Nisqually Delta Phase 1 Estuarine Restoration Fish Monitoring

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Abstract

In the Nisqually Delta, the Nisqually Indian Tribe and the Nisqually National Wildlife Refuge are restoring tidal influence to nearly 850 acres of former pasture and farmland over the next several years. The first phase (Phase 1) was implemented in 2002 and reclaimed approximately 40 acres of pasture. This paper covers the results of our Phase 1 restoration site monitoring efforts from 2003-2005.

Our objectives for the Phase 1 restoration site monitoring were to evaluate the opportunity, capacity, and realized function of the site for juvenile Chinook and to compare and contrast these findings with those from other sloughs within the Nisqually Delta. Opportunity was examined by fyke-trapping each slough, invertebrate densities at each slough were used as measures of capacity, and the diet composition of unmarked and marked (hatchery) Chinook salmon was used to assess the realized function of the sloughs for supporting juvenile Chinook.

Results indicated that the Phase 1 restoration site provided an almost immediate realized function for Nisqually Chinook by producing large quantities of Brachycera flies, which were readily consumed by Chinook at the site. Blind tidal sloughs were found to be an important habitat for several fishes in the Nisqually Delta but the diversity and density of fish varied between the sloughs. The monitoring data enables us to make educated hypotheses about the impact of continued estuary restoration on Nisqually Delta fish ecology.

Introduction

Restoring Puget Sound river delta habitat is recognized as a priority action for the recovery of Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*) in both regional and local recovery plans (SSDC 2007; NCRT 2001). The approximately 5,000 acre Nisqually River Estuary complex represents one of the most restorable river deltas in the region, with most of the land now owned by the U. S. Fish and Wildlife Service Nisqually National Wildlife Refuge (NNWR), the Nisqually Indian Tribe (Tribe), and the Washington Department of Fish and Wildlife (WDFW). The Tribe, the NNWR, and others are aggressively pursuing large scale restoration of the Nisqually Estuary. Using a phased approach, tidal inundation was restored to reclaim approximately 40 acres of diked pasture in 2002 (Phase 1) and an additional 100 acres of pasture in 2006 (Phase 2), both on the east side of the river. The next step will be the restoration of 700 acres of estuarine habitat on the west side of the Nisqually River in the near future (USFWS 2004). This paper describes the results of our Phase 1 Restoration site monitoring efforts from 2003-2005.

The purpose of this specific monitoring project was to assess the ecological performance of restoring and reference estuary habitats for juvenile Chinook. We focused this specific project on juvenile Chinook because they are known to be the most estuarine dependent salmonid (Aitkin 1998), are listed as threatened under the U.S. Endangered Species Act, and their recovery is the driving force behind Nisqually River estuary restoration. The ecological performance of estuarine salt marsh habitats was measured at three levels for juvenile salmon: opportunity, capacity, and realized function (adapted from: Simenstad and Cordell 2000; Simenstad et al. 2001; Gray et al. 2002).

Opportunity is the ability of juvenile salmon to access the estuarine habitat and benefit from the habitat's capacity. We measured opportunity by determining the density and timing of salmonid usage of the reference habitats through fyke trapping. Capacity is defined as habitat attributes that produce conditions beneficial to juvenile salmon growth and survival. Capacity was measured by determining the occurrence and abundance of salmonid prey organisms at the study sites through benthic core sampling and insect fallout trapping. Realized function is the direct measure of juvenile salmon use and benefit from a specific habitat. The diet composition of juvenile hatchery and unmarked Chinook in conjunction with the invertebrate sampling was used to examine the realized function of the restoring and reference estuarine habitats.

Methods

Three monitoring sites were established in the Nisqually Estuary emergent marsh habitat, two located on tidal channels that drain into Red Salmon Slough and the third on a blind tidal channel that drains directly into the Nisqually River (Figure 1). The Phase 1 Restoration (Restoration) site was situated at the outlet of a 32 acre area that was restored in late summer 2002. The Restoration site wetted surface area was approximately 21,166m^2 and the volume was 3971m^3 at an 11.4 foot tide, the average height sampled (Table 1). The Red Salmon Slough Control (Control) site was situated at the outlet of a blind channel that drains into Red Salmon Slough about 800 m to the northeast of the Restoration site. The Control channel surface area was approximately 2542m^2, with a volume of 1528m^3 at tides around 11.2 feet (Table 1). The Animal Slough (Animal) site is one of the only sloughs that connects estuarine emergent marsh habitat directly to the Nisqually River. The Animal slough had an approximate surface area of 10,546m^2 and a volume of 12,745m^3 at an approximately 10.0 foot tide. The tidal station at Dupont Wharf, Nisqually Reach (ID 1093), was used for all tide height data in this report.

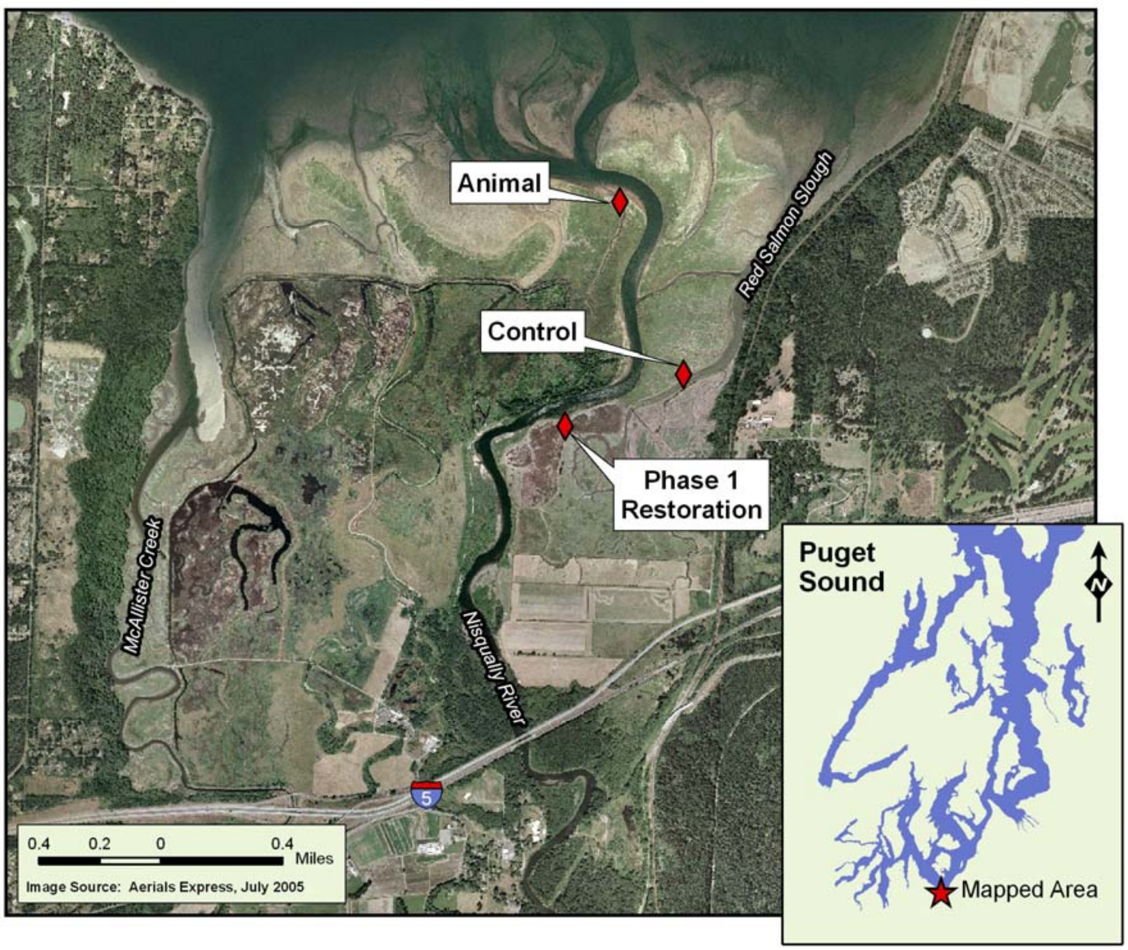

Figure 1. Location of Nisqually River estuary monitoring study sites.

The Restoration site was trapped three times (May, June, and July) in 2003, 10 times in 2004 (March – August), and 8 times in 2005 (March – July) (Table 1). The Control site was trapped 5 times in 2003 (May – October), 10 times in 2004 (March – August), and 7 times in 2005 (March – July). The Animal site was trapped 9 times in 2004 (April – August) and 11 times in 2005 (March – August). The sites were trapped with fyke nets measuring 110 inches deep with 1/8 inch mesh and a live trap in the center of the net with 2 zippered bays for removing fish while trapping. The Restoration, Control, and Animal site nets were 120 feet, 100 feet, and 75 feet long, respectively. Fyke trap nets were set across the channel at high tide (see Table 1 for average tides trapped and duration of trapping) and trapped fish were periodically removed until the traps were pulled several hours later when the site was almost dry.

All captured fish were enumerated and 10 fish of each species were measured by fork length (nearest mm) at each site. On occasions with extremely large catches or especially muddy conditions, a subsample (by volume) was taken and enumerated and then proportionally expanded by species to estimate the unsampled catch. In some cases the large catches of certain species such as shiner perch (*Cymatogaster aggregata*) and sculpin (*Cottus and Leptocottus spp*.) made accurate counts of these species infeasible, so rough estimates were made by eye. Lethal Chinook samples were taken for otolith analysis, coded wire tag reading, and stomach content analysis (2004-05 only). Stomachs were cut out of the fish in the field, stored in bags with ethanol, and combined in batches (based on site, fish origin, and season of capture) for identification and counting of contents by Robert Wisseman at Aquatic Biology Associates in Corvallis, Oregon. Only the diets from the May-June time period are presented in this paper. Salinity, temperature, and dissolved oxygen were measured at each site immediately after the trap was set using a YSI Model 85 handheld meter both at the surface (all years) and near the bottom (2004-05 only).

Benthic macroinvertebrate sampling was conducted at each of the three monitoring sites in March, May, and July of 2005. At each site, five replicate sediment core samples were taken at a depth of 10 cm with a 0.0024 m^2 PVC plastic core described by Cordell et al. (1994, 1998). The samples were sieved in the field with a 0.5mm mesh and preserved in 90% ethanol. The replicate samples were batched for a total of one sample per site per event.

Insect fallout traps were placed in the emergent marsh adjacent to the three fyke trapping sites in March, May, and July in order to measure the density of insects and other marsh associated invertebrates that contribute to a tidal channel salmon prey base. Three replicate fallout samples were collected at each of the three sites. The fallout traps consisted of 55-cm x 38-cm plastic storage bins filled with 4 cm of soapy water (Simenstad et al. 2001). The traps were left for approximately 48 hours. At each site, the contents of the three replicate samples were sieved in the field with a 0.106 mm mesh then batched and preserved in 90% ethanol.

The Nisqually Reach Nature Center (NRNC) staff and volunteers identified and enumerated the fallout trap and benthic core samples.

A percent similarity index (PSI) was used to examine, at each monitoring site in 2005, the similarity between the composition of the Chinook diet samples and the composition of the fallout and benthic core samples (Gray et al. 2002). We used the benthic and fallout data from May and July to bracket the time period from which the diet samples were batched (May 1st – June 30th). The PSI was computed using the following formula (Hurlbert 1978; Yoklavich et al. 1991):

$$\text{PSI} = \sum_{i} \min(p_{1i}, p_{2i}), \quad (1)$$

where p_{1i} is the percentage of individuals from a taxonomic grouping in sample 1 and p_{2i} is the percentage of individuals from a taxonomic grouping in sample 2.

Most diet and invertebrate samples were identified to the family level. However, if different taxonomic levels were identified in the prey and stomach content analyses they were combined to the most inclusive taxonomic level for analysis. For example, in the invertebrate and diet samples, most Brachycera were identified as Dolichopodidae but Dolichopodidae and Ephydridae were combined into the Brachycera suborder for analysis.

Table 1. Nisqually River estuary monitoring study site descriptions.

	Year	# of Sampling Events per Year	Average High Tide Sampled (ft)	Average Length of Time Sampled (hours:minutes)	Surface Area* (m^2)	Volume* (m^3)	Surface Area/Volume	Mouth Width @ Trap (m)	Average Bottom Temperature (ºC)	Average Bottom Salinity (ppt)	Average Botttom Dissolved Oxygen (mg/L)
Phase 1 Restoration	2003 2004 2005	3 9 7	11.4	2:59	21166	3971	5.33	12.2	14.1	22.9	7.6
Red Salmon Slough Control	2003 2004 2005	5 10 7	11.2	2:53	2542	1528	1.66	16.3	13.1	25.2	8.5
Animal Slough	2004 2005	9 11	10.0	4:44	10546	12745	0.83	13.4	12.9	22.6	9.4

*Measured at approximate average high tide sampled.

Results

Shiner perch dominated the catch from the Restoration site trap, accounting for over 66% of the total catch (Table 2). At the Control and Animal sites sculpin were the most abundant fish, constituting over 51% and 44% of the total fish catch, respectively. Shiner perch were also extremely abundant at the Control site, comprising over 40% of the total catch. At the Animal fyke trap, over 25% of the total catch consisted of Pacific sand lance (*Ammodytes hexapterus*) and over 22% of the catch was shiner perch. Chum salmon were the most abundant salmonid at the Control and Animal sites, comprising over 7% and nearly 5% of the total catch at the two sites, respectively (Table 2). Hatchery Chinook (0.58% of the total catch) were slightly more abundant than chum (0.31%) at the Restoration site. Unmarked Chinook were most abundant at the Animal site (0.62%) followed by the Control (0.23%) and Restoration (0.07%) sites.

Hatchery Chinook and unmarked Chinook were captured at the Restoration site on the first trapping event in May 2003, less than a year after dikes at the site were breached (Figure 2), although 2003 densities were very low (<0.0005 fish/m^2). Unmarked and hatchery Chinook catches increased in 2004 with peak catches of 0.001 (June 7th) and 0.012 (June 7th) fish/m^2, respectively. Densities of unmarked and hatchery Chinook were slightly reduced in 2005, with peak catches of 0.0007 (May 12th) and 0.006 (May 12th) fish/m^2, respectively.

Unmarked and hatchery Chinook were captured at the Control site from May through June 2003 with peak densities of 0.0065 unmarked Chinook/m^2 on May 7th and 0.03 hatchery Chinook /m^2 on May 21st (Figure 2). Catches of unmarked and hatchery Chinook declined in 2004 at the Control site to 0.001/m^2 (May 12th) and 0.01/m^2 (May 12th) respectively. The highest densities of unmarked and hatchery Chinook at any site were recorded at the Control site in 2005; unmarked Chinook catch peaked at 0.055/m^2 on April 28th and hatchery Chinook catch reached 0.032/m^2 on May 11th.

Sampling was not conducted at the Animal site in 2003. In 2004, unmarked Chinook were captured at each sampling event from May 25th to July 22nd, peaking on June 9th at 0.001/m^2 (Figure 2). Hatchery Chinook were captured from May 11th to July 22nd and peaked on May 25th at 0.013/m^2. The longest temporal distribution of unmarked Chinook occurred at the Animal site in 2005, where they were captured at each sampling event from March 18th to August 10th. The 2005 peak catch of unmarked Chinook was 0.002/m^2 on March 16th and hatchery Chinook peaked at 0.001/m^2 on March 31st.

Insect densities in the March fallout trap samples at the Restoration, Control, and Animal sites were 468, 380, and 687 insects/m^2 respectively (Figure 3). The Brachycera suborder of flies, primarily Dolichopodidae, made up nearly half of the insect catch at the Restoration site in March. The Control site was dominated by Chironomidae and the Animal site insect catch was divided nearly equally between Psychodidae, Chironomidae, and Brachycera flies. The Restoration and Control site fallout trap catches increased in May to 1647 and 1084 insects/m^2 respectively, while the Animal site catch remained constant at 686 insects/m^2. Brachycera flies accounted for over half of the insect density at the Restoration site in May. Acari and Chironomidae were the primary taxa captured at the Control site while Chironomidae made up nearly half the catch at the Animal site in May. The July insect catch was characterized by dramatic increases in the densities at the Restoration and Animal sites to 5337 and 4732 insects/m^2 respectively; the increase at both sites was driven by an explosion in the abundance of Brachycera flies. The July Control site catch actually decreased to 624 insects/m^2 and was composed of primarily Brachycera and Homoptera insects.

The March Restoration benthic core samples had extremely high densities of Annelida with over 1.4 million/m^3. Other organisms with moderate to high densities included Nematoda (314,745/m^3) and Copepoda (81,487/m^3) (Figure 4). The March Control site benthic sample consisted of primarily Annelida (149,733/m^3) and Copepoda (91,673/m^3). The Animal site March benthic sample was dominated by very high densities of Annelida (824,041/m^3) and Gammaridea (374,842/m^3). In May, the Restoration and Control benthic samples were similar in density (415,585 and 489,943 invertebrates/m^3, respectively) and composition, with Annelida dominating the samples. The May Animal benthic sample density was 283,000 invertebrates/m^3 with Gammaridea accounting for 210,848/m^3. Annelida and Nematoda comprised the bulk of the July Restoration benthic sample (624,736 invertebrates/m^3). The July Control benthic sample was primarily Annelida, for a total density of 578,900 invertebrates/m^3. The Animal benthic sample had high densities and diversity of invertebrates in July with Gammaridea (882,779/m^3), Annelida (359,902/m^3), and Isopoda (81,487/m^3) the most abundant taxa.

The percent contribution (by number) of prey items to the total diet of unmarked and hatchery Chinook salmon captured from the Restoration, Control, and Animal sloughs between May 1st and June 30th in 2004 and 2005 are presented in Figure 5. Diets of hatchery and unmarked Chinook captured from the Restoration site were composed of over 80% Brachycera flies in 2004 and and nearly 70% in 2005. Unmarked and hatchery Chinook captured at the Control site had a more diverse diet than fish from the Restoration site, with Nematocera and Brachycera flies making up the largest proportion of the diets. Chinook diets from the Animal site differed from both the Control and Restoration sites due to the contribution of crustaceans; Copepoda accounted for 68% of 2004 Animal hatchery Chinook diets, Mysidacea were 28% of the total diet of 2004 unmarked Chinook, Mysidacea and Gammaridea contributed 38% and 36% to the diets of 2005 hatchery Chinook respectively and each accounted for 22.5% of the diets of 2005 unmarked Chinook. Aphidae were also important prey items to unmarked Chinook trapped at the Animal site in 2004 (29%) and Chironomidae were important for unmarked Chinook trapped at the site in 2005 (32%).

Percent Similarity Index (PSI) values comparing the contribution of individual taxa to the total stomach contents from Chinook caught in 2005 at each of the three sample sites to the contribution of individual taxa to the total benthic and fallout trap samples from the same sites in 2005 are listed in Table 3. The highest similarity between what was sampled in the environment and what was found in Chinook diets occurred at the Restoration site. The diets of hatchery and unmarked Chinook salmon caught between May 1st and June 30th were 64% and 60% similar to the fallout trap samples from May and 88% and 68% similar to those from July, respectively. At the control site, hatchery Chinook diets were 43% similar to the July fallout samples and unmarked Chinook diets were 38% similar to the July fallout samples. There was little similarity between benthic samples and Chinook diets (<1.5%) at both the Restoration and Control sites. Chinook diets at the Animal site were moderately similar to both the core and fallout trap samples from May and July.

Table 2. Fish catch summary for the Phase 1 Restoration, Red Salmon Slough Control, and Animal Slough fyke traps.

		Chum	Hatchery Chinook	Chinook	Coho	Hatchery Coho	Pink	Steelhead	Coastal Cutthroat	Bull Trout/Dolly Varden	Mountain Whitefish
Phase 1 Restoration 2003-2005 19 Sampling Events	Total # Captured	235	435	53	1	4					
	% of Total Catch	0.311	0.575	0.070	0.001	0.005					
Red Salmon Slough Control 2003-2005 22 Sampling Events	Total # Captured	3235	143	105	1		16				
	% of Total Catch	7.117	0.315	0.231	0.002		0.035				
Animal Slough 2004-2005 20 Sampling Events	Total # Captured	1778	476	222	61	44		29	14	1	1
	% of Total Catch	4.957	1.327	0.620	0.171	0.123		0.081	0.039	0.003	0.003

		Shiner Perch	Sculpin	Sand Lance	Threespine Stickleback	Starry Flounder	Surf Smelt	Pacific Herring	Saddleback Gunnel		Total # Captured
Phase 1 Restoration 2003-2005 19 Sampling Events	Total # Captured	50385	13318	9810	1313	32		14			75599
	% of Total Catch	66.648	17.616	12.976	1.737	0.042		0.019			
Red Salmon Slough Control 2003-2005 22 Sampling Events	Total # Captured	18232	23406	2	54	256	2				45452
	% of Total Catch	40.112	51.496	0.004	0.119	0.563	0.004				
Animal Slough 2004-2005 20 Sampling Events	Total # Captured	8087	15801	9041	259	26	16	2	1		35860
	% of Total Catch	22.551	44.062	25.211	0.722	0.073	0.045	0.006	0.003		

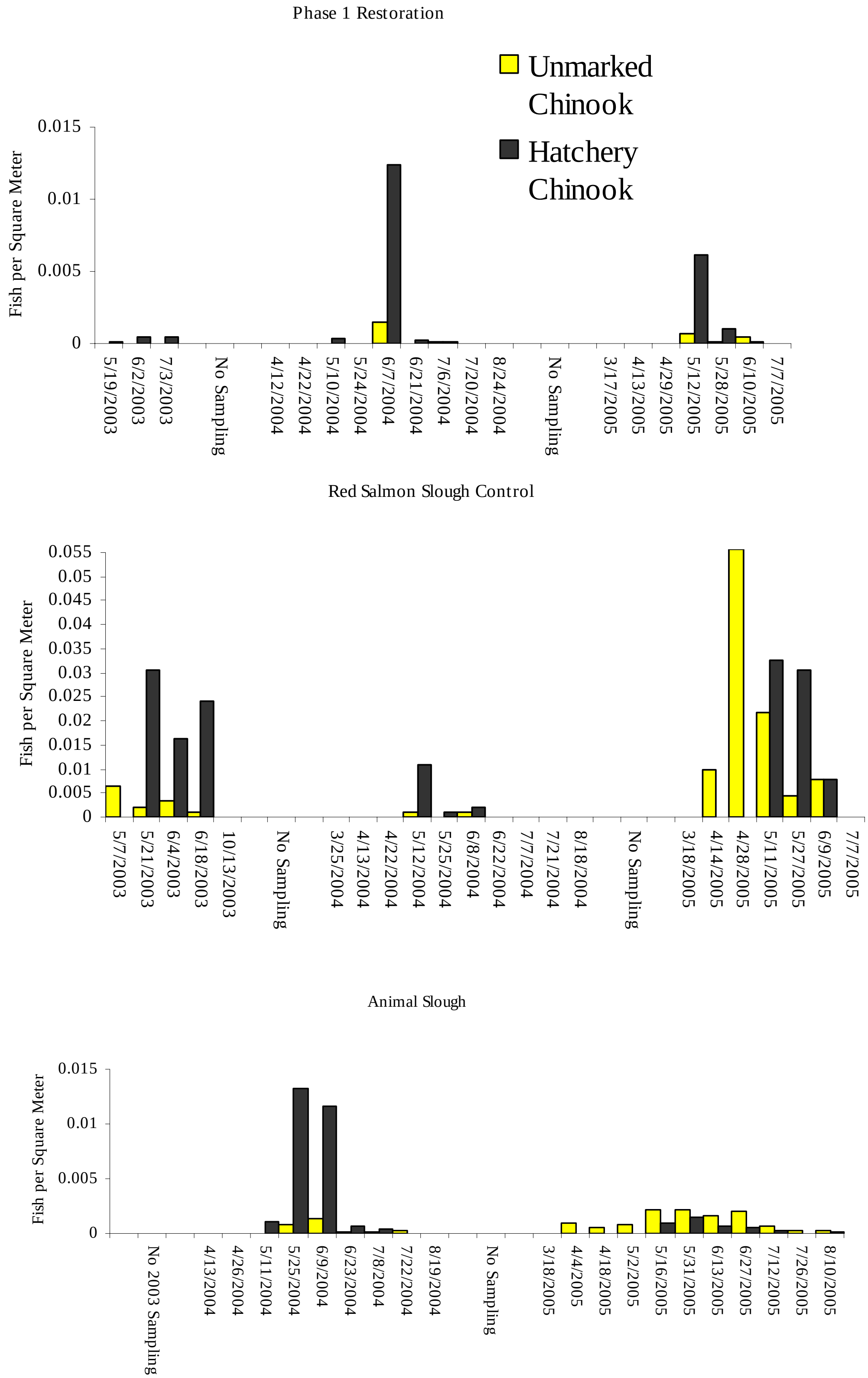

Figure 2. Unmarked and hatchery Chinook catch per square meter from the Phase 1 Restoration, Red Salmon Slough Control, and Animal study sites: 2003-2005.

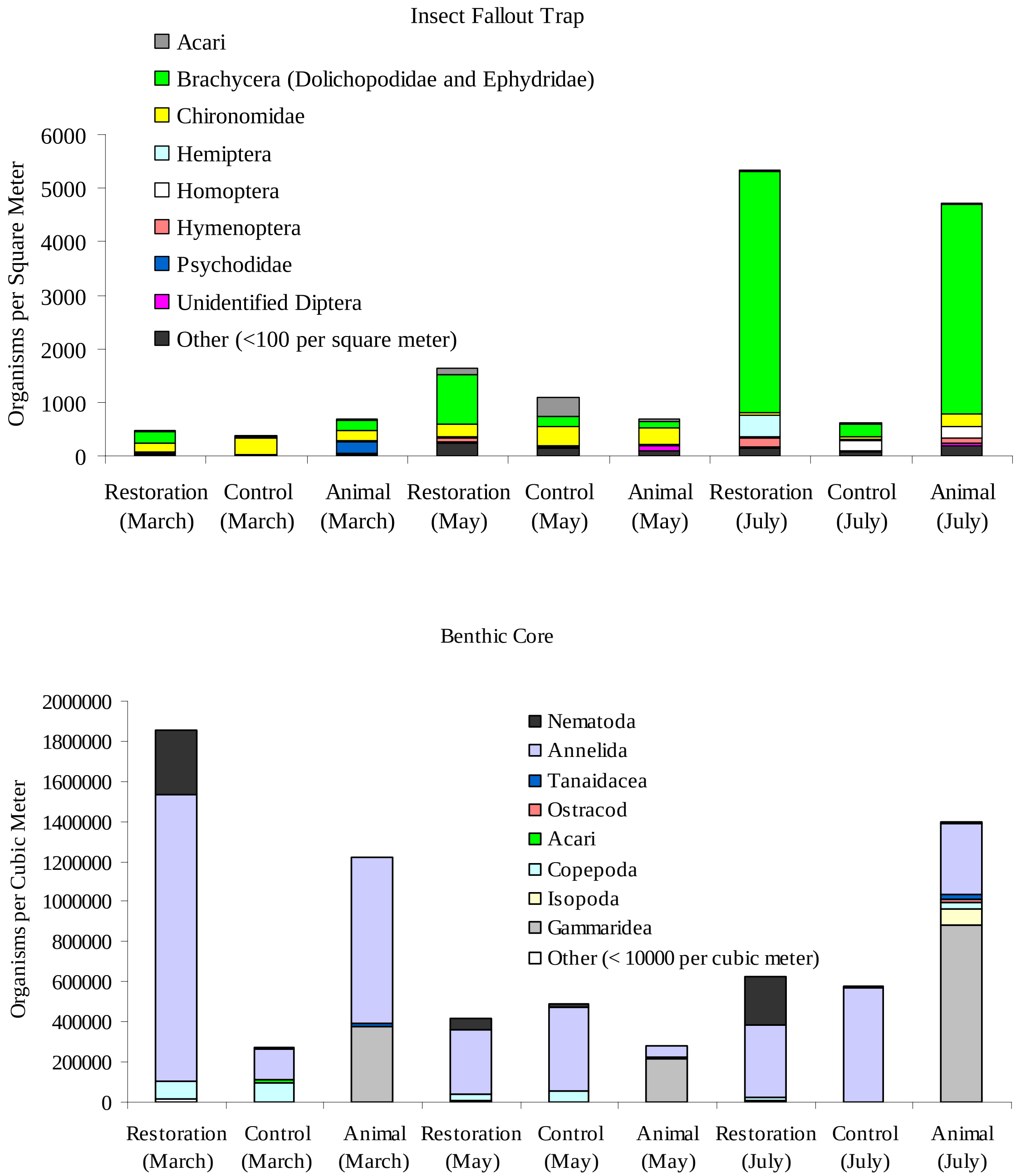

Figure 3. Density of invertebrates sampled with insect fallout traps and benthic cores at the Restoration, Control, and Animal monitoring sites from March, May, and July 2005.

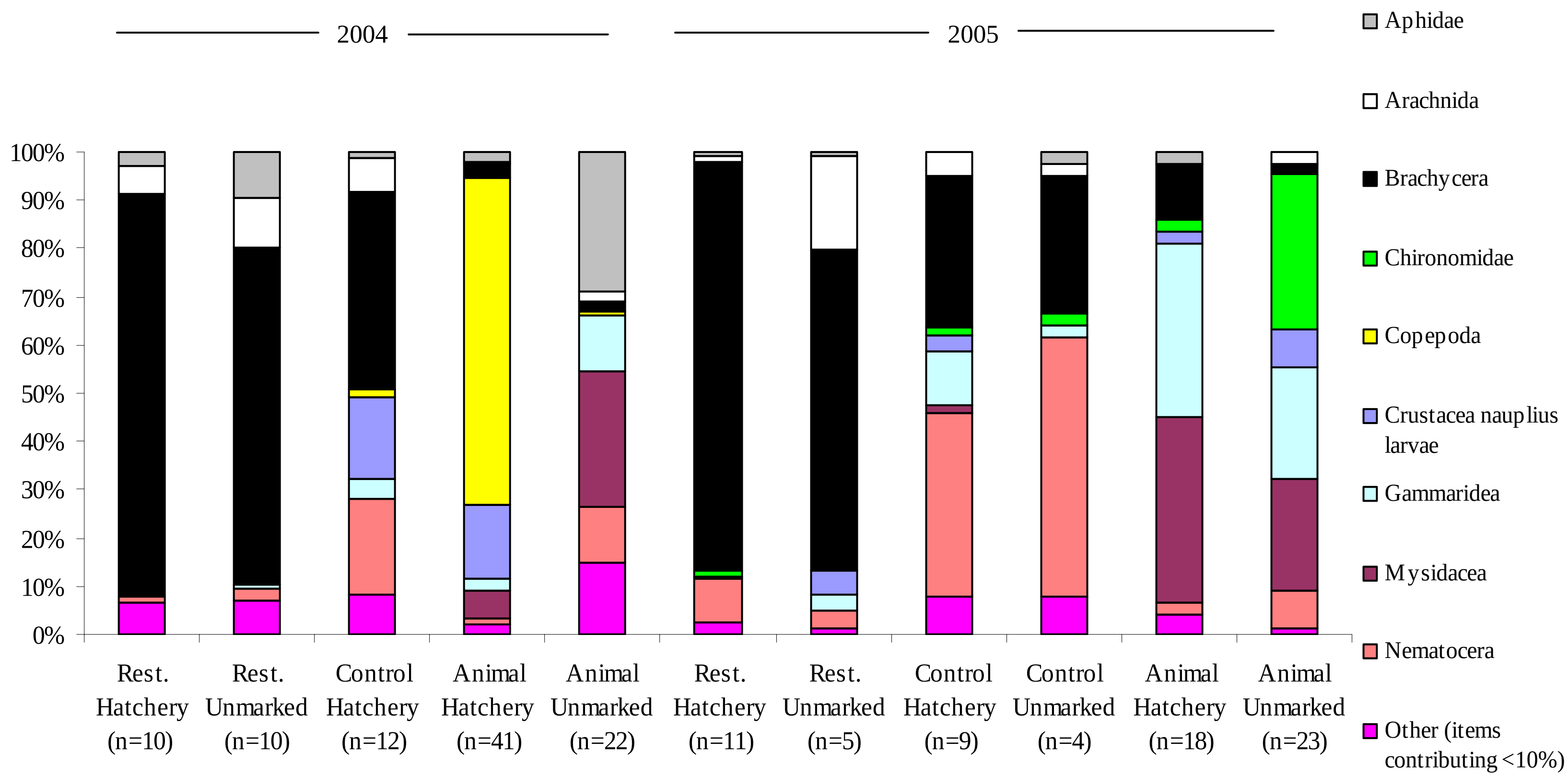

Figure 4. Percent contribution by number of prey items to the total diet composition of unmarked and hatchery Chinook captured at the Restoration (Rest.), Control, and Animal monitoring sites between May 1st and June 30th in 2004 and 2005.

Table 3. Percent similarity index (PSI) comparing composition of stomach contents from Chinook caught at each of 3 sample sites to invertebrate samples (benthic cores and insect fallout traps) gathered at the same sites. Stomach samples were taken between May 1 and June 30, 2005, and were compared to invertebrate trap samples from both May and July 2005. Bold indicates PSI > 50.

	Benthic Cores				Insect Fallout Traps			
Sample Site	May		July		May		July	
	H	U	H	U	H	U	H	U
Animal	36	23	36	22	17	37	16	10
Restoration	0	1	0	1	**64**	**60**	**88**	**68**
Control	0	0	0	0	23	24	43	38

Discussion

Unmarked and hatchery Chinook took advantage of the opportunity to utilize the Phase 1 Restoration site less than a year after the breaching of the dikes, as evidenced by the catch data. Chum salmon, shiner perch, sculpin, Pacific sand lance, and others also took advantage of the newly restored site. Chinook peak catch timing at the Restoration site was similar to the reference sites (May-June).

The temporal distribution at the Restoration site was similar to the nearby Control site, and both had a much narrower timing distribution than the Animal site. The broader temporal distribution of Chinook at the Animal site may be due to differences in abiotic factors such as temperature and salinity which are moderated by the river, providing a longer period of conditions conducive to estuary rearing.
The overall density of Chinook at the Restoration site was much less than at the Control site but similar to the Animal site. However, the Animal site catch densities are considered to be conservative because efficiency tests at this site have yielded much lower trap efficiency estimates compared to the other two trap sites. The high density at the Control site could be due to its small size because fish density and site area are likely not linearly correlated. Other differences between the sites that make direct comparisons difficult include proximity to refuge at low tide, proximity to the mainstem Nisqually, and level of channel network development.

The Restoration site insect community was dominated by the Brachycera suborder of flies (over 50% of organisms caught in fallout traps in May and almost 90% in July). These flies constituted the bulk of Chinook prey items from the site, as evidenced both in the Chinook diets and in the high percent similarity index (PSI) between the fallout trap catch and the diet composition. The diets of Chinook at the Control site had very little to moderate similarity with the insect community and no similarity with the benthic community as sampled at the site. At the Animal site the PSI did reflect moderate to high utilization of both insect (fallout) and crustacean (benthic) prey. The interpretation of the diet data at the Control and Restoration sites is limited by short fyke trapping durations (less than three hours), so there could be carryover in the diet data from feeding that occurred off site. However, the PSI at the Restoration site does provide strong evidence that these fish are feeding at the site and taking advantage of the site’s capacity. The PSI should be considered a conservative estimate of the similarity between the composition of the diet and the composition of the invertebrate community because our invertebrate sampling methods may have been biased towards certain taxa or ineffective at capturing important prey items (i.e., Mysidacea).

Preliminary otolith data (microstructure analysis of inner ear structures, unpublished United States Geological Survey data) indicates that wild delta-rearing Chinook enter the estuary in early June and may reside for over a month. Preliminary otolith results show growth rates in the delta were an average of 28% (up to 67%) higher than in freshwater. The longer residency and higher growth rates of delta-rearing Chinook coincide with apparent peak insect production based on our limited invertebrate sampling. It appears that the Restoration site is providing immediate realized function for Chinook in the form of Brachycera flies that peak at the same approximate time that the Chinook are entering and residing in the estuary. Based on our monitoring data from the 40 acre Phase 1 Restoration site, we anticipate that if the newly completed 100 acre Phase 2 Restoration and the planned 700 acre restoration follow similar recovery trajectories they will increase the Nisqually Estuary’s capacity to support juvenile Chinook and other fishes.

Acknowledgments

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