Habitat use by juvenile salmon in the Columbia River estuary:
Columbia River Channel Improvement Project research

Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

by
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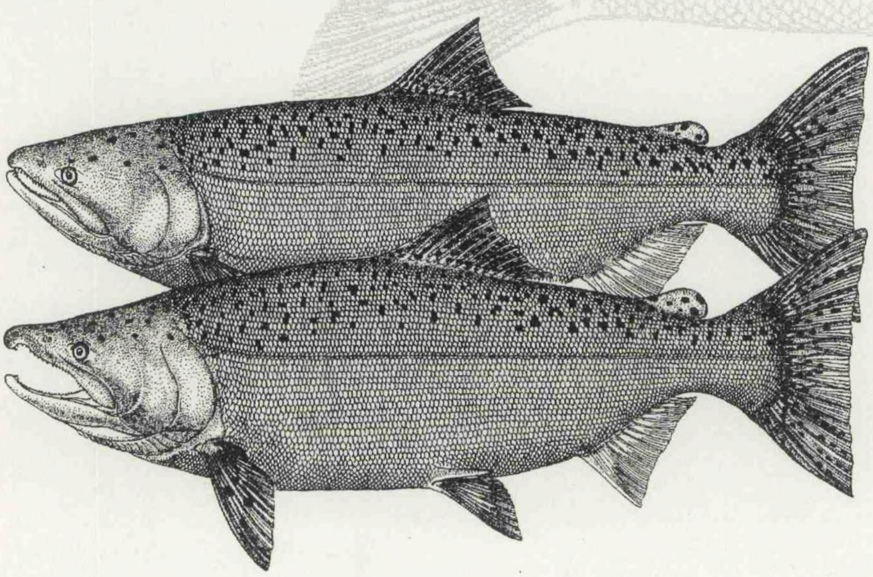
December 2005



Habitat use by Juvenile Salmon in the Columbia River Estuary: Columbia River Channel Improvement Project Research

Anna N. Kagley, Kurt Fresh, Susan Hinton, G. Curtis Roegner, Daniel L. Bottom, and Edmundo Casillas

Report of research by

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EXECUTIVE SUMMARY

Beach seine surveys to examine fish community composition were conducted at six sites near the oligohaline/euryhaline transition zone of the Columbia River estuary within Cathlamet and Grays Bays (RM 22-25) during September 2003 and May, July, and August 2004. Three sites (2004 only) were also sampled in the tidal freshwater zone of the estuary near Wallace Island, Oregon (RM 46-48). Beach-seine sites were selected within each zone to represent relative degrees of exposure to tidal currents and wave energy (exposed, semi-exposed, or protected) based on proximity to the deep shipping channel and on topographic features that could dampen water velocities (e.g., peripheral embayments, island complexes, and backwater areas).

Beach-seine catch was sorted on location. We measured and released a representative sample of each salmonid (n = 100) and non-salmonid (n = 30) species. Fish exceeding this sample number were counted and released. We also measured temperature, salinity, dissolved oxygen, and pH at both sub-surface and near-bottom locations. At the time of sampling, salinity at all sites was at or near zero. Temperatures at both groups of sites averaged approximately 15.0, 22.0, and 22.5°C in May, July, and August, respectively.

We collected 17 species of fish totaling 49,367 individuals. Of these, over 1,500 were juvenile Chinook salmon. Species composition and individual species abundance varied by location and date, with little apparent pattern and no obvious relationship to the a priori site classification based on apparent exposure or protection from tidal currents and wave energy. Threespine stickleback accounted for over 91% of the total catch. Excluding sticklebacks, Chinook salmon comprised >50% of the numerical abundance in 17 of 33 samples.

Chinook salmon used shallow near-shore habitats extensively throughout both survey zones and were found at all sites except north and south Wallace Island in August 2004. Mean salmon length and weight increased with time from spring to summer. In addition, mean sizes increased as fish moved downstream from the Wallace Island sites toward sites in Cathlamet/Grays Bay. And although not significant, salmonids showed a pattern of being smaller at the exposed compared to the protected sites from Cathlamet/Grays Bay.

A maximum of 35 individual juvenile Chinook per site for each month sampled were randomly selected for laboratory analyses to compliment other ongoing studies. Of these, 30 fish were retained for determination of genetic composition from fin clips, stomach content analyses, scale and otolith analyses, and the presence/absence of external abnormalities and/or parasites. The remaining five fish will be analyzed for polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and other chemical contaminant burdens from tissue, liver, and stomach contents. All laboratory samples are currently being processed, and data will be compared with similar results from other estuarine habitats sampled as part of an ongoing monitoring program of the U.S. Army Corps of Engineers and NOAA Fisheries.

CONTENTS

EXECUTIVE SUMMARY iii

INTRODUCTION 1

STUDY SITE 2

METHODS 5

RESULTS 7

CONCLUSIONS 35

ACKNOWLEDGEMENTS 36

REFERENCES 37

INTRODUCTION

Estuaries are important rearing grounds for a wide range of fish species, including ocean-migrating juvenile salmonids. The Columbia River is home to multiple stocks of salmonids, including 12 listed under the Endangered Species Act. All salmonids must pass through the Columbia River estuary during their migration to ocean feeding grounds. As a result, there has been a great deal of speculation about the potential effects on at-risk salmonids of proposed channel improvements by the U.S. Army Corps of Engineers (USACE). According to the 2002 Columbia River Channel Improvements Project Biological Opinion (NMFS 2003), impacts are expected to be short-term and will not reduce the likelihood of survival and recovery of ESA-listed salmonids.

Although the channel improvement project is not predicted to degrade critical estuarine habitat, the USACE proposed additional studies under its biological assessment to improve understanding of estuarine habitat use by juvenile salmonids. To accomplish this task, we sampled diverse habitats within two sections of the Columbia River estuary: 1) six sites near the oligohaline/euryhaline transition zone in the vicinity of Cathlamet and Grays Bays (RM 22-25), and 2) three sites in the tidal freshwater region of the estuary near Wallace Island (RM 46-48). By providing information for new locations and habitat types, this study compliments a larger ongoing monitoring program by NOAA Fisheries for juvenile salmonids throughout the estuary.

The goal of this new study was to describe spatial and temporal habitat use and related benefits to juvenile salmonids (especially subyearling Chinook salmon) across a gradient of shallow-water habitat types within the two estuarine zones, including relatively exposed sites directly adjacent to the deep ship channel, protected backwater areas buffered from strong currents and wave energies, and sites intermediate between these extremes. This study also serves as a baseline assessment of salmonid patterns of use within these habitats prior to further channel improvement efforts.

Specific objectives (Objectives 1 and 2) were to develop baseline spatial and temporal use patterns in abundance, size, and life histories of juvenile salmon 1) at a landscape scale at representative shallow-water habitats spanning the north and south side of the Columbia River in the vicinity of Cathlamet Bay, and 2) in the tidally-influenced freshwater region of the Lower Columbia River.

STUDY SITE

Four sites in Cathlamet Bay and two sites in Grays Bay were sampled in September 2003 and May, July, and August 2004 (Figure 1). The sites included two "exposed" open water habitats directly adjacent to the navigational channel at south east Rice Island (SERI) and north east Miller Sands (NEMS); two "semi-exposed" shallow-water areas, including one within Grays Bay along the Washington shore at Pigeon Bluff (PBGB) and one on the southeast corner of McGregor Island (MI); and two "protected" areas on the interior of Miller Sands "crescent" (INMS) and in the backwaters of South Channel off Settler Point on the Oregon shore (OSP).

This gradient includes habitats with coarse sand deposits created from dredge material at Miller Sands and Rice Island and more natural backwater areas with finer sediments within the peripheral bays. All six of these sites are located near the oligohaline/euryhaline transition zone of the estuary and might be categorized as the upper estuarine mixing zone.

Three additional sites were sampled in May, July, and August, 2004 around Wallace Island to characterize habitat use by salmon in the tidal fluvial region above the maximum extent of saltwater, where the estuary narrows upriver and the deep shipping channel constitutes a relatively larger proportion of the total habitat area (Figure 1). We selected two "exposed" sites on either side of the ship channel, the first on the south end of White Island (SWHI) and the second on the north side of Wallace Island (NWAL). The third site, classified as "semi-exposed," was located on the relatively protected backside of Wallace Island (SWAL).

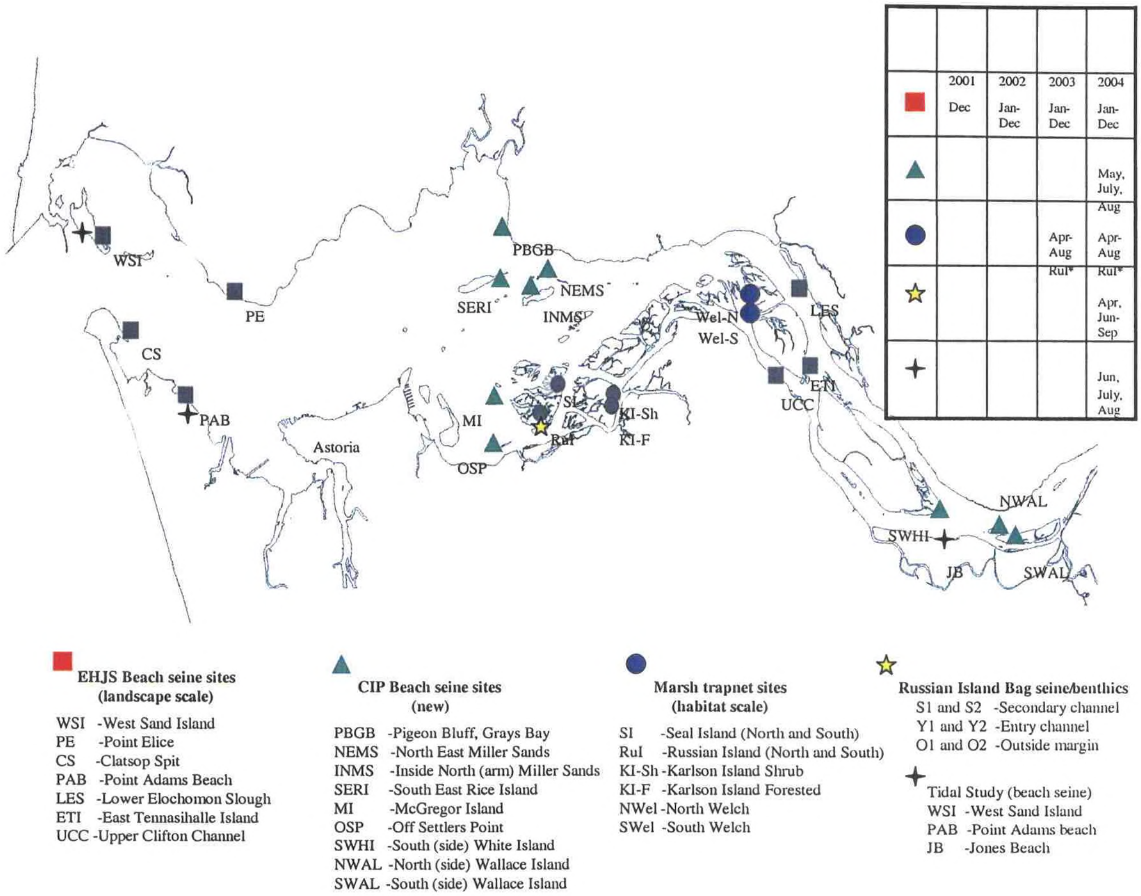

Figure 1. Map showing beach-seine sites (green triangles) of the channel improvement project (CIP) in addition to concurrent biological assessment projects. Cathlamet/Grays Bay sites were Pigeon Bluff, Grays Bay (PBGB); North East and Interior Miller Sand (NEMS and INMS); South East Rice Island (SERI); McGregor Island (MI); and Off Settlers Point (OSP). Sites near Wallace Island sites were South White Island (SWHI) and North and South Wallace Island (NWAL and SWAL).

METHODS

Fish were collected with a 50-m variable-mesh (19.0-, 12.7-, and 9.5-mm) beach seine with knotless web in the bunt to reduce descaling. During deployment, one end of the seine was anchored on the beach while the other was towed by a skiff to enclose a ~2500 m^2 horseshoe-shaped area. If a total of 10 subyearling Chinook were not collected at a site, a second beach-seine haul was made to provide a more adequate sample size for individual fish measurements. Each site was sampled within a few hours of low tide, depending upon depth and water velocity limitations at each location. Coincidental hydrographic data were collected at each site, including salinity, temperature, dissolved oxygen, pH, and depth (salinity and temperature only for the Wallace sites). These measurements were taken immediately after beach seining at depths 0.5 m below the surface and 0.5 m from the bottom.

The catch was sorted by species on location. For non-salmonids, length (nearest 1.0 mm) and weight (for 2003 only and to the nearest 0.1 g), were recorded for up to 30 individuals of each species. The remaining fish were tallied and released. All salmonids were examined for fin clips, external tags, or other marks and scanned for PIT- and coded-wire tags. In both 2003 and 2004, length and weight were recorded for up to 30 salmonids at each site, and condition factor was calculated as described by Ricker (1975). In 2004, lengths were also recorded for up to 100 individuals/salmonid species to provide additional length-frequency data.

A maximum of 35 Chinook/site/month were retained for laboratory analyses; these analyses will be reported elsewhere. For 30 of these fish, fin clips were collected for genetic analyses, otoliths and scales for life history information, lower intestine for parasite screening, stomach for diet and parasite assessment, kidney for bacterial kidney disease (BKD) and parasite screening, and liver and muscle for stable isotope analyses. When adequate numbers of subyearling Chinook were obtained (>30), five additional individuals were retained for chemical analyses. Whole bodies, liver, and stomach contents were screened for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and other chemical contaminants.

A Microsoft Access[†] database was created to record all fish species, counts, measurements, water quality data, and other pertinent information. Each field in the database was independently validated. Field and quality-control attributes were documented and are available upon request.

† Use of trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

RESULTS

Among all sites, 17 species totaling over 49,000 individuals were recorded, but total counts greater than 10 individuals were found for only 8 species (Table 1). Threespine stickleback constituted over 91% of all fish sampled (Figure 2a). The next five most abundant species included juvenile Chinook salmon, peamouth, starry flounder, and two non-indigenous species, American shad and banded killifish (Figure 2b). Species composition and abundance varied by location and date with no strong patterns in relation to degree of habitat exposure (Figure 3).

More fish were sampled from the oligohaline (Table 2-4) than from the fluvial sites, with 41,404 collected from the six Cathlamet/Grays Bay sites and 2,443 from the three Wallace Island sites (Table 5). The total number of individuals was greatest at the protected Cathlamet/Grays Bay locations followed by the semi-exposed and then exposed sites. This trend was explained entirely by variations in the large number of sticklebacks collected from these sites. Juvenile Chinook salmon abundance in Cathlamet/Grays Bay suggested an inverse relationship with the degree of habitat protection: the highest numbers were found at exposed sites near the main shipping channel (589; Figures 4-5), with the second highest at semi-exposed sites (482) and the lowest at protected sites (279).

Some noticeable differences in fish abundance existed between sites of the same habitat type in the Cathlamet/Grays Bay region (Figure 4). For example, of two protected sites, Chinook salmon (n = 131) was more abundant than stickleback (n = 101) at interior Miller Sands (INMS), while stickleback (n = 20,041) dominated catches off Settler Point (OSP; n = 148 for Chinook). The INMS site also had a large starry flounder contribution. Chinook salmon was more abundant, except in July, at Pigeon Bluff (PBGB; n = 301) than at McGregor Island (MI; n = 181), though both were classified as semi-exposed sites. Chinook at south east Rice Island (SERI; n = 493) consistently outnumbered those at north east Miller Sands (NEMS; n = 96) despite both being classified as exposed sites.

Table 1. Common and scientific names and total abundance of fish sampled from sites in Cathlamet/Grays Bay and near Wallace Island.

Common Name	Scientific Name	Total	Percent of total
American shad	*Alosa sapidissima*	1,030	2.09
Banded killifish	*Fundulus diaphanous*	377	0.76
Chinook salmon	*Oncorhynchus tshawytscha*	1,502	3.04
Chum salmon	*Oncorhynchus keta*	2	>0.01
Coho salmon	*Oncorhynchus kisutch*	2	>0.01
Crayfish	*Pacifasticus leniusculus*	2	>0.01
Largemouth bass	*Micropterus salmoides*	1	>0.01
Largescale sucker	*Catostomus macrocheilus*	10	0.02
Northern pikeminnow	*Ptychocheilus oregonensis*	1	>0.01
Pacific staghorn sculpin	*Leptocottus armatus*	33	0.07
Peamouth	*Mylocheilus caurinus*	850	1.72
Prickly sculpin	*Cottos asper*	25	0.05
Rainbow trout (steelhead)	*Oncorhynchus mykiss*	1	>0.01
Starry flounder	*Platichthys stellatus*	310	0.63
Threespine stickleback	*Gasterosteus aculeatus*	45,219	91.60
White sturgeon	*Acipenser transmontanus*	1	>0.01
Unidentified sculpin	NA	1	>0.01
Total fish captured:		49,367	

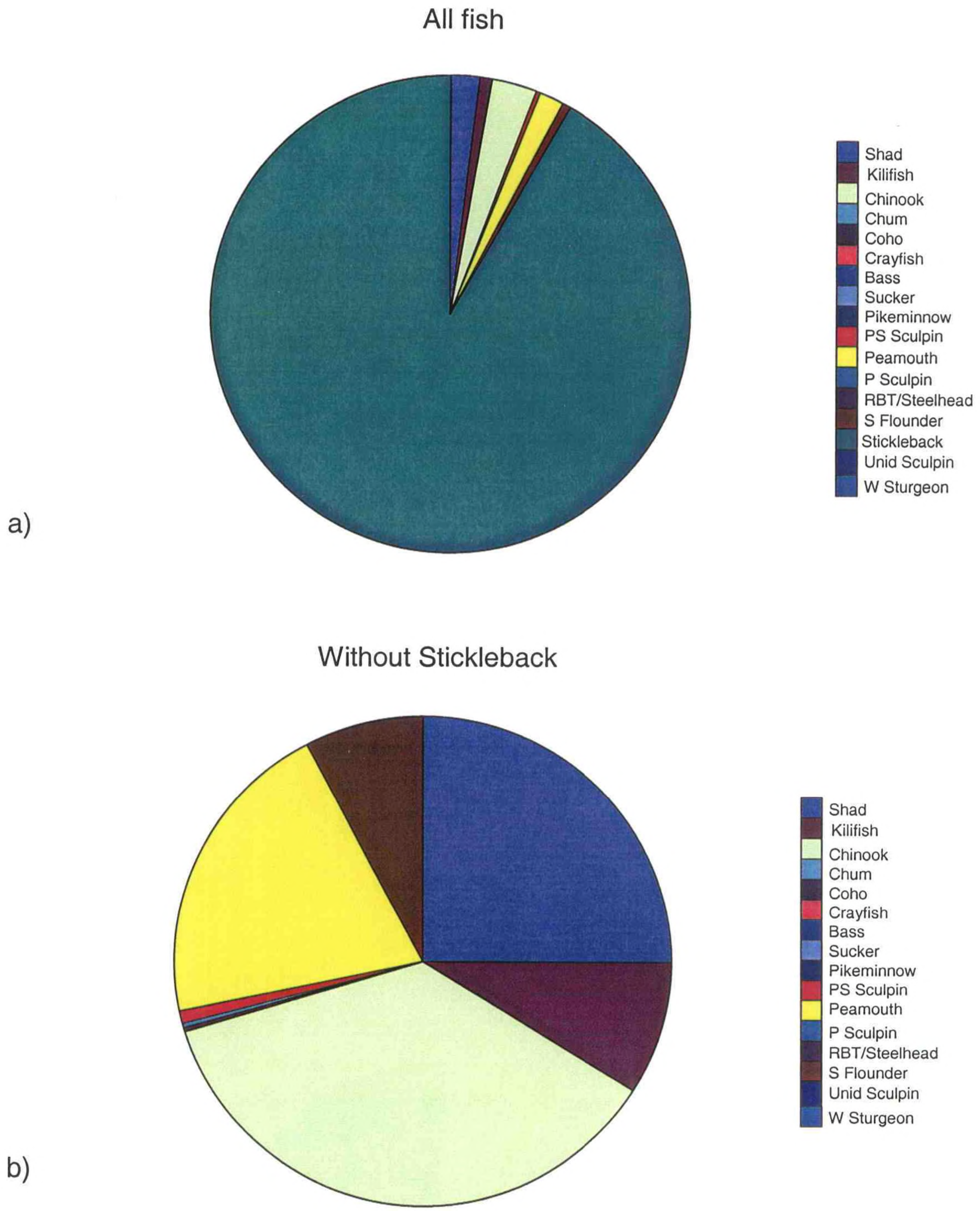

Figure 2. Proportional species composition of fish sampled with beach seines at both sets of sites: a) all fish b) stickleback removed from the analyses.

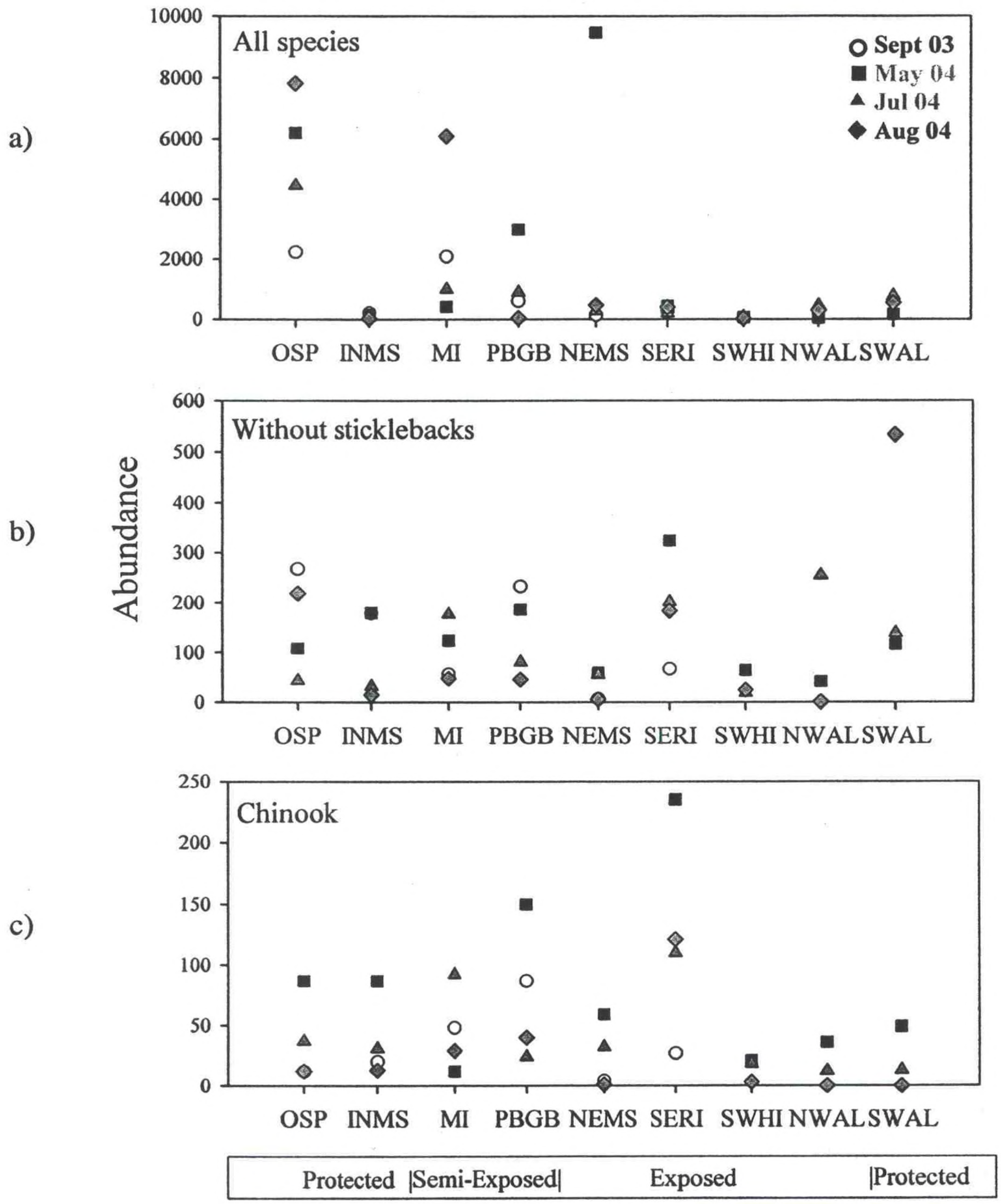

Figure 3. Abundance of a) all species; b) all species without stickleback; and c) Chinook salmon by sample site and date.

Table 2. Species abundance sampled by beach seine from protected oligohaline sites at Cathlamet and Grays Bay.

	Off Settler Point (OSP)				Interior Miller Sands (INMS)				
	9/03	5/04	7/04	8/04	9/03	5/04	7/04	8/04	Total
American shad	164	12	5	176	112	86	1		556
Banded killifish	4		2	31		1		1	39
Chinook salmon	12	87	37	12	20	67	31	13	279
Largemouth bass	1								1
Largescale sucker				1					1
Pacific staghorn sculpin						1			1
Peamouth	81			18		1		1	101
Prickly sculpin	7			9					16
Rainbow trout (steelhead)				1					1
Starry flounder		10			47	4			61
Threespine stickleback	1,962	6,086	4,414	7,579	36	4	50	11	20,142
Totals	2,231	6,195	4,458	7,827	215	164	82	26	21,198

Table 3. Species abundance sampled by beach seine from semi-exposed oligohaline sites at Cathlamet and Grays Bay.

	McGregor Island (MI)				Pigeon Bluff, Grays Bay (PBGB)				
	9/03	5/04	7/04	8/04	9/03	5/04	7/04	8/04	Total
American shad	1		81	4	87	1	14	2	190
Banded killifish	5			13			2		20
Chinook salmon	48	12	92	29	87	150	24	40	482
Coho salmon		1							1
Pacific staghorn sculpin		4				12			16
Peamouth	2			2	59	1	32	1	97
Prickly sculpin	1				7				8
Starry flounder		108	4		2	23	9	3	149
Threespine stickleback	2,021	293	817	6,033	356	2,786	815	1	13,122
White sturgeon				1					1
Totals	2,078	418	994	6,082	598	2,973	896	47	14,086

Table 4. Species abundance sampled by beach seine from exposed Cathlamet/Grays Bay sites.

	North East Miller Sands (NEMS)				South East Rice Island (SERI)				
	9/03	5/04	7/04	8/04	9/03	5/04	7/04	8/04	Total
American shad	2			2	32	20	82	53	191
Banded killifish			23	1	1	1			26
Chinook salmon	4	59	32	1	27	235	110	121	589
Chum salmon						1			1
Largemouth bass						6			6
Pacific staghorn sculpin						7			7
Peamouth	1			1	2	1		1	6
Starry flounder		1	1	1	6	60	10	9	88
Threespine stickleback	126	9,406	217	458	189	102	4	215	10,717
Unidentified sculpin				1					1
Totals	133	9,466	273	465	257	433	206	399	11,632

Table 5. Abundance of species sampled by beach seine from exposed and semi-exposed sites near Wallace Island.

	South White Island (SWHI)[a]			North Wallace Island (NWAL)[b]			South Wallace Island (SWAL)[a]			Total
	5/04	7/04	8/04	5/04	7/04	8/04	5/04	7/04	8/04	
American shad	39			4	2		45		3	93
Banded killifish			17		22		1	52	200	292
Chinook salmon	21	18	3	36	12		49	13		152
Chum salmon				1						1
Coho salmon	1									1
Crayfish								1	1	2
Largescale sucker								2	1	3
Northern pikeminnow					1					1
Pacific staghorn sculpin					1					1
Peamouth	1		1	1	218		20	74	331	646
Prickly sculpin							1			1
Starry flounder	4	1	4	1		1	1			12
Threespine stickleback	1	58		2	195	301	47	629	5	1,238
Totals	67	77	25	45	451	302	164	771	541	2,443

a Exposed

b Semi-exposed

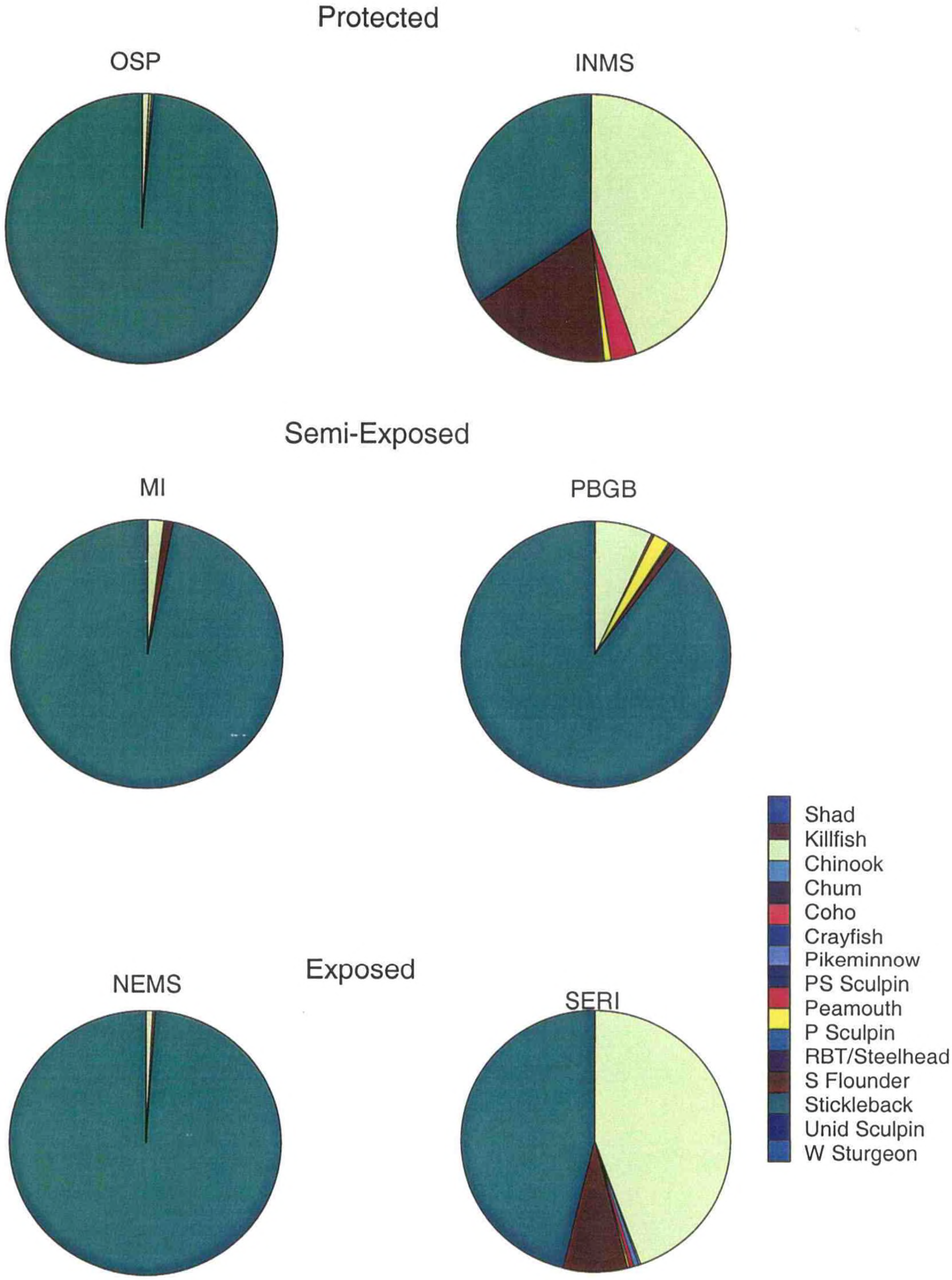

Figure 4. Proportional species composition from Cathlamet Bay/Grays Bay sites. Abbreviations: OSP, off Settler Point; INMS, interior Miller Sands; MI, McGregor Island; PBGB, Pigeon Bluff, Grays Bay; NEMS, north east Miller Sands; SERI, south east Rice Island.

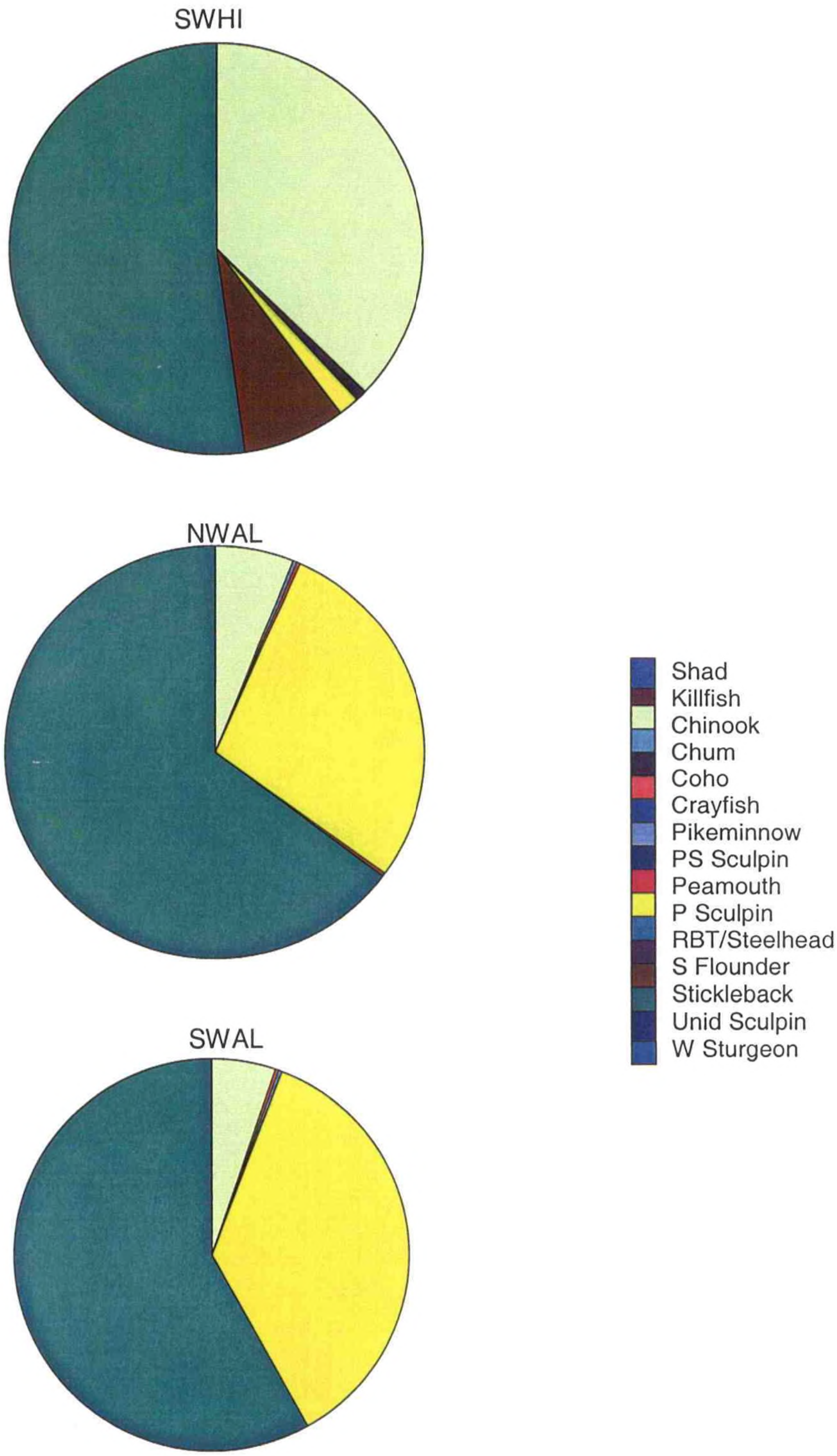

Figure 5. Proportional species composition from around/near Wallace Island sites.

Among the Wallace Island sites, the exposed north Wallace Island (NWAL) was more comparable in species composition to the semi-exposed south Wallace Island (SWAL) than to the similarly exposed south White Island (SWHI; Figure 5). Excluding threespine stickleback, peamouth was more abundant than other species at NWAL and SWAL followed by Chinook salmon, while at SWHI, juvenile Chinook salmon was more abundant than other fish species (Figures 6-7). Excluding stickleback, more than 50% of the total catch was composed of juvenile Chinook salmon in 17 of 33 samples. Juvenile Chinook was found in all collections except those at NWAL and SWAL in August 2004 (Figures 6-7), and made up 36% of the total catch for all samples combined.

Other than juvenile Chinook salmon, the only salmonids caught were two coho salmon, two chum salmon, and one steelhead. Of the 1,502 juvenile Chinook salmon sampled, only two were classified as yearlings based on size classifications from previous research findings (Dawley et al. 1986; Table 6). Both of these fish were collected in May 2004, with one each from interior and north east Miller Sands (INMS and NEMS).

Although Chinook salmon was found throughout the study area, it was less abundant in the Wallace Island area than in the Cathlamet/Grays Bay areas. For example, in 2004, 292 fish were collected from the three Wallace Island sites, while 1,152 were collected from the six Cathlamet/Grays Bay sites. Chinook abundance peaked in May except at McGregor Island, where abundance peaked in July (MI; Tables 2-5). Fish disappeared from the tidal freshwater sites later in the season (In August, no Chinook were captured at the Wallace Island sites NWAL and SWAL, and only three were collected from SWHI). Less than 2% of the subyearling Chinook was hatchery origin (Table 7). A majority of the hatchery fish were adipose-fin clipped (AD), although some were marked with a coded-wire tag (CWT) or a both a fin clip and CWT.

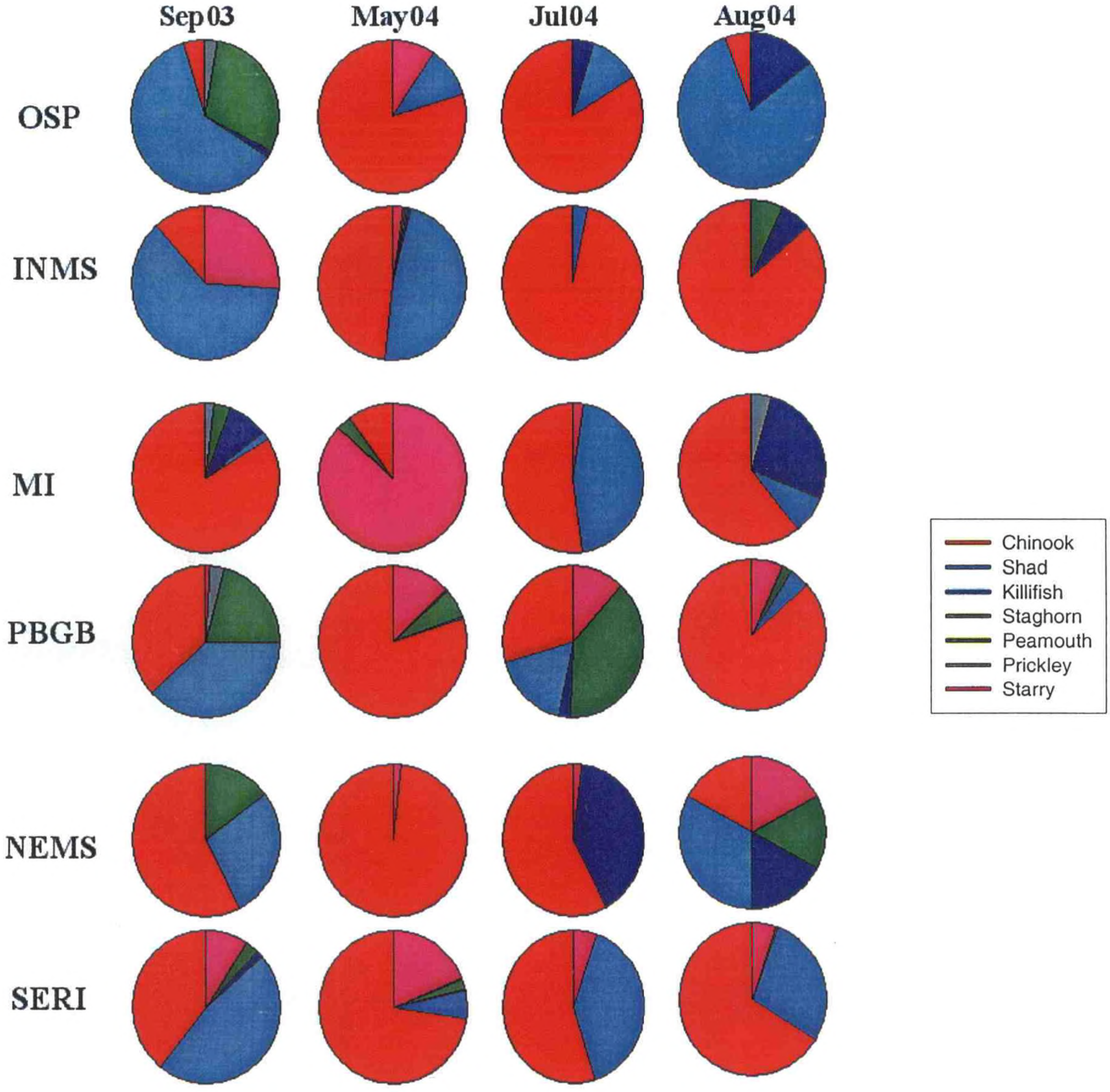

Figure 6. Species composition by date from Cathlamet/Grays Bay sites, neglecting sticklebacks. Abbreviations: OSP, off Settler Point; INMS, interior Miller Sands; MI, McGregor Island; PBGB, Pigeon Bluff, Grays Bay; NEMS, north east Miller Sands; SERI, south east Rice Island.

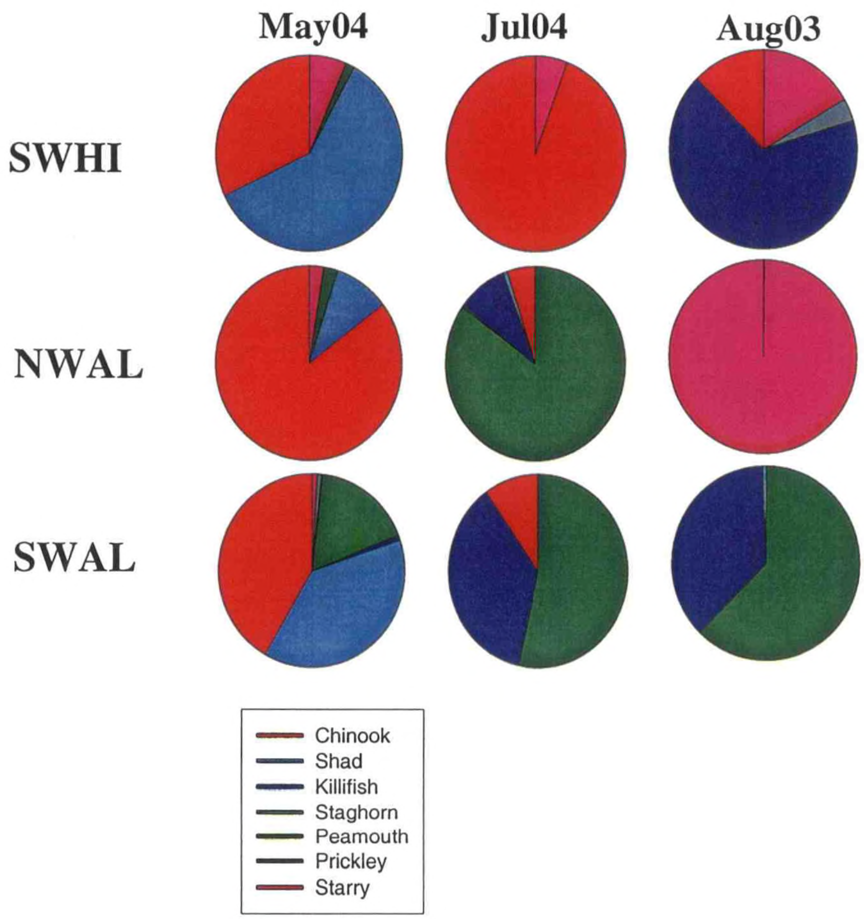

Figure 7. Species composition by date from the around/near Wallace Island sites, neglecting sticklebacks. Abbreviations: SWHI, south White Island; NWAL, north Wallace Island; SWAL, south Wallace Island.

Table 6. General cutoff lengths for separating fall (0+) vs. spring Chinook (1+) used in Columbia River estuary sampling (Dawley et al. 1986, data from 1979-1983).

	Length (mm)	
Month	Days 1-15	Days 16-31
March		90?
April	90	97
May	100	109
June	117	128
July	150	All spring Chinook gone

Table 7. Tag types, dates, and locations of the 25 known hatchery Chinook salmon captured from all sites (1.6% of the total Chinook catch).

Tag or mark		Number by site		Number by date	
Coded wire tag	4	off Settler Point (OSP)	3	Sept 03	7
Adipose clip	16	Interior Miller Sands (INMS)	1	May 04	4
Adipose and CWT	5	McGregor Island (MI)	6	July 04	11
		Pigeon Bluff, Grays Bay (PBGB)	6	Aug 04	3
		NE Miller Sands (NEMS)	3		
		SE Rice Island (SERI)	5		
		North Wallace Island (NWAL)	1		

Monthly length (Figures 8-9), weight (Figures 10-11), and length/weight (Figures 12-13) relationships (condition index) of subyearling Chinook salmon were plotted to determine size-specific patterns of habitat use and the relative condition of individuals using both Cathlamet/Grays Bay areas and the Wallace Island locations. We also compared monthly length (Figure 14) and length/weight (Figure 15) relationships of subyearling Chinook grouped by habitat type.

In general, fish from the Wallace Island sites were smaller (55-74 mm, 1.9-5.1 g, and condition index 0.09607-0.012130) than their downstream counterparts (61-99 mm, 2.9-12.1 g, and CI 0.01035-0.013498) sampled for the same months in 2004. Mean fork length tended to increase with time except for Chinook captured in August at the Cathlamet/Grays Bay exposed sites (mean length over time was 72, 88, 87, and 107 mm for Cathlamet sites vs. 59.5, 65.5, and 66 mm for Grays Bay), and at SWHI (but the latter is most likely attributed to a very small sample size (n = 3); Tables 8-9). Fish were also slightly smaller at exposed sites than at protected sites.

Weight followed a trend similar to that of length (Table 10-11). However, weight did decline in July at INMS (8.4 to 6.4 g), and at both exposed sites between May and August (NEMS 7.3 to 5.6 g; SERI 7.2 to 5.6 g). A small decrease in weight was also observed at SWHI between July and August (3.6 to 3.5 g), but this was likely the result of a small sample size (n = 3).

Mean weight to mean length relationships followed a positive linear trend, reflecting the presence of larger and heavier fish later in the season (Figure 15). Condition index (wt(g)/ln3(cm)) was variable among Cathlamet/Grays Bay sites (Table 12). The most noticeable pattern was a decline in condition index in July samples from OSP (0.010924 to 0.009337), INMS (0.113180 to 0.007578), and NEMS (0.011185 to 0.007635). Condition index increased from May to July in the Wallace Island samples (0.010040 to 0.011440) and from May through August in the White Island samples (0.009607 to 0.011967; Table 13).

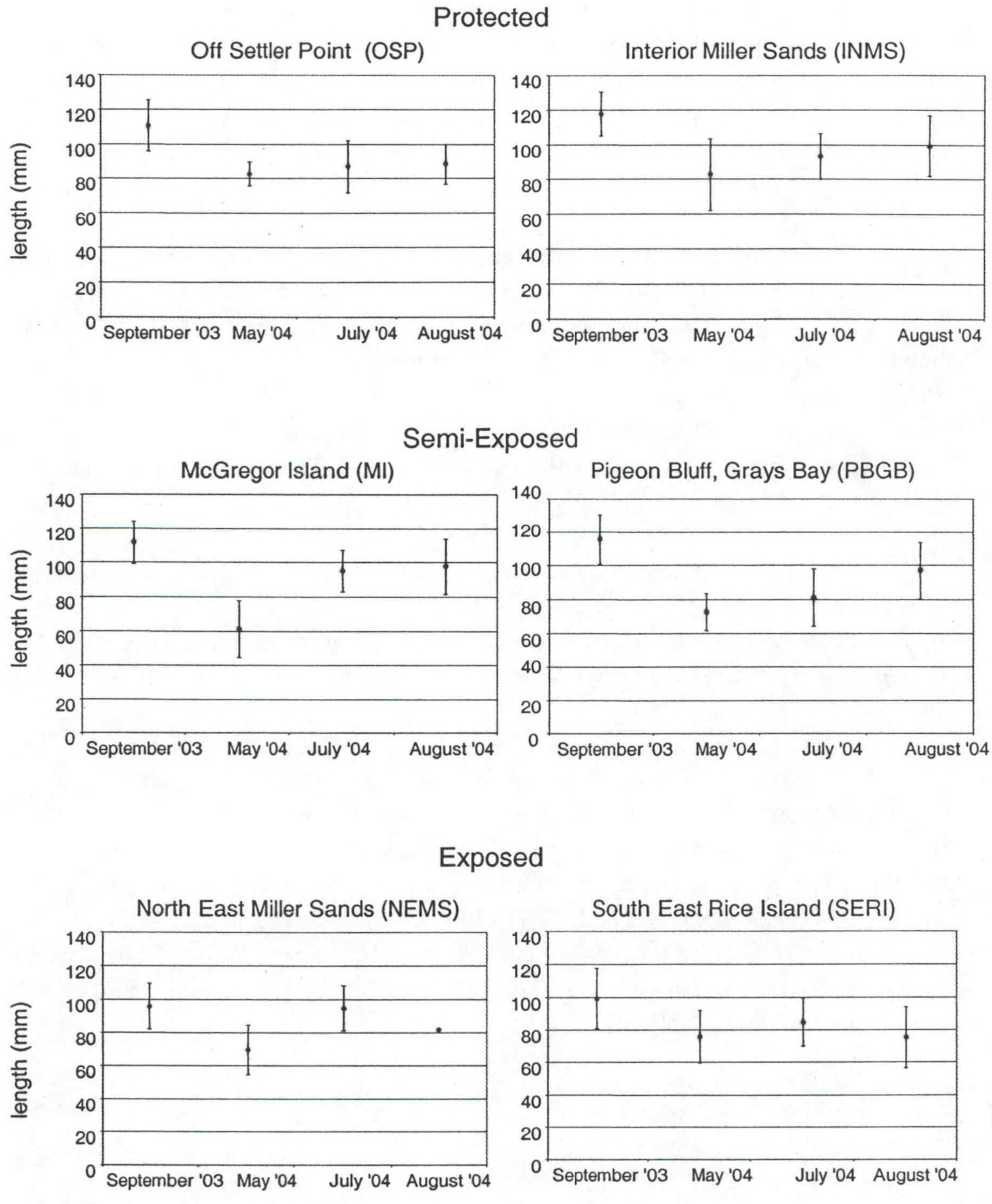

Figure 8. Time series of mean fork length ± SD of juvenile Chinook salmon for Cathlamet/Grays Bay sites.

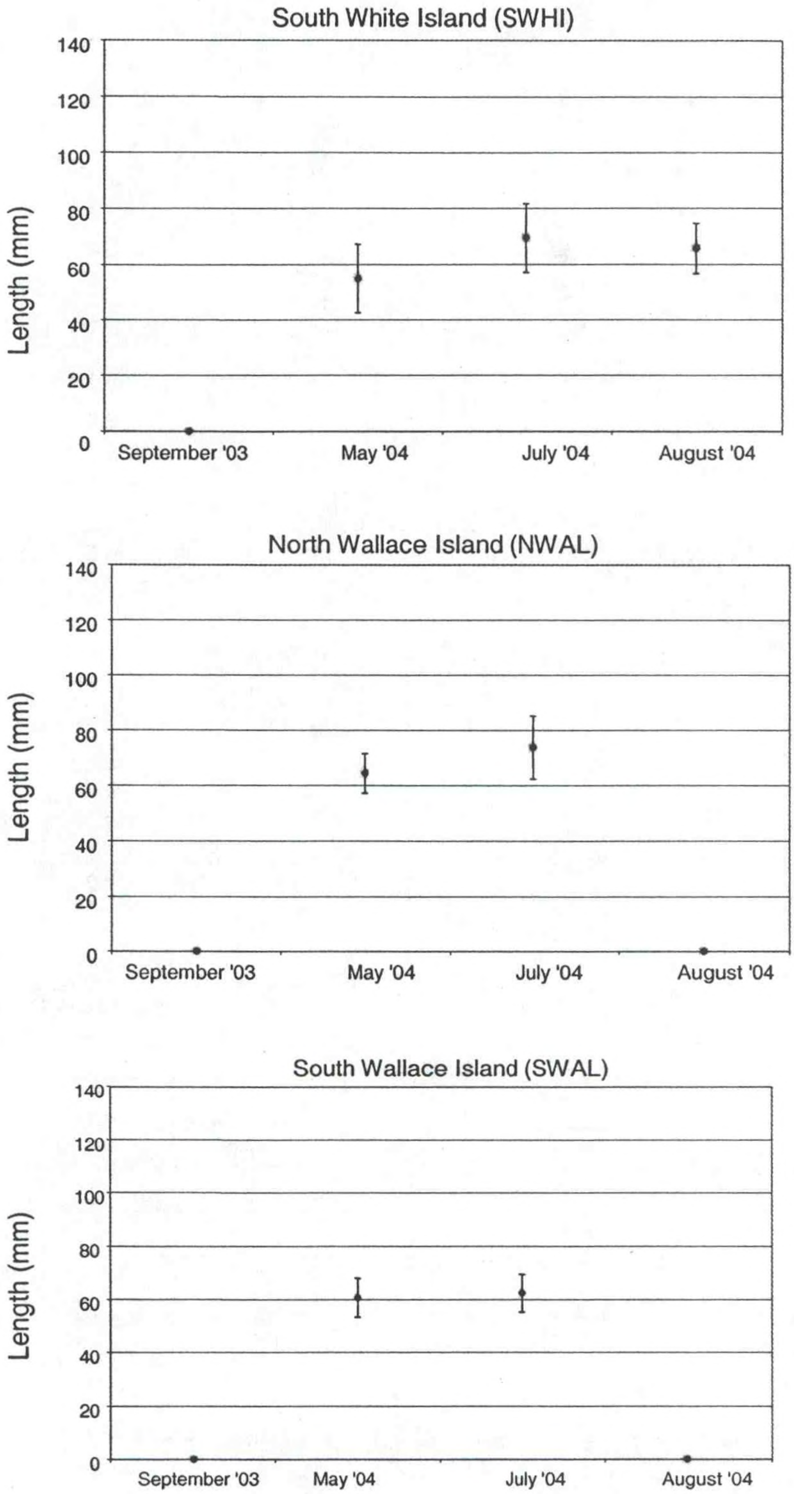

Figure 9. Time series of mean fork length of juvenile Chinook salmon (± SD) for around/near Wallace Island sites.

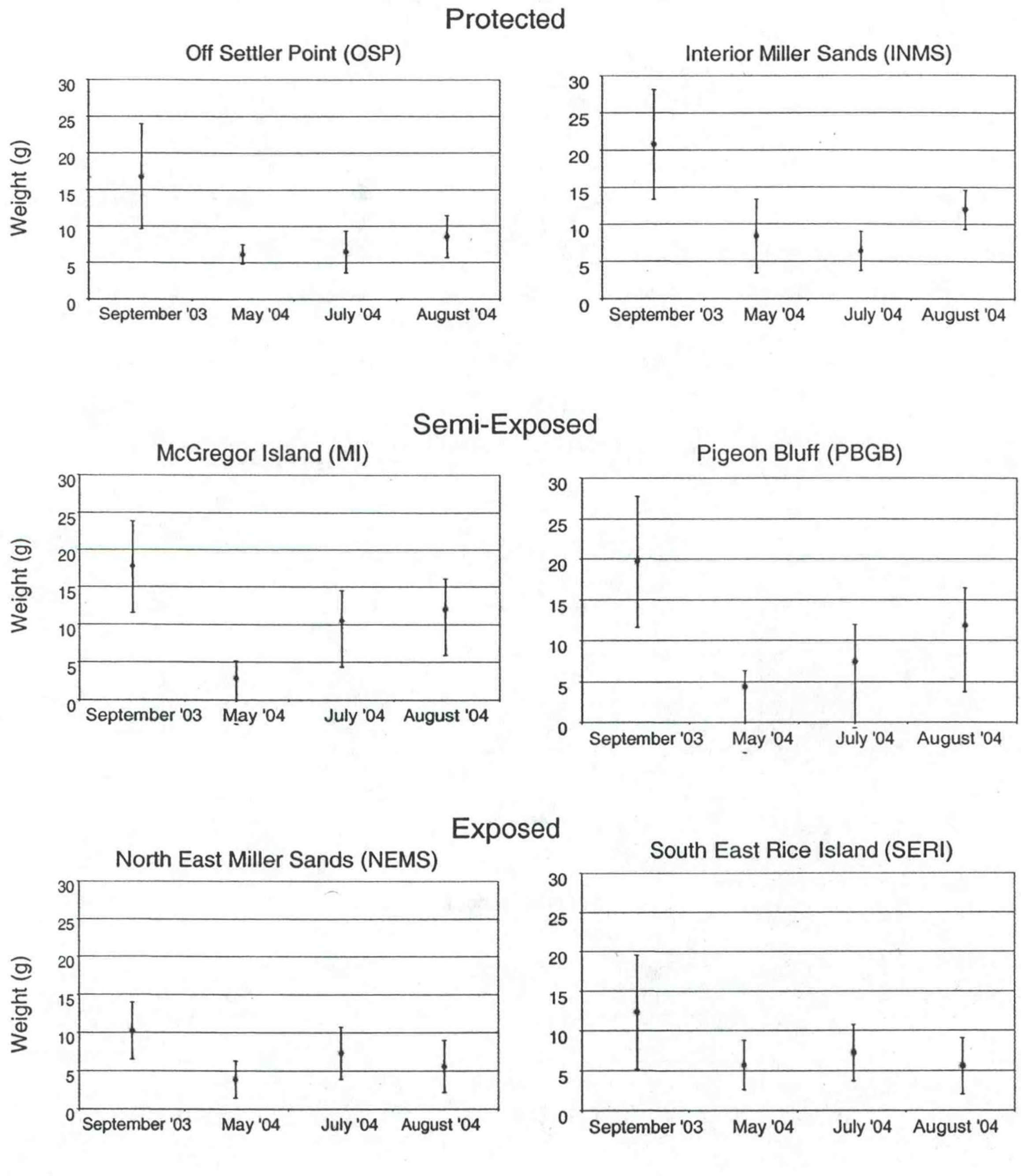

Figure 10. Time series of juvenile Chinook salmon weights ± SD for Cathlamet/Grays Bay sites.

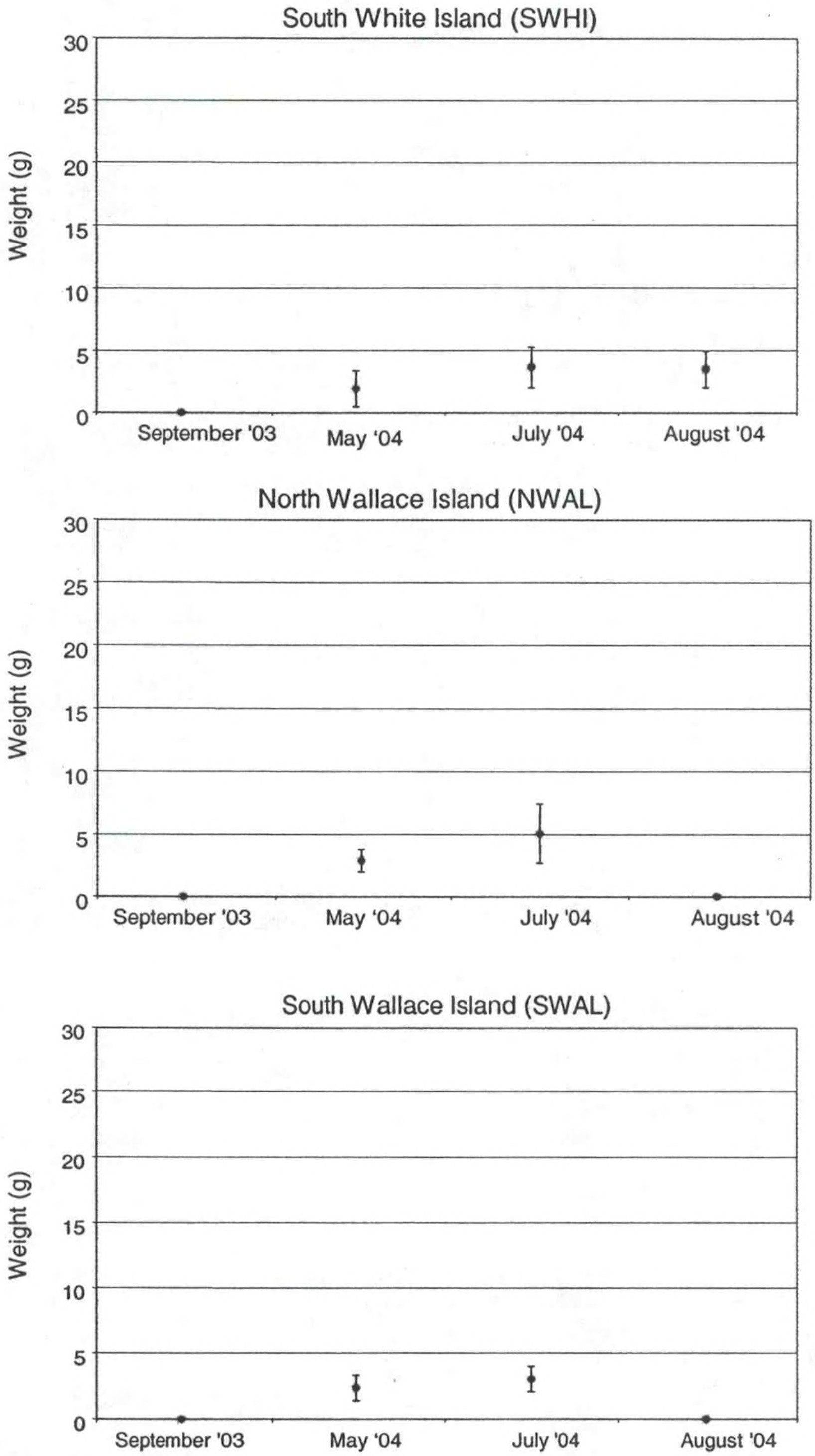

Figure 11. Time series of juvenile Chinook salmon weights ± SD for the sites near Wallace Island.

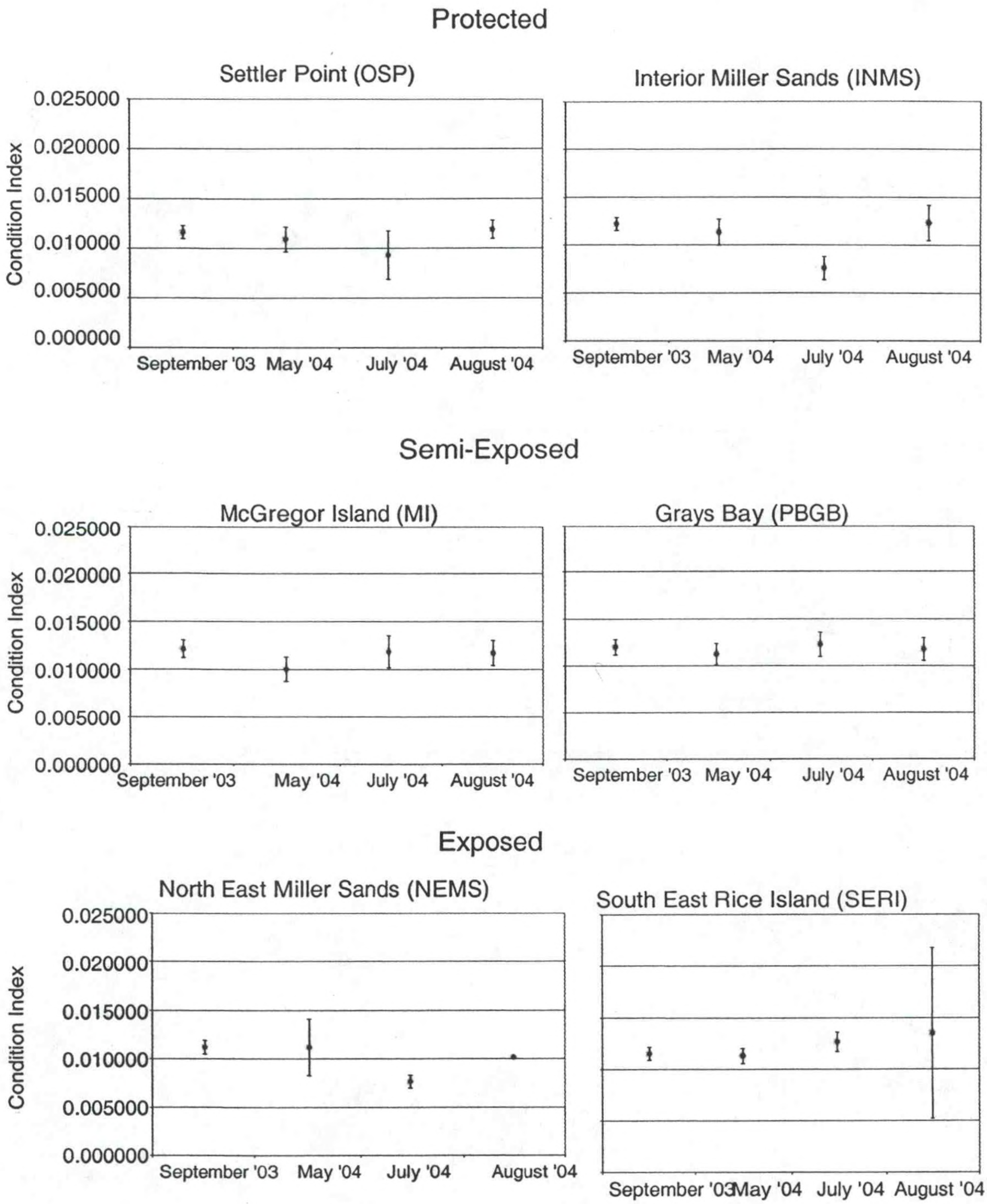

Figure 12. Time series of condition index ± SD of juvenile Chinook salmon at Cathlamet/Grays Bay sites.

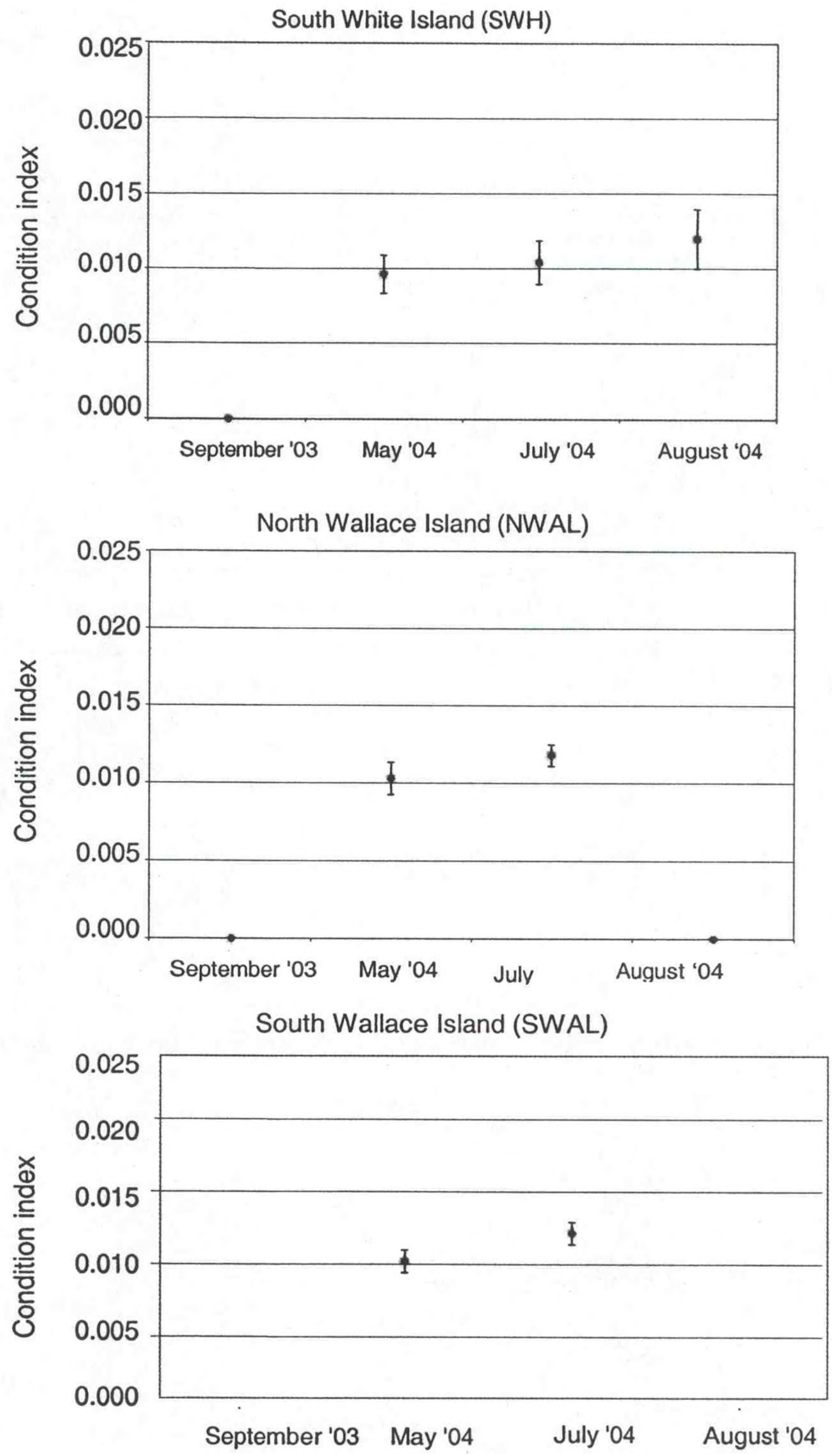

Figure 13. Time series of condition index (± SD) for juvenile Chinook salmon for Wallace Island sites.

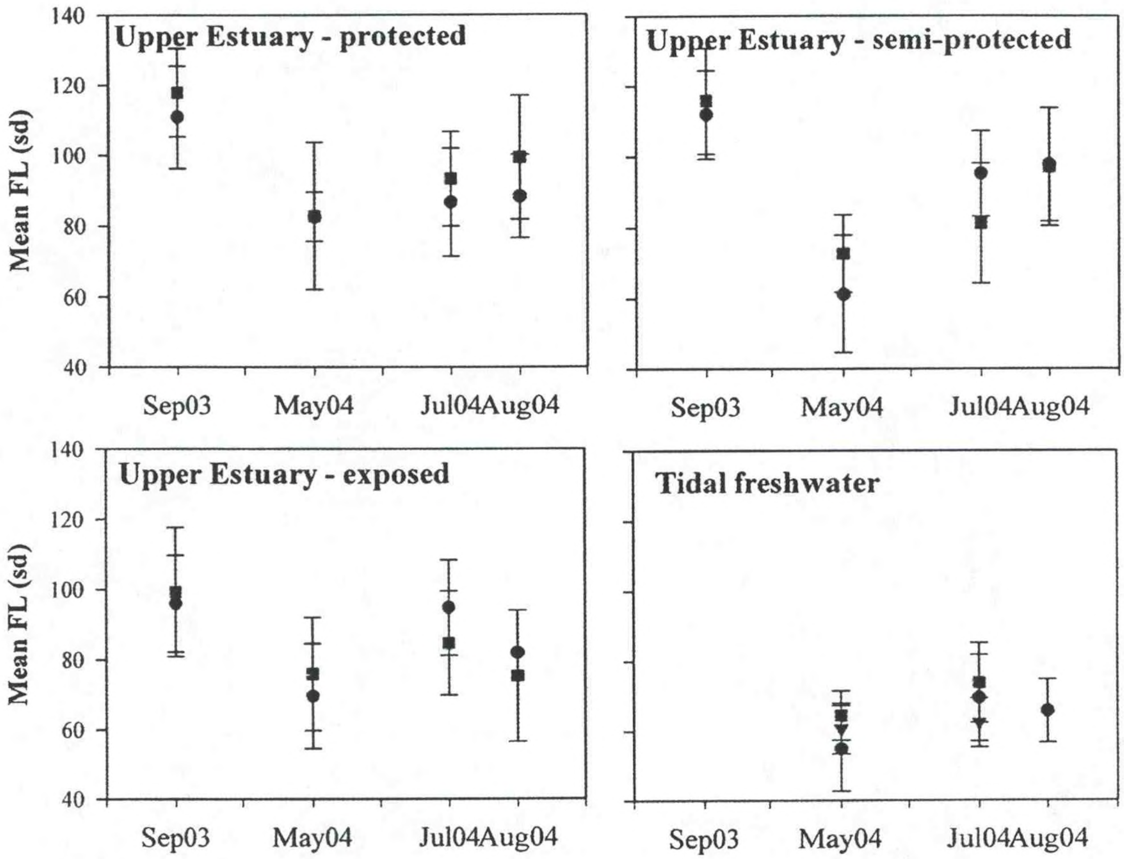

Figure 14. Time series of mean Chinook salmon fork length.

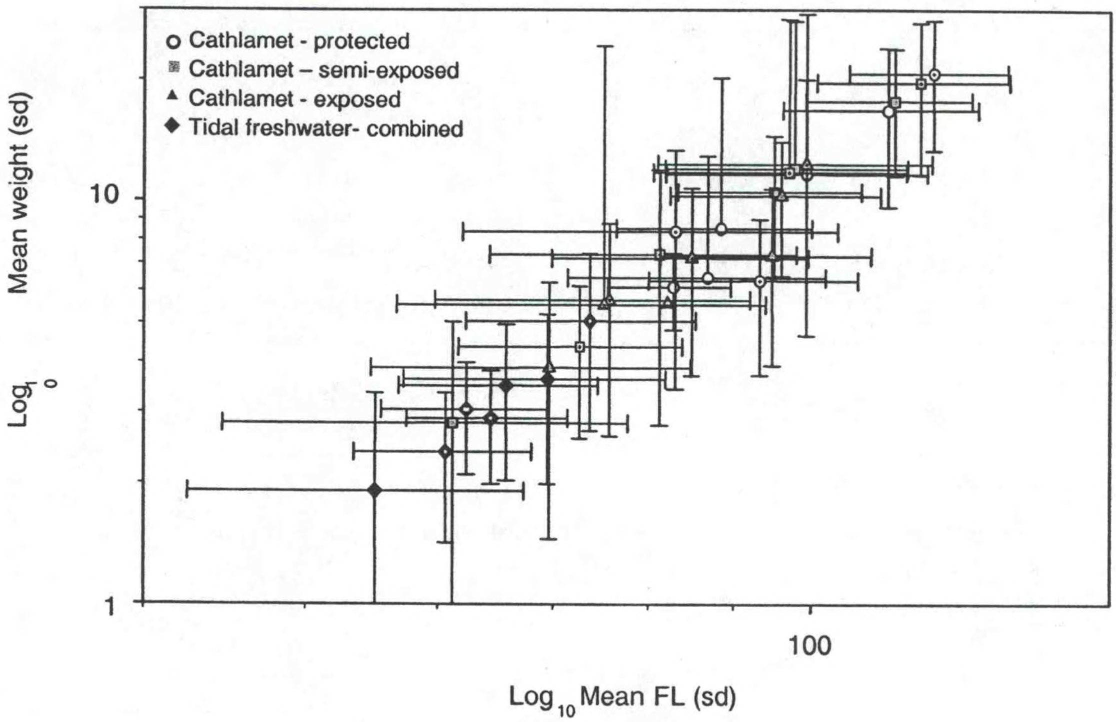

Figure 15. Weight-length relationships for juvenile Chinook salmon at Cathlamet and Wallace Island (tidal freshwater) sites.

Table 8. Average length ± SD by month for Chinook salmon sampled from Cathlamet/Grays Bay sites.

	Mean length (mm)							
Site	9/03	n	5/04	n	7/04	n	8/04	n
OSP	111 ± 15	12	83 ± 7	87	87 ± 15	37	88 ± 12	12
INMS	118 ± 13	20	83 ± 21	67	93 ± 13	30	99 ± 18	14
MI	112 ± 13	43	61 ± 17	12	95 ± 12	91	98 ± 16	29
PBGB	116 ± 15	48	73 ± 11	75	81 ± 17	24	97 ± 17	40
NEMS	96 ± 14	4	70 ± 15	59	95 ± 14	32	82 ± 0	1
SERI	99 ± 18	26	76 ± 16	75	85 ± 15	100	75 ± 19	104

Table 9. Average length ±SD by month for Chinook salmon sampled from Wallace Island sites.

	Mean length (mm)					
Site	5/04	n	7/04	n	8/04	n
SWHI	55 ± 12	21	69 ± 12	18	66 ± 9	3
NWAL	64 ± 7	36	74 ± 11	12	NA	0
SWAL	61 ± 7	49	62 ± 7	13	NA	0

Table 10. Average weight ± SD by month for Chinook salmon sampled from the Cathlamet/Grays Bay sites.

Site	Mean weight (g)							
	9/03	n	5/04	n	7/04	n	8/04	n
OSP	16.8 ± 7.2	12	6.1 ± 1.3	36	6.5 ± 2.9	35	8.6 ± 11.7	12
INMS	20.8 ± 7.4	20	8.4 ± 5.0	35	6.4 ± 2.7	30	12.0 ± 17.5	14
MI	17.7 ± 6.2	43	2.9 ± 2.2	12	10.5 ± 4.0	35	12.1 ± 16.0	29
PBGB	19.7 ± 8.1	48	4.4 ± 2.0	35	7.4 ± 4.6	24	11.8 ± 16.6	40
NEMS	10.3 ± 3.7	4	3.9 ± 2.4	37	7.3 ± 3.4	30	5.6 ± 0.00	1
SERI	12.4 ± 7.2	26	5.7 ± 3.1	35	7.2 ± 3.5	23	5.6 ± 18.7	35

Table 11. Average weight ± SD by month for Chinook salmon sampled from Wallace Island sites.

Site	Mean weight (g)					
	5/04	n	7/04	n	8/04	n
SWHI	1.9 ± 1.4	21	3.6 ± 1.6	18	3.5 ± 1.5	3
NWAL	2.9 ± 0.9	30	5.1 ± 2.4	12	NA	0
SWAL	2.4 ± 1.0	30	3.1 ± 1.0	13	NA	0

Table 12. Average Condition Index ± SD by month for Chinook salmon sampled from the Cathlamet/Grays Bay sites.

	Mean condition index							
Site	9/03	n	5/04	n	7/04	n	8/04	n
Off Settler Point	0.011659 ± 0.000663	12	0.010924 ± 0.001258	36	0.009337 ± 0.002444	35	0.011908 ± 0.000915	12
Int. Miller Sands	0.012192 ± 0.000679	20	0.011318 ± 0.001366	35	0.007578 ± 0.001204	30	0.012311 ± 0.001847	14
McGregor Island	0.012144 ± 0.000915	43	0.010035 ± 0.001289	12	0.011850 ± 0.001666	35	0.011703 ± 0.001305	29
Pigeon Bluff, GB	0.012002 ± 0.000819	48	0.011240 ± 0.001140	35	0.012277 ± 0.001297	24	0.011766 ± 0.001201	40
NE Miller Sands	0.011197 ± 0.000703	4	0.011185 ± 0.002926	37	0.007635 ± 0.000657	30	0.010157 ± 0.000000	1
SE Rice Island	0.011537 ± 0.000628	26	0.011294 ± 0.000748	35	0.012677 ± 0.000953	23	0.013498 ± 0.008254	35

Table 13. Average condition index ± SD by month for Chinook salmon sampled from the around/near Wallace Island sit

	Mean condition index					
Site	5/04	n	7/04	n	8/04	n
SWHI	0.009607 ±0.001280	21	0.010398 ±0.001468	18	0.011967 ±0.00198	3
NWAL	0.010305 ±0.001044	30	0.011793 ±0.000682	12	NA	0
SWAL	0.010207 ±0.000780	30	0.012130 ±0.000761	13	NA	0

Water quality parameters did not vary significantly among the individual sites or between the two sampling areas. Salinity was always less than 1 ppt, which is expected for surface samples taken near low tide, since salt intrusion at the head of Cathlamet Bay is usually restricted to deeper channel areas during flood tides. Water temperatures were similar for both groups of sites and averaged approximately 15.0, 22.0, and 22.5°C in May, July, and August, respectively. Most temperature profiles were nearly isothermal with depth. High temperatures in July and August may have limited salmonid use of these shallow habitats. At the Cathlamet/Grays Bay sites, pH ranged from 7.7-8.2, while dissolved oxygen averaged 80-97% at the surface and 79-97% at the bottom. The values of these latter parameters are not limiting to salmon. Minimum depth sampled ranged from 0.3-0.8 m for the Cathlamet Bay sites and 0.5-1.0 m for the tidal freshwater sites. Maximum depth sampled was 1.4-5.1 m, and 2.0-3.0 m from Cathlamet and the tidal freshwater sites, respectively.

CONCLUSIONS

Variation of fish abundance and species composition showed no statistically significant pattern related to exposure to tidal currents and wave energy as defined by our a priori site selection. This could reflect the short duration, limited area, and small sample sizes of this study or the absence of significant tidal or wave-energy gradients among chosen sites. Chinook salmon were abundant in both upper estuarine and tidal freshwater sections of the lower Columbia River.

Chinook were found in shallow, protected backwaters, sites of intermediate depth and exposure, and exposed unprotected slopes immediately adjacent to the main navigational channels. There was a lack of significant response in abundance by juvenile Chinook salmon to degree of habitat exposure. For the Cathlamet sites there was an inverse trend in abundance with highest abundance found at exposed sites and lowest at protected sites.

Conversely, Chinook salmon size correlated positively with the level of protection. In general, the largest fish were found at protected sites and the smallest at exposed sites. Mean salmon length, weights, and condition indices tended to increase with time from spring through summer and fall and as fish moved downstream. However, it is important to note that over the four-month sampling period in 2004, different Chinook salmon cohorts may have been sampled.

A variety of analyses may help to further clarify these results. For example, genetic analyses may shed further light on the sources of individuals sampled in the estuary through time. Moreover, physical characterization of the sites, including the relative degree of habitat exposure to tidal currents, may be validated independently from continuous data collected at the fixed monitoring stations of the CORIE network maintained by Oregon Health and Science University.

Finally, multivariate analyses (e.g., ordination and cluster analysis) incorporating results from the other estuarine habitats surveyed by NOAA Fisheries may help to identify prominent species assemblages and clarify which physical variables most strongly influence fish distribution and habitat associations. These additional analyses will determine whether continued research is warranted in the chosen estuarine zones to further document temporal and spatial variations in estuarine habitat use and juvenile life history of Chinook salmon.

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