Comparison of the Sampling Efficiency of Three Benthic Trawls
At the Deep Water Site
Off the Mouth of the Columbia River

Final Report

Prepared For:

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Prepared By:

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Comparison of the Sampling Efficiency of Three Benthic Trawls
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1 Introduction

Trawl surveys of the Deep Water Disposal Site (DWS) were conducted using a research otter trawl, a plumb-staff beam trawl, and a commercial otter trawl. The comparative study of beam and otter trawls was undertaken in order to clarify the inter-comparability and suitability of each of these research trawl nets, particularly for monitoring surveys at the mouth of the Columbia River. Catch results were also compared for commercial trawl gear routinely used in local fishery. The primary objectives of this study were to: 1) compare the demersal fish and invertebrate assemblages characterized by the two research trawls; 2) compare sampling efficiencies of the research trawl nets and commercial trawls; 3) determine differences between the size of organisms sampled by commercial nets, otter trawls, and beams trawls; 4) determine representative sampling profiles of each gear type and examine any preferential assessment of the various benthic fish and invertebrate taxa; and 5) examine subregions within the DWS as determined by the different trawl types. The fish and invertebrate community at the DWS is described in detail and compared to the demersal community presented by a previous study (Word, et al 2003).

1.1 Background

Historically, the relative abundance of demersal fish and invertebrates at the mouth of the Columbia River has been determined using semi-balloon research otter trawls (Durkin and Lipovsky 1977; Hinton and Emmett 1994; McCabe et al. 1986; Siipola et al. 1993; Word et al. 2003). However, benthic sampling at offshore locations in Washington State and within estuaries in both Washington and Oregon has also been conducted with beam trawls (Antrim et al. 1994; Gunderson and Ellis 1986; Dinnel et al. 1988; Richardson et al. 1977). Research otter trawls are scaled down versions of the larger otter trawls used in commercial bottom fishing. The plumb-staff beam trawl was developed as an alternative to the otter trawl, primarily to provide a more consistent net opening and to better sample small invertebrates and the sediment-water interface.

There have been previous direct comparisons of the sampling efficiency for these two types of trawls (Dinnel et al. 1988; Gunderson and Ellis 1986 Eaton and Dinnel 1993). Gunderson and Ellis (1986) determined that the Plumb-staff beam trawl was more efficient for shallow-water sampling of small Dungeness crab and flatfish. Dinnel et al. (1988) found that the beam trawl was more efficient for sampling Dungeness crab and small shrimp hiding or digging into the bottom substrates. The otter trawl was more efficient for sampling larger Pandalid shrimp. Similarly, Eaton and Dinnel (1993) found that the plumb-staff beam trawl was more efficient for sampling small fish and invertebrates closely associated with the bottom, particularly Dungeness crab. Otter trawls were more efficient at sampling larger fish, specifically flatfish, while being less effective at sampling smaller fish species and invertebrates, such as eelpouts and gobies.

It is important to note that the methods of deployment and the environs sampled in the previous comparison studies may limit their usefulness in understanding the suitability of otter trawls or beam trawls at the DWS. During Gunderson and Ellis (1986), both samplers were deployed using a 3/8-inch nylon towline. Nylon towlines have inherent buoyancy and variable resistance based on water content. The greater the scope distance (length of line/depth of water), the greater the reverse catenary of the more buoyant deployment line relative to the catenary resulting from use of wire rope. This type of catenary causes an upward tow that reduces the efficiency of the otter doors that spread the net and drive the net down and forward into the bottom enabling the net to capture epibenthic organisms. Some of the observations by Gunderson and Ellis (1986), such as an instance where increasing scope length did not improve bottom contact, may indicate that the use of the nylon line interfered with bottom contact and resulted in off-bottom hauling of the lead lines. Additionally, in the previous comparison studies, the beam trawl had a cod-end liner of 4 mm and an additional outside covering to protect the cod end; whereas, there was an absence of a cod-end liner for the otter trawl, diminishing the otter trawls ability to retain smaller organisms. These deployment methods may be contributing reasons for the relatively poor performance by the otter trawl in these previous comparative surveys. Furthermore, most of the previous comparisons were either conducted in near-shore areas, shallower than the DWS, or in areas with finer-grained material, potentially limiting their suitability for comparison at the DWS.

In order to understand the comparability and suitability of these two research trawl nets, particularly for monitoring surveys off the mouth of the Columbia River, as well as how they compare to the commercial nets used in the fishery, we conducted side-by-side trawl surveys with the research otter trawl, the plumb-staff beam trawl, and a commercial otter trawl. The methods for conducting these surveys are presented in Section 2. Results, data analysis, and a discussion of the sampling characteristics of these three trawl nets are presented in Section 3. The conclusions of this study and a comparison with previous trawl surveys at the mouth of the Columbia River are presented in Section 4.

2 Methods

In order to directly compare the sampling efficiency of three different gear types, stations were surveyed using a Willis, or SCCWRP, research otter trawl (otter trawl), a Plumb-staff beam trawl (beam trawl), and a commercial otter trawl (commercial trawl). All fish and invertebrates were identified, counted, weighed, and measured for each trawl event. In order to assure proper deployment for each gear type, regional experts for each type of trawl gear were on board to provide oversight and ensure optimum use of each gear type.

2.1 The DWS Site

The DWS is located off the mouth of the Columbia River and lies on the continental shelf between 30 to 50 fathoms of water (Figure 1). The substrate at the DWS is dominated by fine to coarse sand; with pockets of finer-grained sediments becoming more common in the summer and early fall. The trawl comparison surveys were conducted at the DWS during the weeks of August 4, 2003 and September 8, 2003. Five stations, A, B, C, D, and E, were identified in the DWS from 30 fm (shallow) to 50 fm (deep); see Figure 2. The station locations were based on a stratified sampling design used during the 2002 DWS surveys (Word et al. 2003) and were intended to represent the placement area and the surrounding buffer zone, as well as the range of depths and community types previously described at the DWS. Two replicate trawls within each station area were conducted with the research otter trawl and beam trawl. To prevent "over sampling" of fish and invertebrates, one commercial trawl was conducted at each of the five station areas. The direction of each trawl was determined by the direction and strength of the current. The sequence of sampling with the beam and otter trawls was determined using a

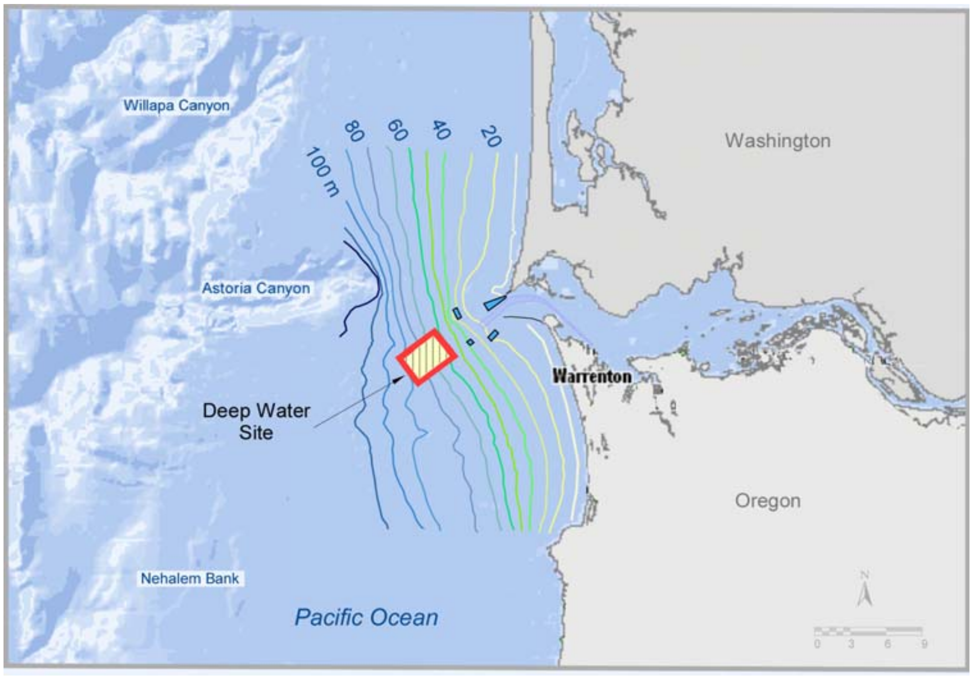


Figure 1. Location of the Deep Water Site at the Mouth of the Columbia River.

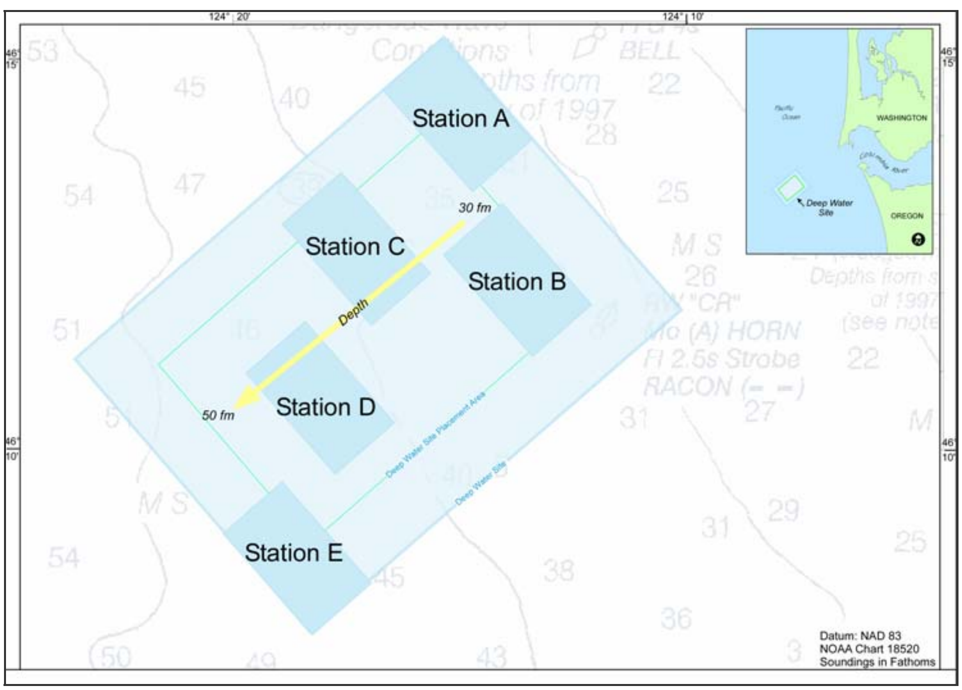


Figure 2. Location of Target Sampling Areas within the DWS.

systematic random sampling design, where the gear for the first trawl was randomly determined, and then alternating for the subsequent stations.

2.2 Sampling Vessel

The Limit Stalker, a 65-ft commercial fish and shrimp trawler stationed in Warrenton, Oregon, was used for all sampling activities. This vessel is outfitted with commercial otter trawls for fish and shrimp trawling, as well as scientific and engineering consulting services off the coasts of Washington and Oregon. The vessel is operated by Captain Tom Jones, a skipper with more than 20 years of experience in Oregon and Washington coastal waters, including the Columbia River Bar and environs. The vessel is equipped with winches, davits, and an A-Frame with an extensive open area on the back deck to accommodate all sampling gear and operations.

2.3 Trawl Gear

2.3.1 Commercial Trawl

Commercial trawls were conducted with a 4-seam, otter trawl net constructed of 2 in. by 2 in. polyethylene mesh with an opening height of 1.8 m. and an operational width of 7.9 m (Figure 3). The net was deployed with steel otter boards measuring (approximately 1.8 m x 2.7 m) and standard mud gear, consisting of rubber rings mounted on a cable along the foot rope. Scope ranged from 3.1:1 at 48 fathoms to 3.7:1 at 34 fathoms. The opening of the net between the otter boards was used to determine the width of the trawled area (7.9 m). Due to the size and weight of the commercial trawl net, all commercial trawls were conducted on the first day of the summer and fall surveys, after which the commercial net was removed from the boat. Commercial fisherman, Mr. Tom Jones was chief scientist for the commercial trawls.

Figure 3. Commercial Trawl Net Under Deployment.

Figure 4. Beam Trawl Under Deployment

2.3.2 Plumb-Staff Beam Trawl

Beam trawls were conducted with a 3-m plumb-staff beam trawl developed by Gunderson and Ellis (1986), shown in Figure 4. The beam trawl was constructed of 5/8” by 5/8” coated nylon mesh with a 1.3 cm stretch-mesh liner at the cod end. The net had an opening height of 0.6 m and an opening width of 2.3 m. The net was held open with a 3-m aluminum staff and weights on each side of the net held it on the bottom. The net was fitted with a tickler chain that dragged along the bottom, immediately before the mouth of the net. The beam trawl was towed with 3/8' steel line and a scope of 3.5:1 at 50 fathoms to 4.6:1 at 41 fathoms. Mr. Charlie Eaton of BioMarine Enterprises was chief scientist for the beam trawls.

2.3.3 Research Otter Trawl

Research otter trawls were conducted with a 7.6-m Willis/SCCWRP otter trawl (Figure 5). The trawl net was constructed with coated nylon mesh (5/8" x 5/8" and 1.3 cm stretch mesh liner at the cod end), with an opening of 1 m in height and door spread of 4.6 m (Mearns and Stubbs 1974, Gunderson 2003). The net was fitted with 20" x 30" mahogany otter boards, with a 4-chain bridle oriented to drive the boards downward and outward. Chain sewn into the foot rope and a float line in the head rope maintained the open net. Dr. Jack Word was the chief scientist for the otter trawls.

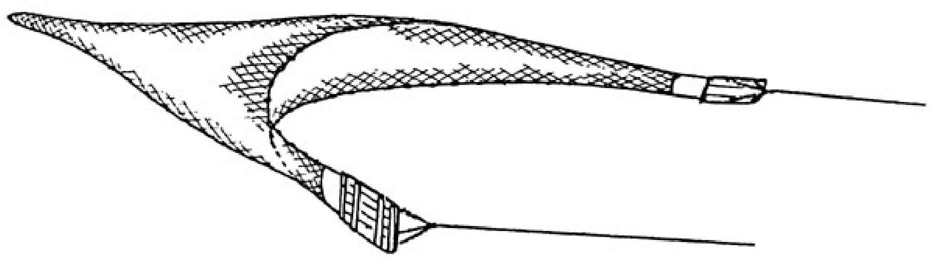


Figure 5. Schematic of Otter Trawl Net.

2.4 Processing of Benthic Fauna

Following each trawl, the net was retrieved and the collected organisms were slaked to the end of the net where they are released into large plastic tubs. The fish and invertebrates were sorted into species, measured, weighed, and examined for external lesions (see Figure 6). The demersal fish were identified and measured to the nearest millimeter. Length and weight were measured for the first 30 individuals of a given fish species. Length was measured for the next 40 fish and weights were recorded for the batch. Any remaining fish were counted and weighed as a batch. Demersal invertebrates were identified to species, counted, and weighed. Individual weights, sex, carapace width, and shell hardness were recorded for Dungeness crab. Unidentified organisms were returned to MEC's laboratory for identification.

2.5 Statistical analysis

Mean abundance and biomass and standard deviations were calculated for each gear type at each station. To determine the relative importance of each species within a gear type, percentage of the total abundance or biomass was calculated for fish and invertebrates separately. Statistical comparisons were made for selected demersal flatfish and roundfish, crab, and demersal invertebrates between stations and between gear types using a 3x5 factorial ANOVA and a Tukey's multiple range tests. Size class distributions for selected fish species and crab were used to determine if there were consistently smaller or larger individuals collected with either gear type for these key demersal species.

Figure 6. Processing the Benthic Fish and Invertebrate Catch on Board the Research Vessel.

2.6 Cluster Analyses

Differences in fish and invertebrate assemblages sampled with the different gear types, as well as differences in how the DWS is characterized by subregions were evaluated using cluster analysis. Two measures of dissimilarity were used, the Canberra Metric and Bray-Curtis. These measures were selected because they have a tendency to show groupings differently. Canberra Metric enhances the influence of species held in common among stations, while the Bray Curtis is more influenced by the similarity in relative numerical abundance (Romesburg, 1984). Each cluster analysis was performed with raw data using all species collected at each trawl location and using only those species occurring more than once.

3 Results and Discussion

3.1 Station Characterization

A total of 51 trawls were conducted in the DWS in August and September 2003. A depth gradient occurs within the site. Trawls conducted in the vicinity of Station Areas A and B are approximately 30 fm in depth, those conducted in the vicinity of Station Area C are approximately 40 fm in depth, and those conducted in the vicinity of Station Areas D and E are approximately 50 fm in depth. A summary of the trawl coordinates and trawl data for sampling are presented in Tables 1 and 2. A more detailed record of trawl sampling events is presented in Appendix A. With the exception of Beam Trawl A1, all trawls were successful and were included in our analyses. For the commercial trawls, towing speeds ranged from 1.9 to 3.2 kts ground speed; distance towed ranged from 0.25 to 0.50 nm. The area swept for first commercial trawl (August, Station A) was 0.74 ha; however, due to the sizable catch for this trawl, the commercial trawl distance was henceforth shortened, reducing the area swept to between 0.37 and 0.48 ha. The location of each commercial trawl is presented in Figure 7.

Towing speed for the beam trawl ranged from 1.6 to 2.0 kts and trawl lengths were 0.5 nm (Station A1 in August was 0.25 nm; however this trawl data is not included in our analysis). The area swept for the beam trawls was 0.17 ha. The location for each beam trawl is presented in Figure 8. The trawl lengths for the otter trawls were adjusted to approximate the area swept for the beam trawls and ranged from 0.17 to 0.21 ha, with the exception of trawl in August at Station C1 (which was 0.43 ha). Towing speeds ranged from 2.3 to 2.6 kts. The location for each otter trawl is presented in Figure 9.

3.2 Demersal Fish

The demersal fish community in both August and September was dominated by flatfish species, regardless of gear type. The dominant species were Dover Sole, English sole, Pacific sanddab, Rex sole, Petrale sole, and Slender sole. Other species that were relatively abundant within certain gear types were Lingcod, Pacific hake, Sablefish, Bluespotted poacher, Slim sculpin, and Blackbelly eelpout. Only one species of rockfish was observed at the DWS, the Dark-blotched rockfish (*Sebastes crameri*), with a total of four juveniles occurring in the otter and beam trawls. Because there were considerable differences between the species composition, abundance, and biomass per area surveyed between the different gear types, these data are presented separately in the sections below. A summary of fish abundance and biomass for key species is presented in Tables 3 through 5. The mean abundance and biomass for all species is summarized in Appendix B and the detailed record for all replicates is presented in Appendix C.

3.2.1 Commercial Trawls

Mean total fish abundance in August ranged from approximately 486 fish/ha in Stations D and E to 1,145 fish/ha in Station B. Mean species richness ranged from 10 to 14 species per station. The fish assemblage was dominated by Pacific sanddab in the shallower stations (Stations A, B, and C), with abundance ranging from 439 to 972 fish/ha (Table 3). In the deeper stations (D and E), Sablefish and Pacific hake were also dominant species, with mean abundance ranging from 71 to 221 fish/ha. Total fish biomass ranged from 174 kg/ha to 256 kg/ha. Biomass was dominated by the Pacific sanddab and English sole in Stations A and B, transitioning to Pacific hake and Sablefish in stations C, D, and E. Other species occurring in the August commercial

Table 1. Trawl Station Coordinates, Distance, and Area Swept for August 2003.

Gear	Station	Date	Tow Start, End	Depth (fm)	Latitude	Longitude	Trawl Distance, nm *(Speed)*	Area Swept (ha)
Commercial Trawl	**A**	4-Aug-03	**Start**	32.0	46º 12.47' N	124º 12.80' W	0.503	0.74
			End	31.0	46º 12.79' N	124º 12.24' W	*(3.2 kts)*	
	B	4-Aug-03	**Start**	33.0	46º 10.98' N	124º 11.27' W	0.319	0.47
			End	ND	46º 11.21' N	124º 11.59' W	*(1.9 kts)*	
	C	4-Aug-03	**Start**	39.0	46º 11.12' N	124º 13.19' W	0.269	0.39
			End	ND	46º 11.32' N	124º 13.45' W	*(2.3 kts)*	
	D	4-Aug-03	**Start**	44.0	46º 10.11' N	124º 13.77' W	0.292	0.43
			End	ND	46º 10.34' N	124º 14.03' W	*(1.95 kts)*	
	E	4-Aug-03	**Start**	48.0	46º 08.80' N	124º 13.90' W	0.329	0.48
			End	ND	46º 09.06' N	124º 14.19' W	*(2.2 kts)*	
Beam Trawl	**A I**	5-Aug-03	**Start**	33.5	46º 13.047' N	124º 12.811' W	0.25	0.11
			End	ND	46º 12.863' N	124º 12.566' W		
	A II	5-Aug-03	**Start**	34.0	46º 12.956' N	124º 12.709' W	0.5	0.21
			End	34.0	46º 12.572' N	124º 12.244' W	*(1.6 kts)*	
	A III	5-Aug-03	**Start**	35.5	46º 12.849' N	124º 12.762' W	0.5	0.21
			End	34.5	46º 12.496' N	124º 12.249' W	*(1.6 kts)*	
	B I	5-Aug-03	**Start**	35.4	46º 12.849' N	124º 12.762' W	0.5	0.21
			End	ND	46º 11.006' N	124º 11.202' W	*(1.6 kts)*	
	B II	5-Aug-03	**Start**	35.2	46º 11.393' N	124º 11.544' W	0.5	0.21
			End	38.0	46º 11.005' N	124º 12.013' W	*(1.9 kts)*	
	C I	6-Aug-03	**Start**	41.5	46º 11.319' N	124º 13.631' W	0.5	0.21
			End	38.1	46º 11.684' N	124º 13.135' W	*(1.9 kts)*	
	C II	6-Aug-03	**Start**	42.0	46º 11.173' N	124º 13.933' W	0.5	0.21
			End	40.0	46º 11.547' N	124º 13.453' W	*(1.9 kts)*	
	D I	6-Aug-03	**Start**	44.0	46º 10.716' N	124º 13.860' W	0.5	0.21
			End	47.0	46º 10.295' N	124º 14.251' W	*(1.9 kts)*	
	D II	6-Aug-03	**Start**	45.0	46º 10.544' N	124º 13.908' W	0.5	0.21
			End	48.0	46º 10.200' N	124º 13.433' W	*(1.9 kts)*	
	E I	7-Aug-03	**Start**	50.3	46º 09.040' N	124º 14.562' W	0.5	0.21
			End	48.0	46º 09.424' N	124º 14.099' W	*(1.95 kts)*	
	E II	7-Aug-03	**Start**	49.0	46º 09.060' N	124º 14.580' W	0.5	0.21
			End	47.0	46º 09.372' N	124º 14.016' W	*(2.0 kts)*	
Otter Trawl	**A I**	7-Aug-03	**Start**	35.2	46º 12.525' N	124º 12.309' W	0.25	0.21
			End	35.3	46º 12.719' N	124º 12.566' W	*(2.4 kts)*	
	A II	7-Aug-03	**Start**	34.7	46º 12.426' N	124º 12.108' W	0.25	0.21
			End	35.2	46º 12.712' N	124º 12.377' W	*(2.45 kts)*	
	B I	7-Aug-03	**Start**	36.0	46º 11.153' N	124º 11.911' W	0.25	0.21
			End	35.0	46º 11.313' N	124º 11.632' W	*(2.5 kts)*	
	B II	7-Aug-03	**Start**	35.0	46º 11.371' N	124º 11.683' W	0.25	0.21
			End	36.5	46º 11.209' N	124º 11.961' W	*(2.43 kts)*	
	C I	6-Aug-03	**Start**	41.5	46º 11.355' N	124º 13.761' W	0.5	0.43
			End	39.2	46º 11.749' N	124º 13.314' W	*(2.48 kts)*	
	C II	6-Aug-03	**Start**	41.0	46º 11.500' N	124º 13.667' W	0.25	0.21
			End	41.0	46º 11.683' N	124º 13.403' W	*(2.36 kts)*	
	D I	6-Aug-03	**Start**	46.0	46º 10.393' N	124º 14.238' W	0.25	0.21
			End	44.0	46º 10.566' N	124º 13.963' W	*(2.5 kts)*	
	D II	6-Aug-03	**Start**	45.0	46º 10.507' N	124º 14.040' W	0.25	0.21
			End	47.0	46º 10.331' N	124º 14.302' W	*(2.43 kts)*	
	E I	7-Aug-03	**Start**	49.0	46º 09.251' N	124º 14.169' W	0.25	0.21
			End	49.5	46º 09.071' N	124º 14.428' W	*(2.3 kts)*	
	E II	7-Aug-03	**Start**	49.0	46º 09.125' N	124º 14.400' W	0.25	0.21
			End	48.0	46º 09.268' N	124º 14.102' W	*(2.4 kts)*	

Table 2. Trawl Station Coordinates, Distance, and Area Swept for September 2003.

Gear	Station	Date	Tow Start, End	Depth (fm)	Latitude	Longitude	Trawl Distance, nm *(Speed)*	Area Swept (ha)
Commercial Trawl	**A**	8-Sep-03	**Start**	34	46 12.404' N	124 12.096' W	0.258	0.38
			End	34	46 12.614' N	124 12.312' W	*(2.45 kts)*	
	B	8-Sep-03	**Start**	36	46 11.704' N	124 12.122' W	0.257	0.38
			End	36	46 11.505' N	124 11.888' W	*(2.26 kts)*	
	C	8-Sep-03	**Start**	40	46 11.197' N	124 13.196' W	0.254	0.37
			End	40	46 11.395' N	124 13.425' W	*(2.39 kts)*	
	D	8-Sep-03	**Start**	45	46 10.668' N	124 14.465' W	0.252	0.37
			End	45	46 10.486' N	124 14.213' W	*(2.20 kts)*	
	E	8-Sep-03	**Start**	48	46 09.364' N	124 14.246' W	0.254	0.37
			End	49	46 09.113' N	124 14.306' W	*(2.21 kts)*	
Beam Trawl	**A I**	10-Sep-03	**Start**	35	46 13.030' N	124 12.754' W	0.402	0.17
			End	34	46 12.688' N	124 12.449' W	*(1.98 kts)*	
	A II	10-Sep-03	**Start**	35	46 13.024' N	124 12.847' W	0.409	0.17
			End	35	46 12.694' N	124 12.499' W	*(1.97 kts)*	
	B I	10-Sep-03	**Start**	36	46 11.741' N	124 12.145' W	0.407	0.17
			End	35	46 11.411' N	124 11.800' W	*(1.88 kts)*	
	B II	10-Sep-03	**Start**	36	46 11.761' N	124 12.190' W	0.405	0.17
			End	35	46 11.444' N	124 11.827' W	*(1.97 kts)*	
	C I	10-Sep-03	**Start**	39	46 11.696' N	124 13.505' W	0.4	0.17
			End	41	46 11.401' N	124 13.896' W	*(1.89 kts)*	
	C II	10-Sep-03	**Start**	40	46 11.630' N	124 13.410' W	0.4	0.17
			End	41	46 11.293' N	124 13.720' W	*(1.97 kts)*	
	D I	11-Sep-03	**Start**	43	46 10.685' N	124 14.012' W	0.401	0.17
			End	44	46 10.350' N	124 14.329' W	*(1.87 kts)*	
	D II	11-Sep-03	**Start**	44	46 10.672' N	124 14.120' W	0.409	0.17
			End	46	46 10.340' N	124 14.465' W	*(1.86 kts)*	
	E I	11-Sep-03	**Start**	48	46 09.216' N	124 14.131' W	0.4	0.17
			End	49	46 08.984' N	124 14.602' W	*(1.99 kts)*	
	E II	11-Sep-03	**Start**	48	46 09.175' N	124 14.077' W	0.397	0.17
			End	48	46 08.780' N	124 14.139' W	*(1.86 kts)*	
Otter Trawl	**A I**	10-Sep-03	**Start**	34	46 13.021' N	124 12.796' W	0.295	0.25
			End	34	46 12.783' N	124 12.545' W	*(2.46 kts)*	
	A II	10-Sep-03	**Start**	35	46 13.014' N	124 12.833' W	0.207	0.18
			End	34	46 12.836' N	124 12.681' W	*(2.50 kts)*	
	B I	10-Sep-03	**Start**	35	46 11.654' N	124 12.056' W	0.205	0.17
			End	35	46 11.476' N	124 11.909' W	*(2.48 kts)*	
	B II	10-Sep-03	**Start**	35	46 11.618' N	124 12.057' W	0.23	0.20
			End	35	46 11.434' N	124 11.857' W	*(2.56 kts)*	
	C I	10-Sep-03	**Start**	41	46 11.734' N	124 13.955' W	0.199	0.17
			End	40	46 11.583' N	124 13.767' W	*(2.61 kts)*	
	C II	10-Sep-03	**Start**	40	46 11.583' N	124 13.410' W	0.2	0.17
			End	40	46 11.405' N	124 13.543' W	*(2.62 kts)*	
	D I	11-Sep-03	**Start**	45	46 10.357' N	124 14.292' W	0.2	0.17
			End	44	46 10.503' N	124 14.095' W	*(2.54 kts)*	
	D II	11-Sep-03	**Start**	44	46 10.614' N	124 14.099' W	0.201	0.17
			End	45	46 10.432' N	124 14.223' W	*(2.54 kts)*	
	E I	11-Sep-03	**Start**	48	46 09.317' N	124 14.148' W	0.2	0.17
			End	48	46 09.169' N	124 14.342' W	*(2.47 kts)*	
	E II	11-Sep-03	**Start**	48	46 09.187' N	124 14.246' W	0.201	0.17
			End	49	46 08.990' N	124 14.301' W	*(2.51 kts)*	

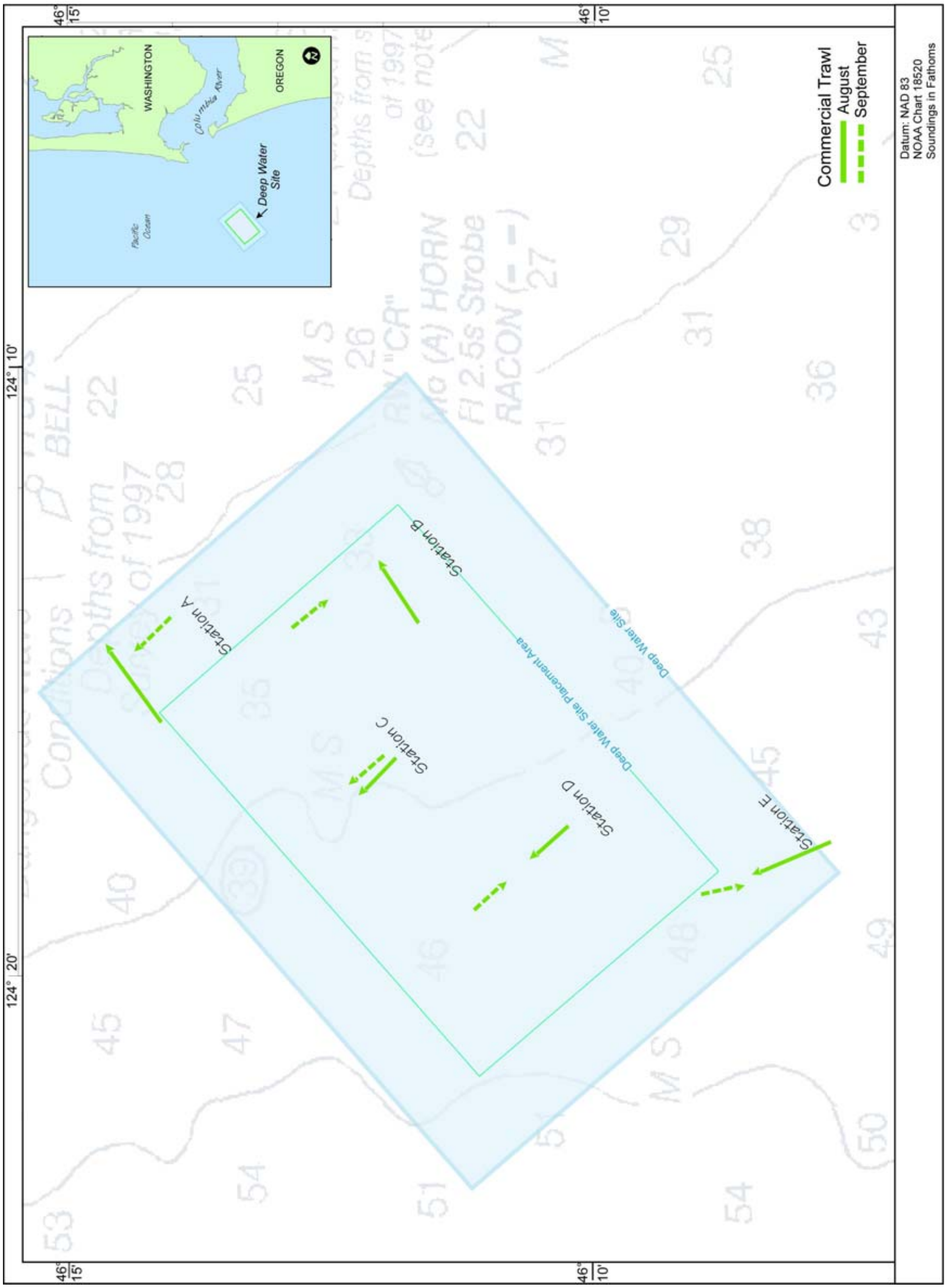


Figure 7. Locations of Single Commercial Trawls during August and September 2003 Sampling Events.

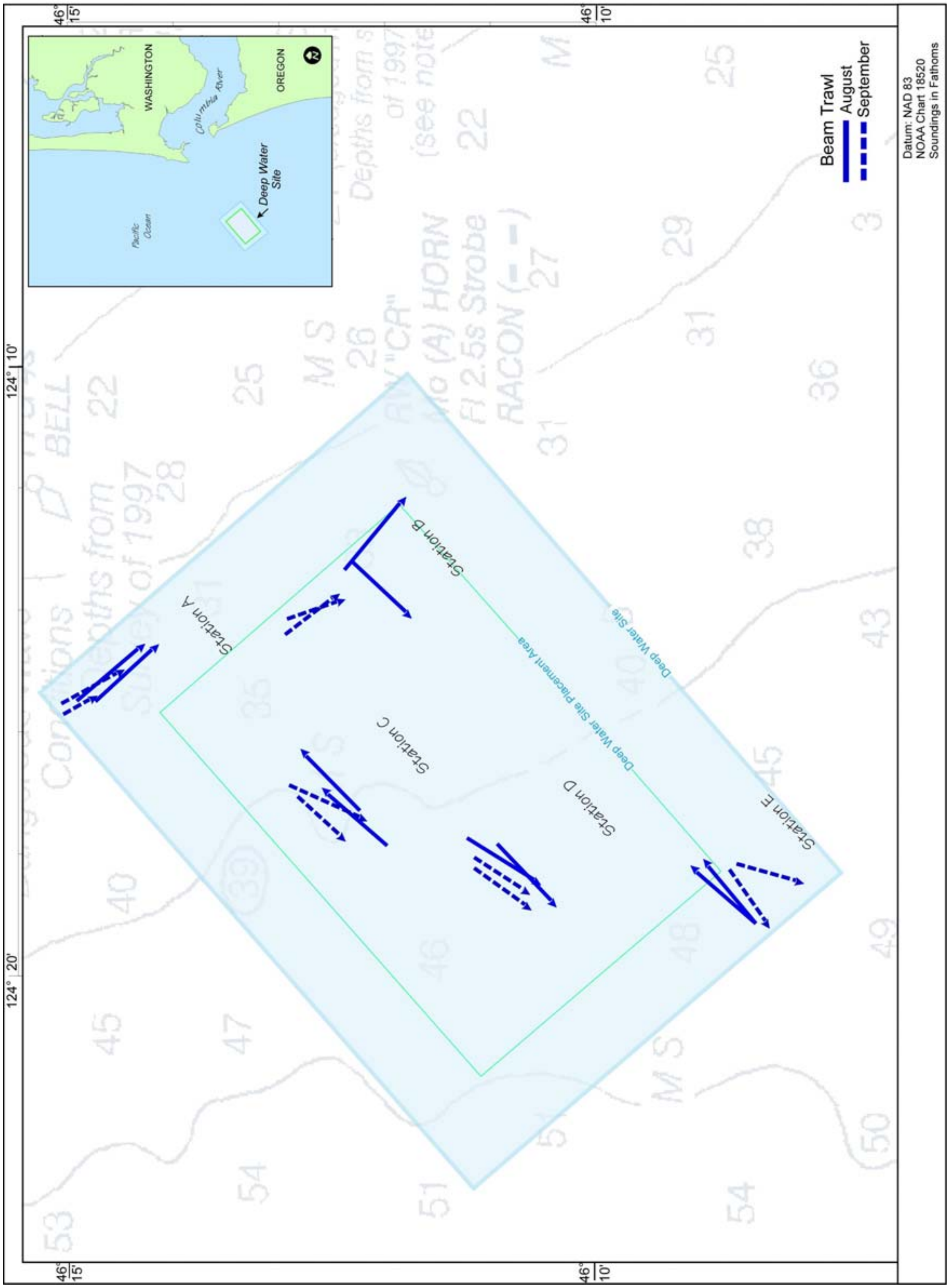


Figure 8. Locations of Replicate Beam Trawls during August and September 2003 Sampling Events.

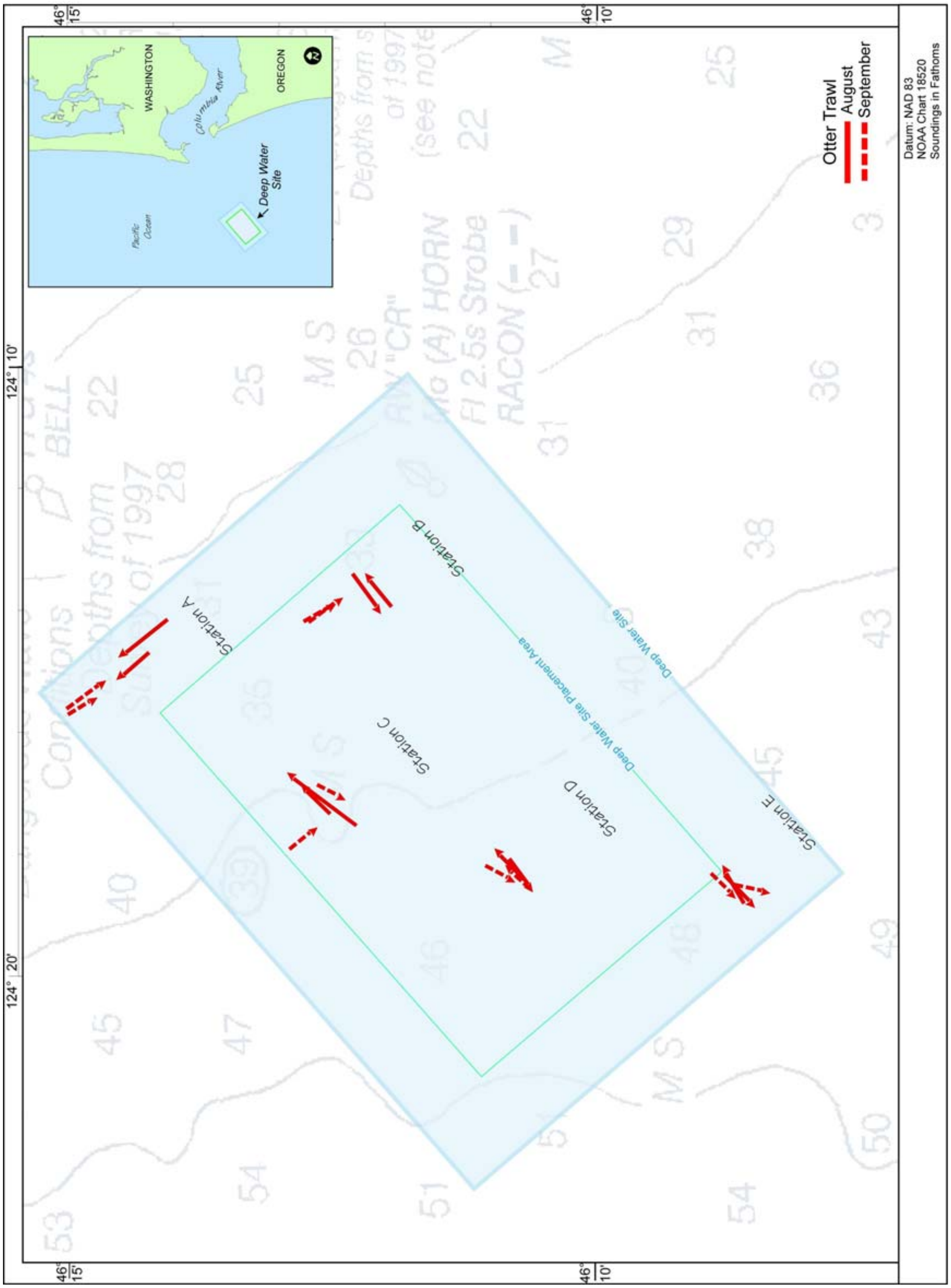


Figure 9. Locations of Replicate Otter Trawls during August and September 2003 Sampling Events.

Table 3. Total Mean Catch Statistics for Benthic Fish, August and September 2003.

Station	Mean Total Abundance (No. per hectare)		Mean Total No. Species		Mean Total Biomass (kg per hectare)	
	Aug	Sept	Aug	Sept	Aug	Sept
Commercial Trawl						
A	1,066	246	14	6	192	106
B	1,145	251	13	9	197	108
C	769	185	10	11	186	176
D	486	190	12	8	174	96.8
E	488	147	10	7	256	71.2
Beam Trawl						
A	438	494	8	6	17.7	16.1
B	798	282	9	8	17.0	9.7
C	419	615	6	8	5.5	24.6
D	783	1,082	8	7	13.7	12.4
E	1,005	935	10	4	14.9	10.9
Otter Trawl						
A	8,202	3,780	12	10	688	427
B	4,714	2,113	11	6	265	133
C	1,229	1,547	10	7	92.1	120
D	1,643	1,497	12	8	108	91.9
E	1,295	1,465	10	10	67.0	88.8

Table 4. Mean Abundance of Key Fish Species Captured with Type of Each Trawl Gear in 2003 (#/Hectare).

Station	Arrowtooth Flounder		Blackbelly Eelpout		Bluespotted Poacher		Dover Sole		English Sole		Pacific Hake		Pacific Sanddab		Rex Sole		Sablefish		Slender Sole		Slim Sculpin	
	Aug	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*
Commercial Trawl																						
A	8	0	0	0	0	0	45	41	134	0	26	3	688	150	89	126	3	0	0	0	0	0
B	6	3	0	0	0	0	17	16	49	24	6	3	972	232	26	74	19	0	2	0	0	0
C	0	0	0	0	0	0	0	8	59	57	108	5	439	78	49	75	39	0	0	3	0	0
D	2	0	0	0	0	0	19	35	61	51	86	14	119	103	42	27	116	0	0	0	0	0
E	10	0	0	0	0	0	8	41	44	22	71	14	65	92	33	24	221	0	0	0	0	0
Beam Trawl																						
A	2	0	26	0	41	0	24	27	0	3	0	0	83	41	188	144	0	0	45	6	0	9
B	2	0	17	0	26	3	86	21	0	0	0	0	207	106	336	106	0	0	79	9	38	24
C	0	0	2	35	7	0	14	129	0	6	0	0	7	35	219	241	0	0	21	103	136	59
D	0	0	12	24	2	0	141	79	0	3	0	0	24	12	338	218	0	0	126	118	112	77
E	0	0	7	168	17	0	345	0	0	0	0	0	33	0	312	397	0	0	210	247	55	124
Otter Trawl																						
A	29	3	19	0	0	0	307	473	38	470	12	0	3,524	843	3,810	1,847	0	0	417	77	5	0
B	12	0	5	0	5	0	252	43	24	82	0	0	2,517	1,177	1674	763	0	0	174	42	17	0
C	0	0	2	18	0	0	62	179	6	77	0	0	615	518	420	671	5	0	66	59	38	24
D	2	6	10	50	0	0	171	277	2	59	0	0	645	444	643	527	0	2	119	112	17	21
E	0	3	36	32	0	6	131	603	2	29	2	0	491	344	429	327	0	0	169	97	12	9

Table 5. Mean Biomass of Key Fish Species Captured with Type of Each Trawl Gear in 2003 (kg/Hectare).

Station	Arrowtooth Flounder		Blackbelly Eelpout		Bluespotted Poacher		Dover Sole		English Sole		Pacific Hake		Pacific Sanddab		Rex Sole		Sablefish		Slender Sole		Slim Sculpin	
	Aug	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*	*Aug*	*Sept*
Commercial Trawl																						
A	7.4	0	0	0	0	0	2.2	13.4	35.8	0	23.4	5.3	0.2	38.1	16.2	25.3	1.7	0	0	0	0	0
B	2.0	2.3	0	0	0	0	3.5	4.2	12.2	7.0	4.5	1.9	0.2	51.1	6.1	11.2	12.0	0	0.1	0	0	0
C	0	0	0	0	0	0	0	2.2	15.4	18.8	7.4	7.2	88.9	15.6	11.0	15.3	41.4	0	0	.05	0	0
D	0.4	0	0	0	0	0	6.8	13.5	18.4	17.0	60.0	16.9	18.2	15.7	8.5	5.0	0.1	0	0	0	0	0
E	12.0	0	0	0	0	0	5.3	17.8	14.4	6.7	42.4	13.1	10.5	14.9	6.0	4.7	0.3	0	0	0	0	0
Beam Trawl																						
A	0.1	0	0.5	0	0.08	0	1.5	2.8	0	0.3	0	0	5.9	1.4	8.1	11.2	0	0	1.4	0.4	0	0.01
B	0.3	0	0.2	0	0.01	0.03	1.8	1.1	0	0	0	0	4.7	1.4	8.0	6.1	0	0	1.8	0.2	0.8	0.02
C	0	0	0.02	0.6	0.01	0	0.3	12.5	0	0.7	0	0	0.2	1.2	4.2	7.4	0	0	0.2	2.0	0.5	0.2
D	0	0	0.1	0.4	0.01	0	4.2	3.6	0	1.5	0	0	0.2	0.7	7.6	4.4	0	0	1.2	1.3	0.4	0.3
E	0	0	0.04	2.6	0.03	0	4.9	0	0	0	0	0	1.8	0	4.1	4.1	0	0	3.1	3.6	0.2	0.7
Otter Trawl																						
A	6.7	2.6	0.3	0	0	0	31.7	57.2	9.9	53.9	7.6	0	403	105	200	196	0	0.2	17.1	4.6	0.01	0
B	1.5	0	0.02	0	0.01	0	19.6	3.2	5.2	10.9	0	0	158	84.9	69.6	31.1	0	0	5.5	1.7	0.09	0
C	0	0	0.03	0.3	0	0	4.0	27.3	1.1	14.5	0	0	58.0	46.9	20.6	26.6	3.1	0	2.1	2.0	0.2	0.1
D	0.3	2.8	0.07	0.8	0	0	15.2	23.7	0.6	12.9	0	0	50.8	30.0	26.1	18.6	0	0	4.6	3.1	0.06	0.1
E	0	1.2	0.04	0.4	0	24	9.6	42.0	0.6	5.3	0.7	0	35.2	22.2	12.0	12.6	0	0	4.6	2.2	0.04	0.05

trawls were the Big skate, Arrowtooth flounder, Lingcod, Rex sole, and the Spiny dogfish. No rockfish were observed in any of the August stations.

Fish abundance and numbers of species were slightly lower in the September commercial trawls, with mean abundance ranging from 147 to 251 fish/ha and richness ranging from 7 to 11 species. As in August, Pacific sanddab were the most common species captured in the commercial trawl net, however, abundance was lower (78 to 232 fish/ha). Other dominant species in September were Rex sole, English sole, Dover sole, and Petrale sole. Mean total fish biomass in September was less than half that of August and ranged from 71.2 kg/ha to 176 kg/ha. In addition to the flatfish species, Pacific hake, Ratfish, and Big skate represented a significant percentage of the biomass. As in August, no rockfish were observed in the September commercial trawls.

3.2.2 Beam Trawls

Mean total fish abundance in August beam trawls ranged from 419 to 1005 fish/ha, with mean richness ranging from 6 to 10 species per station. Rex sole was the most dominant fish species, with mean abundance ranging from 188 to 338 fish/ha. Other dominant species occurring in the August beam trawls were Dover sole, Pacific sanddab, Slim sculpin, and Slender sole. One juvenile Dark-blotched rockfish was observed in Trawl E1. Total biomass in the August beam trawls ranged from 5.5 kg/ha to 17.7 kg/ha. Rex sole, Dover sole, Pacific sanddab, and Slender sole represented the largest percentage of the total biomass.

The September fish assemblage sampled by the beam trawl was similar to that of August, with mean abundance ranging from 282 to 1,082 fish/ha and mean species richness ranging from 5 to 11 species. As in August, the most dominant species was Rex sole, with mean abundance ranging from 106 to 397 fish/ha. Other dominant species were Pacific sanddab, Dover sole, English sole, Slim sculpin and Slender sole. No rockfish were observed in the September beam trawls. Mean fish biomass increased in September, with total biomass ranging from 9.7 kg/ha to 24.6 kg/ha. Rex sole represented the greatest proportion of the biomass; however it is interesting to note that Blackbelly eelpout and Slender sole represented 24% and 21% of the total biomass in Station E, despite both having relatively small individual weights.

3.2.3 Otter Trawls

Mean total fish abundance in the August otter trawls ranged from 1,004 to 6,625 fish/ha, with mean species richness ranging from 12 to 16 species. The dominant species were Rex sole and Pacific sanddab, with the two species comprising 71% to 89% of all fish sampled. Mean abundance for the two species was similar at each station, and ranged from 420 fish/ha to 3,810 fish/ha. Other dominant species were Dover sole, and Slender sole. One juvenile Darkblotched rockfish was caught in Trawls D1 and E2. Biomass in the August otter trawls ranged from 67.0 kg/ha to 688 kg/ha. Both Pacific sanddab and Rex sole were dominant species, however due to their larger size, the Pacific sanddab comprised a larger portion of the overall biomass (47% to 63% of the total).

In September, fish abundance was slightly lower than in August, however, this was primarily due to a decrease in the number of Rex sole and Pacific sanddab in Station A. Mean total fish abundance ranged from 1,465 to 3,780 fish/ha, and richness was 8 to 14 species per station. Rex sole and Pacific sanddab were dominant species, with mean abundance ranging from 327 to 1,847 fish/ha for each species (45% to 92% of the catch). Dover sole and English sole were also dominant species in September. One juvenile Darkblotched rockfish was observed in Trawl E1. Biomass ranged from 88.8 kg/ha to 427 kg/ha. Pacific sanddab represented the largest portion of the biomass in the shallower stations, whereas Dover sole were more dominant in the deeper stations.

3.2.4 Comparison of Gear Types:

In terms of fish abundance, biomass, and species diversity, each gear type presented a different picture of the demersal fish community at the DWS. In general, the range of mean species richness, abundance, and biomass for fish/ha was larger at each station when sampling with the otter trawl or commercial trawl. In order to compare the performance for the three different trawls in more detail, the total abundance, total biomass and species richness for each individual trawl were directly compared (Figures 10 through 12). Fish abundance in August was highest in the otter trawls (Figure 10), with statistically higher numbers of fish/ha than either the commercial trawl or beam trawls (Table 6). This trend was driven primarily by the large number of Pacific sanddab and Rex sole captured by the otter trawl. Abundance in the commercial trawl was significantly higher than the beam trawl. This was due, not only to large numbers of Pacific sanddab, but also Sablefish and Pacific hake. In September fish abundance was significantly higher in the otter trawl than either the beam trawl or the commercial trawl, with mean fish abundance in the otter trawl nearly five times that of the beam trawl. Fish abundance in the September beam trawls was similar to that of August; however, abundance in the September commercial trawls was significantly lower, in part due to fewer hake and Sablefish in the deeper stations.

Despite lower fish abundance, the commercial trawl had significantly higher biomass in August than either the otter trawl or beam trawl (Figure 11). This was likely due to the larger mesh size in the commercial trawl, which selectively retains larger (but fewer) fish. Otter trawl biomass was significantly higher than that of the beam trawl, with a total biomass that was an order of magnitude higher than of the beam trawl. In September, fish biomass in the otter trawls were significantly higher than either the commercial or otter trawl. This was due to a large number of Pacific sanddab and Rex sole in the otter trawl, and a reduced abundance of large sablefish and hake in the commercial trawl.

Fish species richness was similar among the three different trawls (Figure 12). Although the mean number of species in the otter trawls in both August and September were significantly higher than that of the beam trawl, the range of species richness overlapped for all gear types and was generally between 6 and 12 species.

It is important to note that sampling efficiency for certain species varied with gear type, which in turn altered the characterization of the fish community. The commercial trawl was most effective at capturing larger and faster fish species such as English sole, Lingcod, Pacific hake, Sablefish, Petrale sole, and larger Arrowtooth flounder (Figure 13). The commercial trawl sampled 51% of the fish species observed at the DWS. Species that were exclusively sampled in the commercial gear were Spiny dogfish and Ratfish.

In general, the beam trawl was most effective for sampling the smaller, more debris-, or rock-related fish species, including Bluespotted poachers, Slim sculpin, Slender sole, and Snailfish. The beam trawl sampled 61% of fish species observed in the DWS. Species that were exclusively sampled in the beam trawls were the Brown Irish lord, Northern spearnose poacher, Pygmy poacher, and Snailfish.

The otter trawl appeared to sample both bottom-dwelling fish, as well as some of the larger, faster fish found in the commercial trawl. The otter trawl was most efficient for sampling Pacific

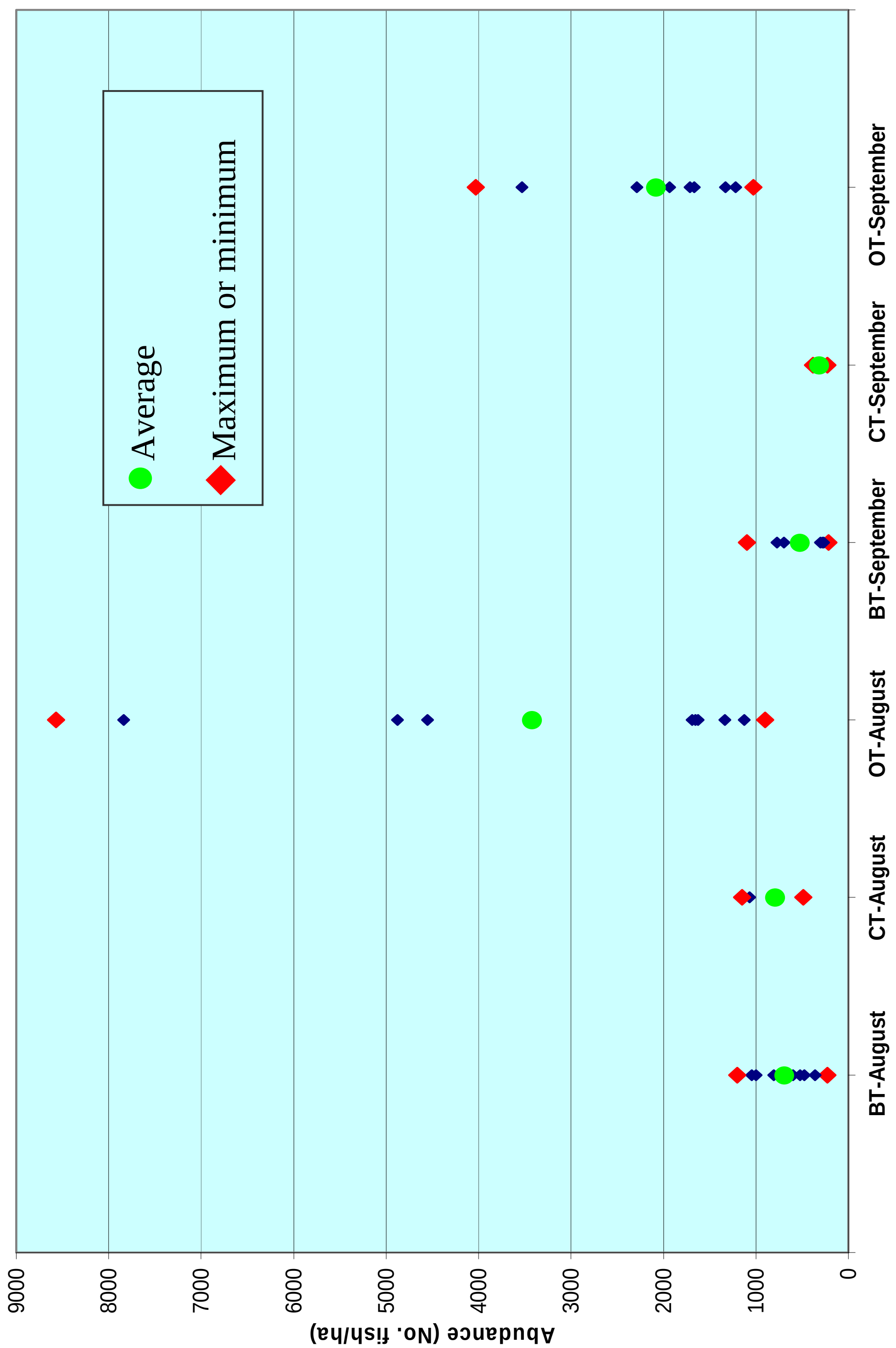


Figure 10. Comparison of Fish Abundances Captured by the Three Trawl Types, August and September 2003.

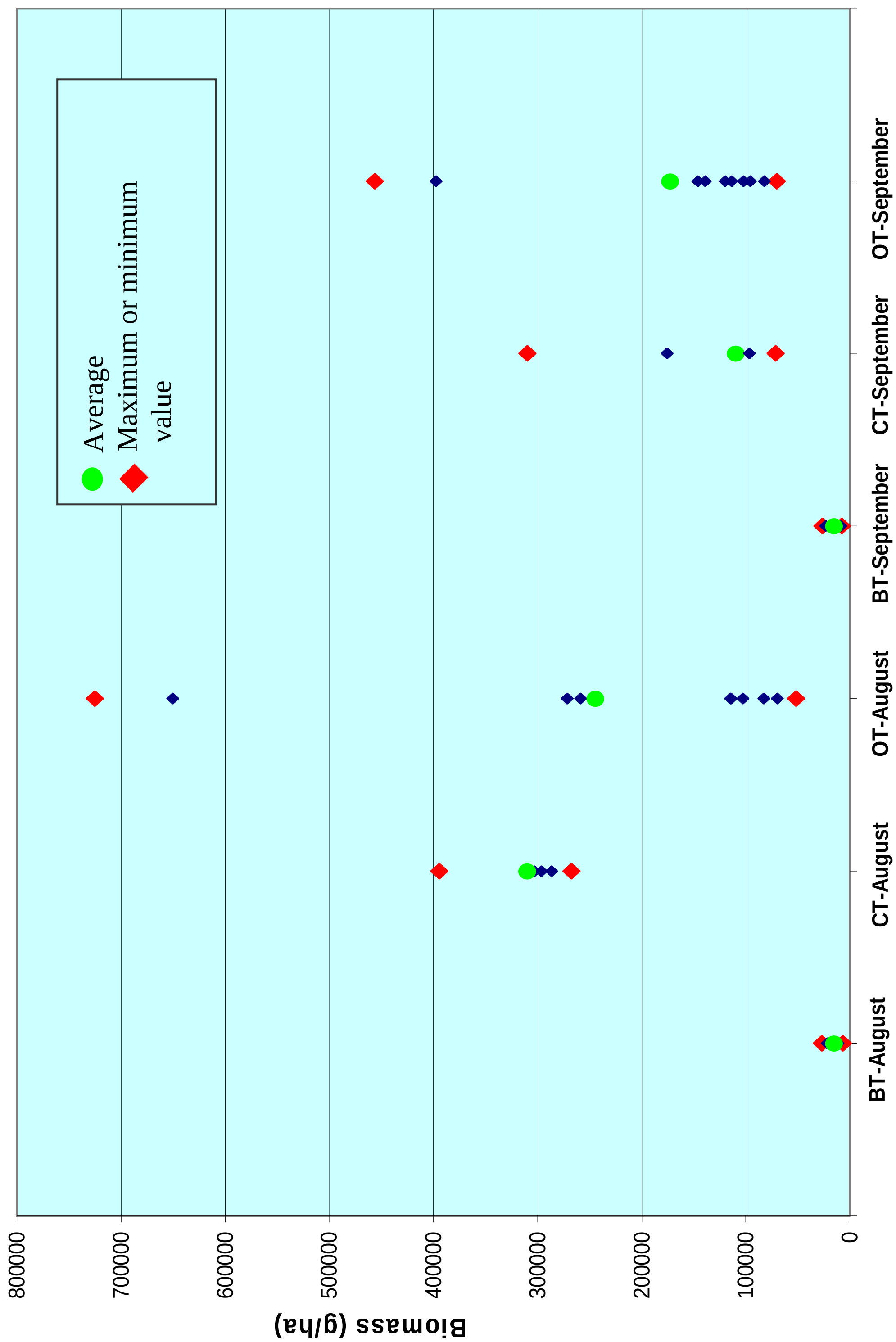


Figure 11. Comparison of Fish Biomass Collected Using Three Types of Trawls, August and September 2003.

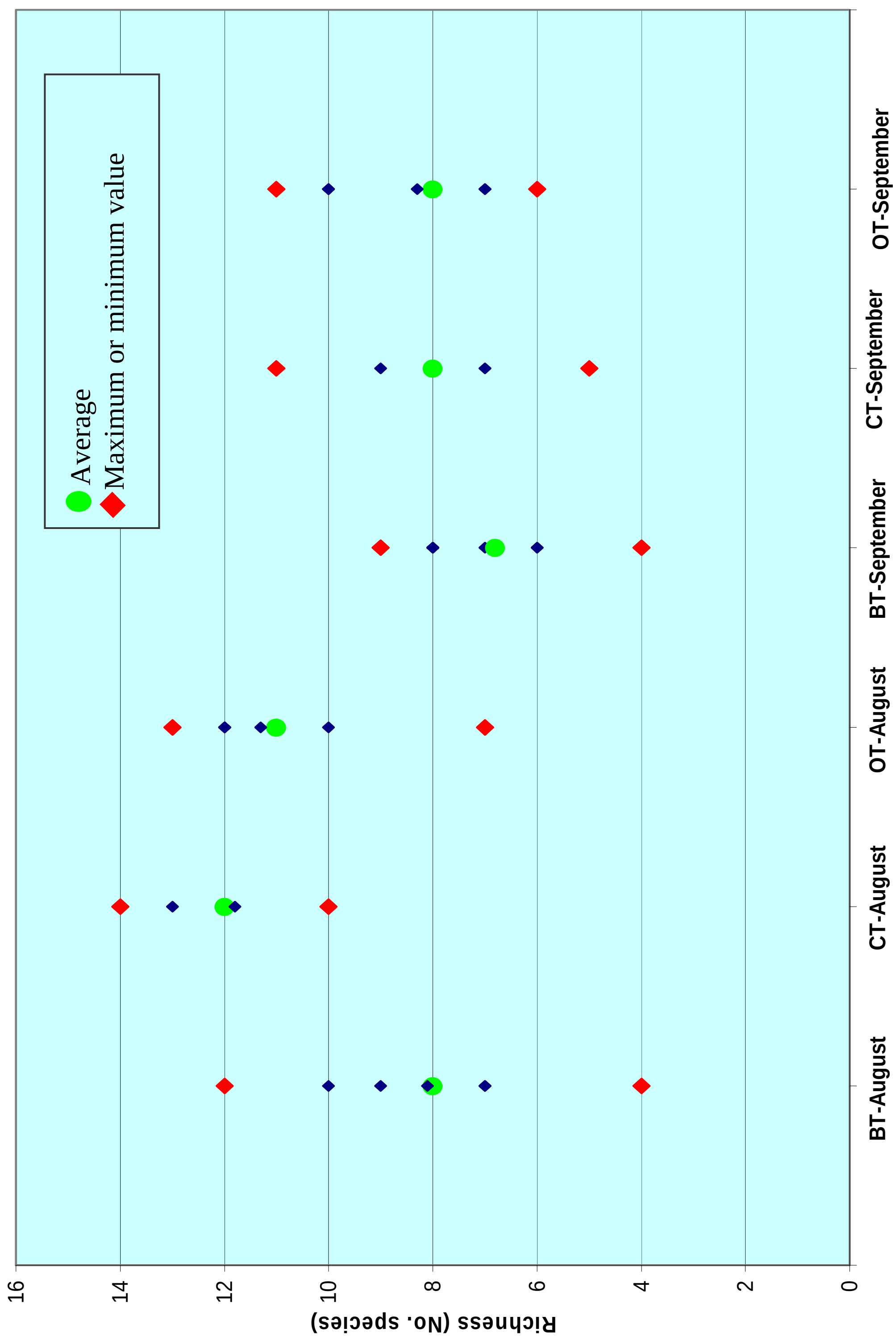


Figure 12. Comparison of Species Richness Derived from Using Three Types of Trawl Gear, August and September 2003.

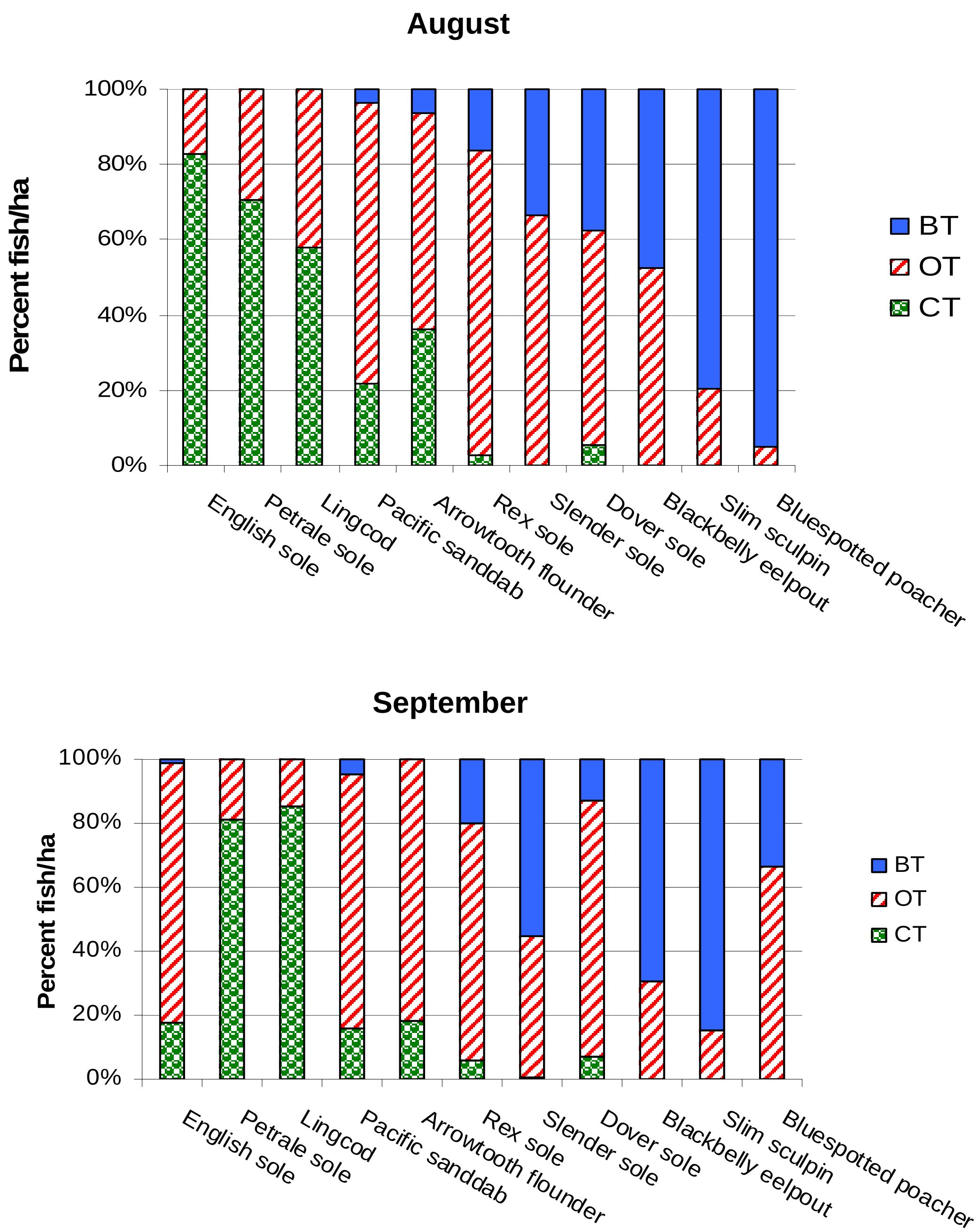


Figure 13. Sampling Efficiency (% Total Abundance) for Fish Species by Gear Type, August and September 2003.

Table 6. Summary of the Statistical Comparisons of Abundance Between Gear Types Using ANOVA and the Tukey's Test (p<0.05 denotes significant difference).

Species/Category	Sampling Period	P	Result	Comments
Arrowtooth Flounder	August	0.0166	CT=OT>BT	
	September	0.7798	NS	
Blackbelly Eelpout	August	0.0654	NS	*See Comment A*
	September	0.0021	BT=OT>CT	
Bluespotted Poacher	August	0.8102	NS	*See Comment B*
	September	ND	ND	
Dover Sole	August	0.0010	OT=BT>CT	
	September	<0.0001	OT>CT=BT	
English Sole	August	<0.0001	CT>OT>BT	
	September	<0.0001	OT>CT>BT	
Lingcod	August	0.0024	CT>OT=BT	
	September	0.0023	CT>OT=BT	
Pacific Hake	August	<0.0001	CT>OT>BT	
	September	<0.0001	CT>OT=BT	
Pacific Sanddab	August	<0.0001	OT>CT>BT	
	September	<0.0001	OT>CT>BT	
Rex Sole	August	<0.0001	OT>BT>CT	
	September	<0.0001	OT>BT>CT	
Sablefish	August	<0.0001	CT>OT>BT	
	September	0.5674	NS	*See Comment C*
Slender Sole	August	<0.0001	OT=BT>CT	
	September	<0.0001	OT=BT>CT	
Slim Sculpin	August	<0.0001	BT>OT>CT	
	September	<0.0001	BT>OT>CT	
Richness	August	0.0101	CT=OT>BT	
	September	0.007	OT=CT>CT=BT	
Total Abundance	August	<0.0001	OT>CT>BT	
	September	<0.0001	OT>BT>CT	
Total Biomass	August	<0.0001	CT>OT>BT	
	September	<0.0001	OT>CT>BT	

P<0.05 results in a significant difference
A: No Blackbelly eelpouts were observed in the commercial trawls.
B: No Bluespotted poachers were observed in the commercial trawls.
C: No Sablefish were observed in the beam trawls.

sanddab, Arrowtooth flounder, Rex sole, Slender sole, Dover sole, as well as Bluespotted poacher, Blackbelly eelpout and Lingcod. Of the 31 fish species observed at the DWS, 77% were observed in the otter trawls. Species exclusively sampled in the otter trawls were Eulachon, Red Irish lord, Whitebart smelt, and the Roughback sculpin; however, these species were not common and it is likely that they would be sampled by the beam trawl if they occurred in greater abundance.

The results of statistical comparisons for selected fish species are presented in Table 6. The otter trawl collected significantly greater numbers of flatfish than the beam trawl, with the exception of Dover sole (August) and Slender sole. Differences in roundfish abundance varied depending upon species. For the larger, faster species (Pacific hake and Sablefish) the otter trawl had significantly higher abundance than in the beam trawl. It should be noted, however, that the abundance of these species in the otter trawl was fairly low. There were no significant differences between the two gear types for Blackbelly eelpout, Bluespotted poacher, or Lingcod. The beam trawl had significantly higher abundance of Slim sculpin.

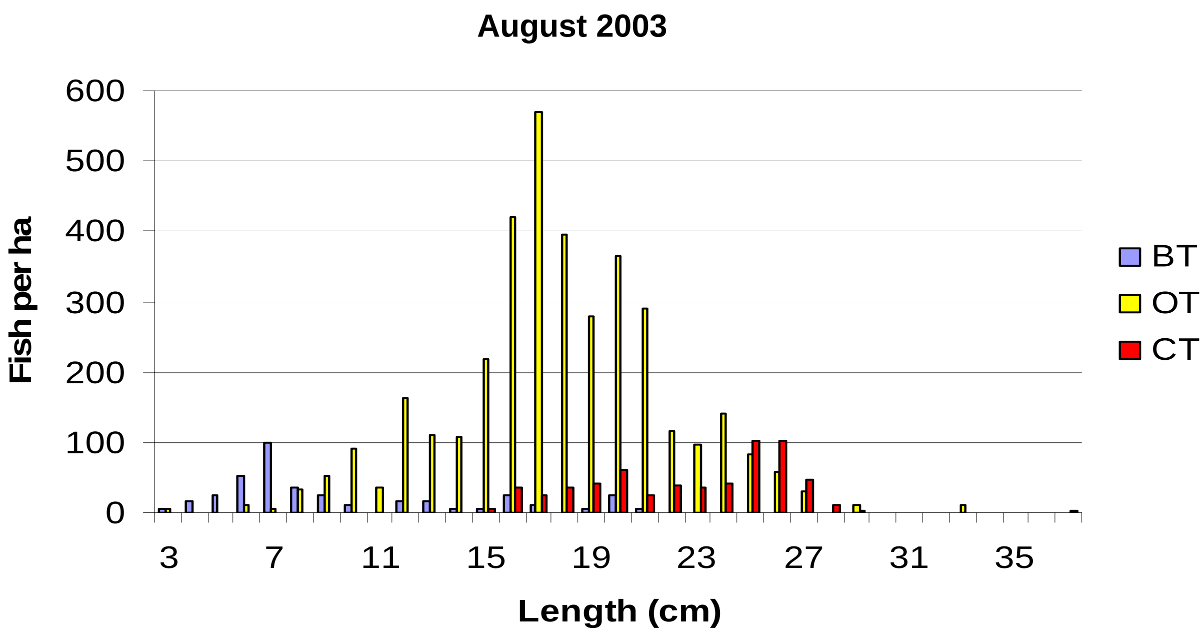
The commercial trawl had significantly higher abundance of roundfish (Lingcod, Pacific Hake, and Sablefish). Abundance of English sole (August) and Petrale sole was highest in the commercial trawl. For Pacific sanddab, and English sole (September), abundance in the commercial trawl was significantly higher than that of the beam trawl. The commercial trawl had the lowest abundance for the smaller flatfish species (Rex sole and Slender sole) and the smaller demersal species (Blackbelly eelpout, Bluespotted poacher, Slender sculpin).

3.3 Comparison of Size Classes

Fish lengths were measured for the first 70 fish for each species caught during each trawl event. Board lengths (the length from snout to the tip of the caudal peduncle) were then divided into groups at ten millimeter intervals. The number of fish per hectare within a given interval for each gear type were then plotted to allow for a comparison of the size groups that are sampled by each gear type.

There were three size-distribution patterns that were observed at the DWS. For some species, such as Pacific sanddab and English sole, there was size selectivity by gear type (Figure 14, also see Appendix D). In each case, the commercial trawl collected the largest size classes and the beam trawl sampled the smallest size classes. The otter trawl collected intermediate size classes, overlapping both the low and high end of the length range.

The second size-distribution pattern also indicated size selection by gear type (CT>OT>BT); however, in this case, the size distribution for the fish population was bimodal, with two apparent size classes being sampled (Figure 15, Appendix D). In each case, the sampling efficiency was higher in the beam trawl for the smaller size group and higher in the otter trawl for the larger size group. Again, the commercial trawl more effectively sampled the largest size classes. This trend is best illustrated in the size distribution for Rex sole. The two size groups appear to be centered about 9 cm and 18 cm. Although both the beam trawl and otter trawl effectively sampled fish within each size grouping, the sampling efficiency of the beam trawl for 9 cm fish was twice that of the otter trawl. Likewise, the number of fish per hectare in the 18 cm size group captured in the otter trawl was more than twice than of the beam trawl. This trend was also observed for Slender sole and Dover sole. This type of distribution further illustrates the differences in size selectivity between the three different gear types.



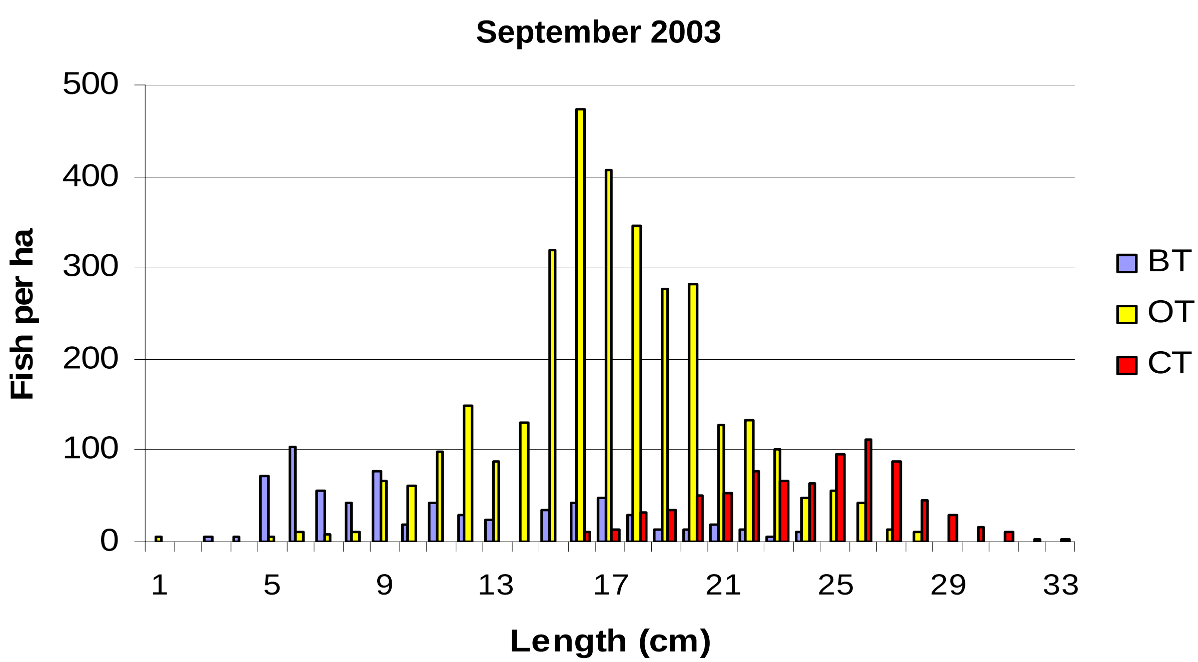
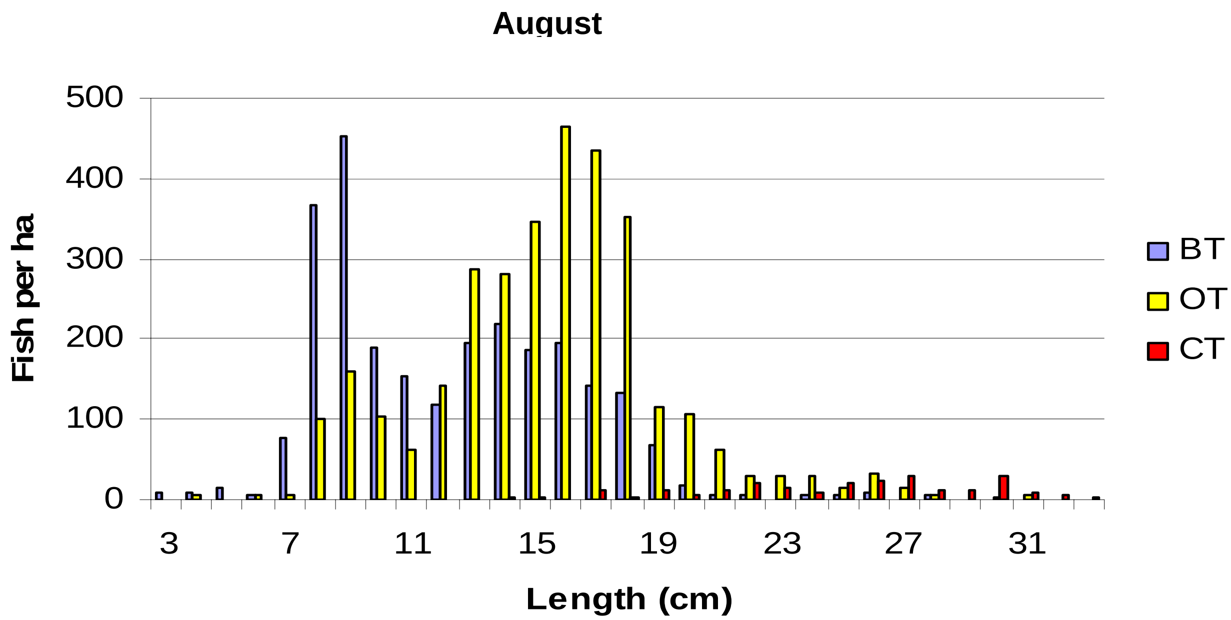


Figure 14. Comparison of Size Class Distribution for Pacific Sanddab among the Three Gear Types, August and September 2003. (BT = Beam Trawl, OT = Otter Trawl, CT = Commercial Trawl).



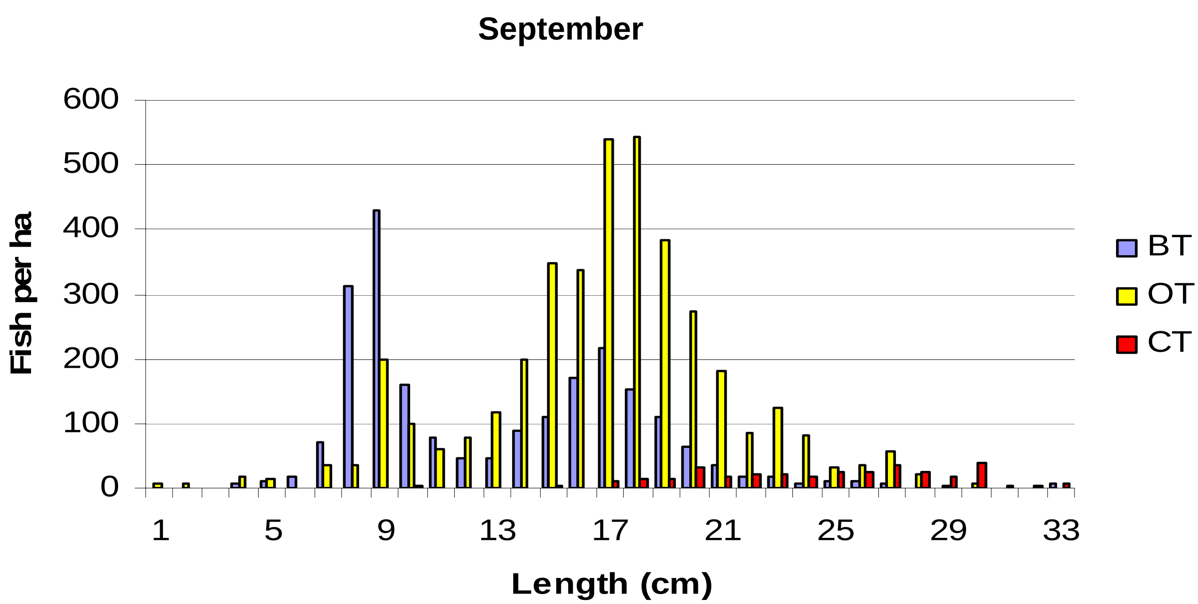


Figure 15. Comparison of Size Class Distribution for Rex Sole among the Three Gear Types, August and September 2003.
(BT = Beam Trawl, OT = Otter Trawl, CT = Commercial Trawl)

The third size-distribution pattern showed little discernable size selectivity among gear types – all fish sampled fell into similar size categories, regardless of gear type. This was true for Arrowtooth flounder, Lingcod, Pacific hake, Petrale sole, and Blackbelly eelpout (Figure 16, Appendix D). For the Lingcod, Arrowtooth flounder, and hake, it is unclear whether the lack of size selectivity was due to small sample size.

3.4 Demersal Invertebrates

The demersal invertebrate community at the DWS was dominated by *Cancer magister*, *Crangon* shrimp, and the starfish *Luidia foliolata* and *Pycnopodia helianthoides*. However, the invertebrate assemblage differed considerably by gear type. A summary of invertebrate abundance and biomass is presented in Tables 7 through 9. A summarization of the mean abundance and biomass for all species (occurring at <1%) is in Appendix B and the detailed record for all replicates is presented in Appendix C.

3.4.1 Commercial Trawls

The number of invertebrate species was very low in the commercial trawls, selectively collecting Dungeness crab and starfish. In August, mean total invertebrate abundance ranged from 24 ind./ha at Station A to 77 ind./ha in Station E and species richness was 1 to 3 species. The catch was comprised almost entirely of Dungeness crab, with a small number of *Pisaster brevispinus* or *P. helianthoides* at several stations. Biomass in the commercial trawls ranged from 12.6 kg/ha to 32.8 g/ha.

In September, the abundance was much higher, due a large number of molting male Dungeness crab collected in the commercial net. Mean abundance ranged from 500 ind./ha at Station to 711 ind./ha, and biomass was 3,030 kg/ha to 7,366 kg/ha. The invertebrate assemblage in the September commercial trawl was exclusively *C. magister*. A more detailed discussion of the Dungeness crab at the DWS is presented below, in Section 3.5. The small number of invertebrate species observed in the commercial trawl was presumably due to the small size of most of the invertebrates at the DWS and the large mesh size of the commercial trawl.

3.4.2 Beam Trawls

The beam trawl proved to be effective at collecting invertebrates, particularly shrimp and mollusks closely associated with the bottom. The most common species observed were the shrimp, *Crangon alaskensis* and *C. communis*, the clam, *Cyclocardia ventricosa* (in the deeper trawls), brittle stars, *Ophiura* spp., and hermit crabs (Paguridae). Mean total abundance in August ranged from 492 ind./ha at Station A to 1,338 ind./ha at Station E. The higher abundance at Station E was driven primarily by the presence of *P. jordani*; whereas the most common species observed in the August beam trawls, *C. alaskensis*, did not show any significant trend with station or depth. Mean biomass ranged from 3.1 kg/ha to 24.9 g/ha, with crab and *Metridium senile* (Station E) dominating the biomass. The mean number of species in the August beam trawls ranged from 5 to 16.

In September, mean abundance at Station C increased to 747 ind/ha and to 2,547 ind./ha at Station B, primarily due to an increase in the abundance of *Crangon* shrimp in the shallower stations (Stations A and B), and *C. magister* at all stations. The mean biomass increased in September, ranging from 23.1 kg/ha at Station E to 59.2 kg/ha in Station D. Biomass was dominated by *C. magister*, *M. senile*, and *P. helianthoides.* The mean species richness in the September beam trawls ranged from 10 to 14 species.

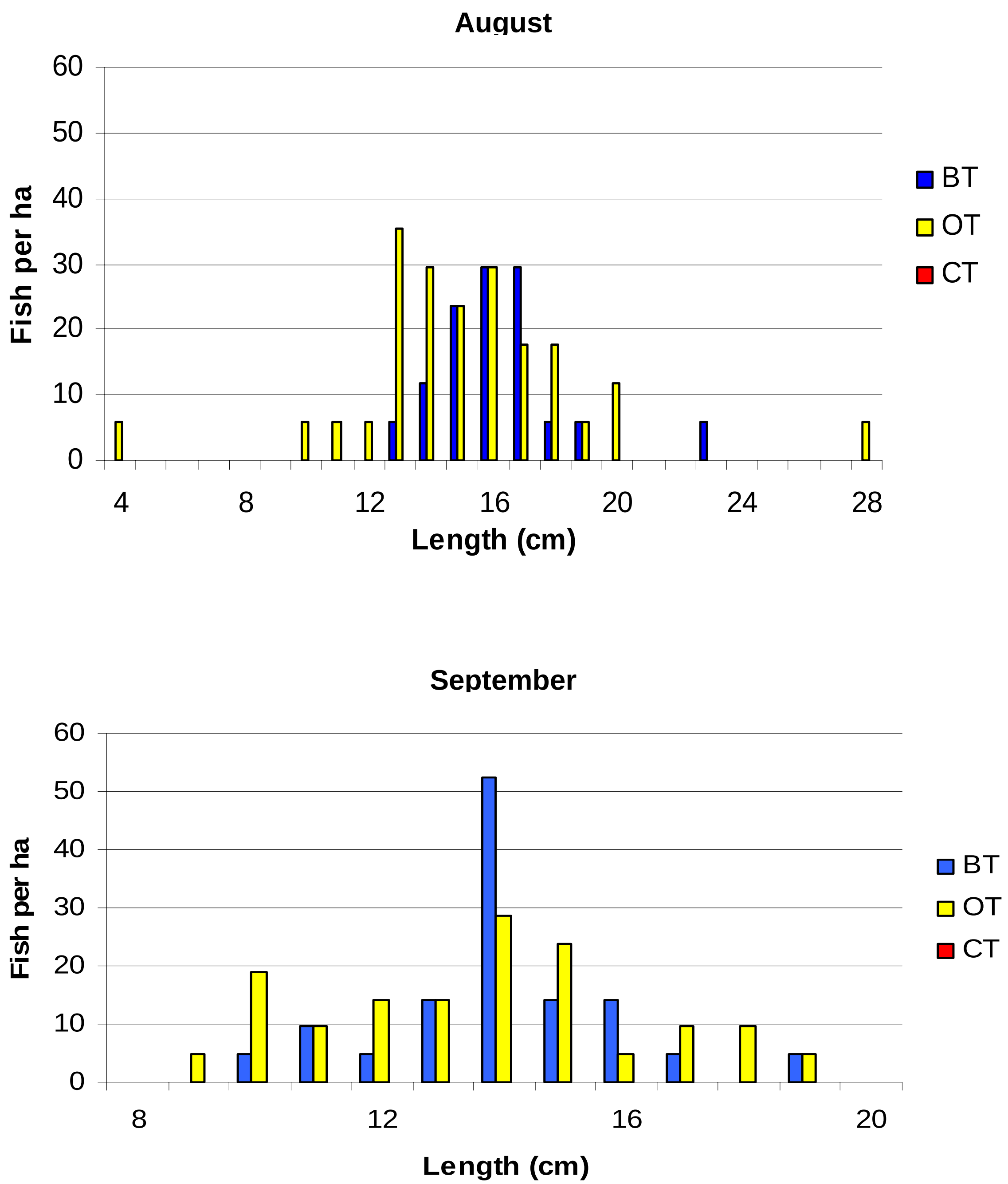


Figure 16. Comparison of Size Class Distribution for Blackbelly Eelpout among the Three Gear Types, August and September 2003.
(BT = Beam, OT = Otter Trawl, CT = Commercial Trawl)

Table 7. Total Mean Catch Statistics for Benthic Invertebrates, August and September 2003.

Station	Mean Total Abundance (No. per hectare)		Mean Total No. Species		Mean Total Biomass (kg per hectare)	
	Aug	Sept	Aug	Sept	Aug	Sept
Commercial Trawl						
A	24	500	1	1	12.6	3,030
B	47	500	3	1	20.1	4,032
C	49	592	1	1	25. 7	5,086
D	58	711	1	1	32.8	7,366
E	77	570	3	1	31.8	5,628
Beam Trawl						
A	492	1,785	10	6	3.1	54.0
B	821	2,547	13	5	15.9	25.9
C	719	747	12	6	7.2	25.2
D	488	962	11	11	18.0	59.2
E	1,338	1,088	14	16	24.9	23.1
Otter Trawl						
A	45	147	8	10	11.5	55.3
B	81	62	4	6	10.9	19.8
C	168	79	8	7	20.6	27.5
D	167	94	10	8	16.9	25.7
E	510	94	7	10	18.0	27.6

Table 8. Mean Abundance of Key Invertebrate Species Captured with Type of Each Trawl Gear in 2003.

Station	***Mean Abundance** (#/Hectare)*											
	Cancer magister		***Crangon alaskensis***		***Cyclocardia ventricosa***		***Luidia foliolata***		***Pandalus jordani***		***Pycnopodia helianthoides***	
	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Commercial Trawl												
A	24	500	0	0	0	0	0	0	0	0	0	0
B	43	500	0	0	0	0	0	0	0	0	2	24
C	49	592	0	0	0	0	0	0	0	0	0	57
D	58	711	0	0	0	0	0	0	0	0	0	51
E	67	570	0	0	0	0	0	0	0	0	2	22
Beam Trawl												
A	2	112	381	1574	0	0	43	50	0	0	2	9
B	24	44	541	2418	0	0	83	11	2	0	7	24
C	7	41	524	606	76	0	19	68	0	6	0	9
D	2	74	143	179	114	468	141	100	2	0	7	18
E	21	24	450	88	169	585	91	124	295	0	0	6
Otter Trawl												
A	14	130	0	0	0	0	24	11	0	0	7	3
B	17	41	36	0	0	0	19	8	0	3	2	5
C	20	59	73	3	0	0	40	12	0	0	13	6
D	24	41	81	6	0	0	17	18	0	0	10	0
E	24	59	86	6	0	0	17	18	336	0	2	0

Table 9. Mean Biomass of Key Invertebrate Species Captured with Type of Each Trawl Gear in 2003.

Station	Mean Biomass *(Kg/Hectare)*											
	Cancer magister		***Crangon alaskensis***		***Cyclocardia ventricosa***		***Luidia foliolata***		***Pandalus jordani***		***Pycnopodia helianthoides***	
	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Commercial Trawl												
A	12.6	3,030	0	0	0	0	0	0	0	0	0	0
B	19.8	4,032	0	0	0	0	0	0	0	0	0.01	0
C	25.7	5,086	0	0	0	0	0	0	0	0	0	0
D	32.8	7,366	0	0	0	0	0	0	0	0	0	0
E	31.8	5,627	0	0	0	0	0	0	0	0	0	0
Beam Trawl												
A	1.2	47.0	0.08	0.6	0	0	1.5	4.2	0	0	0	2.3
B	8.0	17.8	0.3	1.0	0	0	2.7	1.5	<0.01	0	2.4	5.2
C	3.6	17.6	0.2	0.3	0.1	0	1.1	4.4	<0.01	0.04	0	2.4
D	1.0	31.1	0.08	0.2	0.2	0.7	7.8	10.3	<0.01	0	2.4	5.6
E	8.0	8.3	0.2	0	0.3	1.3	1.3	2.2	0.6	0	0	0.9
Otter Trawl												
A	7.2	54.2	0	0	0	0	1.6	0	0	0	2.7	1.1
B	1.0	18.1	0.02	0	0	0	0.8	0.3	0	0.02	0.4	1.3
C	7.9	24.7	0.02	0	0	0	4.5	1.0	0	0	5.4	1.9
D	10.4	21.7	0.01	0	0	0	0.7	1.7	0	0	3.5	0
E	8.8	26.1	0	0	0	0	0.6	1.4	1.1	0	0.8	0

3.4.3 Otter trawls:

The mean total abundance of invertebrates in the August otter trawls ranged from 45 ind/ha at Station A to 510 ind./ha at Station E, with species richness ranging from 4 to 10 species. In August the invertebrate assemblage was dominated by *C. alaskensis*, *C. magister*, *L. foliolata*, and *P. jordani* at the deep station (Station E). Mean total biomass ranged from 10.9 kg/ha at Station B to 20.9 kg/ha at Station C. Biomass was dominated by *C. magister* and the starfish, *L. foliolata* and *P. helianthoides.*

The September invertebrate assemblage was further dominated by *C. magister*, *L. foliolata*, and *P. helianthoides* with an increased abundance of each species. Mean abundance increased to 62 ind./ha at Station B to 147 ind./ha at Station A. Biomass was again dominated by *C. magister* and the two starfish, and ranged from 19.8 kg/ha at Station B to 55.3 kg/ha at Station A. The mean number of species ranged from 6 to 10 species per trawl.

3.4.4 Comparison of Gear Types

As with the demersal fish assemblage, the invertebrate assemblage differed when characterized by the three different trawls. Also similar to the demersal fish, the commercial trawl and beam trawl appeared to represent two ends of the invertebrate sampling spectrum. In order to compare the performance for the three different trawls, abundance, biomass and species richness for each individual trawl are presented in Figures 17 through 19.

As expected, the commercial trawl captured only larger invertebrate species, with no retention of the smaller species. The commercial trawl sampled the fewest number of species (Figure 17), with only Dungeness crab collected in the commercial net in September. In contrast, the beam trawl effectively sampled the demersal invertebrates in the sediment surface, at the sediment-water interface or in association with rocks and debris (*Argis, Crangon, and Spironticaris* shrimp, anemones, *Cyclocardia* and *Macoma* clams, snails, and *Ophiura* spp.), as well as species more loosely associated with the sediment (crab, *P.jordani*, and larger starfish). As a result, the beam trawl sampled the highest number of species per trawl and the highest abundance in both August and September. The otter trawl sampled some of the smaller bottom-oriented demersal invertebrates and the larger more mobile species, such as *C. magister* and starfish. The number of species sampled by the otter trawl was less than that of the beam trawl, but greater than the commercial trawl.

Total invertebrate abundance was significantly higher in the beam trawl (Figure 18, Table 10) than in either the otter trawl or commercial trawl. This was presumably due to the large diversity of invertebrates sampled by the beam trawl. Total abundance was similar between the otter trawl and commercial trawl in August; however in September, the commercial trawl abundance was greater than that of the otter trawl due to the large number of crab in the commercial net.

Trends in invertebrate biomass were driven largely by Dungeness crab and starfish. Despite lower abundance, the commercial trawl had the highest biomass observed at the DWS (Figure 17). Despite differences in abundance, biomass estimates for the beam trawl and otter trawl were not significantly different in August or September. This was largely due to a similar number of Dungeness crab sampled by the two different gear types.

With the exception of Dungeness crab, *P. helianthoides*, and *P. jordani*, the beam trawl had the highest sampling efficiency for demersal invertebrates (Figure 20). The beam trawl sampled 98% of the species observed at the DWS; whereas the commercial trawl sampled 1% of the species observed. The otter trawl sampled 50% of the species observed at the DWS. Species

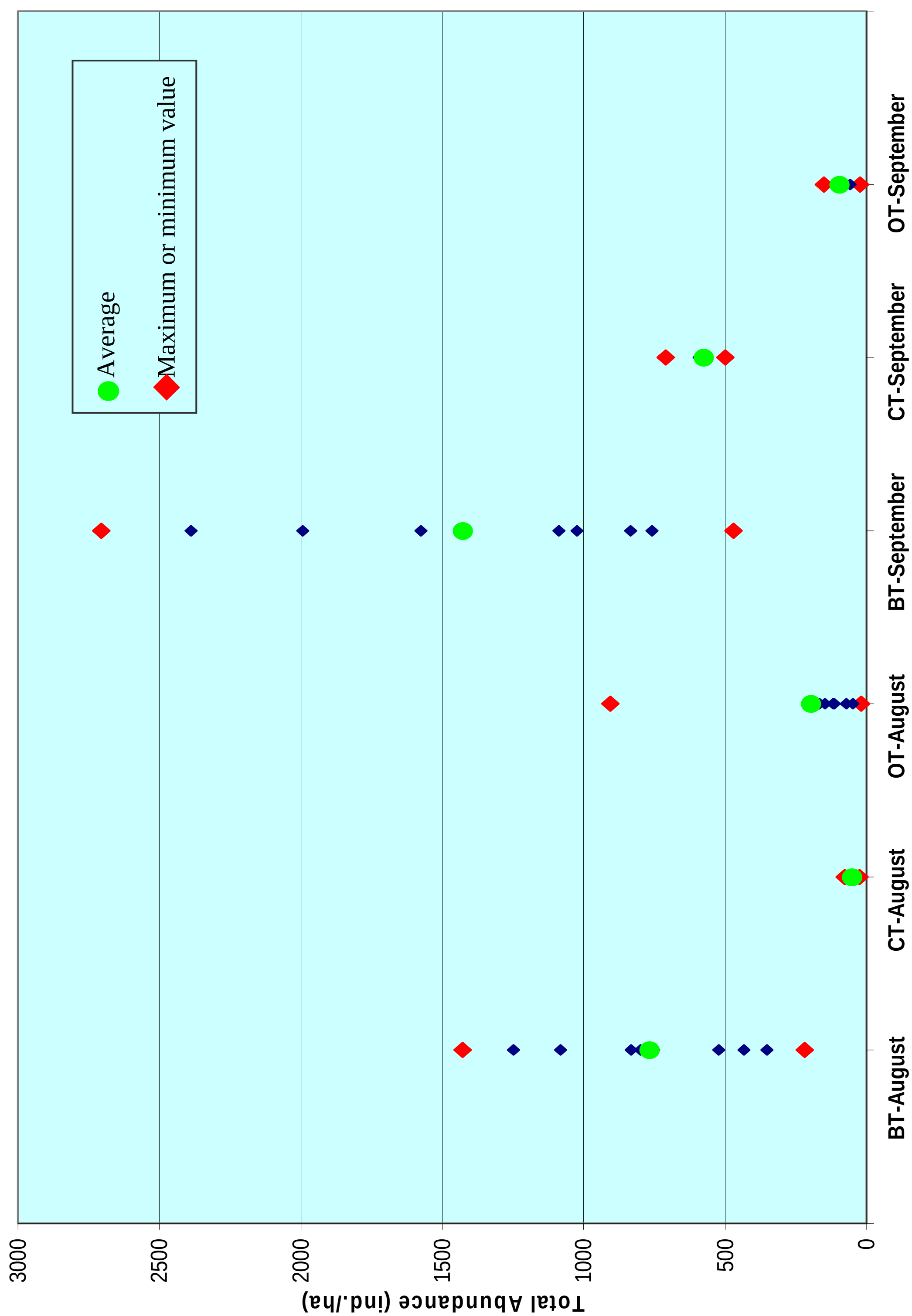


Figure 17. Comparison of Invertebrate Total Abundance Captured by Each Trawl.
(BT = Beam Trawl, CT = Commercial Trawl, OT = Otter Trawl)

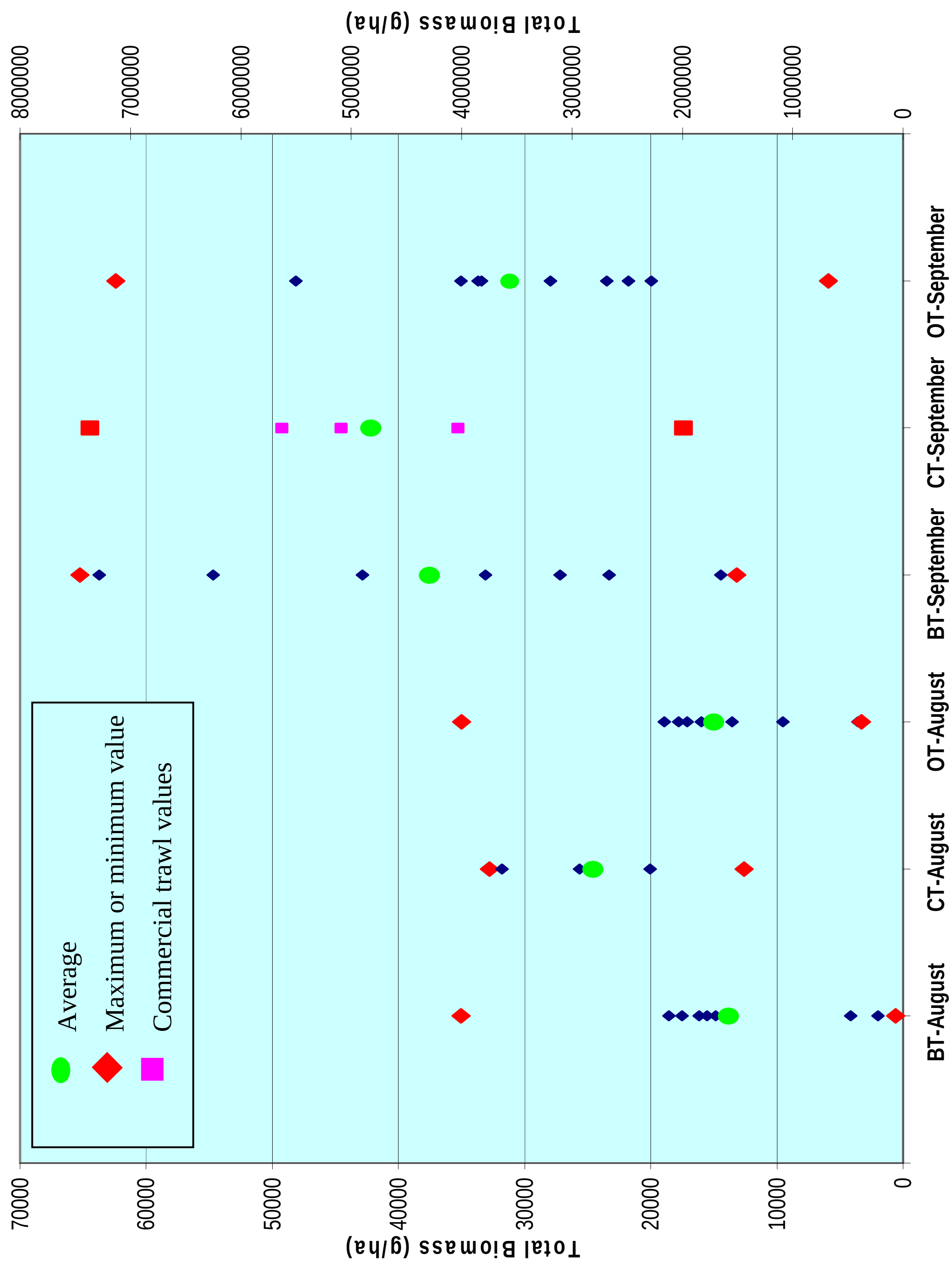


Figure 18. Comparison of Total Biomass of Invertebrates Captured By Each Trawl.
(BT = Beam Trawl, CT = Commercial Trawl, OT = Otter Trawl).
Note: Commercial trawl Biomass is plotted on the alternate Y-axis.

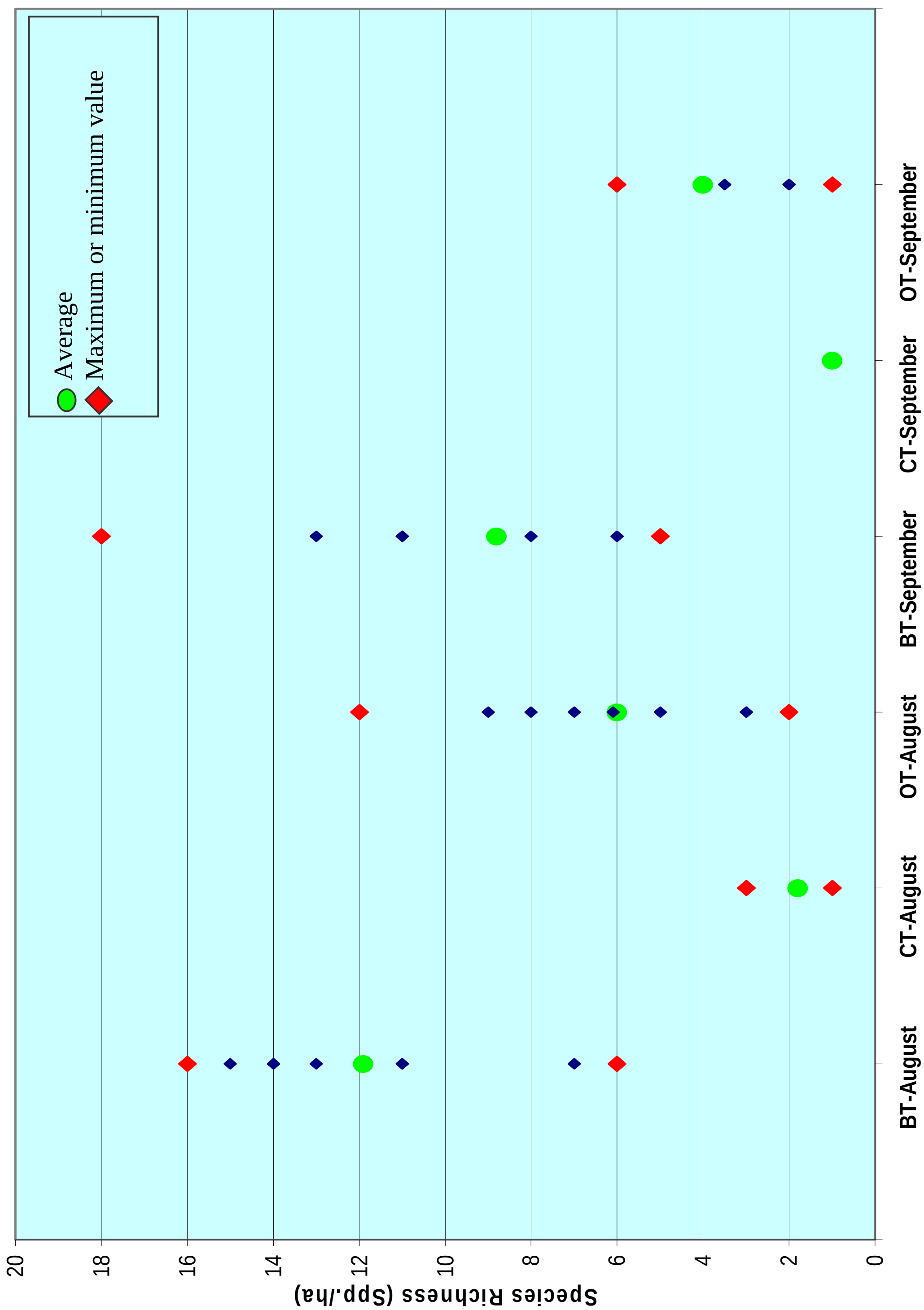
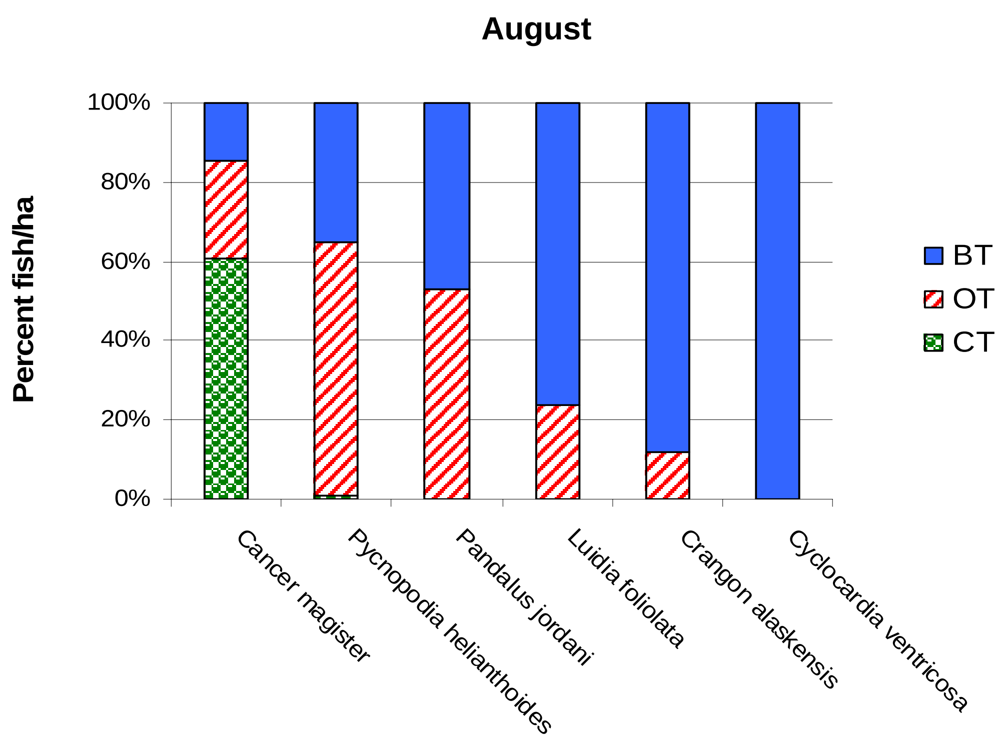


Figure 19. Comparison of Invertebrate Species Richness Captured By Each Trawl.
(BT = Beam Trawl, CT = Commercial Trawl, OT = Otter Trawl).

Table 10. Results of ANOVA Analyses for Benthic Invertebrates.

Species/Category	Sampling Period	P	Result	Comments
Cancer magister	August	0.0200	CT=OT>OT=BT	
	September	<0.0001	CT>OT=BT	
Crangon alaskensis	August	0.0001	BT>OT>CT	
	September	<0.0001	BT>OT>CT	
Crangon communis	August	ND	NS	*Comment A*
	September	0.0583	NS	*Comment B*
Cyclocardia ventricosa	August	0.0022	BT>OT=CT	
	September	<0.0001	BT>OT=CT	
Luidia foliolata	August	0.0002	BT=OT>CT	
	September	<0.0001	BT>OT>CT	
Pycnopodia helianthoides	August	0.1472	NS	
	September	0.0083	BT=OT>OT=CT	
Richness	August	<0.0001	BT>OT>CT	
	September	<0.0001	BT>OT>CT	
Total Abundance	August	<0.0001	BT>OT=CT	
	September	<0.0001	BT>CT>OT	
Total Biomass	August	0.1702	NS	
	September	<0.0001	CT>BT=OT	

P<0.05 results in a significant difference
A: No *C. communis* were observed in August.
B: No *C. communis* were observed in the commercial trawls.



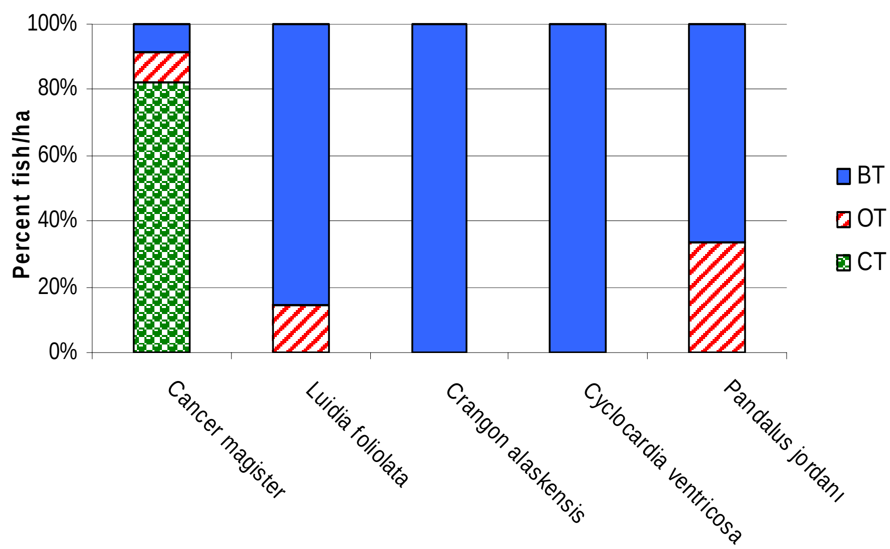


Figure 20. Sampling Efficiency (% Total Abundance) for Invertebrate Species by Gear Type, August and September.

sampled by the beam trawl that were not sampled by either the otter trawl or the commercial trawl are *Acanthodoris* sp., *Brada* sp., the molluscs *Cyclocardia ventricosa*, *Nassarius* spp., *Neptunea*, *Macoma calcarea*, and *Yoldia*, as well as *Pinnixa* sp., ophiuroids, and Pagurid hermit crabs. *Pisaster brevispinus* was not observed in any of the beam trawls.

The result of the statistical comparisons for selected invertebrate species is presented in Table 10. No significant differences between the beam trawl and the otter trawl were observed for *C. magister*, the shrimp *P. jordani* and *C. communis*, or the starfish *P. helianthoides* or *Luidia foliolata* (August). There were significantly higher numbers of the shrimp, *C. alaskensis*, in the beam trawl for both August and September. The beam trawl also had significantly higher numbers of the shrimp *S. lamellicornis* (there were none in the otter trawl). The commercial trawl collected significantly higher numbers of crab than the beam trawl in August and both the otter and beam trawls in September.

3.5 Dungeness Crab

Dungeness crab appeared to be somewhat segregated by sex and season. Female Dungeness crabs were more abundant than male crabs for all trawl methods during August surveys. Conversely, in September male Dungeness crabs were much more abundant than female crabs for all trawl methods. Female Dungeness were more prevalent than males in August than in September (Figures 21 and 22) with no considerable shift in size (measured as carapace width) between months. Males, though, were much more prevalent in September trawls (Figures 21 and 22). However, although male Dungeness crab abundance increased dramatically from August to September in the commercial trawls, there was only a slight shift toward smaller male crabs. No gravid female Dungeness crabs were caught during this survey. There were no statistical differences in crab abundance between transects A through E in either August or September. The majority of crabs in both August and September surveys had shell strengths considered “soft” (Table 11). There was no statistical difference in shell strength between months or trawl method.

There was no statistical difference in crab abundance between beam trawls and otter trawls or between commercial trawls and otter trawls for August field surveys. However, there was a statistically significant difference in catch rates between beam trawls and commercial trawls (Tukey’s [HSD] $p < 0.05$). For September surveys there was again no statistical difference in crab abundance between beam trawls and otter trawls. However, otter trawls and beam trawls both differed significantly from commercial trawls (Tukey’s [HSD] $p < 0.05$).

Commercial trawls consistently caught more Dungeness crabs than either of the other two trawl methods combined. In both months the commercial trawl density estimates were greater than the otter trawl which were greater than the beam trawl estimates (Tables 12 and 13). For the month of August this density ratio was 4.2:1.7:1, respectively (Table 12). For the month of September the difference was even more pronounced in regards to commercial: otter: beam density ratio of 9.8:1.1:1 (Table 13). This pronounced difference for the September surveys is due to the increased abundance of male crabs.

The commercial trawl consistently collected larger crabs than either the beam or otter trawls at all stations, except at Station B in August where the otter trawl had the largest mean size crab (Table 11). As with demersal fish, this was likely due to the larger mesh size in the commercial trawl, selectively retaining larger crabs. Size class categories were the same as used during the 2002 survey: I (<50mm), II (50-99mm), III (100-129mm), IV (130-159mm), and V (>159mm). For all

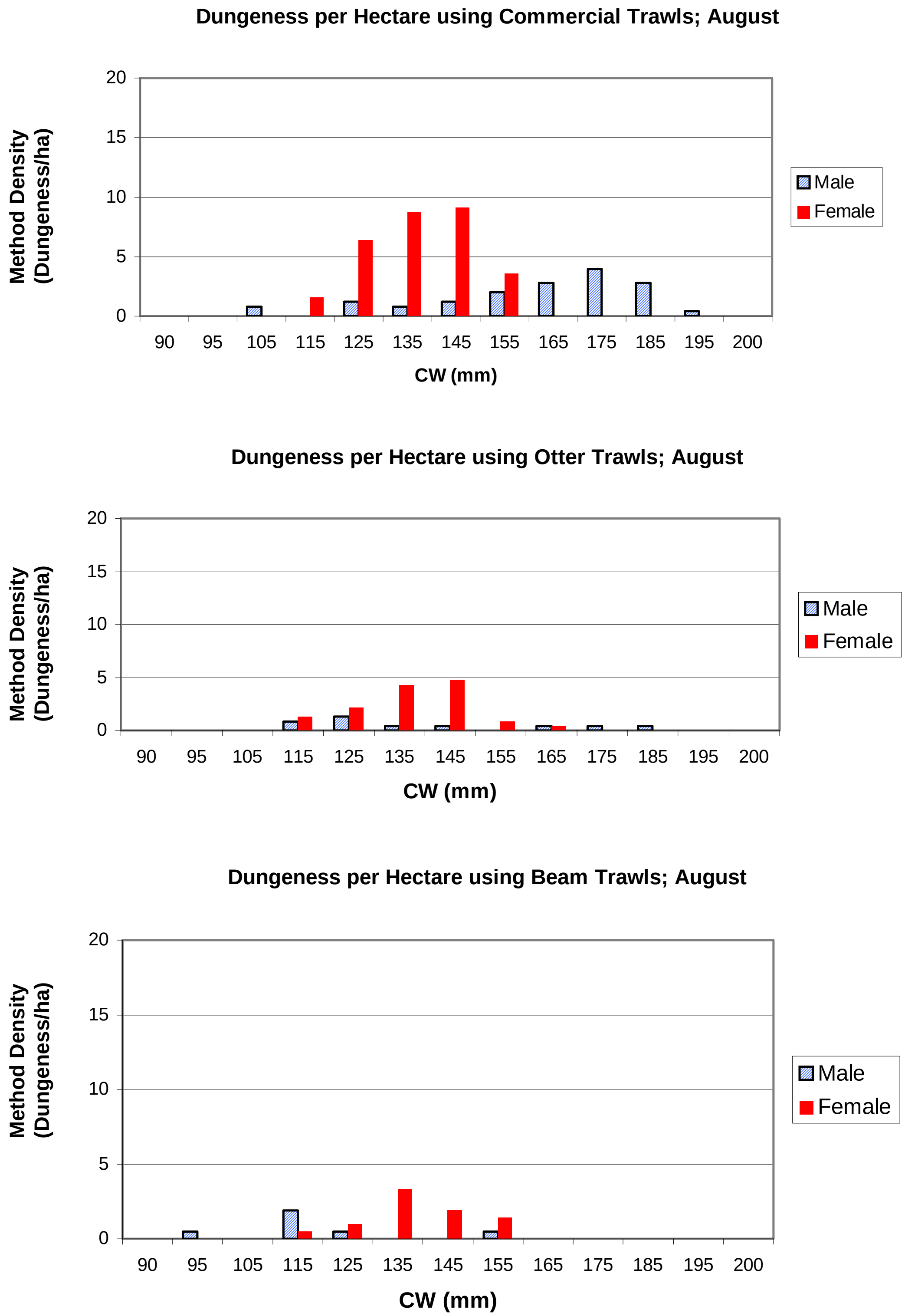


Figure 21. Dungeness Crab Size Frequency Density Distribution; August 2003.

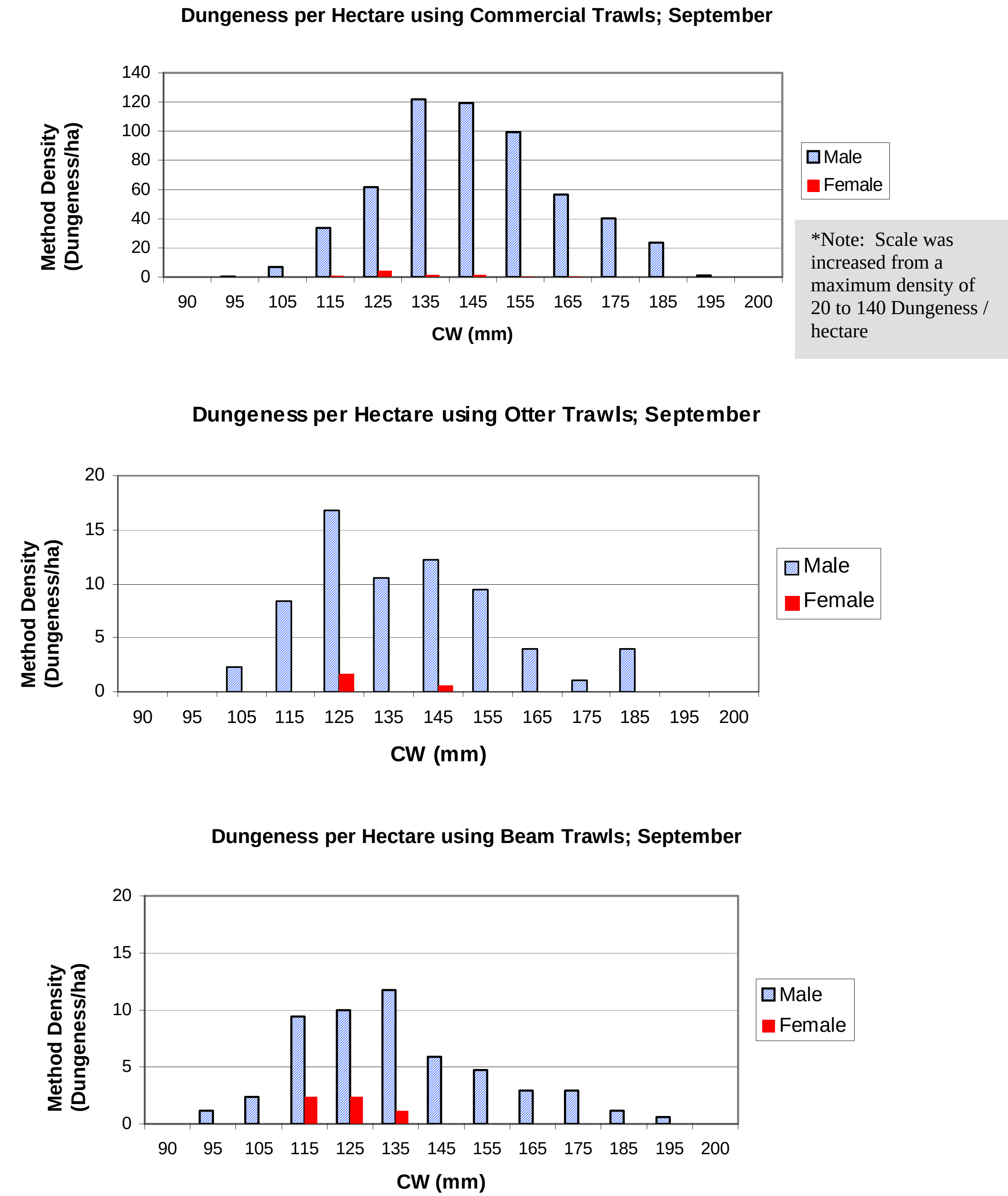


Figure 22. Dungeness Crab Size Frequency Density Distribution; September 2003

Table 11. Dungeness Crab Size Class Distribution and Shell Thickness.

Site	Date	Method	Gender	Total Crabs Caught	Min CW (mm)	Max CW (mm)	Mean CW (mm)	STD	2003 Size Class Distribution Percentages					% Soft
									I (<50mm)	II (50-99mm)	III (100-129mm)	IV (130-159mm)	V (>159mm)	
A	Aug.	Comm.	Female	15	121	152	141	8.2	0%	0%	7%	93%	0%	53%
			Male	3	157	188	176	16.6	0%	0%	0%	33%	67%	67%
			Total	18	121	188	147	16.2	0%	0%	6%	83%	11%	56%
		Otter	Female	2	115	134	125	13.4	0%	0%	50%	50%	0%	0%
			Male	4	122	180	141	26.5	0%	0%	50%	25%	25%	50%
			Total	6	115	180	136	23.1	0%	0%	50%	33%	17%	33%
		Beam	Female	1	141	141	141	-	0%	0%	0%	100%	0%	100%
			Male	0	0	0	0	-	-	-	-	-	-	-
			Total	1	141	141	141	-	0%	0%	0%	100%	0%	100%
	Sept.	Comm.	Female	1	127	127	127	-	0%	0%	100%	0%	0%	100%
			Male	189	97	183	142	18.4	0%	1%	26%	56%	17%	100%
			Total	190	97	183	142	18.4	0%	1%	27%	56%	17%	100%
		Otter	Female	3	126	145	133	6.2	0%	0%	67%	33%	0%	100%
			Male	54	102	182	137	19.2	0%	0%	44%	44%	11%	100%
			Total	57	102	182	136	18.8	0%	0%	46%	44%	11%	100%
		Beam	Female	0	0	0	0	-	-	-	-	-	-	-
			Male	38	106	196	137	22.6	0%	0%	47%	34%	18%	97%
			Total	38	106	196	137	22.6	0%	0%	47%	34%	18%	97%
B	Aug.	Comm.	Female	17	121	153	138	8.8	0%	0%	18%	82%	0%	71%
			Male	3	142	184	168	22.9	0%	0%	0%	33%	67%	100%
			Total	20	121	184	142	15.7	0%	0%	15%	75%	1%	75%
		Otter	Female	5	137	156	147	8.3	0%	0%	0%	100%	0%	20%
			Male	2	148	178	163	21.2	0%	0%	0%	50%	50%	50%
			Total	7	137	178	151	13.6	0%	0%	0%	86%	14%	29%
		Beam	Female	8	111	136	128	8.5	0%	0%	27%	63%	0%	88%
			Male	3	97	121	109	12	0%	33%	67%	0%	0%	100%
			Total	11	97	136	123	12.7	0%	9%	45%	45%	0%	91%
	Sept.	Comm.	Female	2	128	160	144	22.6	0%	0%	50%	0%	50%	50%
			Male	188	105	190	140.5	18.6	0%	0%	28%	55%	16%	98%
			Total	190	105	190	140.5	18.5	0%	0%	28%	55%	17%	98%
		Otter	Female	0	0	0	0	-	-	-	-	-	-	-
			Male	16	113	187	139	20.3	0%	0%	31%	56%	13%	100%
			Total	16	113	187	139	20.3	0%	0%	31%	56%	13%	100%
		Beam	Female	1	120	120	120	-	0%	0%	100%	0%	0%	0%
			Male	14	106	182	136	21.9	0%	0%	50%	43%	14%	86%
			Total	15	106	182	135	21.5	0%	0%	53%	4%	13%	8%

Table 11. Dungeness Crab Size Class Distribution and Shell Thickness. *(Continued - 2)*

Site	Date	Method	Gender	Total Crabs Caught	Min CW (mm)	Max CW (mm)	Mean CW (mm)	STD	2003 Size Class Distribution Percentages					% Soft
									I (<50mm)	II (50-99mm)	III (100-129mm)	IV (130-159mm)	V (>159mm)	
C	Aug.	Comm.	Female	12	120	158	137	12.2	0%	0%	25%	75%	0%	75%
			Male	7	150	184	166	13.1	0%	0%	0%	29%	71%	71%
			Total	19	120	184	148	18.9	0%	0%	16%	58%	26%	74%
		Otter	Female	9	110	147	135	12.2	0%	0%	22%	78%	0%	67%
			Male	0	-	-	-	-	-	-	-	-	-	-
			Total	9	110	147	135	12.2	0%	0%	22%	78%	0%	67%
		Beam	Female	3	138	151	144	6.6	0%	0%	0%	100%	0%	100%
			Male	0	-		-	-	-	-	-	-	-	-
			Total	3	138	151	144	6.6	0%	0%	0%	100%	0%	100%
	Sept.	Comm.	Female	3	116	132	124	8	0%	0%	67%	0%	0%	33%
			Male	216	103	188	146.5	17.8	0%	0%	14%	63%	23%	98%
			Total	219	103	188	146.2	17.9	0%	0%	15%	63%	22%	97%
		Otter	Female	0	0	0	0	-	-	-	-	-	-	-
			Male	20	100	187	136	22.9	0%	0%	45%	45%	10%	90%
			Total	20	100	187	136	22.9	0%	0%	45%	45%	10%	90%
		Beam	Female	3	115	127	121	6	0%	0%	100%	0%	0%	100%
			Male	11	97	171	136	20.3	0%	9%	27%	55%	9%	91%
			Total	14	97	171	133	19.1	0%	7%	43%	43%	7%	93%
D	Aug.	Comm.	Female	10	125	147	136	7.5	0%	0%	30%	70%	0%	80%
			Male	15	107	193	159	24.4	0%	0%	20%	20%	60%	60%
			Total	25	107	193	150	22.4	0%	0%	24%	40%	36%	68%
		Otter	Female	9	119	161	135	12.7	0%	0%	44%	44%	11%	5%
			Male	1	169	169	169	-	0%	0%	0%	0%	100%	0%
			Total	10	119	169	138	16.1	0%	0%	40%	40%	20%	50%
		Beam	Female	1	140	140	140	-	0%	0%	0%	100%	0%	0%
			Male	0	-	-	-	-	-	-	-	-	-	-
			Total	1	140	140	140	-	0%	0%	0%	100%	0%	0%
	Sept.	Comm.	Female	7	115	152	133.7	12.8	0%	0%	43%	57%	0%	57%
			Male	256	107	189	149.2	18.1	0%	0%	14%	60%	27%	99%
			Total	263	107	189	148.8	18.1	0%	0%	14%	60%	26%	98%
		Otter	Female	1	124	124	124	-	0%	0%	100%	0%	0%	0%
			Male	13	120	183	145	20	0%	0%	23%	54%	23%	92%
			Total	14	120	183	143	19.9	0%	0%	29%	50%	21%	86%
		Beam	Female	4	115	136	122	9.9	0%	0%	75%	25%	0%	75%
			Male	21	99	175	136	20.7	0%	5%	29%	52%	14%	86%
			Total	25	99	175	134	20	0%	4%	36%	48%	12%	84%

Table 11. Dungeness Crab Size Class Distribution and Shell Thickness. *(Continued - 3)*

Site	Date	Method	Gender	Total Crabs Caught	Min CW (mm)	Max CW (mm)	Mean CW (mm)	STD	2003 Size Class Distribution Percentages					% Soft
									I (<50mm)	II (50-99mm)	III (100-129mm)	IV (130-159mm)	V (>159mm)	
E	Aug.	Comm.	Female	20	112	156	132	13	0%	0%	50%	50%	0%	75%
			Male	12	107	187	157	25.6	0%	0%	17%	25%	58%	100%
			Total	32	107	187	141	22	0%	0%	38%	41%	22%	84%
		Otter	Female	7	124	146	136	7.7	0%	0%	14%	86%	0%	14%
			Male	3	113	126	119	6.6	0%	0%	100%	0%	0%	100%
			Total	10	113	146	131	10.6	0%	0%	40%	60%	0%	40%
		Beam	Female	4	132	151	145	8.8	0%	0%	0%	100%	0%	50%
			Male	5	110	152	122	17.4	0%	0%	80%	20%	0%	40%
			Total	9	110	152	132	18.1	0%	0%	44%	56%	0%	44%
	Sept.	Comm.	Female	4	121	142	127.5	9.8	0%	0%	75%	25%	0%	25%
			Male	207	109	184	147.5	15.9	0%	0%	11%	67%	23%	99%
			Total	211	109	184	147.1	16	0%	0%	12%	66%	22%	97%
		Otter	Female	0	0	0	0	-	-	-	-	-	-	-
			Male	20	103	169	137	19.9	0%	0%	40%	45%	15%	100%
			Total	20	103	169	137	19.9	0%	0%	40%	45%	15%	100%
		Beam	Female	2	112	133	123	14.8	0%	0%	50%	50%	0%	0%
			Male	6	116	154	130	13.8	0%	0%	67%	33%	0%	100%
			Total	8	112	154	128	13.3	0%	0%	63%	38%	0%	75%

Table 12. Density Distribution of Dungeness Crab from Commercial, Otter, and Beam Trawls, August 2003.

August							
Date	**Method**	**Station**	**Crabs Caught**	**Area Swept** (ha)	**Density** (crabs / ha)	**Method Mean Density** (crabs / ha)	**Standard Deviation**
Commercial Trawls							
8/4/2003	Commercial	A1	18	0.74	24.3	48.1	16.1
8/4/2003	Commercial	B1	20	0.47	42.6		
8/4/2003	Commercial	C1	19	0.39	48.7		
8/4/2003	Commercial	D1	25	0.43	58.1		
8/4/2003	Commercial	E1	32	0.48	66.7		
Otter Trawls							
8/7/2003	Otter	A1	3	0.21	14.3	19.8	12.2
8/4/2003	Otter	A2	3	0.21	14.3		
8/7/2003	Otter	B1	5	0.21	23.8		
8/7/2003	Otter	B2	2	0.21	9.5		
8/6/2003	Otter	C1	1	0.43	2.3		
8/6/2003	Otter	C2	8	0.21	38.1		
8/6/2003	Otter	D1	4	0.21	19		
8/6/2003	Otter	D2	6	0.21	28.6		
8/7/2003	Otter	E1	2	0.21	9.5		
8/7/2003	Otter	E2	8	0.21	38.1		
Beam Trawls							
8/5/2003	Beam	A2	0	0.21	0	11.4	10.6
8/5/2003	Beam	A3	1	0.21	4.8		
8/5/2003	Beam	B1	5	0.21	23.8		
8/5/2003	Beam	B2	5	0.21	23.8		
8/6/2003	Beam	C1	0	0.21	0		
8/6/2003	Beam	C2	3	0.21	14.3		
8/6/2003	Beam	D1	1	0.21	4.8		
8/6/2003	Beam	D2	0	0.21	0		
8/7/2003	Beam	E1	5	0.21	23.8		
8/7/2003	Beam	E2	4	0.21	19		

Table 13. Density Distribution of Dungeness Crab from Commercial, Otter, and Beam Trawls, September 2003.

September							
Date	**Method**	**Station**	**Crabs Caught**	**Area Swept** (ha)	**Density** (Crabs/ ha)	**Method Mean Density** (crabs/ ha)	**Standard Deviation** (from avg)
Commercial Trawls							
9/8/2003	Commercial	A1	190	0.38	500	574.6	86.6
9/8/2003	Commercial	B1	190	0.38	500		
9/8/2003	Commercial	C1	219	0.37	591.9		
9/8/2003	Commercial	D1	263	0.37	710.8		
9/8/2003	Commercial	E1	211	0.37	570.3		
Otter Trawls							
9/10/2003	Otter	A1	36	0.25	144	66.1	38.5
9/10/2003	Otter	A2	21	0.18	116.7		
9/10/2003	Otter	B1	3	0.17	17.6		
9/10/2003	Otter	B2	13	0.17	65		
9/10/2003	Otter	C1	8	0.17	47.1		
9/10/2003	Otter	C2	12	0.17	70.6		
9/11/2003	Otter	D1	7	0.17	41.2		
9/11/2003	Otter	D2	7	0.17	41.2		
9/11/2003	Otter	E1	13	0.17	76.5		
9/11/2003	Otter	E2	7	0.17	41.2		
Beam Trawls							
9/10/2003	Beam	A1	16	0.17	94.1	58.5	35.5
9/10/2003	Beam	A2	22	0.17	129.4		
9/10/2003	Beam	B1	11	0.17	64.7		
9/10/2003	Beam	B2	4	0.17	23.5		
9/10/2003	Beam	C1	7	0.17	41.2		
9/10/2003	Beam	C2	7	0.17	41.2		
9/11/2003	Beam	D1	12	0.17	70.6		
9/11/2003	Beam	D2	13	0.17	76.5		
9/11/2003	Beam	E1	2	0.17	11.8		
9/11/2003	Beam	E2	6	0.17	35.3		

trawl methods, only four size class II crabs were caught during either month. These crabs were all males, with one crab caught in each of Site A, B, C, and D. Three of these crabs were caught in beam trawls, while the fourth was caught in a commercial trawl. All other Dungeness crabs caught occurred in size classes III, IV, and V, with the majority of the crabs in size class IV (Table 11).

In order to better display the size range, the data were displayed in 10 mm size range bins (e.g. from 120-129 mm centered at 125 mm) by sex for each method in both months rather than displayed in the five size class blocks. Data are graphed as density (crabs / hectare), rather than total number of individuals caught. Detailed records of crab data are presented in Appendix E.

3.6 Comparison of Site Characterizations - Cluster Analysis

Cluster analyses were used to further compare the fish and invertebrate assemblages sampled with each gear type and to compare how each of the gear types grouped stations across the DWS. A total of eight cluster analyses were evaluated using Bray-Curtis and Canberra-Metric clusters using either all species or those species occurring in a sample more than once). The eight different cluster diagrams and a summary of those species in determining cluster grouping are provided in Appendix F. For the purposes of comparing gear and station clusters here, we used the Bray-Curtis evaluations of those species occurring in a sample more than once. Three ranges of dissimilarities were used to indicate cluster groups. Dissimilarity values in excess of 2 indicated those groups that were most dissimilar. Dissimilarity values between 1 and 2 identified those subgroups that were considered somewhat similar. A few subgroups had dissimilarity values that were less than 1, representing those stations with the greatest degree of similarity. The Bray-Curtis dissimilarity values permitted a comparison of the trawl catches by using the relative abundance of species as the primary grouping criterion (Figures 23 and 24).

3.6.1 General observations

For each of the clusters, the commercial trawls were most distinct. This is demonstrated by the commercial trawls (Group I) being separated from the beam and otter trawls (Group II) with the highest degree of dissimilarity (dissimilarity values >2). The otter trawls and the beam trawls were generally separated from each other (Groups II-A and II-B), but at a lower level of dissimilarity, indicating that the assemblage of dominant species in the beam and otter trawls are more similar to each other than to those of the commercial trawls. Because these groupings are driven both by species assemblage and by station, the resulting clusters provide insights as to how the three different trawls characterize the demersal community and the sub regions of the DWS.

3.6.2 Species Assemblage by Gear Type

The differences in species assemblage collected by each trawl can result from the capture of different groups of species or a change in the relative abundance similar species. To evaluate differences on a community scale requires the examination of species abundance and the variation in abundance among samples that are clustered together. The following sections describe the fish and invertebrate communities that were captured with each sampler type and define the selectivity of the three trawls for various groups of organisms.

3.6.2.1 Commercial Trawl

In August, Dungeness crab and Pacific hake distinguished the catch in the commercial trawls from the catch of the beam and otter trawls. Both species occurred at higher numbers than in either the otter or beam trawl catches (5 to10 fold higher for Dungeness crab and at least 27 fold

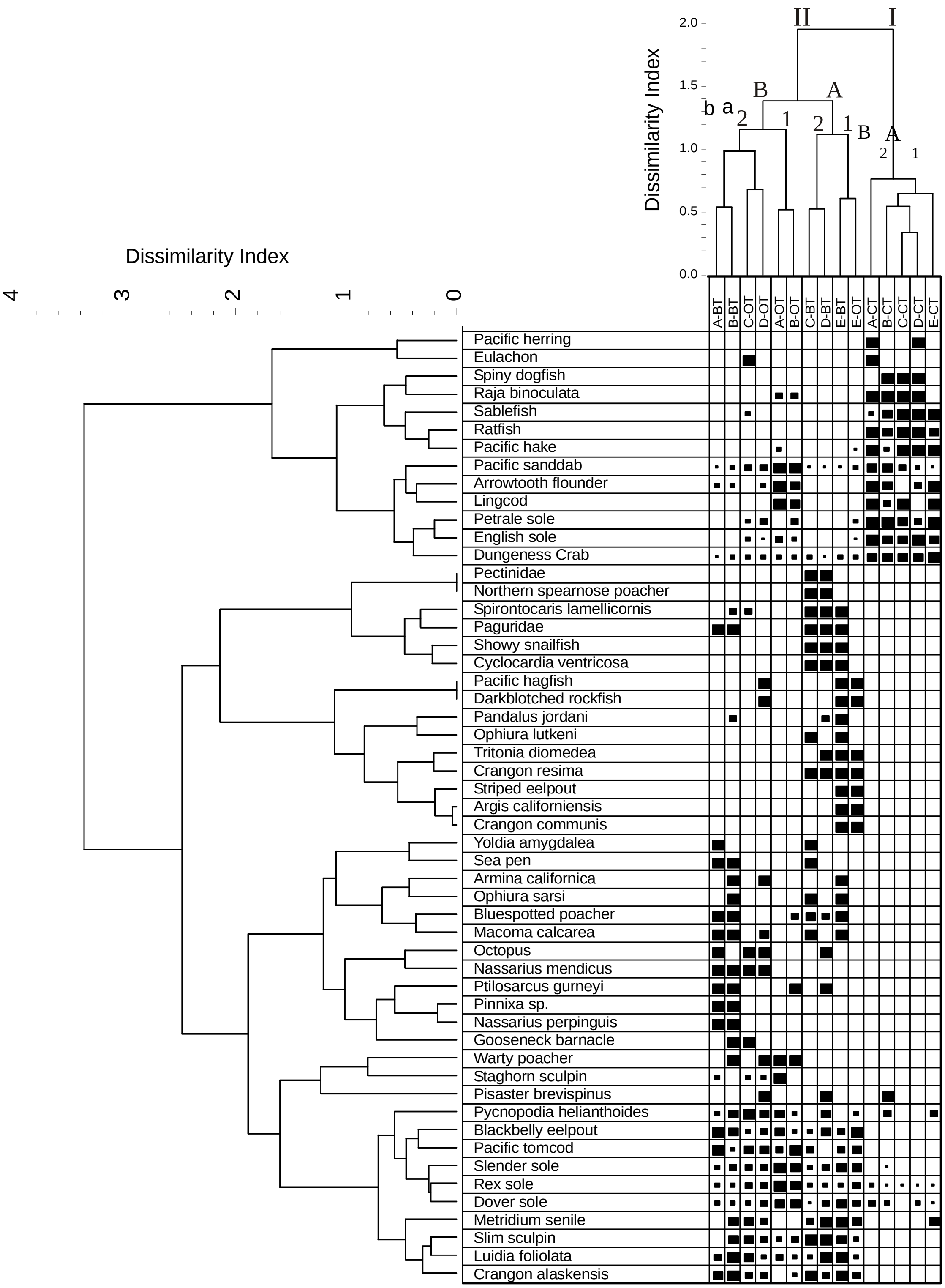


Figure 23. Bray-Curtis Cluster Diagram; August 2003
(All gear, species occurring in more than 1 sample).

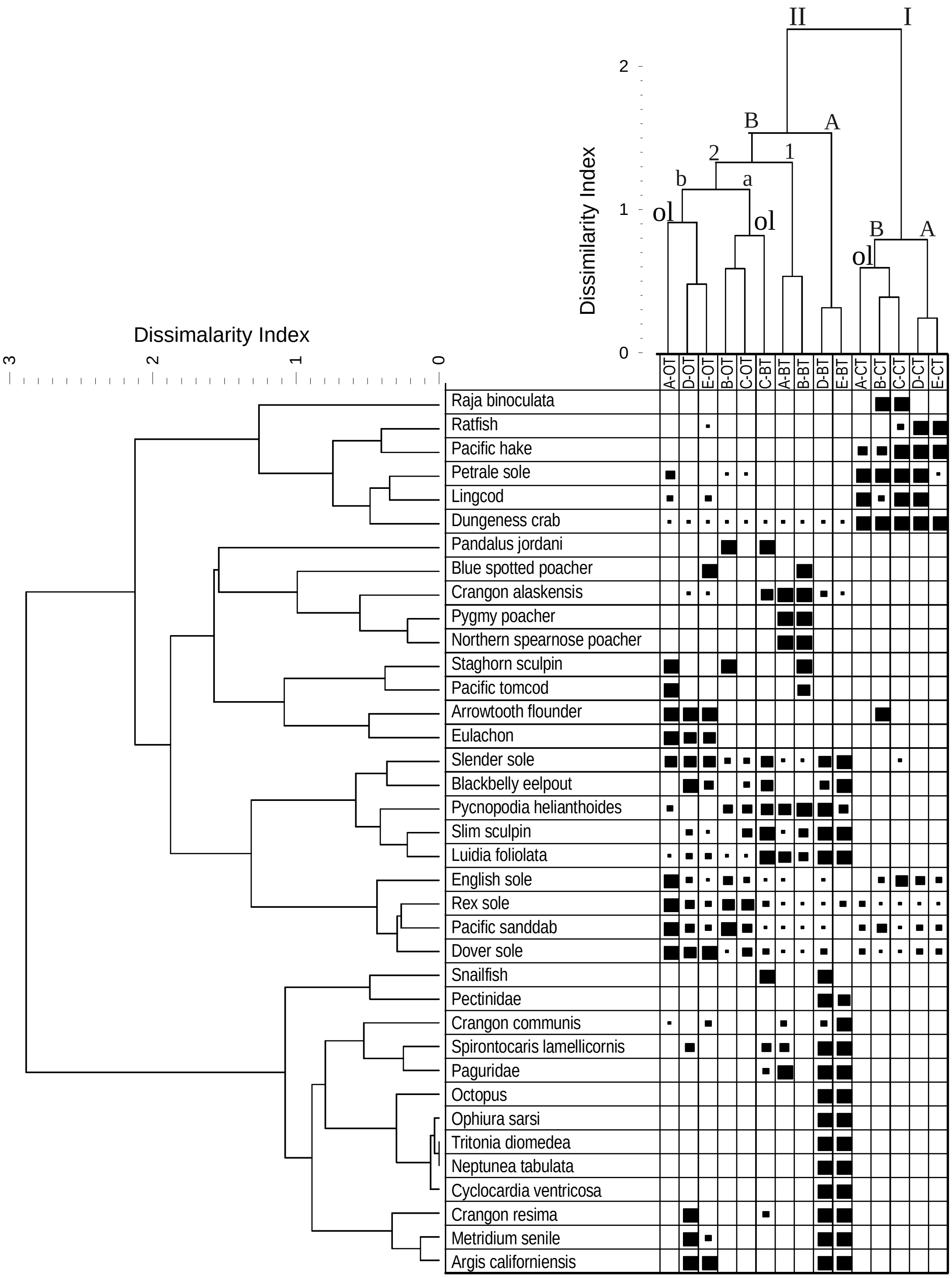


Figure 24. Bray-Curtis Cluster Diagram, September 2003.
(All gear, species occurring in more than 1 sample).

higher for the Pacific hake; see Appendix F). Other species that were more abundant in the commercial gear included Arrowtooth flounder, Big skate, English sole, Lingcod, Pacific hake, Petrale sole, Ratfish and Sablefish. Species that were important in the community described by the commercial trawl catch but were more abundant in the otter or beam trawls, included Dover sole, Pacific sanddab and Rex sole.

In September, the clustering of the commercial trawls was driven primarily by the high abundance of Dungeness crab, which exceeded that of the otter and beam trawls for all stations by a factor of 12 to 20. This species was the most abundant organism captured by the commercial trawl gear (>200/trawl) and had the least amount of variation among stations, with a 12% coefficient of variation. Other species that were more abundant in the commercial trawls than either the otter or beam trawls included the Big skate, Lingcod, Petrale sole and Ratfish. Other species important to the commercial trawl grouping, but not the most abundant compared to other sampler types, included the Arrowtooth flounder, Dover sole, English sole, Pacific sanddab, Rex sole and Slender sole.

3.6.2.2 Otter Trawl

In contrast to the commercial trawl which was driven by one or two species, the clusters for the otter trawl were driven by an assemblage of flatfish species (Dover sole, English sole, Pacific sanddab and Rex sole). These four species were collected in greater abundance throughout the DWS using the otter trawl than with either the beam trawl or the commercial trawl. In addition, the otter trawl captured more Blackbelly eelpout, Dover sole, Pacific sanddab, *Pandalus* spp., Rex sole and Slender sole than with any of the other samplers.

As in August, the September clusters were distinguished by flatfish species (3 to 7-fold greater than the commercial trawl and 5 to 40-fold higher than in the beam trawl; Table 2). While not the most abundant species, the Dungeness crab were an important component of the otter trawls in September, as were Slender sole. Again, the primary distinction of the otter trawl was the higher abundance of flatfish than in either the beam or commercial trawl.

3.6.2.3 Beam Trawl

The assemblage observed in the beam trawls was distinguished by a high total number of species, particularly small fish and invertebrates and the lack of larger fish. In August, the beam trawl captured between 24 and 28 species of fish and invertebrates. Of these species, 10 were commonly encountered at all stations within the DWS using the beam trawl gear. The August assemblage was dominated by Slim sculpin, *C. alaskensis, C. ventricosa, L. foliolata, Neptunea* spp, *Ophiura* spp, unidentified Paguridae and a shared maximum abundance with the otter trawl for Blackbelly eelpout, Bluespotted poachers and *Pandalus* spp.

During the September sampling, the beam trawl captured between 14 and 24 species of fish and invertebrates. Of these species, seven were commonly encountered at all stations using the beam trawl gear. The beam trawl had a diverse group of species that were captured in greater abundance with this gear type than either of the others, including Slender sole, Blackbelly eelpout, *C. alaskensis, C. ventricosa, L. foliolata, Neptunea* spp, *Ophiura* spp, unidentified Paguridae and a shared maximum abundance with the otter trawl with Blue spotted poachers and *Pandalus* spp. Dungeness crab were also an important component of the clusters, but were much less abundant than in the commercial trawl. Again, the primary distinction between the beam trawls and the commercial and otter trawls was a greater number of invertebrate species and smaller fish, as well as a complete lack of larger fish (Appendix F).

3.6.3 Station Groupings by Gear Types

The similarities, or dissimilarity, of stations across the DWS provided an indication of whether or not the three different types of gear would similarly characterize the DWS. The results of these cluster groups are presented for each gear type separately, and then compared below.

3.6.3.1 Commercial Trawl

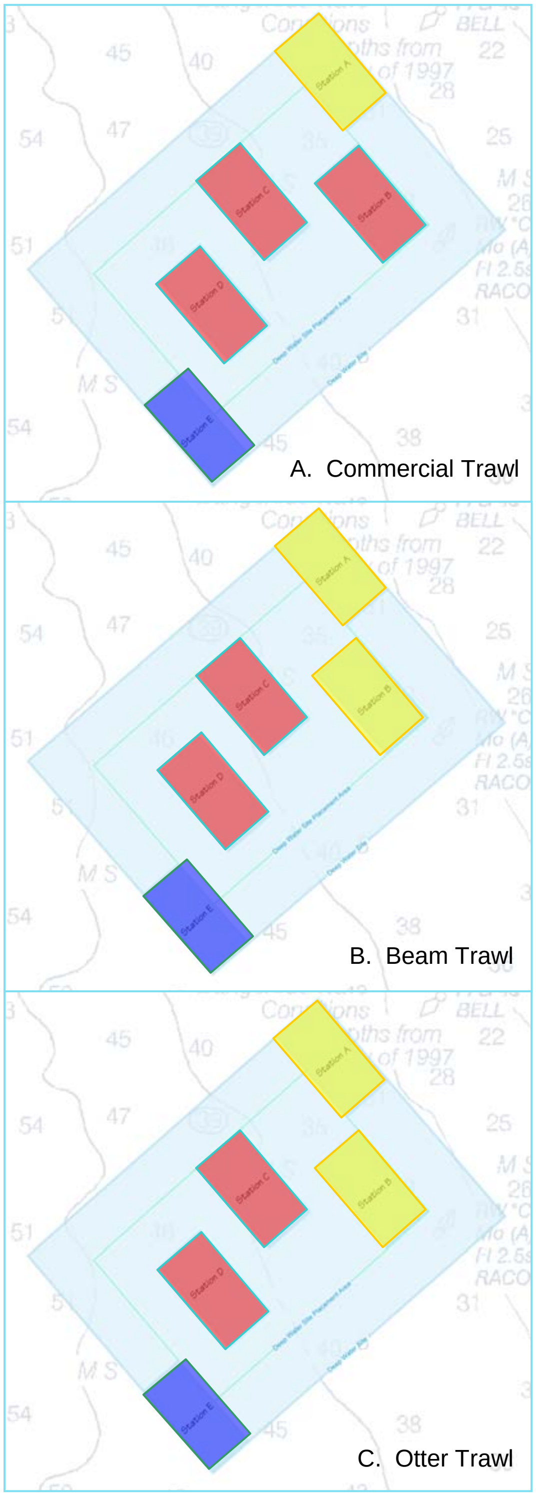
Each of the commercial trawls clustered into Group I. Within Group I, the five clusters were grouped by depth across the DWS. In August, Station A (Group I-B), the shallowest station, was distinctly different from Stations B, C, and D (Group I-A2), which were grouped together. The deepest station, Station E, was also grouped by itself (Group I-A1). The station cluster groups were determined by a difference in the relative abundance of eleven species common to all the DWS stations. Group I-B (Station A) had a higher abundance of Arrowtooth flounder, Big skate, English sole, Petrale sole, Dover sole and Rex sole. Group I-A2 (Stations B, C, and D) was transitional and had intermediate numbers of the eleven species common to the commercial trawls. Group I-A1 (Station E) was defined by more Dungeness crab, Pacific hake and Sablefish than either of the other two station groups.

The September Bray-Curtis groups and subgroups within the commercial trawl community assessment consisted of either samples collected at the deeper stations D and E (Group I-A) or samples obtained from depths of less than approximately 40m of depth at stations A or B and C (Group I-B; Figures 25 and 26). Group I-A was distinguished by a greater abundance of Dungeness crab, Pacific hake and Ratfish. Group I-B was defined by the greater number of Lingcod, Petrale sole and Rex sole at the shallowest station (A) and the greater numbers of Pacific sanddab at the center-most stations (B and C). Despite differences in species composition, the total abundance of organisms in these subgroups was very similar (<10% difference between abundance with either group). For the commercial trawls, the differences between the communities within sub regions of the DWS were based on the relative frequency of the six commonly held species rather than a distinctly different group of species contained in either group.

3.6.3.2 Otter Trawl

In August, the groups and subgroups for the otter trawl consisted of samples collected at Stations A and B (Group II-B1), Stations C and D (subgroup II-B2a), and Station E (Group II-A1; Figures 25 and 26). The differences within these subgroups were the relative abundance of 11 commonly held species (refer to Appendix F). Group II-B1 were the shallower stations and were defined by a much higher abundance of Pacific sanddab, Rex sole, Dover sole, and Slender sole.

As in August, the September groups and subgroups consisted of samples collected in deeper water (subgroup II-B2b; Stations D and E) or samples obtained from depths of less than approximately 40m (Stations A or B and C). The differences between these subgroups were based on the greater abundance of five of the eight commonly held species in the shallower stations. Relative abundance of these five species at Station A compared to the subgroups containing Stations B and C or D and E was approximately 5 fold (Stations B and C) to 11-fold (Stations D and E). In both August and September, differences between communities occurring in regions of the DWS, as characterized by the otter trawl, were based on the decreased abundance of commonly encountered fish and invertebrate species with depth, rather than a shift to different groups of species.

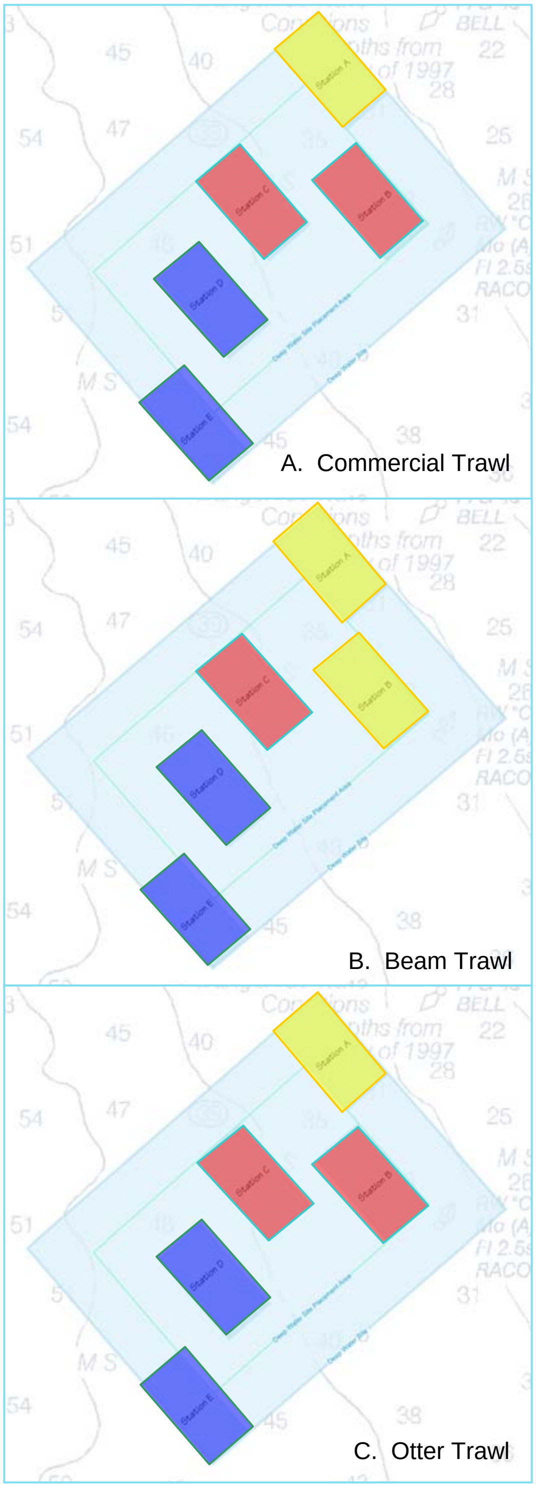


Species	Mean Abundance of Key Species		
	IB (yellow)	IA2 (red)	IA1 (blue)
Arrowtooth Flounder	6	1	5
Big Skate	5	5	0
Dover Sole	33	5	0
Dungeness Crab	18	21	32
English Sole	99	24	21
Lingcod	6	1	7
Pacific Hake	19	27	34
Pacific Sanddab	509	226	31
Petrale Sole	25	5	7
Ratfish	9	10	3
Rex Sole	66	16	16
Sablefish	2	25	106

Species	Mean Abundance of Key Species		
	IIB2a (yellow)	IIA2 (red)	IIA1 (blue)
Blackbelly Eelpout	5	2	2
Bluespotted Poacher	8	2	4
Crangon alaskensis	89	70	95
Cyclocardia ventricosa	0	12	36
Dover Sole	12	17	73
Dungeness Crab	4	1	5
Luidia foliolata	14	2	19
Ophiura sp.	6	3	14
Pacific Sanddab	31	4	7
Pandalus	1	1	9
Paguridae	3	3	62
Rex Sole	56	59	66
Slender Sole	14	16	44
Slim Sculpin	4	27	12
Spirontocaris	1	3	6

Species	Mean Abundance of Key Species		
	IIB1 (yellow)	IIB2 (red)	IIA1 (blue)
Arrowtooth Flounder	5	1	0
Blackbelly Eelpout	3	2	8
Crangon alaskensis	4	21	18
Dover Sole	59	28	28
Dungeness Crab	4	5	5
English Sole	7	2	1
Lingcod	3	0	0
Luidia foliolata	5	8	4
Pacific Sanddab	635	158	103
Pandalus sp.	0	0	71
Petrale Sole	1	3	2
Rex Sole	576	139	90
Slender Sole	63	24	36
Slim Sculpin	3	8	3

Figure 25. Commercial, Beam, and Otter Trawl Cluster Diagrams Based on Bray Curtis Analysis and Associated Data for Key Species, August 2003. [Red indicates greatest species abundance between groups]



Species	Mean Abundance of Key Species		
	IB ol	IB	IA
Dungeness Crab	190	192	232
Dover Sole	16	5	14
Lingcod	10	4	4
Pacific Sanddab	38	59	36
Petrale Sole	10	9	4
Rex Sole	48	28	10
English Sole	0	15	14
Pacific Hake	1	2	5
Ratfish	0	1	10

Species	Mean Abundance of Key Species		
	IIB1	IIB2aol	IIA
Blackbelly Eelpout	0	60	17
Bluespotted Poacher	1	0	0
Crangon alaskensis	359	103	16
Cyclocardia ventricosa	0	0	50
Dover Sole	5	22	7
Dungeness Crab	14	7	9
Luidia foliolata	8	12	19
Neptunea	0	0	41
Ophiura sp.	0	0	4
Pacific Sanddab	13	6	1
Paguridae	2	1	6
Rex Sole	22	41	53
Slender Sole	2	18	31
Slim Sculpin	3	10	17

Species	Mean Abundance of Key Species		
	IIB2bol	IIB2a	IIB2b
Arrowtooth Flounder	1	0	1
Blackbelly Eelpout	0	2	8
Crangon alaskensis	0	0	1
Dover Sole	102	20	75
Dungeness Crab	29	9	9
English Sole	103	14	8
Lingcod	1	0	1
Luidia foliolata	2	2	3
Pacific Sanddab	184	154	68
Pandalus sp.	0	1	0
Petrale Sole	4	1	0
Rex Sole	400	129	73
Slender Sole	17	9	18
Slim Sculpin	0	4	3

Figure 26. Commercial, Beam, and Otter Trawl Cluster Diagrams Based on Bray Curtis Analysis and Associated Data for Key Species, September 2003.
[OL= Outlier; red indicates greatest species abundance between groups]

3.6.3.3 Beam Trawl

As with the otter and commercial trawls, the station clusters in August for the beam trawl consisted of deeper water stations (Station E; subgroup II-A1), the middle depths (subgroup II-A2; Stations C and D) and the shallower stations at depths of less than approximately 40m (subgroup II-A2b; Stations A and B). The differences between these subgroups were due to the more abundant Pacific sanddab in the shallower stations and the greater abundance of 11 species at Station E. The relative abundance between station clusters varied substantially and differed by up to a factor of 60 (Appendix F). The differences between the communities within sub regions of the DWS as defined by the beam trawl in August were based on the relative frequency of the commonly held species with the presence of the clam *C. ventricosa* in the deeper sites.

The September station groupings were similar to those of August, and appeared to be related to depth. Differences between subgroups were increased Dungeness crab, *C. alaskensis* and Pacific sanddab abundance in the shallower A and B stations, and a reduced abundance of *C. alaskensis* and an increase in the abundance of Rex sole, Slender sole, Dover sole and Slim sculpin at Station C. These trends continued with decreasing abundance of *C. alaskensis* and increasing abundances of Rex sole, Slender sole and Slim sculpin at Stations D and E. Other distinctions between these shallower groupings of stations and the deeper stations was the increased abundance of other species of crangonidae shrimp, *C. communis* and *C. resima*, the presence of the clam *C. ventricosa* and greater numbers of Blackbelly eelpouts in the deeper water samples. The predominate differences driving the beam trawl clusters was the reduced abundance of the Crangonid shrimp in deeper waters and the presence of *C. ventricosa* in the deeper stations.

3.6.4 Conclusions of Cluster Analysis

Two basic conclusions can be made from these cluster groupings. First, the three types of trawl gear are capturing different species or different relative abundances of species. As a result, stations are separated into different groups based on trawl type. These groups were consistent regardless of whether Bray-Curtis or Canberra-Metric cluster analysis was used. The dissimilarity between gear types is sufficiently large that there is little overlap between the types of trawls and their collections of fish and invertebrates from common areas. Second, within each trawl type there is a similar segregation of stations at the DWS into sets of deeper or shallower stations. These separations are essentially the same using any of the three trawls.

4 Conclusions

The primary objectives of this study were to 1) compare the demersal fish and invertebrate assemblages characterized by the two research trawls; 2) compare sampling efficiencies of the research trawl nets and commercial trawls; 3) determine differences between the size of organisms sampled by commercial nets, otter trawls, and beam trawls, 4) determine representative sampling profiles of each gear type and examine any preferential assessment of the various benthic fish and invertebrate taxa, and 5) examine subregions within the DWS as determined by the different trawl types.

4.1 Comparison of Beam and Otter Trawls:

In parallel sampling at the DWS, the fish assemblage sampled by the otter trawl had significantly greater species richness, total abundance, and total biomass than that of the beam trawl. This was true both in the August and September sampling events. Similar to Eaton and Dinnel (1993), this study found differences in the fish assemblage sampled by the beam and otter trawls, with the beam trawl proving effective for sampling smaller species that were closely associated with the bottom or with debris. At the DWS, this included Snailfish, Blackbelly eelpout, Slim sculpin, Slender sole, and Bluespotted poachers. However, contrary to Eaton and Dinnel (1993), the otter trawl also effectively sampled some of these smaller species in the DWS, with no significant difference in the numbers of Blackbelly eelpout, Bluespotted poacher, and Slender sole, relative to the beam trawl. The otter trawl was also significantly more effective than the beam trawl at sampling both the large, more mobile fish species, as well as many of the flatfish present at the DWS.

As with the fish assemblage, there were differences in the invertebrate assemblages sampled by the two research trawls. For Dungeness crab and Pandalid shrimp abundance, there was no significant difference between the beam and otter trawls. There were more Dungeness crab in the otter trawls in August; however, this was not a statistically significant difference. For other invertebrates, the beam trawl was more efficient than the otter trawl. The beam trawl collected a significantly higher number of species and had higher invertebrate abundance. There were no significant differences between total biomass in the otter trawl and the beam trawl; however, this was driven primarily by the similar numbers of Dungeness crab. The species assemblage sampled by the beam trawl included nearly all species sampled, collecting those invertebrates closely associated with the bottom and in the sediment-water interface (e.g., *C. ventricosa* and *M. calcarea*), as well as more mobile species (*P. jordani* and starfish). The invertebrate assemblage observed in the otter trawls was more limited, and included *P. jordani*, *C. alaskensis*, and the starfish *L. foliolata* and *P. helianthoides*.

4.2 Comparison with the Commercial Trawl

The fish and invertebrate assemblage characterized by the commercial trawls differed dramatically from the beam trawls, as a consequence of the larger mesh of the commercial trawl selecting for the larger species. There were some similarities to the catch observed in the otter trawls, such as with English sole and Arrowtooth flounder. The commercial trawl proved to be more efficient at catching Sablefish, Pacific hake, Petrale Sole, Spiny dogfish and Lingcod than either the beam trawl or otter trawl. The commercial trawl also was more effective for sampling Dungeness crab, especially during the September sampling event. For both months there was a statistical difference between the commercial and beam trawls for relative total catch of Dungeness crabs. The otter trawls appeared to bridge the gap between the commercial and beam trawls in August and the otter trawl crab abundance was not statistically different from either of the other two trawl methods. However, this was not the case in September where the commercial gear was much more proficient than the other two trawl types.

4.3 Size Selection by Gear Type

For many of the fish species observed at the DWS, there were differences between the size classes sampled by the three different nets. Not surprisingly, the commercial trawl specialized in capturing the largest size classes, overlapping with the otter trawl, but seldom overlapping with the beam trawl. The beam trawl consistently sampled the smaller size classes or all size classes of the smaller fish species (i.e., eelpout and poachers). The otter trawl captured a wider distribution of size classes, more effectively sampling the middle size classes and overlapping the size classes for both the beam trawl and the commercial trawl. This distinction between the otter and beam trawls was further illustrated for those fish populations with a bimodal size class distribution. For these species, the beam trawl was more efficient at sampling the smaller size group and the otter trawl was more efficient at sampling the larger size group.

For Dungeness crab, the commercial trawl consistently caught larger crab than either the otter or beam trawls. There did not appear to be differences in the size classes sampled for the otter and beam trawl, although three of the four class II crabs were caught in the beam trawl. Overall, the majority of Dungeness crab was class IV. The most plausible explanation for why the majority of the crabs were in this size class is that these crabs are just under the legal size for Dungeness crabs for the previous year's commercial crab fishery. The effective removal of larger crab by the commercial fishery is likely the primary factor influencing the prevalence of size class IV crabs at the site. Regardless of the population's size frequency structure, the commercial trawl consistently caught more crabs than the other two trawls combined. This may have resulted from the site being populated by Class IV and larger crabs, and the efficiency with which commercial trawls capture and retain these larger animals.

4.4 Sampling Profiles by Gear Type

Each trawl net was more effective at capturing a sector of the fish and invertebrate community at the DWS. The cluster analysis of the relative abundance of species in the trawls helped to define the sampling profiles for each gear type.

- The commercial trawl captured larger, more mobile species of fish and poorly represented smaller fish of the same or smaller species of fish. It was the most effective sampler of Dungeness crab.
- The otter trawl captured a wider distribution of size classes of flatfish, more species of fish than either of the other two trawl nets, as well as representative invertebrate species. It also captured Dungeness crab in numbers comparable to the beam trawl. It was less effective at capturing debris-associated fish and invertebrates as well as the largest of the more active fish species (Sablefish, Pacific hake, Lingcod, larger flatfish individuals, Big skates, Ratfish and Spiny dogfish). The otter trawl also captured a total of three juvenile Dark-blotched rockfish.
- The beam trawl captured a wide array of small fish and invertebrates, many of which can be described as debris related. The beam trawl also sampled a narrow size-class flatfish (mostly juvenile to small subadults), but none of the more mobile predatory fish or the larger flatfish. The beam trawl sampled a comparable to slightly lower number of Dungeness crab than the otter trawl (much fewer than the commercial trawl), and one juvenile Dark-blotched rockfish.

Despite differences in organisms collected in each of these sampler types, the DWS was characterized in essentially the same way with each of the sampler types.

- During the August sampling event, all trawl types differentiated the deepest station (E) from all other stations. The shallowest stations, Stations A and B (or Station A alone), were also grouped separately. The remaining stations formed a mid-depth grouping (Stations C and D or stations B, C and D). For both the beam trawl and the otter trawl, these different groups were based on a shift in abundance of commonly held species across the site. For the commercial trawl, this transition was driven by a shift in species, from Pacific sanddab, Rex sole, and English sole to Pacific hake, Sablefish, and Dungeness crab.

- The September sampling for all trawl types also differentiated between the deeper stations and the mid-depth and shallow stations. However, there was a shift of the deeper assemblages towards the shallower stations. A slight difference was observed between the groupings of stations with the beam trawl from those with either the commercial or scientific otter trawls at the shallower stations. For the otter and commercial trawls, Station A was separated from B and C; whereas, the beam trawl separated Station C from Stations A and B. Similar to August, the station clusters for the otter and beam trawls were driven by species that occurred in different abundance across the site; whereas the commercial trawl differentiated stations based on the transition from Rex sole and Pacific sanddab to Dungeness crab at the deeper stations.
- Each gear type used a different assemblage to segregate the DWS into similar stations that were related to depth.

4.5 Comparison to Previous Surveys

The demersal fish community collected with the otter trawl during this survey was similar to the assemblage that was observed in 2002 (Word et al. 2003). Flatfish were the dominant species, both in summer and fall. Abundance was much higher in 2003, with mean total abundance typically exceeding 1,000 fish/ha, as opposed to 294 to 353 fish/ha in 2002. Flatfish, the dominant demersal fish taxa in the DWS, are a dominant inner shelf species along the entire west coast. Resident populations have been noted in the vicinity of the mouth of the Columbia River (MCR) (Durkin and Lipovsky 1977) and the Pacific Sanddab, English sole, Dover sole, and Rex sole were all among the dominant species observed in the bottom fish surveys conducted in California, Oregon, Washington, and Southern British Columbia (NOAA 2001). Pacific hake, occurring in moderate numbers in the DWS trawls, were the most common fish species observed by NOAA. This difference in relative abundance of hake may be due in part with location, interannual variation in populations, or habitat trawled. The assemblage observed in the DWS resembles that typical of the area south of the MCR (Durkin and Lipovsky 1977). Demersal fish densities observed here were similar to previous studies by Siipola et al (1993) which observed demersal fish densities of 1,702 to 3,564 fish/ha. While previous surveys have indicated that young-of-the-year flatfish may be found in the vicinity of the DWS (Durkin and Lipovsky 1977), this survey found no evidence that the DWS could be considered a unique nursery ground.

The demersal invertebrate assemblage, excluding Dungeness crab, observed in the 2002 otter trawls was more similar to that of the beam trawl in 2003. The otter trawl last year successfully sampled many of the small species, such as *C. ventricosa*, Pagurids, and *Crangon* shrimp. It is unclear why the otter trawl did not collect those species as well in 2003. The epifaunal invertebrate community of the DWS is similar to that observed in the inner continental shelf of Oregon and Washington. Epifaunal abundance is typically low along the inner shelf and increases with increasing depth. Carey (1972) noted epifaunal invertebrate densities of less than 50 individual/ha at depths of 50 m and 100 m along the central Oregon coast. Dominant epifaunal species along the Oregon and southern Washington coast include Crangonid shrimp, starfish and Dungeness crab (Carey, 1972; McCauley 1972). Shrimp and starfish were also dominant epifaunal species in trawls at locations in Washington, Oregon and California conducted by NOAA (2001) as part the triennial groundfish surveys.

4.5.1 Dungeness Crab

The three trawl methods used in 2003 showed a population structure similar to that of the 2002 otter trawl and crab pot survey (Word et al. 2003). Although there was a greater difference between sampling periods 2002 (July to September/October) than in 2003 (August to September), female crabs were, more abundant than males in the earlier sampling periods. The majority of the crabs in both years were Class IV crabs. However, the 2002 survey caught more Dungeness crabs <100 mm in both the otter trawls and crab pots utilized for that survey than the three trawl methods utilized in 2003. General differences in Dungeness crab abundance were also consistent between the 2002-2003 surveys. Crab abundance was higher and predominantly male during the later sampling periods. One noteworthy difference between the two surveys is the relative number of "soft" crabs. In 2002, crab pots and otter trawls caught crab that, on average, had harder shells than those observed in the 2003 survey. The reason for the observed difference in shell strength is unknown, although it could be related to a number of factors including water temperatures delaying the onset of molting.

The general vicinity of the area currently identified as the Deep Water Site has been periodically surveyed over the last 20 or so years. McCabe *et al*. (1985) surveyed both the inner estuary and the coastal waters near the Deep Water Site from November 1983 through October 1984. Their survey was conducted using an 8-m semi-balloon shrimp trawl. Abundance estimates at these six stations were highly variable, ranging from 0 to 1,892 crabs/ha. One location (Station 94), with the highest recorded abundance (1,892 crab in January) did not produce a catch of more than six Dungeness crabs during any other month. Aside from Station 94, the McCabe *et al*. 1985 Dungeness crab density estimates ranged from 3 (April and May) to 21 (January) crabs/ha for all sites during any one-month period. This is much lower than density range observed during the 2003 survey (11 to 575 crab/ha).

Few comprehensive studies have been published on coastal Dungeness crab populations in Oregon and Washington, with the regional scientific focus on estuarine recruitment, entrainment, and habitat loss. In addition, commercial Dungeness crab catch data for the region is aggregated and managed for very large areas and cannot be used to determine site-specific crab habitat conditions. The Columbia estuary is similar to other large estuaries in the region (e.g. Willapa Bay and Grays Harbor), with respect to providing Dungeness crab nursery habitat and supporting relatively large Dungeness crab year classes. As a result, studies such as McCabe *et al*. (1985) are rare, which, combined with the cyclical nature of Dungeness crab populations make it difficult to compare data for this site over more than a season or two.

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