	5.7	0.0	6.8	0.07	11.4	160	0	3.1	23	0	0	38	3.3
148E	3.5	3.7	0.0	7.4	0.08	10.3	176	100	0.1	7	24	0	220	2.6
167W	0.3	5.8	0.0	7.5	0.08	10.8	229	83	0.1	6	0	0	83	3.0
200E	14.6	14.7	0.0	7.3	0.08	10.4	164	100	1.8	27	3	1	106	3.0
203W	4.0	13.3	9.8	7.4	0.08	10.5	153	100	4.8	23	72	0	18	5.2
219W	11.2	18.8	0.0	7.3	0.07	10.6	200	100	0.3	21	0	0	250	3.3

APPENDIX 4

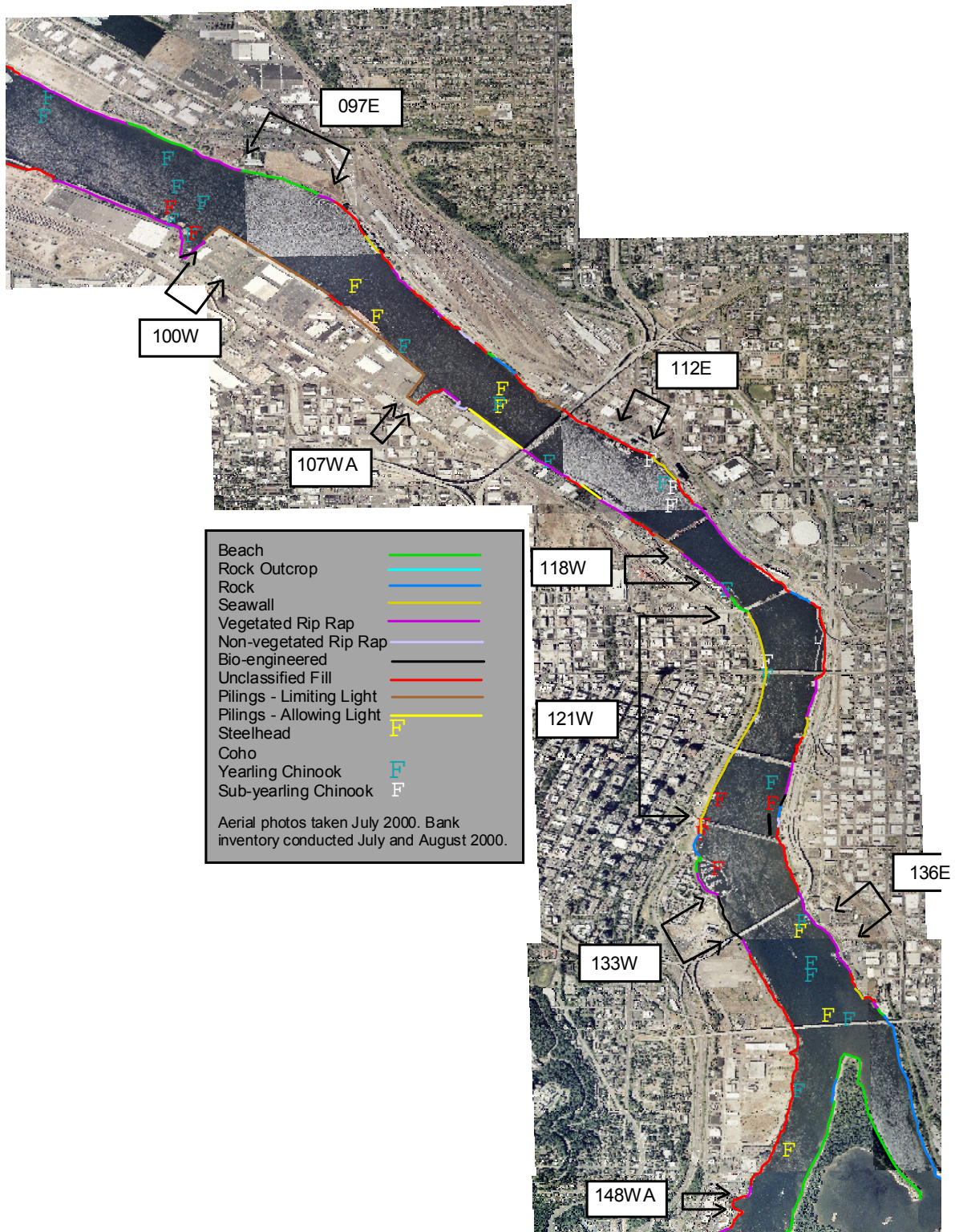
Aerial Photographs of Sampling Sites, Bank Treatment Type, and Relocations of Radiotagged Juvenile Salmonids



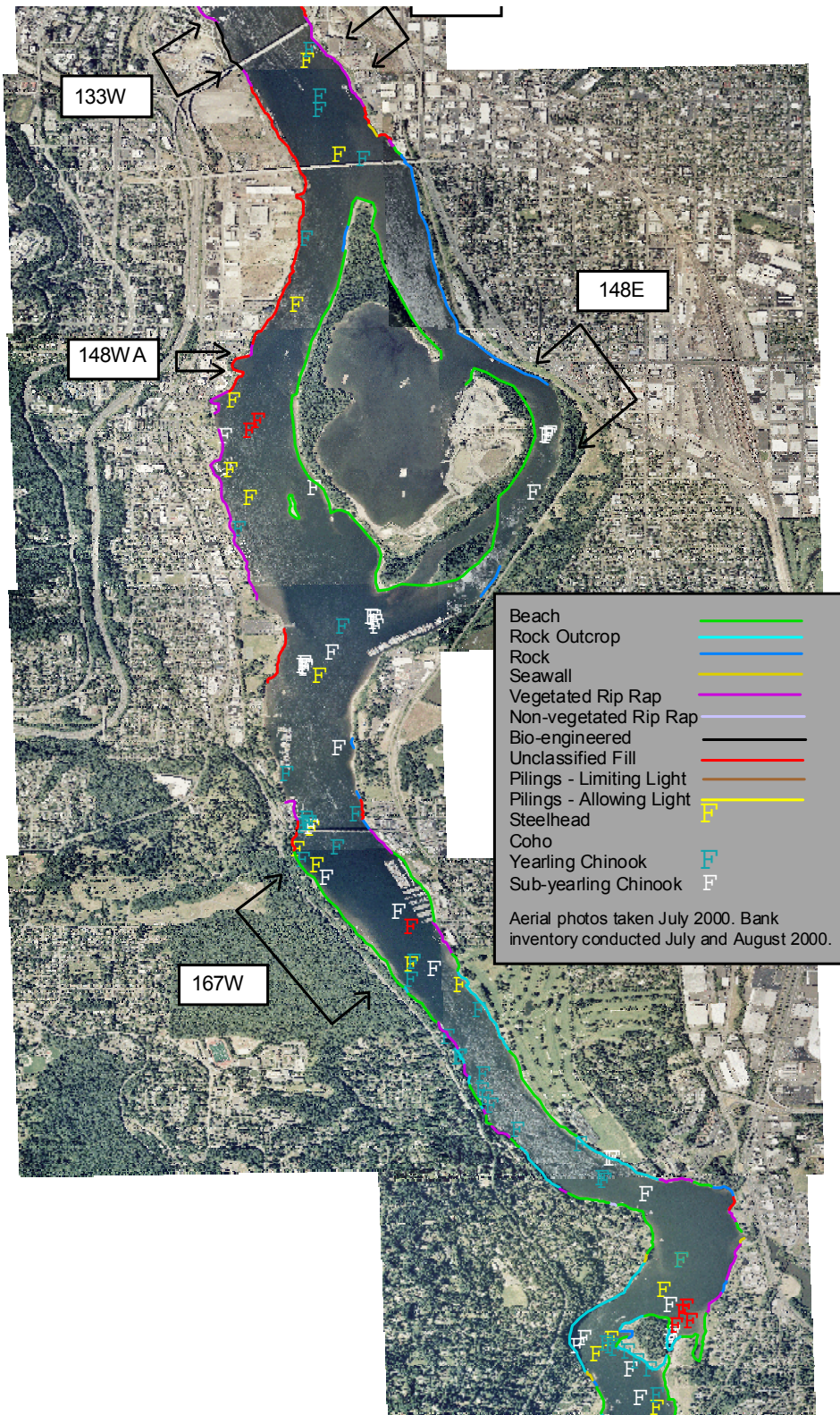
Appendix 4; Figure 1. Lower Willamette River sampling sites, bank treatment types, and recoveries of radiotagged juvenile salmonids, river miles 0-5.



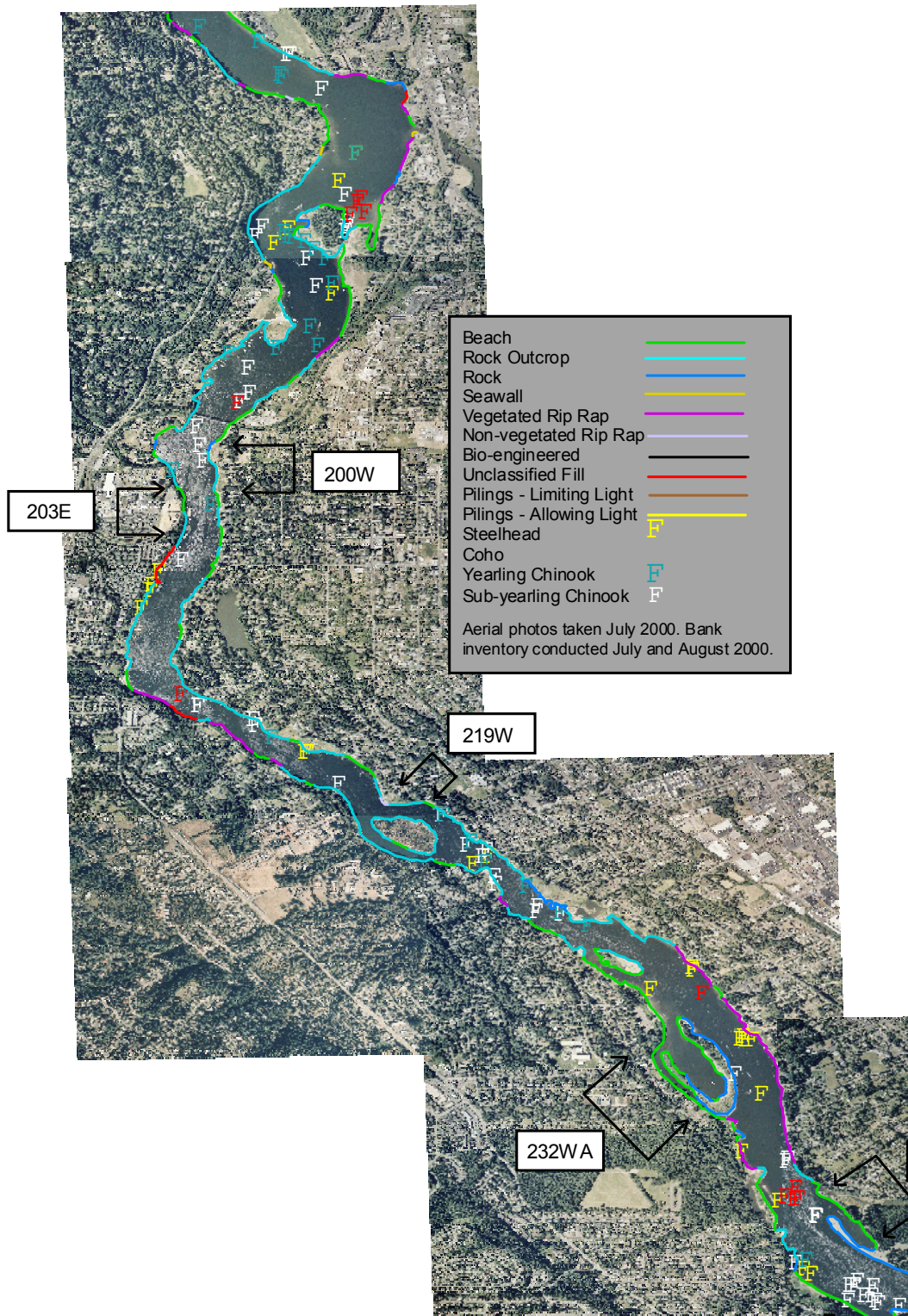
Appendix 4; Figure 2. Lower Willamette River sampling sites, bank treatment types, and recoveries of radiotagged juvenile salmonids, river miles 5-9.



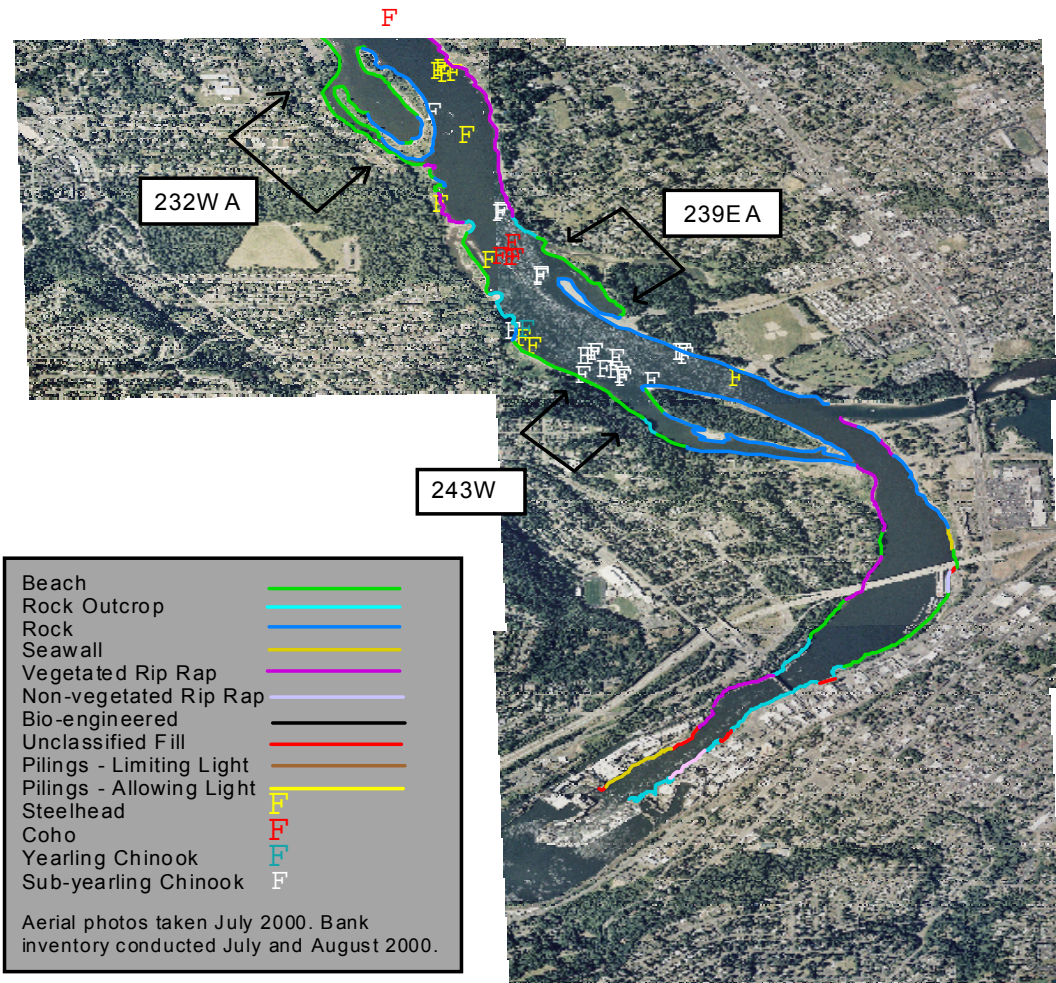
Appendix 4; Figure 3. Lower Willamette River sampling sites, bank treatment types, and recoveries of radiotagged juvenile salmonids, river miles 9-15.



Appendix 4; Figure 4. Lower Willamette River sampling sites, bank treatment types, and recoveries of radiotagged juvenile salmonids, river miles 15-19.



Appendix 4; Figure 5. Lower Willamette River sampling sites, bank treatment types, and recoveries of radiotagged juvenile salmonids, river miles 19-24.



Appendix 4; Figure 6. Lower Willamette River sampling sites, bank treatment types, and recoveries of radiotagged juvenile salmonids, river miles 23-25.