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Key Words

chinook salmon, juvenile salmon, Puget Sound, shallow water habitat, shoreline, fish sampling, enclosure nets, underwater videography, snorkel surveys

Executive Summary

Four sampling techniques were pilot-tested in order to determine their effectiveness in sampling juvenile salmonids at various habitat types along City of Seattle marine shorelines: (1) enclosure nets, (2) underwater videography, (3) snorkel surveys, and (4) above water observations. Success of each technique varied under different habitats and conditions.

Enclosure nets had the obvious benefits associated with physical capture of fish, including actual density measurements, exact species identification, and opportunity for fish diet analysis. Drawbacks associated with enclosure nets were the small sample size and large time and workload involved with setting one net per day, and the inability to sample underneath docks and piers as well as in areas deeper than 4 m at high tide.

Snorkeling and underwater videography both had the benefit of being able to sample around docks and piers, with the ability to conduct several transects per day. The drawback was that effective sampling was dependent on water clarity, as turbid water complicated species identification and counts. Videography measurements were not as accurate as snorkeling, and also involved time-consuming analysis in the laboratory.

We found that above water observations were only effective at observing chum salmon. Water surface distortion and light reflectance also made data collection difficult.

Based on these pilot tests, we recommend combining enclosure nets and snorkel transects in future surveys of juvenile salmonids along City of Seattle marine shorelines. We present different scenarios that maximize the benefits of each sampling methodology under varying conditions.

Introduction

Studies of juvenile chinook salmon in the Pacific Northwest indicate that they use nearshore habitats early in their outmigration and rearing period (Simenstad et al. 1982; Healey 1998). This is true of Puget Sound, where juvenile chinook captured in King County were commonly found in nearshore habitats from late January through September (KCDNR 2001). Although previous studies indicate that juvenile salmon are present along City of Seattle marine shorelines, there is little specific information about whether or not juvenile salmon preferentially use (or avoid) certain types of shorelines, and what functions the different shoreline types provide for them. Research conducted in the Puget Sound region suggests that juveniles of chinook (*Oncorhynchus tshawytscha*) and chum salmon (*O. keta*) prefer shallow areas along estuarine and marine shorelines, including beaches and eelgrass beds (Simenstad et al. 1982; Simenstad and Cordell 2000). However, in urban settings, it is unknown how juvenile salmon behavior is influenced by the diversity of anthropogenic structures and impacts: do the salmon select some habitats and avoid others, or are they simply randomly distributed along the shoreline?

The purpose of this study was to develop and test a variety of sampling methods and identify those that will be most effective in statistically based studies comparing abundance and behavior of juvenile salmon along Seattle's marine shorelines. A secondary goal of these studies will be to provide samples of juvenile salmon for indication of type of habitat use based on diet composition. It is intended that the recommended methodologies, when linked with a habitat classification and delineation of the marine shoreline, will be able to test hypotheses such as "there is no significant difference in juvenile salmon abundance among City of Seattle shoreline types." Such statistically rigorous results are important to resource managers who need to identify potential impacts of nearshore activities on salmon, prioritize recovery actions, and identify approaches that provide maximum protection to those nearshore marine areas that are important to juvenile salmon.

Most prior sampling for shoreline oriented juvenile salmon in the Puget Sound region has been conducted using beach seines, which are only effective for sampling certain habitat types such as shallow beaches at specific tide levels. Density estimates from seining can also be severely compromised by varying sampling efficiencies over different substrates and water depths (Rozas and Minello 1997). In addition, beach seines are "instantaneous" measures of fish assemblage structure and densities, and as such do not supply information about on-site behavior.

We tested four different sampling techniques in order to determine their effectiveness in sampling juvenile salmonids at various habitat types: (1) enclosure nets, (2) underwater videography, (3) snorkel surveys, and (4) above water observations. Rozas and Minnelo (1997) recommend using enclosure nets for estimating densities of small nekton in shallow estuarine habitats, as they provide the most reliable quantitative data and provide comparable results between sites and studies. Underwater videography has been increasingly used in marine settings, for observations in which netting is impractical (Hixon and Carr 1997; Hindell et al. 2002). Snorkel surveys and other visual census techniques for assessing fish abundance are often conducted with success in freshwater and coral reef environments, but usage in estuarine and shallow water marine settings is lacking (Bohnsack and Bannerot 1986; Slaney and Martin 1987; Hankin and Reeves 1988; St. John et al. 1990; Graham 1992; Haggarty 2001; Tabor and Piaskowski 2002). Above water observations have the potential for generating comparative data, but few studies have provided quantitative results (Haggarty 2001; Tabor and Piaskowski 2002). We will provide sampling recommendations for juvenile salmonids along marine shorelines based on pilot tests utilizing these four techniques.

Material and Methods

Study Sites

Sampling locations were all within City of Seattle boundaries (Fig. 1). Fieldwork was conducted between 5/20/02 and 7/12/02. Three sites in Shilshole Bay that represented different habitat types were the main locations for testing methodologies:

- **Boulder**: Shallow cobble beach at the base of the bluff by Discovery Park - similar to much of the Seattle Puget Sound natural shoreline.
- **Breakwater**: West side of outer Shilshole Marina - similar to rip-rap along the railroad tracks and elsewhere in developed areas.
- **Overwater**: Pier just south of Shilshole marina, containing dense pilings with overhead structure - similar to Shilshole/Elliott Bays and parts of the Duwamish waterway.

One site was used for initial testing of gear deployment:

- **Groundswell**: A protected sandy beach, directly downstream from the Ballard Locks.

Three sites were sampled once, in order to apply the methods to several additional habitats.

- **West Point**: A shallow sandy beach.
- **Myrtle Edwards**: A steep seawall directly south of Myrtle Edwards Park.
- **Alki**: A shallow slope, exposed area south of Alki Point.

Sampling Techniques – Collection

Enclosure Nets

The presence and abundance of fish in shallow-water habitats were tested using enclosure net sampling. This consisted of using a 60-m long, 4-m deep, 0.64-cm mesh net placed around poles to corral a rectangular section of the shoreline (Fig. 2). The poles were installed at low tide the day before net deployment, so as to minimize disturbance at time of sampling (Fig. 3). The enclosure net was installed at high tide (Fig. 4). Fish were removed with either a small pole seine (4 ft. x 30 ft., ¼" mesh) or dip nets as the tide receded, usually starting at mid-tide a few hours after net deployment (Fig. 5). All fish were removed before low tide. Fish captured in the net were identified and counted, and forklengths of salmonids recorded up to n = 5 for each: (1) species, (2) hatchery or wild status, and (3) size class (Fig. 6). The data resulting from the enclosure sampling produced per unit area and volume densities of juvenile salmon and other fish on each unit of shoreline sampled. Nets were typically set as shown in Figure 2, sampling a 20-m square section of shoreline. Volume was determined by measuring the water depth at the poles when the net was set, as well as the water depth at shore (if not zero; e.g. due to rip-rap embankment), assuming a steady slope from shore to the poles. Sampling took place during spring tides to take advantage of higher tidal heights, since the goal was to assess fish utilization close to shorelines.

Physical measurements of water salinity and temperature were opportunistically taken with a portable YSI meter. Water visibility was measured by taking vertical secchi disc depths (Fig. 7).

Although this study was designed for testing gear, some subsamples of salmonids were sampled for diet by gastric lavage. This method consisted of placing fish in a bucket of seawater with a small amount of the anesthetic MS-222 for approximately 30-

60 seconds. Each fish was removed from the bucket and forklength measured; gut contents were then removed using a modified garden pump sprayer with a custom nozzle and filtered seawater (Fig. 8; Hartleb and Moring 1995). Contents were washed into a fine mesh sieve and fixed in 10% formaldehyde solution. Fish were immediately placed in a bucket of seawater for recovery (approximately 2-3 minutes), and then released. Gut contents were later analyzed in the laboratory, and prey items ranked based on modified Index of Relative Importance values (IRI; Pinkas et al. 1971; Simenstad et al. 1991):

$$\text{IRI} = \begin{matrix}\text{\% frequency}\\ \text{of occurrence}\end{matrix} \text{ X } \left[\begin{matrix}\text{\% numerical}\\ \text{composition}\end{matrix} + \begin{matrix}\text{\% gravimetric}\\ \text{composition}\end{matrix} \right]$$

All sampling techniques were monitored for any potential injury to salmonids, which could include entanglement in nets or over-anesthetization with MS-222. Based on past research, potential for injury by these methods was expected to be negligible.

Beach Seine

Although beach seines were not an emphasis of this study, we seined twice in order to verify fish identifications and compare the process to enclosure net sampling. A standard 30-m Puget Sound beach seine set from a boat was utilized (Simenstad et al. 1991).

Sampling Techniques - Observation

Snorkel Surveys

Previous work along a similar city shoreline in Vancouver Harbor, British Columbia developed direct observation survey techniques that maximized probability of observing juvenile salmon (Haggarty 2001). We incorporated these findings into designing and conducting our snorkel surveys along transects parallel to shore (Fig. 9). Numbers of fish counts were standardized by length and visibility (number/[transect length x horizontal secchi depth]). We tried many different transect techniques, varying factors such as water depth and distance from shore. At modified sites such as Overwater and Breakwater, transects were typically conducted directly along shore, as these sites had deeper water due to the shoreline modifications. Data that was collected during snorkeling transects included:

- Transect length (m)

- Transect direction (compass point)
- Direction of observations (away from shore, toward shore)
- Water depth (m)
- Distance from shore (m)
- Horizontal secchi disc visibility measurement (m)
- Fish identification
- Approximate fish length (cm)
- Water column position of fish (surface, mid-water, bottom)
- Distance from diver to fish (m)
- Water depth at fish (m)
- Substrate type (mud, sand, gravel, cobble, boulder, bedrock, rip-rap, rip-rap/sand interface, dock/pier, kelp)
- Fish behavior (unaffected, swim away, flee, schooling)

Underwater Videography

We initially tested both color, and black and white underwater cameras. Based on these tests, we determined that color cameras provided superior observations with better clarity, so for the majority of sampling we utilized a color underwater video camera with 100 ft. of cable (Fig. 10). We tested the camera in four ways: (1) stationary deployment on a temporary pole with human monitoring (Fig. 11); (2) stationary deployment on a piling of a pier (Fig. 12); (3) combined with mobile snorkeling and boat transects; and (4) combined with enclosure nets, to monitor possible fish escapement and behavior during sampling. Numbers of fish counts were standardized by visibility and time (number/[horizontal secchi depth x time]). Data that was collected during video observations included:

- Camera orientation (parallel or perpendicular to shore)
- Camera direction (compass point)
- Time of recording (start-end)
- Type of deployment (stationary on a T-post, stationary on a piling, stationary on a enclosure net, from a boat, with a snorkeling transect)

- Water depth (m)
- Distance from shore (m)
- Horizontal secchi disc visibility measurement (m)
- Substrate type (mud, sand, gravel, cobble, boulder, bedrock, rip-rap, rip-rap/sand interface, dock/pier, kelp)

The video tapes were brought back to the laboratory and processed for:

- Fish identification and count
- Water column position of fish (surface, mid-water, bottom)
- Location of fish in relation to camera (foreground, midground, background)
- Fish behavior (unaffected, swim away, flee, schooling)

Above Water Observations

Apparently a considerable amount of this type of observation has been conducted in the Pacific Northwest (personal communications from various sources), but very little of the data has been rigorously validated or published. Problems with visibility during over water observations include "mirror" effect on cloudy calm days and surface distortion on rainy/windy days (Haggarty 2001). Therefore, we did not emphasize this type of observation, but opportunistically combined overwater observations with other efforts. Data from shore observations were similar to those for snorkeling (i.e., presence or absence of fish in relation to transect length).

Results

We completed a total of 148 sampling events throughout the pilot tests. Table 1 summarizes the types and numbers of each methodology.

Enclosure Nets

Surface area sampled by the enclosure nets was 400 m^2 for a 20 m length set, and volumes ranged from 240 – 849.6 m^3, with an average of 477.3 m^3 (Table 2). Sampling was conducted between 6/11/0 and 7/12/02. Enclosure net sampling produced density measurements of salmonids both per water volume (Fig. 13) and surface area (Fig. 14).

Although this was not a statistically replicated sampling design, our pilot test sampling showed highest salmon densities at Breakwater. Breakwater was also the site with the deepest water, and water volumes were higher than at the other sites (Table 3). Measurements of water volume were not taken during our initial test deployment of the net at Groundswell.

During the sampling period, the most common salmonids were hatchery and wild chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*), and chum (*O. keta*); pink (*O. gorbuscha*) and sockeye (*O. nerka*) were less common (Figs. 13-15). In this report, we designate adipose-clipped salmonids as hatchery, and those with adipose fins as wild fish. Chum and pink salmon had shorter forklengths than chinook and coho, and hatchery coho were longer than wild coho (Fig. 16).

Enclosure net sampling also produced density measurements of non-salmonids per unit water volume (Fig. 17) and surface area (Fig. 18). Sandlance (*Ammodytes hexapterus*), shiner perch (*Cymatogaster aggregata*), staghorn sculpin (*Leptocottus armatus*), and threespine stickleback (*Gasterosteus aculeatus*) dominated non-salmonid species composition.

Prey items of salmonids consisted of a diverse array of insects, crustaceans, and fish in the diets of chinook, coho, and chum salmon (Fig. 19). A sample size beyond 5 for each species and size class was difficult to accomplish, due to the limit of time as the tide dewatered in the enclosure nets.

Snorkel Surveys

Identification of salmon species while snorkeling was sometimes difficult, as it was often hard to see distinguishing characteristics due to water turbidity and short time of viewing. Therefore, identifications were often made in broader categories (Fig. 20). Salmon densities were highest at Overwater. Overwater was also the deepest site due to shoreline modifications; average water depth along the overwater structure was 4.5 m, while 1.7 m at Breakwater and only 1.4 m at Boulder. Identification of non-salmonids was not as difficult as salmonids, since characteristics were easier to distinguish (Fig. 21). Turbidity played an important role in the success of snorkel surveys, reducing both numbers of fish seen and ability to identify fish. We found that if secchi depth readings were below 3.5 – 4.0 m, snorkel surveys were not that successful. Secchi depths varied throughout the pilot study (Fig. 22). At unmodified shorelines with a gradual slope, we found that shallow water transects (< 2m water depth) were more successful than deep water transects (> 2m; Fig. 23). This was also beneficial as it categorized fish usage closer to shore.

Underwater Videography

As with snorkeling, salmon identifications from underwater video were sometimes compromised by water turbidity and light levels (Fig. 24). In such cases, identifications were combined into broader categories. Semi-permanent deployment on a stationary object was the most successful method. Densities are illustrated as numbers of fish (Fig. 25), and number of schools (Fig. 26). Schools tended to be larger at Overwater (9.8 average salmon/school), and smaller at Breakwater (2.1) and Boulder (1.0). Deploying the camera perpendicular to shore produced higher numbers than did parallel placement (Fig. 27).

One method to alleviate the problems with species identification of salmonids is to apply the relative percent composition of salmon species from accompanying enclosure net data (Fig. 28). Such "ground-truthing" methodologies are often employed in similar circumstances both in hydroacoustics and snorkel surveys in streams and rivers, when physical capture of fish is used to calibrate estimates from less accurate but easier and more replicable sampling (Slaney and Martin 1987; Hankin and Reeves 1988; Godø et al. 1998).

Non-stationary video was less consistent then stationary video (Fig. 29). The main problems were lack of a controlled reference position and excessive camera movement, leading to uncertainty and difficulties in processing the data. Cameras placed inside the enclosure nets showed no instances of harm or fish escapement.

Above Water Observations

Compared to the other tested methods, above water observations were ineffective. Problems with water surface reflection and distortion due to combinations of sun, wind, and waves prevented accurate observations (Fig. 30). Chum salmon were the only juvenile salmonid observed during above water transects.

Discussion

We have generated criteria that evaluate the effectiveness of each of the four pilot-tested methods (Table 4). Enclosure nets were the only method that allowed capture of fish and reliable measures of density, fish size, and species identification (Fig. 6). Enclosure net sampling has the additional benefit of allowing diet analyses. This may provide valuable information about habitat use, as foregut contents of fish held for several hours in the enclosure net prior to sampling will most likely reflect food obtained therein. Enclosure net sampling was also effective at all tested habitat types, and in all of the weather and water conditions encountered. The major difficulty with enclosure net sampling is that it is very time consuming and labor intensive. It was only possible to sample one site per day using one net and a crew of at least three people. It also is advisable to set the poles the day before at low tide to minimize disturbance. Thus, sampling 4 sites per week is the maximum number with one net and sampling crew. As with many netting techniques, it was impossible to set enclosure nets under docks and piers.

Unlike nets, snorkeling and underwater videography methods could be used under and around docks and piers (Fig. 12). These may be potentially valuable methods, because we often observed large schools of juvenile salmon congregated around the edges of (though not underneath) piers (e.g. the Overwater site, Fig. 20). Multiple and/or replicated transects could reveal preference/avoidance for specific shoreline features or locations along piers and docks. Because our observations took place at the outer edges of the piers, the water depth was often deeper than at natural shorelines, which may explain the larger schools of juvenile salmon observed in these areas. Another benefit of snorkeling and video is the ease of replication, as it is possible to conduct several transects in one day. Data on fish behavior and habitat characteristics that is not available with netting techniques can also be collected.

The obvious drawbacks to snorkeling and video are that fish are not physically captured. Although this is the best-case scenario for not harming the fish, it can lead to problems with species identification and accurate counts. Since water clarity often dictated success, it is impossible to know until we are in the water whether or not we will be able to collect meaningful data with these techniques. However, these drawbacks can be somewhat alleviated when combined with applying the relative percent composition of captured fish using enclosure net techniques, as is similarly done in hydroacoustics and snorkel surveys in streams and rivers (Slaney and Martin 1987; Hankin and Reeves 1988; Godø et al. 1998). In future work, it could also be beneficial to beach seine immediately after video and snorkeling in order to generate percent species composition, in situations where application of enclosure net data is not possible.

Although snorkeling and video had similar capabilities for successful data generation, we found that snorkeling was a more reliable and cost-effective technique. Fish counts and identifications could be made to finer detail using snorkel surveys (Figs. 20, 25). Also, video required time-consuming viewing and analysis of the videotapes in the laboratory, while snorkeling produced instantaneous numbers in the field. Based on these findings and the similarity of the techniques, it is clear that snorkeling should be utilized above video in future studies.

It is important to note that the above techniques produced the same rankings of salmon densities between sites. When the three main techniques (enclosure net, video, snorkel) were used, all three ranked Breakwater with more salmon than Boulder. When two techniques were used that included the Overwater site (video and snorkel), Overwater had the most salmon followed by Breakwater then Boulder.

We found that above water observation transects were only effective at observing chum salmon, as we did not observe any other species of juvenile salmonids using this method. Although we did observe some chinook and coho during the course of the fieldwork from the boat and shore, there was no pattern to these observations. A study of the Vancouver, B.C. shoreline also found this, and attributed it to the fact that chum are more surface oriented while chinook are generally found slightly more offshore (Haggarty 2001). Additional problems with visibility during above water observations included "mirror" effects on cloudy calm days, and surface distortion on rainy/windy days (Haggarty 2001).

Based on the discussion above, we recommend that a combination of enclosure nets and snorkel surveys be utilized in order to effectively differentiate between sites and habitat types. Two possible scenarios for additional studies along Seattle marine shorelines are outlined below:

(1) <u>Intensive effort at one site per day (1 boat, 4 person crew).</u> Install the enclosure net poles at low tide the day before to minimize disturbance (Fig. 3). Arrive at high tide the next day and deploy the enclosure net (Fig. 4). As the tide recedes, two people in dry-suits and snorkel gear each conduct two 100 m snorkel transects (Fig. 9). The other two people monitor equipment and record snorkel data, and when the tide is low enough for netting, they begin removing fish and pumping stomachs for diet analysis (Figs. 5, 8). Everyone helps collect fish and disassemble the net at low tide. If continued for one week, this would generate comparative data across four sites at similar tidal heights for each technique. Success of the snorkeling will be dependent on water clarity, with secchi depth measurements above 3.5 – 4.0 m required for success. *This scenario would be most effective during spring tides, and not possible at overwater structures.*

(2) <u>Effort distributed among three sites per day (1 boat, 4 person crew).</u> Select three sites that are relatively close together, and sample each site using snorkel transects at or near high tide. Arrive at the first site one hour before high tide. Two people in dry-suits and snorkel gear each conduct two 100 m snorkel transects. The other two people monitor and record snorkel data, and provide boat support. Repeat at the second site at high tide, and at the third site an hour after high tide. This would yield data for all three sites using the same techniques at similar tidal heights. As with the first scenario, success would depend on water clarity. *This scenario would be most effective during neap tides, and is applicable to overwater structures.*

These base scenarios could be modified by: (1) Increasing the number of sites by doubling the effort and employing two boats with an eight person crew, or even tripling the effort with three boats and a twelve person crew, (2) combining them by utilizing scenario 1 at a subset of sites during spring tides, and scenario 2 at an expanded list of sites during neap tides, and (3) employing scenario 1 during neap tides in addition to spring tides (although the enclosure nets would sample a smaller volume of water). Underwater videography could also still be used opportunistically, in situations where documentation of fish activities is deemed important (e.g. placing of the video camera inside the enclosure nets to monitor fish behavior and possible harm or escapement). By incorporating such scenarios into a comprehensive research plan, we will be able to analyze juvenile salmonid abundance and behavior along City of Seattle marine shorelines in future research.

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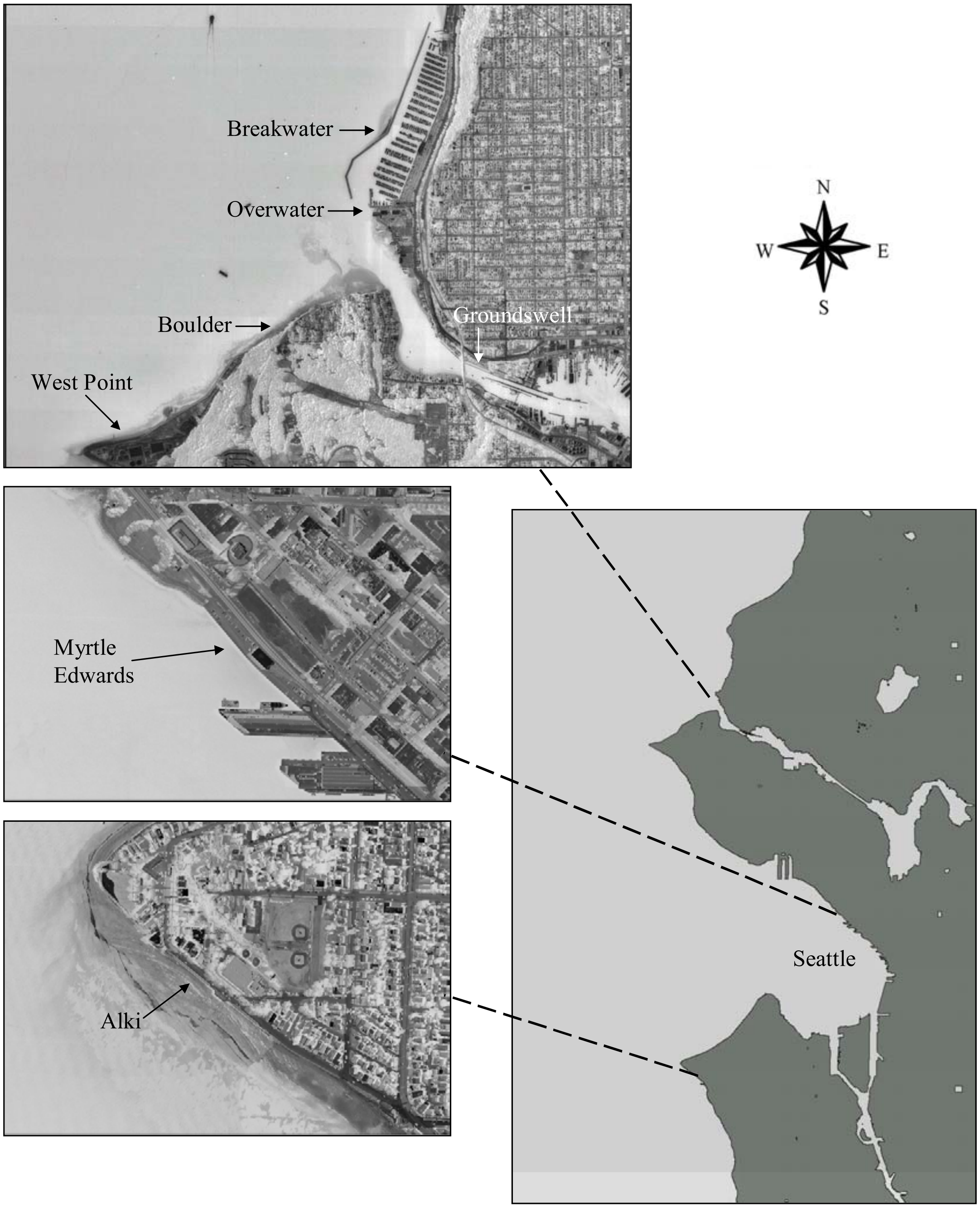

Figure 1. Sampling sites in the City of Seattle. Breakwater, Overwater, and Boulder were the primary sampling sites, Groundswell was a pilot test site, and West Point, Myrtle Edwards, and Alki were one-time sampling events.

Aerial View of Enclosure Net Schematic

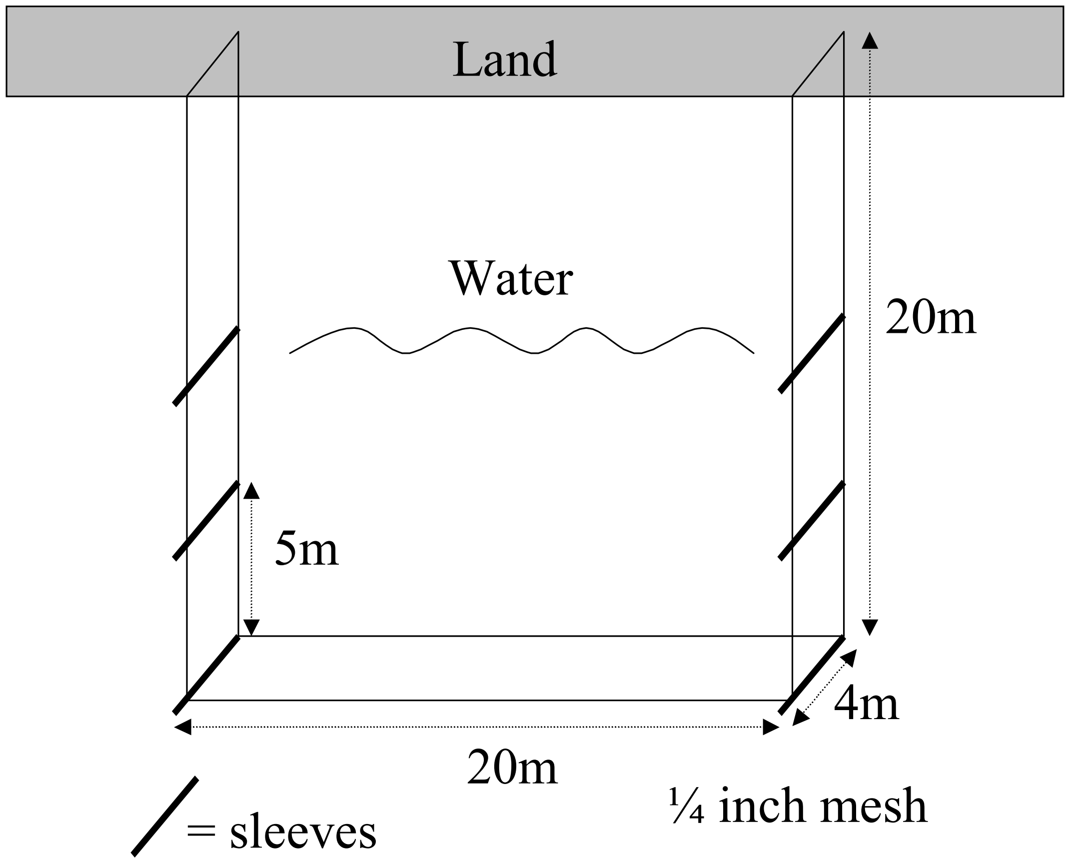

Figure 2. Enclosure net typical deployment: total net is 60-meters long, 4-m high. 4-inch diameter sleeves sewn into net at 10, 15, and 20-m in from each side (to have several options for the length of the sides).

Figure 3. Installation of enclosure net and video mounting poles at West Point during low tide the day before sampling.

Figure 4. Enclosure net after deployment at Breakwater during high tide.

Figure 5. Enclosure net at Boulder during mid tide.

Figure 6. Measuring the forklength of a juvenile coho salmon.

Figure 7. Taking a vertical secchi disc depth to measure water visibility.

Figure 8. Sampling fish gut contents using gastric lavage.

Figure 9. Beginning of a snorkeling transect at Breakwater.

Figure 10. Underwater video camera attached to a mounting pole.

Figure 11. Underwater video camera deployed on a semi-permanent pole at Boulder.

Figure 12. Underwater video camera attached to a piling at Overwater.

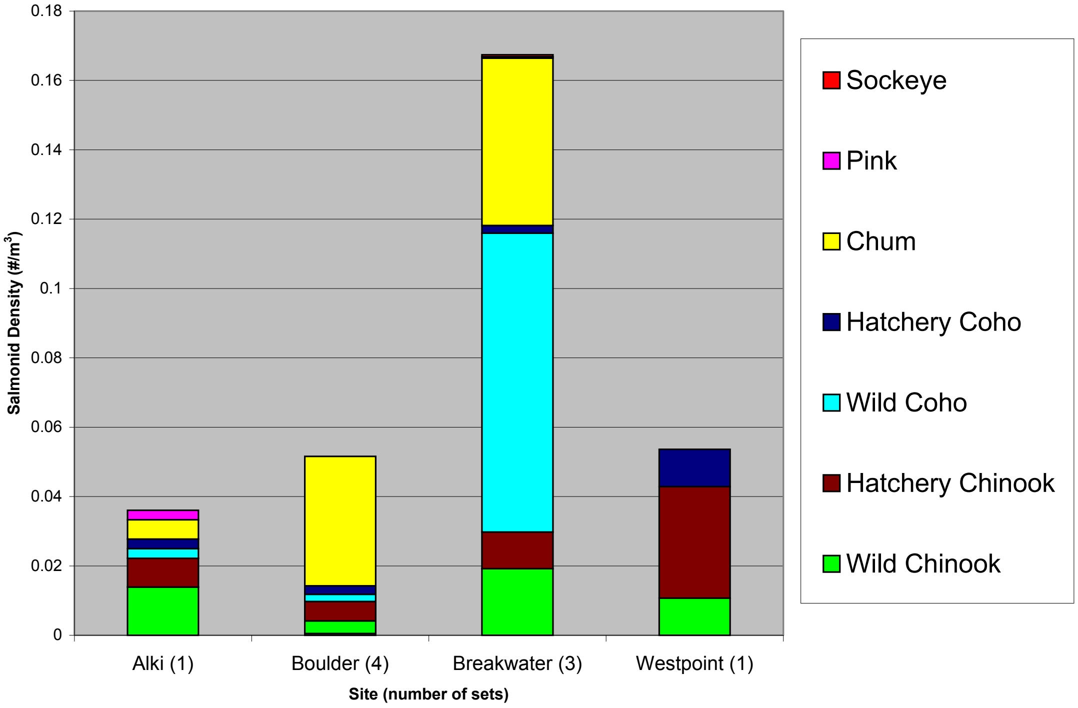

Figure 13. Salmonid enclosure net density per water volume (#/m^3).

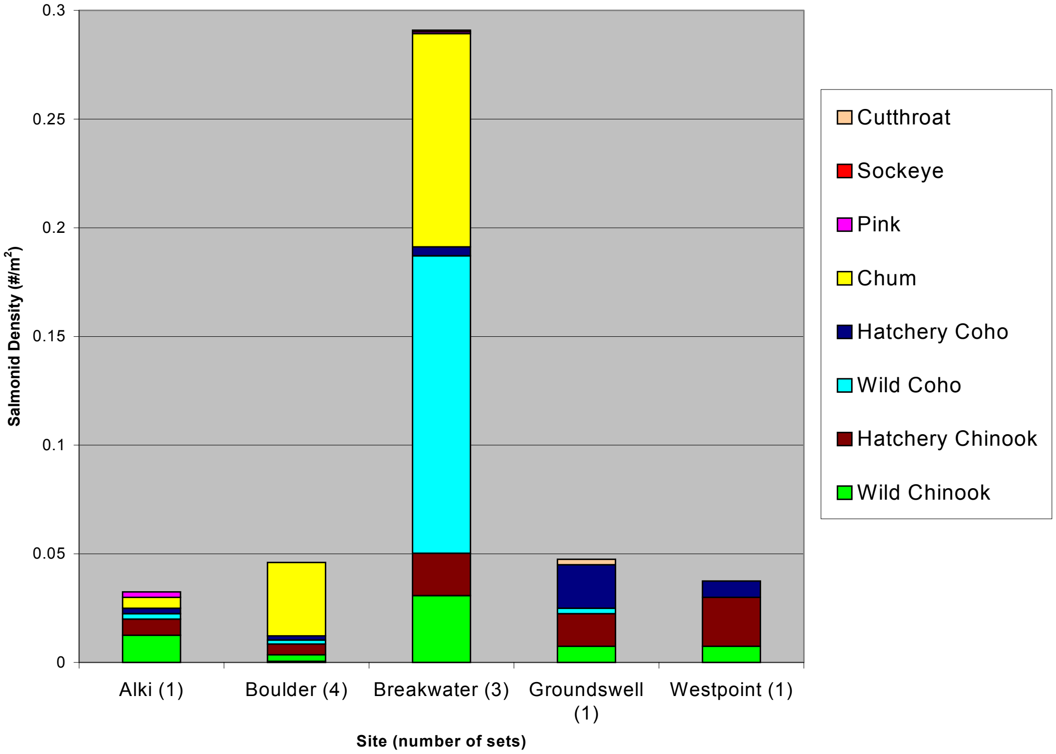

Figure 14. Salmonid enclosure net density per water surface area (#/m^2).

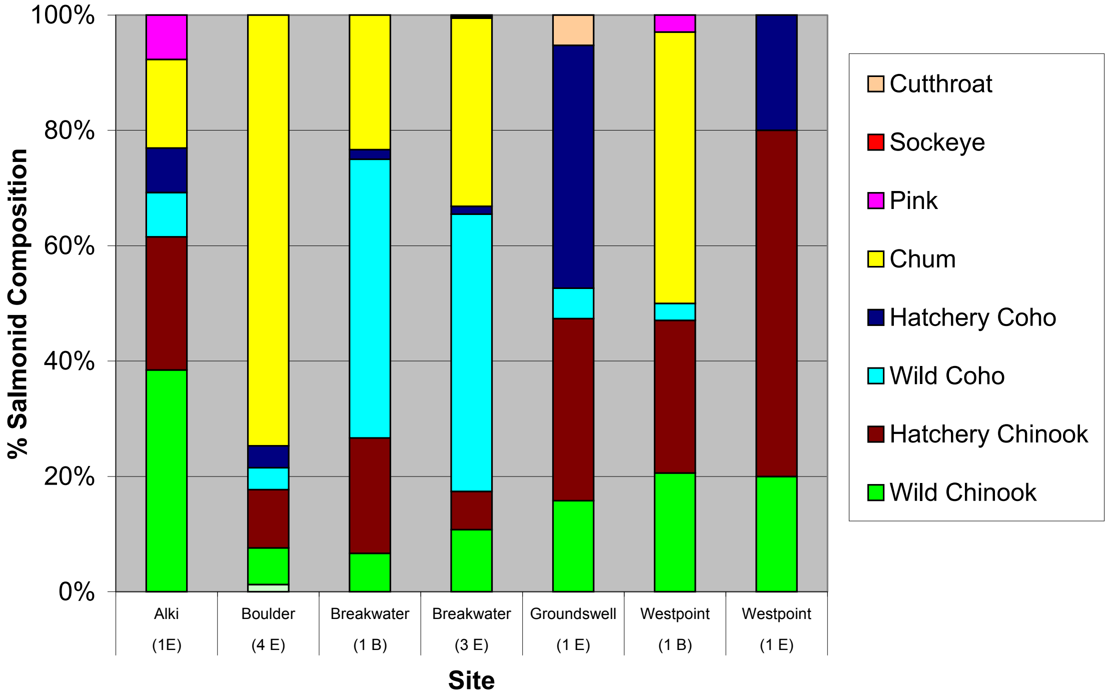

Figure 15. Percent composition of salmonids from all net sampling. E = Enclosure nets and B = Beach seines.

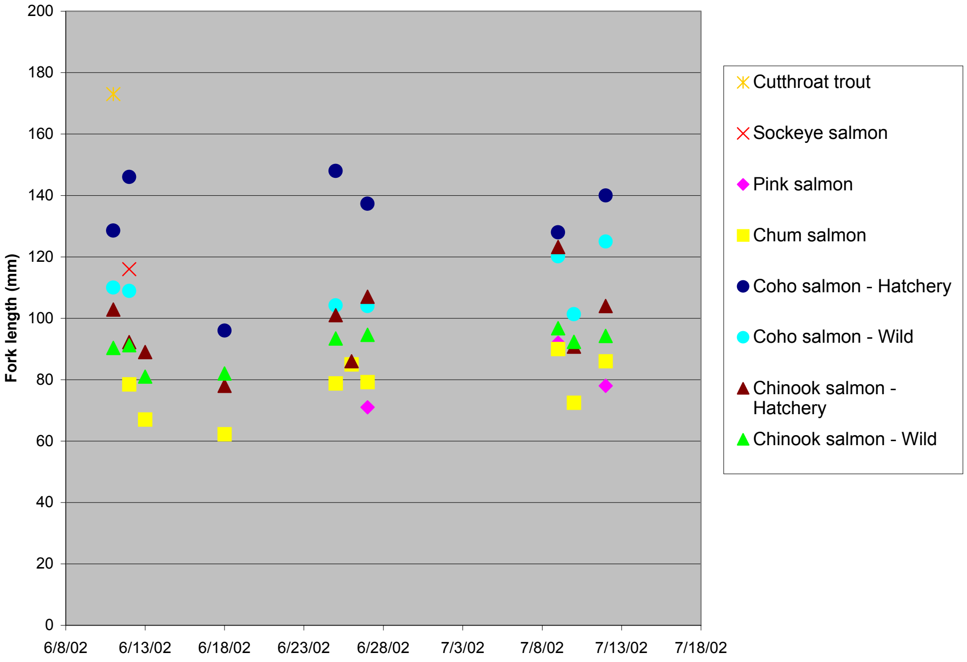

Figure 16. Forklengths (mm) of salmonids from net sampling.

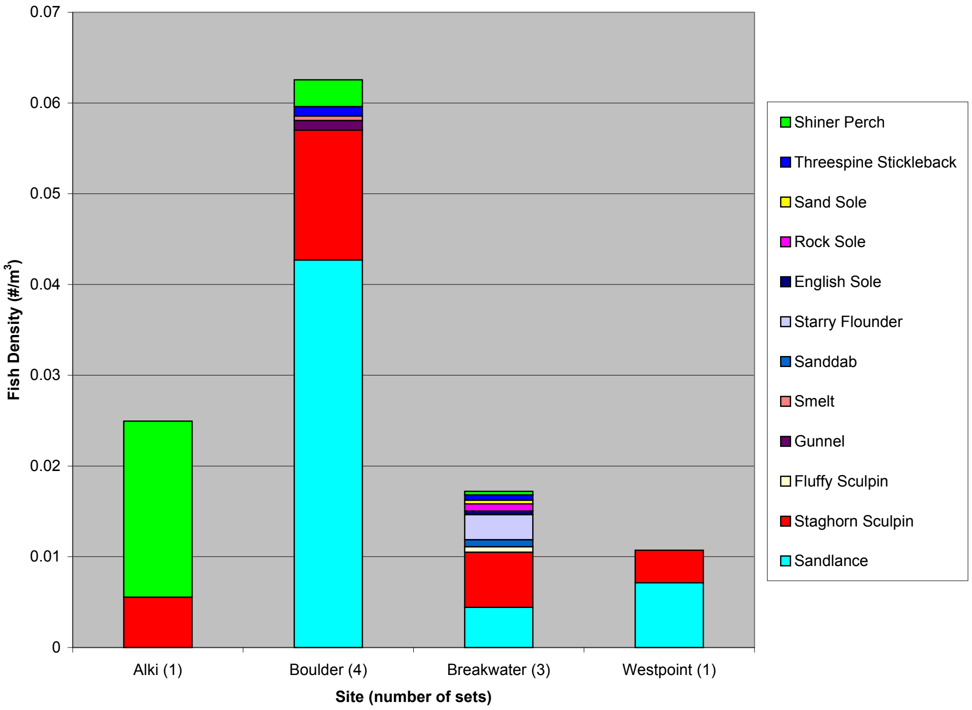

Figure 17. Non-salmonid enclosure net density per water volume (#/m^3).

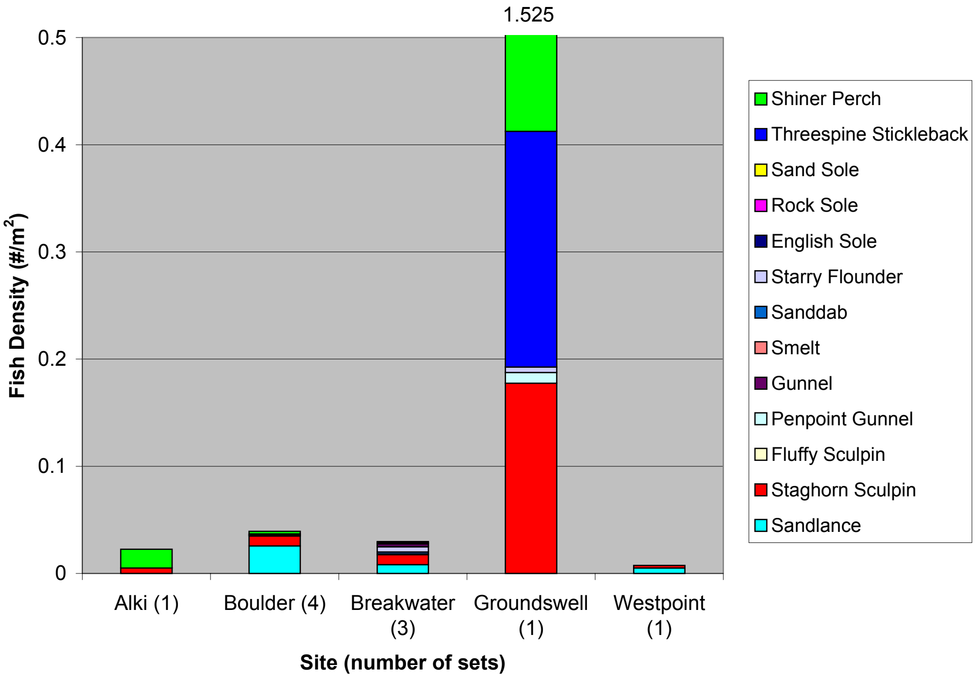

Figure 18. Non-salmonid enclosure net density per water surface area (#/m^2).

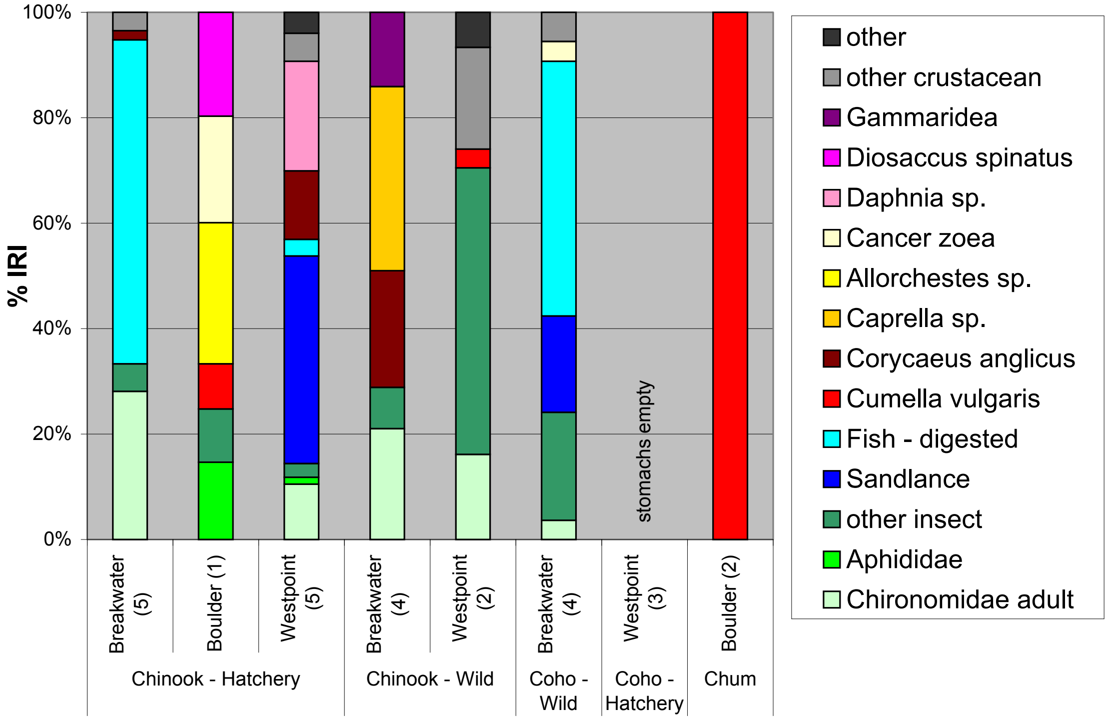

Figure 19. Gut contents of salmonids sampled with gastric lavage June 25-27. Insects are green, fish are blue, and crustaceans are other colors. Sample size is in parentheses.

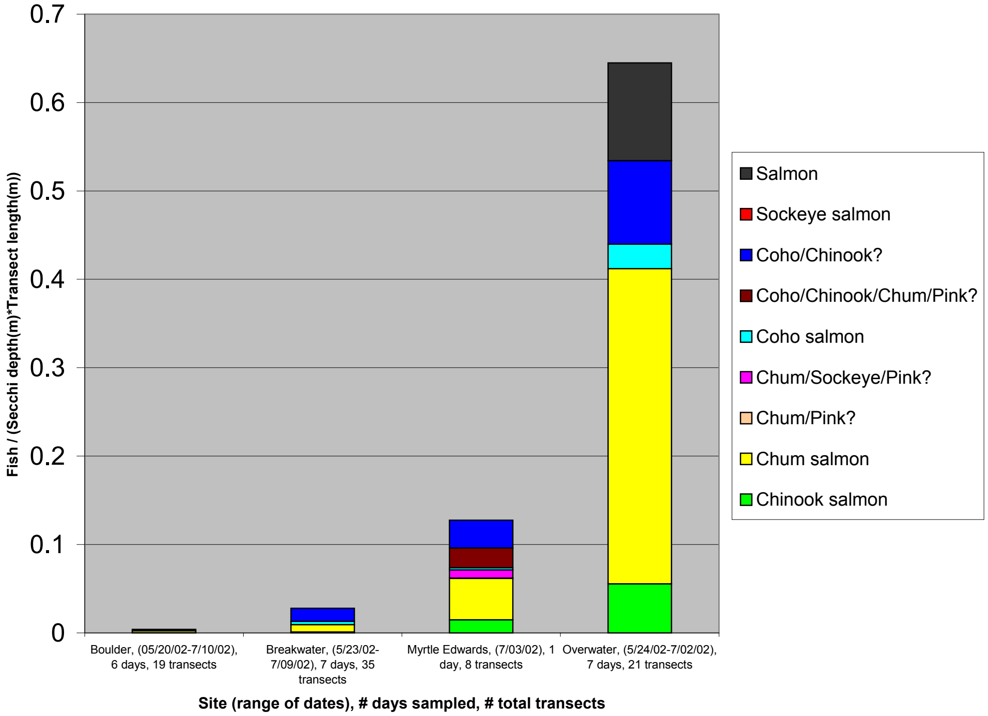

Figure 20. Salmon densities from snorkel surveys.

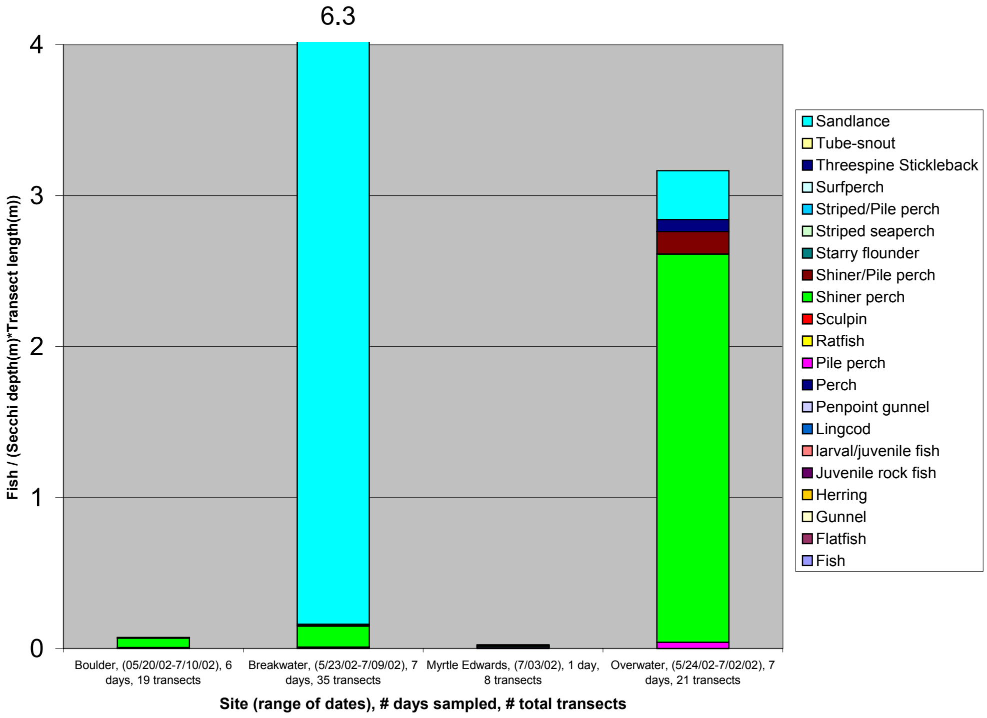

Figure 21. Non-salmon densities from snorkel surveys.

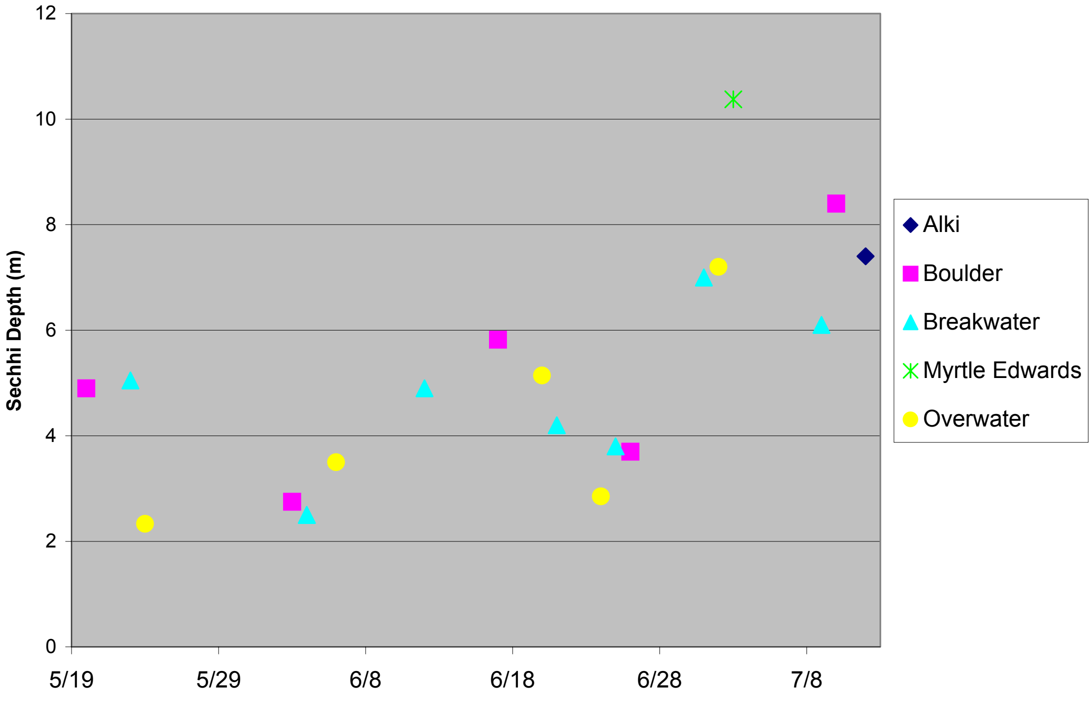

Figure 22. Average secchi depth from snorkel surveys.

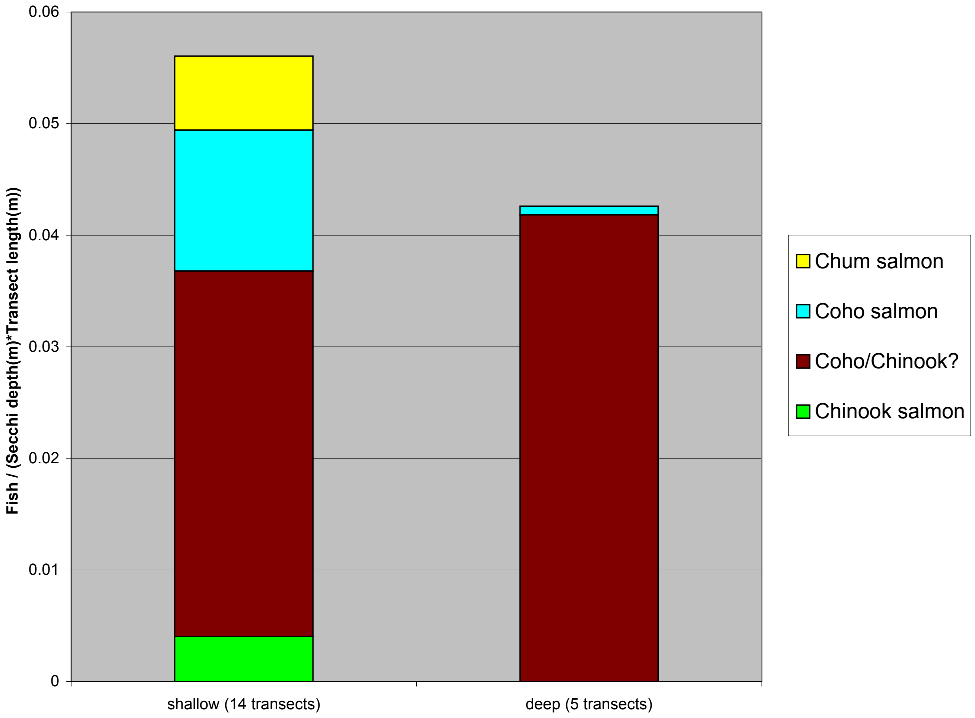

Figure 23. Shallow (< 2m water depth) and deep (≥ 2m) comparison of salmon densities from snorkel surveys at Breakwater, for dates containing both types (5/23, 6/21, 7/01).

Figure 24. Video-still of juvenile salmon swimming in front of the camera.

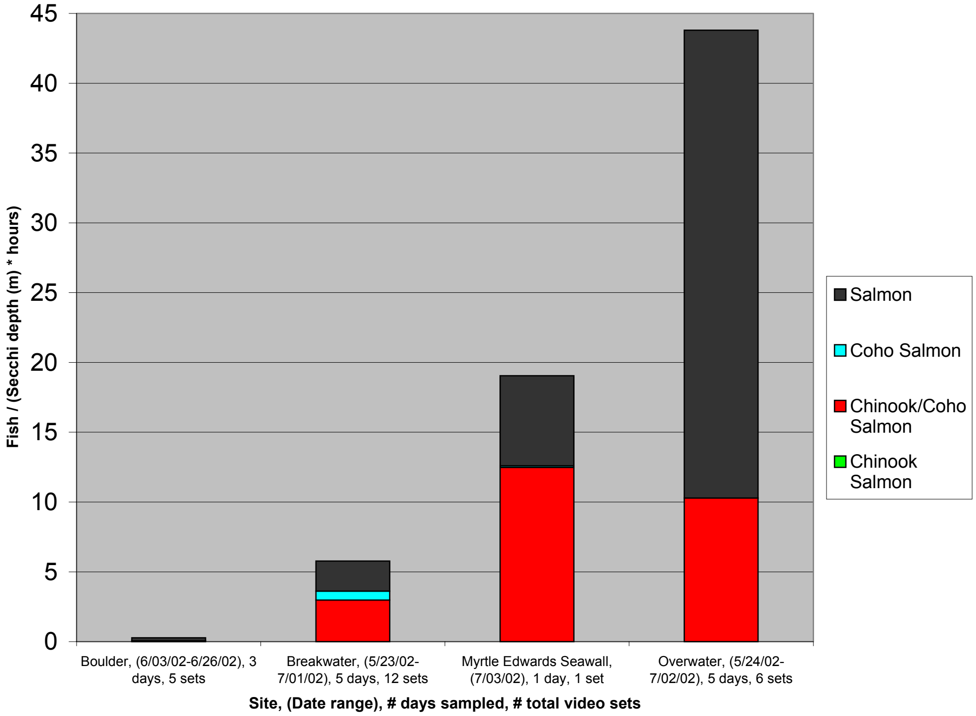

Figure 25. Salmon densities from stationary deployed video.

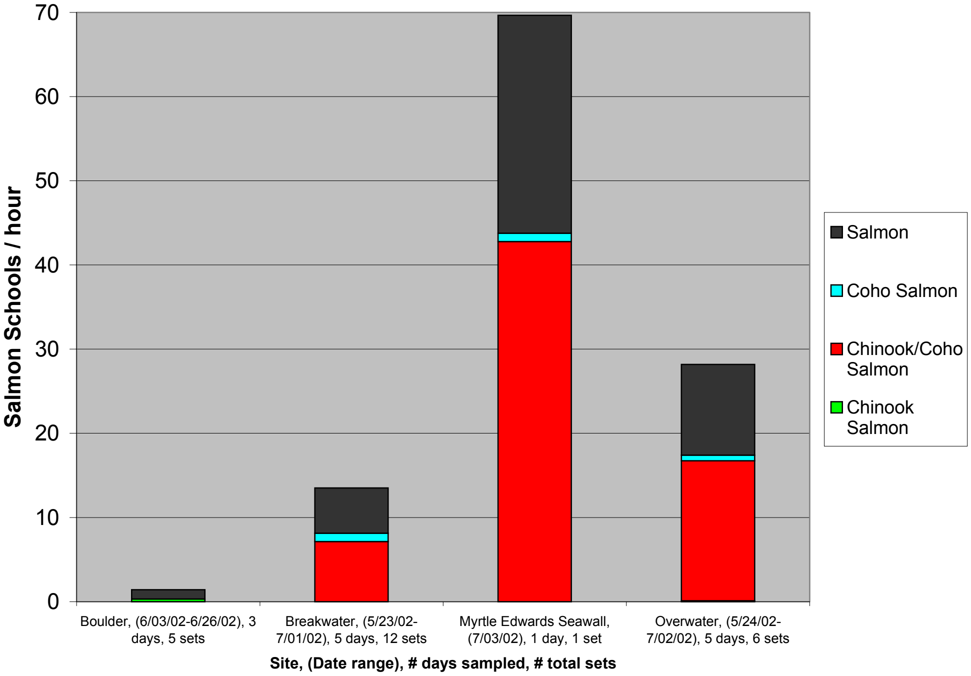

Figure 26. Salmon school densities from stationary deployed video.

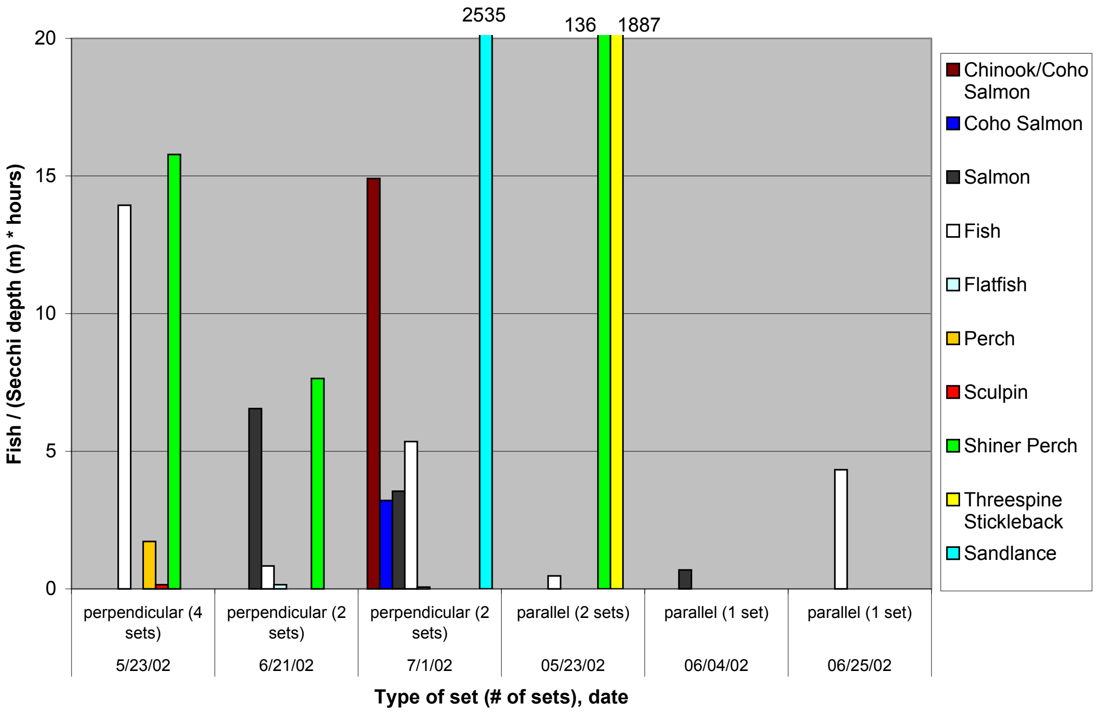

Figure 27. Comparison of stationary video deployed perpendicular and parallel to shore at Breakwater.

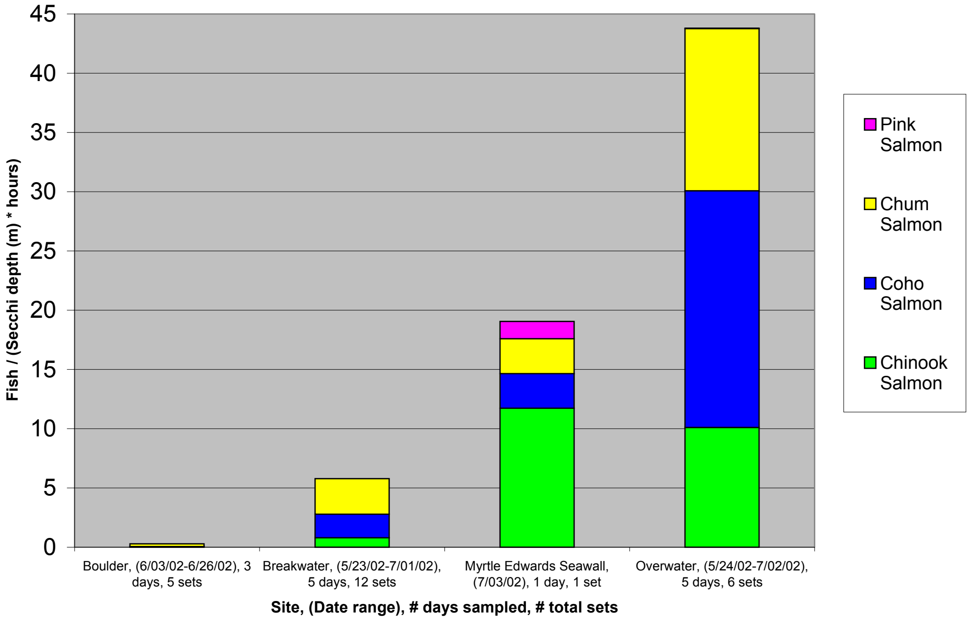

Figure 28. Relative salmon densities from stationary deployed video, with nearest and most recent % species composition from enclosure net sampling applied to unknown salmonid species identifications.

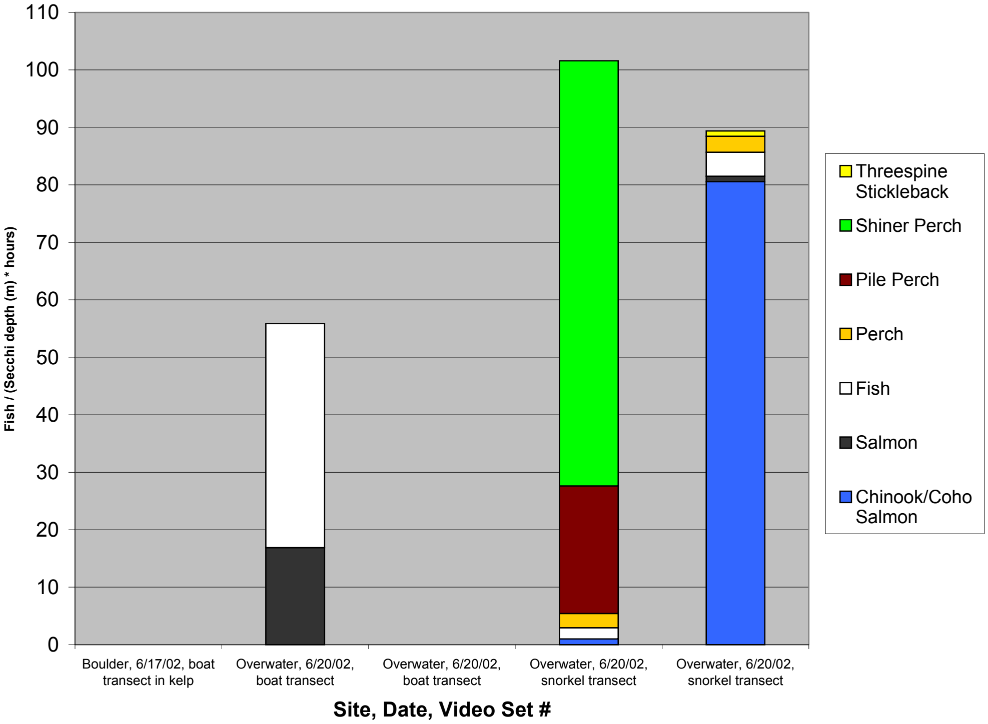

Figure 29. Salmon densities from non-stationary deployed video, camera combined with either a boat or a snorkel transect.

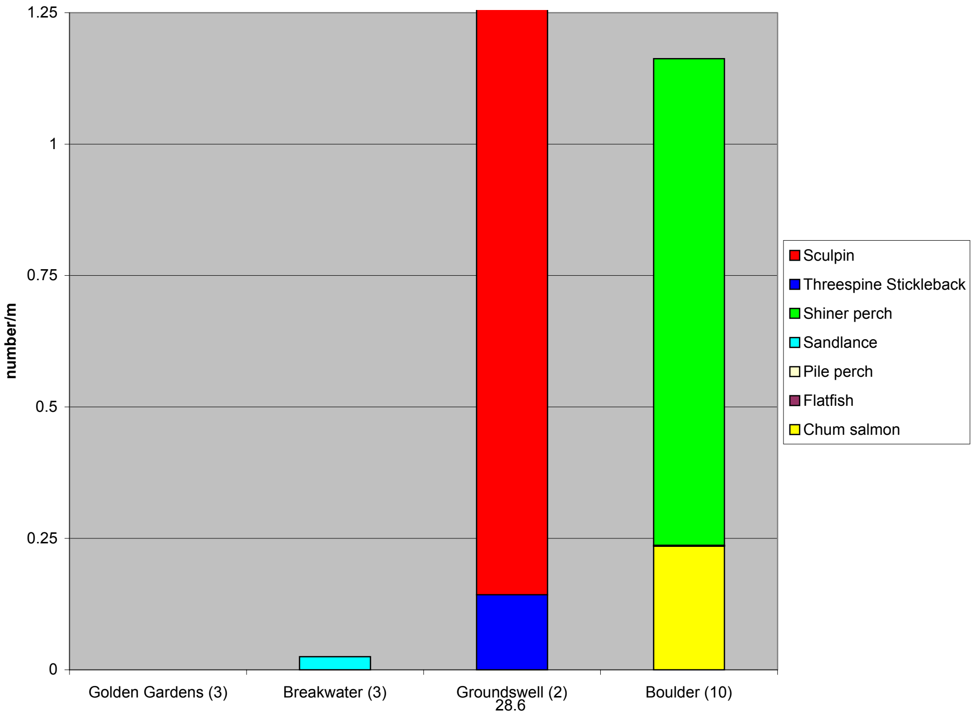

Figure 30. Fish densities from above-water observations.

Table 1. Matrix of the type and number of pilot tests using each methodology.

Type	**Number**
Enclosure Nets	10
Beach Seine	2
Snorkel < 2m water depth	41
Snorkel ≥ 2m water depth	38
Stationary Parallel Video	14
Stationary Perpendicular Video	13
Non-stationary video	5
Video inside Enclosure Net	3
Boat Above-Water Observation	1
Walking Above-Water Observation	21

Table 2. Raw data from net sampling. E = Enclosure net and B = Beach seine.

SITE	Breakwater				Boulder				Groundswell	Westpoint		Alki
DATE	6/4/02	6/12	6/25	7/9	6/13	6/18	6/26	7/10	6/11	6/27	6/27	7/12
COLLECTION #	B 1	E 2	E 5	E 8	E 3	E 4	E 6	E 9	E 1	B 2	E 7	E 10
Net Dimensions (m)		15x30	20x20	20x20	15x30	20x20	20x20	20x20	20x20		20x20	20x20
Tide ht at set (m)	2.38	2.90	2.96	2.87	2.41	2.29	3.05	3.02	2.80	2.47	2.68	2.83
Max. Water Depth when net set (m)		2.9	2.8	3.04	2.2	1.2	1.6	1.8			1.4	1.8
Surface Area (m^2)		450	400	400	450	400	400	400	400		400	400
Volume (m^3)		569.8	819.9	849.6	495.0	240.0	320.0	360.2			280.0	360.7
Species												
Wild Chinook	4	19	16	4	1	1		3	3	7	3	5
Hatchery Chinook	12	5	13	6	2	1	1	4	6	9	9	3
Chinook (H/W?)					1							
Wild Coho	29	88	70	16				3	1	1		1
Hatchery Coho	1	1	3	1		1		2	8		3	1
Chum	14	2	113	3	44	13	2			16		2
Pink				1						1		1
Sockeye		1										
Cutthroat									1			
Sandlance	46	2	8			41				19	2	
Staghorn Sculpin		7	2	3		11	1	3	71	5	1	2
Fluffy Sculpin		1										
Penpoint Gunnel									4			
Gunnel						1						
Smelt					1							
Sanddab				2								
Starry Flounder		2	2	2					2			
English Sole				1								
Rock Sole			1	1								
Sand Sole				1						1		
Shiner Perch	1			1	1	1		2	610			7
Threespine Stickleback		1				1			88			

Table 3. Average of Water Volume (m^3) sampled by enclosure nets at each site.

SITE (n)	Average Water Volume of Enclosure Net
Alki (1)	360.7
Boulder (4)	353.8
Breakwater (3)	746.5
Westpoint (1)	280.0

Table 4. Criteria evaluating methodology effectiveness under different conditions. "Yes" satisfies criterion, "No" does not satisfy criterion, "-" contingent (see footnotes).

Criteria	Enclosure Nets	Snorkel Surveys	Underwater Videography	Above Water Observations
Physical Capture of Fish	Yes	No	No	No
Sampling under Docks and Piers	No	Yes	Yes	No
Opportunity for Fish Diet Analysis	Yes	No	No	No
Positive Species Identification [a]	Yes	-	-	-
Effective on all Substrate Types	Yes	Yes	Yes	Yes
Effective in Turbid Water	Yes	No	No	No
Effective for all Species of Fish	Yes	Yes	Yes	No
Observing Fish Behavior	No	Yes	Yes	Yes
Multiple Replication Possible	No	Yes	Yes	Yes
Sampling at Night [b]	-	-	-	-

[a] Dependent on water conditions - turbidity, light reflectance, waves, etc.

[b] Night sampling not conducted - potentially all methods could be effective with utilization of lights, but lights could modify fish behavior.