2009 Environmental Studies Program in the Northeastern Chukchi Sea:

Benthic Ecology of the Burger and Klondike Survey Areas

Annual Report

Prepared for

ConocoPhillips and Shell Exploration & Production Company

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EXECUTIVE SUMMARY

ConocoPhillips and Shell Exploration and Production Company are managing a multi-disciplinary environmental studies program to establish baseline conditions within two survey areas in the northeastern Chukchi Sea. The Klondike and Burger survey areas are located where successful lease bids were made in the February 2008 Chukchi Sea Lease Sale 193. The overall field program will provide information on physical, chemical, and biological (including zooplankton and benthic ecology), and oceanographic baseline trends. The study was initiated in 2008 and continued sampling in 2009.

Objectives of the benthic ecology component in 2009 were to document macrofaunal community structure within the Burger and Klondike survey areas and determine associations of community structures with environmental factors. Infauna (sediment-dwelling organisms retained on a 1.0 mm sieve) and environmental parameters were sampled at 52 stations in the Burger (26 stations) and Klondike (26 stations) survey areas. Six stations were also sampled in a area where gray whales were observed feeding. Epifauna (invertebrate organisms captured by trawling) were sampled twice at 26 sites sampled during two cruises to the Burger (13 stations) and Klondike (13 stations) survey areas. This report summarizes the results of the benthic ecology portion of the 2009 northeastern Chukchi Sea Environmental Studies Program (CSESP).

Benthic infauna in Burger and Klondike survey areas are abundant, contain many animals with high biomass, and comprise diverse communities. Average abundance, biomass, and number of taxa (average of the number of taxa found at each survey area) of infauna were significantly higher in Burger than in Klondike but macrofaunal communities in both survey areas were similarly diverse. Most fauna occurred in both survey areas although faunal distributions demonstrated greater patchiness in Klondike than in Burger. Multivariate analyses indicated that macrofaunal community structure was correlated with environmental characteristics (percent sand, salinity, and phaeopigment concentration) associated with topography, water currents, and other related factors within the survey areas. There were no interannual differences within each survey area between 2008 and 2009.

The infaunal community found in the gray whale feeding area was different from that of the Burger and Klondike survey areas. This area was located northwest of Wainwright and six stations were established here. The whale feeding stations were dominated by amphipods, a

preferred prey item for gray whales, whereas the faunal communities found in Burger and Klondike were dominated by bivalves and polychaete worms.

The macrofaunal communities sampled in Burger and Klondike were very similar to those found in 1986. The investigation of infauna by Dr. Howard Feder in 1986 was broader in geographic scope as it encompassed much of the northeast Chukchi Sea. Multivariate analysis of the 1986, 2008, and 2009 data demonstrated that the fauna communities are comparable. There appears to be no temporal differences representing ecologically-significant environmental change in the macrofaunal community composition.

As with the infauna, the epifaunal communities of Burger and Klondike comprised taxon groups with high abundance and biomass reflecting diverse communities. Variances of estimates for biological summary measures were very high so no significant differences were noted in average abundance, biomass, or the number of taxa between Burger and Klondike. However, the multivariate analyses demonstrated that the epifaunal community structures were different although many species were shared between the two survey areas. The community differences were associated with percent sand, phaeopigment concentration, and water depth which reflect the strong environmental gradients between Burger and Klondike. There were no significant differences between sampling cruises in 2009.

INTRODUCTION

ConocoPhillips (CP) and Shell Exploration and Production Company (SEPCO) are managing a multi-disciplinary environmental studies program to establish baseline conditions for two survey areas in the northeastern Chukchi Sea. The survey areas are Klondike and Burger, where successful lease bids were made in the February 2008 Chukchi Sea Lease Sale 193. The overall research program will provide information on physical, chemical, biological (including zooplankton and benthic ecology), and oceanographic baseline trends for the Klondike and Burger survey areas. The Chukchi Sea Environmental Studies Program (CSESP) was initiated in 2008 and continued in 2009.

Since the 2008 lease sale, interest in understanding the arctic environment has grown, with regulatory agencies and academia directing efforts toward improving the understanding of the environment, including the Chukchi Sea (Hopcroft et al., 2006). Resources in the Chukchi Sea are of great value to a broad variety of stakeholders including Native subsistence hunters, environmental organizations, and those interested in extracting resources of economic value. In the Chukchi Sea, biological resources of interest include marine mammals and seabirds, many of which feed on sediment-dwelling organisms (benthic species such as polychaete worms, amphipods, clams, shrimp, crabs) (Lovvorn et al., 2003; Grebmeier et al., 2006). Benthic organisms in the northern Bering Sea and Chukchi Seas are important food resources for higher trophic level organisms such as demersal fishes, various seals, walrus, and gray whales (e.g. Oliver et al., 1983; Feder et al., 1994a, b; Coyle et al., 1997; Green and Mitchell, 1997; Moore et al., 2003; Highsmith et al., 2006; Bluhm et al., 2007; Bluhm and Gradinger, 2008). Traditional hot spots for feeding gray whales and walrus are located south of St. Lawrence Island and the Chirikov Basin (both in the Bering Sea), and the south-central Chukchi Sea with a few areas identified in the northeastern Chukchi Sea (Moore and Clarke, 1990; Feder et al 1994b; Highsmith et al., 2006; Bluhm and Gradinger, 2008).

The northeastern Chukchi Sea is a productive shallow body of water influenced by advective processes (Grebmeier et al., 2006). Water masses moving into the region include Bering Shelf water and Alaska Coastal water (e.g., Coachman, 1987). Bering Shelf water has relatively high nutrient concentrations (derived in part from water from the Gulf of Anadyr off the coast of Russia) that enhance benthic biomass. In contrast, the Alaska Coastal water is comparatively nutrient poor (Feder et al., 1994b; Codispoti et al., 2005; Grebmeier et al., 2006). The differences in nutrient concentrations in water masses lead to substantial differences in primary production, and thus, benthic community structure (Feder et al., 1994b) and food web structure. Factors identified as important predictors of benthic community structure in the Chukchi Sea include sediment granulometry (e.g., percent gravel, sand, or mud) and sediment organic carbon to nitrogen ratios (C/N ratio) (Feder et al., 1994b). Sediment granulometry reflects a number of environmental processes, such as hydrodynamics (strong currents, storm effects, ice gouging, etc.), sediment deposition, and proximity to sediment sources.

Investigations of carbon cycling in the Chukchi Sea demonstrated strong linkages between primary production and distributions of macrofauna. The reduced numbers of pelagic (water-column) grazers results in strong pelagic-benthic coupling because of the large flux of uneaten phytoplankton reaching the benthos which drives a very abundant and diverse macrofaunal community (Dunton et al., 2005; Grebmeier et al., 2006). As a result, interannual and seasonal variability in primary production and zooplankton communities may be a substantial source of variability for benthic communities.

Scientific studies conducted intermittently over the last 37 years provide a basis for understanding the benthic ecology of the northeastern Chukchi Sea. The first study of macrofaunal community structure in the northeast Chukchi Sea was performed in 1971 to 1974 by Stoker (1978, 1981). This study was followed in 1985 and 1986 by investigations of the benthos/environmental interactions by Feder et al. (1994a, b). Following the latter study, Grebmeier et al. (1988) documented the strong association between annual pelagic production reaching the bottom and the benthic communities (pelagic-benthic coupling) in the southeastern Chukchi Sea. The macrofauna of the Chukchi Sea are abundant and biomass high due to the comparatively high quantities of unconsumed primary production (pelagic and ice-edge production) reaching the benthos (Grebmeier et al., 2006). A rich epifaunal community is also present in the northeastern and southeastern Chukchi Sea including numerous mollusks, crabs, and echinoderms (e.g., Feder et al., 1994a, 2005; Ambrose et al., 2001). Recent and on-going investigations in the northeastern Chukchi Sea include the Shelf-Basin interaction study (SBI; http://sbi.utk.edu; Grebmeier et al., 2009), the Russian-American Long-term Census of the Arctic (RUSALCA), and the Minerals Management Service's (MMS) Chukchi Sea Offshore

Monitoring in Drilling Area (COMIDA) program. All of the latter programs focus on broad-scale sampling throughout the northeast Chukchi Sea with SBI focusing on processes along the continental margin, RUSALCA encompassing the northern Chukchi Sea, and the COMIDA program focusing on the US offshore Lease Sale Planning area. These studies will contribute to building databases adequate for evaluating long-term trends with confidence (e.g., repeated sampling at similar locations over space and time using similar sampling methods) in macrofaunal communities of the northeast Chukchi Sea.

The multi-year, CP/SEPCO-sponsored CSESP initiated in 2008 and continued in 2009 will contribute to understanding the benthic ecology within the survey areas. Benthic communities in Burger and Klondike, sampled in 2008, were diverse and fauna abundant and comparable to those found in prior research (Feder et al., 1994b; Blanchard et al., 2010). The community structure and distributions of benthic organisms found in 2008 were associated with environmental gradients including the persistent water mass differences between the survey areas (Weingartner, 2009). The results of the 2008 and 2009 investigations in the northeastern Chukchi Sea will contribute to developing the necessary benchmark to determine potential changes in the benthos from climate change or other natural environmental fluctuations. The results will also provide a basis for measuring the effectiveness of mitigation and monitoring activities conducted by the oil and gas industry during exploration and/or development.

OBJECTIVES

The objectives of the benthic ecology component of the 2009 CSESP were similar to those of the 2008 program:

- Sample infaunal and epifaunal organisms within the Burger and Klondike survey areas to document benthic macrofaunal community structure;
- Assess species composition, abundance, and biomass of benthic communities within the two survey areas and determine associations of community structures with environmental factors; and
- Sample the infauna in areas where marine mammals were observed feeding (six stations were sampled where gray whales were observed feeding in 2009).

GEOGRAPHIC SETTING

The Chukchi Sea is unique among arctic shelf seas as it is strongly influenced by waters derived from the Pacific Ocean entering through the Bering Strait (Weingartner et al., 2005). Key water masses moving northward in the eastern Bering Sea through the Chukchi Sea to the Arctic basin include nutrient-rich Anadyr water, nutrient-depleted Alaska Coastal water (ACW), and Bering Shelf water which in the Chukchi Sea is sandwiched between the other two (Grebmeier et al., 2006). These water masses of southern origin transport heat, nutrients, carbon, and animals to the Chukchi Sea and Arctic Ocean and are vitally important for maintenance of the ecological structure of the region (Weingartner et al., 2005; Grebmeier et al., 2006; Hopcroft et al., in submission). Within the Chukchi Sea, the cold, saline and nutrient-enriched Bering Sea water flows northward, ultimately to join waters exported into the basin of the Arctic Ocean (Faulkner et al., 1994; Weingartner et al., 2005). Weingartner (2009, 2010) demonstrates higher water temperature and salinity values for the Klondike survey area in late summer, as compared to the Burger survey area, reflecting the persistence of winter water at Burger. The combined effect of seasonal ice cover and the influx of water through the Bering Strait is a major influence on the productivity of the Chukchi Sea. Melting sea ice stratifies the water column creating conditions favorable for the primary production that results in a summer bloom supported by the nutrient-rich, Bering Sea water, the timing of which is dependent on the seasonal sea ice cover (e.g., Hopcroft et al., 2009).

METHODS

Infaunal Sampling Methods

Sampling for infauna was performed from September 5 to 19, 2009. Fifty-two stations were sampled from the M/V *Westward Wind* on cruise WWW0903 as well as six additional stations where gray whales were observed feeding (Table 1 and Fig. 1). The term “infauna” is herein limited to invertebrate animals residing in sediments and retained on a 1.0 mm mesh screen. Large, mobile organisms or those not adequately sampled by the grab (the epifauna) are excluded. The term “macrofauna” is often considered synonymous with “infauna” but the exclusion of mobile and epifaunal organisms in this project favors the use of the term “infauna”. Thirteen fixed and thirteen random sites sampled in the Klondike and Burger survey areas during cruise WWW0903. Fixed locations were selected to maximize spatial coverage of sampling stations. They included a subset of the stations sampled for physical oceanography and zooplankton portions of the 2009 CSESP (see Hopcroft et al., 2009 and Weingartner, 2009). Random selection of additional sampling stations was also done to ensure that conclusions were valid over the whole of the study region. Six stations were also sampled in an area where gray whales were observed feeding. Sampling stations were identified with a one character code for the two areas, Klondike (K) and Burger (B), a one character code for the type of station sampled as fixed (F) or random (R), and lastly, the station number. Whale feeding stations were given the character code TM.

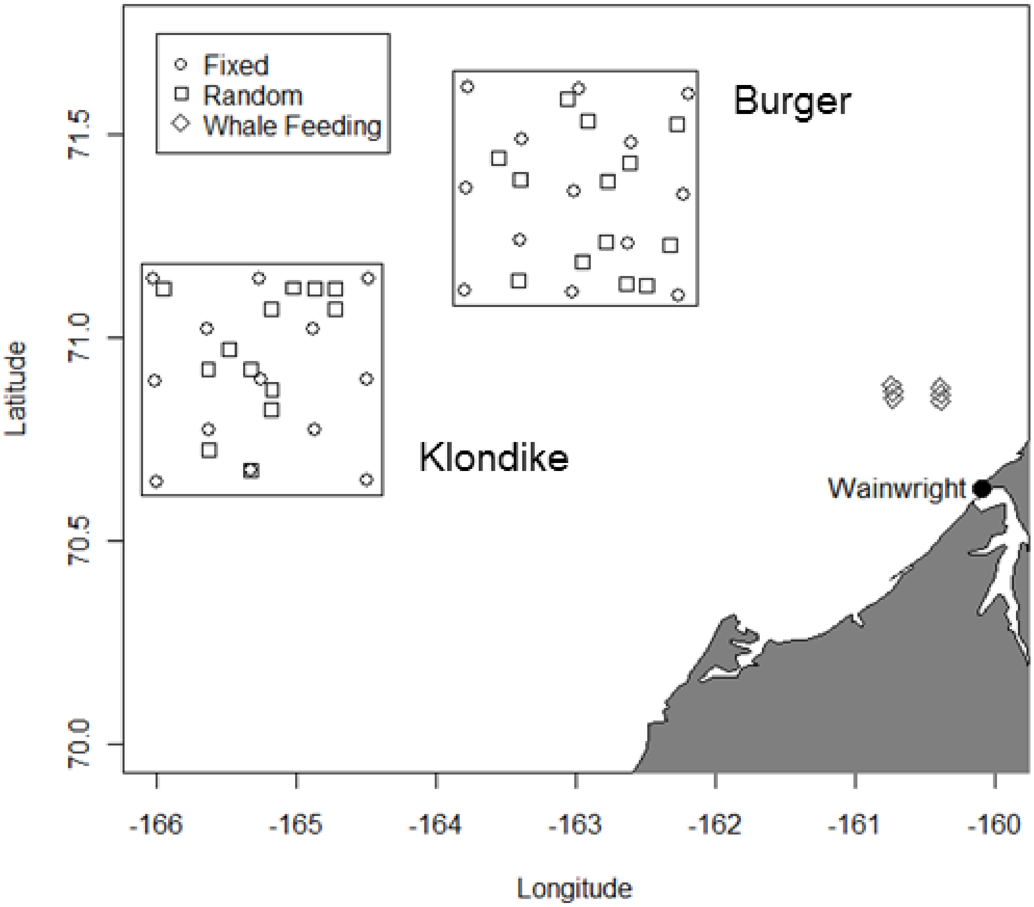

Figure 1. Map of stations sampled during the 2009 CSESP. Fixed sites were sampled for both infauna and epifauna.

Infauna was sampled using a double van Veen grab with two 0.1 m^2 adjoining grabs to collect sediments for analyzing sediment grain-size, phaeopigments, and infauna. Material from each grab collected for macrofauna was washed on a 1.0 mm stainless steel screen and preserved in 10% formalin-seawater buffered with hexamine. In the laboratory, samples were rinsed and transferred to 50% isopropyl alcohol. During sorting, sediment was spread out in petri dishes, and rough sorted by hand under a dissecting microscope. Taxonomic identifications of benthic organisms were performed by trained taxonomists supervised by a taxonomic specialist. All organisms were counted and wet weights measured (after excess moisture was removed with an absorbent towel following protocols of Feder et al., 1994b). For each replicate sample, identifiable tissue fragments were grouped together and recorded as one individual at the family level or higher, and the wet weight of the composite fragment category weighed.

Once weighed, organisms were placed into sealed plastic jars for storage. (Jar edges are wrapped with Teflon tape before screwing the lid on to reduce moisture loss during storage.) Organism names, counts, and weights were entered into a Microsoft (MS) Access database and a datasheet printed. Datasheets are stored at the University of Alaska's Institute of Marine Science (UAF IMS) as a record of taxonomic changes (changes in nomenclature) and a backup for the electronic database.

Sediment samples collected from each station were wet sieved through 2 mm and 63 µm nested sieves to determine proportions of gravel (>2 mm), sand (63 µm – 2 mm), and mud (<63 µm) (Wentworth, 1922). The flow-through water containing suspended particles <63 µm was captured to determine the weight of mud. The resulting fractions were dried at 60 °C for a minimum of 12 hours and up to 24 hours to determine dry weight. Water content of the entire sediment sample was determined by weighing a wet subsample, drying at 60 °C for a minimum of 12 hours and up to 24 hours then weighed again. The dried sample was then combusted at 550 °C for three hours to determine total organic content (TOC) similar to Wu and Shin (1997).

Table 1. Station information for sampling of infauna during 2009 CSESP. Date, time of sampling, intended positions (degree, minute format), and sampling depths are given for each station. K = Klondike, B = Burger, F = fixed station, R = random station, TM = whale feeding stations. Time = Alaska Standard Time of first sample, and Depth = average depth of three replicates.

Station	Date	Time	Latitude, N	Longitude, W	Depth, m
BF001	9/13/2009	1:12	71.11862	-163.80010	40.4
BF003	9/14/2009	21:39	71.11363	-163.03200	42.8
BF005	9/16/2009	0:11	71.10350	-162.26680	44.6
BF007	9/14/2009	0:37	71.24139	-163.40340	42.1
BF009	9/16/2009	22:32	71.23324	-162.63446	43.3
BF011	9/13/2009	4:25	71.36892	-163.78659	42.7
BF013	9/15/2009	2:42	71.36251	-163.01069	43.1
BF015	9/16/2009	4:20	71.35232	-162.23021	42.8
BF017	9/14/2009	5:01	71.49010	-163.38697	39.9
BF019	9/17/2009	2:32	71.48226	-162.60235	41.5
BF021	9/13/2009	7:43	71.61794	-163.77233	39.1
BF023	9/15/2009	8:15	71.61184	-162.98170	39.7
BF025	9/16/2009	9:29	71.60180	-162.19073	41.4
BR005	9/15/2009	7:11	71.58721	-163.06320	39.2
BR016	9/15/2009	6:14	71.53562	-162.91690	40.2
BR020	9/16/2009	6:45	71.52843	-162.28131	42.2
BR032	9/14/2009	3:43	71.44266	-163.55195	40.0
BR038	9/17/2009	1:15	71.43305	-162.61267	43.0
BR043	9/14/2009	2:46	71.39170	-163.39532	41.5
BR047	9/15/2009	3:52	71.38467	-162.77248	43.7
BR077	9/14/2009	23:41	71.23576	-162.78996	43.4
BR080	9/16/2009	2:37	71.22947	-162.32714	43.9
BR086	9/14/2009	22:43	71.18759	-162.95101	42.6
BR093	9/13/2009	20:40	71.14122	-163.41487	42.1
BR098	9/15/2009	22:05	71.13395	-162.64565	42.4
BR099	9/15/2009	22:50	71.13098	-162.49225	42.9
KF001	9/5/2009	21:44	70.64547	-165.99919	41.2
KF003	9/7/2009	21:58	70.67357	-165.32693	40.1
KF005	9/10/2009	22:12	70.64833	-164.49921	43.8
KF007	9/6/2009	23:34	70.77210	-165.63418	39.2
KF009	9/11/2009	2:06	70.77435	-164.87220	37.2
KF011	9/6/2009	2:10	70.89513	-166.01279	40.3
KF013	9/8/2009	2:51	70.89896	-165.25478	39.1
KF015	9/11/2009	5:36	70.89598	-164.49672	35.8
KF017	9/7/2009	4:18	71.02177	-165.63625	40.7
KF019	9/10/2009	3:38	71.02296	-164.87786	33.0

Table 1. Continued.

Station	Date	Time	Latitude, N	Longitude, W	Depth, m
KF021	9/6/2009	6:40	71.14459	-166.02544	41.1
KF023	9/10/2009	1:04	71.14750	-165.26132	41.9
KF025	9/12/2009	1:10	71.14514	-164.48564	40.3
KR001	9/6/2009	7:26	71.12019	-165.94887	41.1
KR007	9/8/2009	21:16	71.12299	-165.02615	42.7
KR008	9/8/2009	22:22	71.12169	-164.87204	39.4
KR009	9/10/2009	5:54	71.12230	-164.72189	38.6
KR016	9/8/2009	7:08	71.07213	-165.18053	40.2
KR019	9/10/2009	4:56	71.07231	-164.72146	40.9
KR034	9/8/2009	4:55	70.97218	-165.48531	39.8
KR043	9/7/2009	2:13	70.92253	-165.63479	40.1
KR045	9/8/2009	3:49	70.92374	-165.33256	39.0
KR056	9/8/2009	1:32	70.87349	-165.17624	38.8
KR066	9/8/2009	0:21	70.82299	-165.17797	39.2
KR083	9/6/2009	22:03	70.72226	-165.62753	40.3
KR095	9/7/2009	21:55	70.67370	-165.32657	40.7
TM001	9/19/2009	14:01	70.88400	-160.74527	51.0
TM002	9/19/2009	14:51	70.86648	-160.73465	51.7
TM003	9/19/2009	15:48	70.85010	-160.73558	50.0
TM004	9/19/2009	17:33	70.87748	-160.39723	51.4
TM005	9/19/2009	18:31	70.86117	-160.39362	50.8
TM006	9/19/2009	19:30	70.84397	-160.39220	49.2

The first few centimeters of sediment were also collected from van Veen grabs to determine chlorophyll-*a* and phaeopigment concentrations. Sediment samples for chlorophyll analysis were kept frozen and in the dark until processing, at which time they were thawed and chlorophyll extracted in 7 ml 90% acetone for 24 hours in the freezer. The extracts were allowed to come to room temperature in the dark and centrifuged for 5 minutes at 4000 rpm. Chlorophyll-*a* concentrations were determined using a Turner Trilogy fluorometer. Phaeopigment (the degradation product of algal chlorophyll pigment) concentrations were determined by adding 10% HCl to each sample and re-measuring fluorescence, similar to Arar and Collins (1992). Chlorophyll-*a* and phaeopigment concentrations were highly correlated so phaeopigments (reflecting detritus and decomposition products) were used to assess associations of faunal community structure to primary production in multivariate analyses.

Epifaunal Sampling Methods

Twenty-six stations were sampled for epifauna in the Burger and Klondike survey areas aboard the M/V *Westward Wind* on two cruises WWW0902 and WWW0904. Sampling was performed from August 14 - 29, 2009 (WWW0902) and September 25 to October 10, 2009 (WWW0904). Sampling was conducted at the 13 odd-numbered fixed stations in the Burger and Klondike survey areas (Table 2). Random stations were not sampled for epifauna. The term "epifauna", for the purposes of this report is limited to invertebrate animals residing on the sediment or closely associated with the surface sediment (e.g., large clams near the surface). Small organisms and those not adequately sampled by a bottom trawl (the infauna) are excluded. The term "megafauna" can be considered as synonymous with "epifauna" but may include a wider range of organisms, therefore, in this report, the term "epifauna" will be used to indicate invertebrate organisms collected by a bottom trawl.

Epifauna was sampled using a plumb staff 3.05 m beam trawl with a 4 mm codend liner and 7 mm mesh. The beam trawl covers a swath that is 2.26 m wide. Trawls were towed at a constant speed of 1.5 knots for 3 minutes at Burger stations and 5 minutes at Klondike stations. The shorter tow duration at Burger was an attempt to reduce the amount of mud captured in the net. Six stations from cruise WWW0902 were only sampled for presence and not catch per unit effort due to logistical difficulties (i.e., bad weather, equipment failure, or time constraints, etc.). These stations include KF001, KF007, KF017, BF001, BF007, and BF011. Material from each trawl was dumped onto a large sorting table located on deck and all bottom fishes were retained. The remaining catch was remixed on the sorting table and subsampled until the volume of the subsample was approximately 2 gallons (catches from 3 Klondike stations in each cruise were not subsampled). Occasionally an extremely muddy trawl sample was washed on a 1.0 mm stainless steel screen to remove mud particles before sorting. Taxonomic identifications of benthic organisms were performed by a trained taxonomist to ensure consistency of identifications. All organisms in the subsample were counted and wet weights measured

Table 2. Station information for sampling of epifauna during 2009 CSESP. Date, time of sampling, intended positions (degree, minute format), and sampling depths are given for each station. K = Klondike, B = Burger, F = fixed station and R = random station. Time = Alaska Standard Time of first sample.

WWW0902

Station	Haul	Date	Time	Latitude (N)	Longitude (W)	Depth (m)
BF003	17	8/21/2009	7:37:37 AM	71.11485	-163.03500	43.5
BF005	25	8/23/2009	7:35:51 AM	71.10090	-162.25877	44.5
BF009	22	8/22/2009	11:31:55 PM	71.23305	-162.63934	43.6
BF013	16	8/21/2009	3:54:50 AM	71.36208	-163.00517	43.2
BF015	24	8/23/2009	3:59:20 AM	71.34957	-162.22696	43.0
BF017	20	8/22/2009	2:28:32 AM	71.49016	-163.37510	40.2
BF019	21	8/22/2009	5:57:38 AM	71.48259	-162.59508	41.6
BF021	31	8/29/2009	9:44:06 AM	71.61748	-163.76042	38.6
BF023	18	8/21/2009	9:56:54 PM	71.61110	-162.99180	39.7
BF025	26	8/23/2009	10:12:55 PM	71.60172	-162.19594	41.4
KF003	8	8/17/2009	5:06:59 AM	70.64602	-165.24355	40.7
KF005	9	8/19/2009	9:40:32 PM	70.64925	-164.50842	45.1
KF009	10	8/20/2009	12:12:30 AM	70.77040	-164.88633	38.4
KF011	3	8/16/2009	3:05:16 AM	70.89435	-166.01518	39.5
KF013	7	8/17/2009	1:29:44 AM	70.89905	-165.27151	39.5
KF015	29	8/28/2009	11:15:17 PM	70.90125	-164.49539	34.1
KF019	11	8/20/2009	4:19:57 AM	71.02215	-164.87736	33.6
KF021	12	8/20/2009	9:16:59 AM	71.14797	-166.02475	41.1
KF023	13	8/20/2009	12:22:21 PM	71.14574	-165.24468	42.4
KF025	30	8/29/2009	2:56:24 AM	71.14795	-164.47587	40.4

WWW0904

Station	Haul	Date	Time	Latitude (N)	Longitude (W)	Depth (m)
BF001	31	10/1/2009	9:29:23 PM	71.11993	-163.79808	40.5
BF003	51	10/10/2009	1:42:19 AM	71.11248	-163.03182	42.8
BF005	53	10/10/2009	4:51:32 AM	71.10490	-162.26577	44.9
BF007	34	10/6/2009	12:22:22 AM	71.24342	-163.40298	42.7
BF009	49	10/9/2009	10:52:22 PM	71.23418	-162.63170	44.1
BF011	29	10/1/2009	6:03:06 AM	71.37047	-163.78573	43.2
BF013	39	10/6/2009	8:55:18 AM	71.36622	-163.01113	43.2
BF015	45	10/7/2009	5:36:24 AM	71.35115	-162.23313	42.7
BF017	37	10/6/2009	4:44:42 AM	71.49022	-163.38518	40.2
BF019	43	10/7/2009	1:20:12 AM	71.48087	-162.60430	41.8
BF021	27	9/30/2009	4:36:29 AM	70.87302	-165.18138	39.0
BF023	41	10/6/2009	10:32:14 PM	71.61443	-162.97988	40.9
BF025	47	10/7/2009	9:31:56 AM	71.60128	-162.19583	41.8
KF001	4	9/26/2009	6:19:45 AM	70.64353	-165.99972	40.5

Table 2 Continued.

Station	Haul	Date	Time	Latitude (N)	Longitude (W)	Depth (m)
KF003	10	9/27/2009	7:11:47 AM	70.64555	-165.24038	40.3
KF005	20	9/29/2009	2:01:24 AM	70.64840	-164.49518	44.2
KF007	8	9/27/2009	3:12:17 AM	70.77178	-165.63073	38.9
KF009	18	9/28/2009	10:04:34 PM	70.77397	-164.87222	37.4
KF011	2	9/26/2009	2:02:18 AM	70.89538	-166.01378	39.5
KF013	14	9/28/2009	1:45:21 AM	70.89953	-165.25260	39.0
KF015	22	9/29/2009	5:57:07 AM	70.89733	-164.49368	36.0
KF017	6	9/26/2009	11:16:24 PM	71.02317	-165.63340	40.8
KF019	16	9/28/2009	5:48:58 AM	71.02023	-164.86943	34.6
KF021	1	9/25/2009	9:58:18 PM	71.14415	-166.02817	40.7
KF023	12	9/27/2009	9:51:30 PM	71.14833	-165.25818	41.7
KF025	24	9/29/2009	10:03:54 PM	71.14792	-164.48398	41.0

(weight after excess moisture was removed with an absorbent towel). Colonial organisms such as ascidiaceans, hydrozoans, bryozoans, and sponges were noted for presence and their wet weights determined. Additional representatives of each taxa were frozen for stable isotope analysis to determine the food web structure within the survey areas. Once weighed, all organisms, except those kept for a voucher collection and stable isotope analysis, were returned to the sea. Data collected in the field were recorded on water resistant paper and then entered into the TigerNav system.

The TigerNav system was developed for the CSESP to assist with data collection in the field while simultaneously linking field data with the ship's navigation system. This allows for real-time geographic coordinates and oceanographic conditions to be linked with biological data. Data managers, onboard the vessel, were able perform onsite quality control checks to assist with minimizing input errors of the data. The TigerNav system transcribed the data into a MS Access database which was archived at UAF IMS with the raw datasheets.

Sediment samples for analyzing sediment granulometry and chlorophyll concentrations were collected during the WWW0903 cruise, when benthic infauna was being sampled.

Quality Assurance Procedures

Representative specimens of each taxon encountered during the 2009 CSESP were archived at IMS. These voucher specimens provide records of identification of organisms encountered in the study. While archived specimens may be sent to experts for further identification and/or verification, a complete collection of fauna will be maintained at IMS.

The following quality control procedures were followed in processing infaunal samples in the laboratory. The work of sorters was monitored throughout the project by a trained taxonomist. Once fully trained, a minimum of 10% of samples sorted by student employees were re-sorted to be certain that greater than 95% of the organisms in each sample were removed. One hundred percent of the work performed by junior taxonomists was checked and verified by a senior taxonomist with verification tapering off as they approach the skill level expected for a senior taxonomist. Work was verified to ensure that all counts were accurate and all organisms were correctly identified. Fauna identified in the 2009 CSESP were compared to the voucher collection from the 1986 investigation by Feder et al. (1994b) and to current references (e.g., other benthic programs and our work in the same survey area in 2008) to ensure accuracy, consistency between studies, and to the best of our abilities, consistency with current taxonomic status. After one year from the date of collection, the sorted debris (considered nonhazardous after rinsing and removal of biological tissues) will be discarded following protocols determined by University of Alaska Fairbanks (UAF) Risk Management. Original data forms and MS Access databases will be archived at IMS and delivered to ConocoPhillips Alaska, Inc., in accordance with prescribed data management protocols.

Prior to analyses of infaunal data sets, taxonomic information was scrutinized for consistency as a further quality control check. Pelagic, meiofauna, and epibenthic taxa [i.e., barnacles, tanaidaceans, benthic copepods, brittle stars, sea stars, crabs, etc.] were excluded from analytical data sets. Taxonomic information of epifaunal data sets was also scrutinized for consistency and pelagic and obvious infaunal taxa were excluded from data sets analyzed.

Representative samples of epifaunal organisms were preserved in 10% formalin-seawater buffered with hexamine and returned to Fairbanks to confirm identifications. Organisms were identified to the lowest taxonomic category possible and identifications evaluated by a team of taxonomists. Identification of epifauna in the field was to higher categories due to the difficulty of species identifications without microscopes and other tools.

Statistical Methods

Data were summarized using a variety of descriptive methods. Summary statistics include average abundance, biomass (wet weight), average number of taxa, total number of taxa, and diversity values. Standard deviations and 95% confidence intervals were also calculated. Multivariate statistical methods were applied to a Bray-Curtis similarity matrix calculated from species abundance values. Data are maintained and processed on a computer at UAF IMS. Fragments and taxa identified at family level or above were included in abundance and biomass calculations and diversity indices but excluded from multivariate analyses. For epifaunal analyses, organisms noted only as being present, as well as colonial organisms were excluded in abundance calculations and diversity indices but were included in biomass calculations and multivariate analyses.

Species diversity is a measurable attribute of an assemblage of taxa. It consists of two components: number of taxa or "taxon richness" and relative abundance of each taxa or "evenness." Four indices were calculated: Simpson dominance (Simpson, 1949; Odum, 1975), Shannon diversity (Shannon and Weaver, 1963), taxon richness (Margalef, 1958), and Whittaker's β diversity (Magurran, 2004).

The Simpson dominance index (Simpson, 1949; Odum, 1975) was calculated as:

$$S = \sum \frac{n_i(n_i - 1)}{N(N - 1)}$$

where n_i = number of individuals of species $i_1, i_2, i_3 \ldots i_x$ and

N = total number of individuals.

As the Simpson dominance index increases, diversity decreases representing increasing dominance of the community by a few taxon categories (Magurran, 2004).

The Shannon diversity function was calculated as:

$$H' = -_i \sum p_i \log p_i$$

where $p_i = n_i/N$,

n_i = number of individuals of the ith species, and

N = total number.

The Shannon diversity function assumes that a random sample has been taken from an infinitely large population. Shannon diversity increases with greater numbers of taxa categories containing moderate to many individuals.

Taxon richness (Margalef, 1958) was calculated as:

$$TR = \frac{(T - 1)}{\ln N}$$

where T = the number of taxa and

N = the total number of individuals.

Since some taxa levels higher than species were used for the calculation of richness, this measure was always referred to as taxon richness in this report. Richness generally increases as the number of taxa increases.

Whittaker's β diversity (Magurran, 2004) was calculated as:

$$\beta = \frac{S}{\overline{\alpha}}$$

where S = the total number of taxa identified for the and

$\overline{\alpha}$ = the average number of taxa identified for each survey area.

β reflects the spatial change in faunal assemblages or replacement of species among stations. The maximum value possible is the number of stations used to calculate $\overline{\alpha}$. This measure is also commonly called turnover diversity as it reflects how species are replaced among stations and along gradients. Values close to 1 indicate little taxa replacement while values close to the maximum (number of stations, N = 26 for infaunal survey areas and N = 13 for epifauna) reflect nearly complete replacement. When comparing two stations, β ranges from 1 to 2 with values near 1 indicating nearly total overlap of species and values near 2 indicating none or few species in common. When considering multiple stations, β may range from 1 to the number of stations (n, the maximum value possible). In the latter case, values near the maximum value of n indicate none or few species in common.

Analysis of ecological community data often begins with a multivariate analysis to determine the similarity among stations and species assemblages. Faunal community structure is then interpreted from the similarities among stations in the resulting plots and listing of the dominant organisms in each multivariate group. These procedures consist of four steps:

1. Calculation of a measure of similarity between entities to be classified.
2. Sorting through a matrix of similarity coefficients to arrange the entities in a hierarchy or dendrogram (for cluster analysis) or in a two-dimensional plot (ordination).
3. Recognition of classes within the hierarchy or plot based on the agreement of multiple multivariate procedures.
4. Determination of the dominant species assemblages comprising each station group.

Similarity of stations is determined by their closeness in the cluster dendrogram or ordination. This approach is called an indirect gradient analysis since environmental variables are not directly included in these relationships but are inferred from patterns in the plotted results. Indirect gradient analysis is useful for detecting patterns in overall community structure and similarities among species assemblages.

Cluster analysis and ordination (where new "axes" that summarize community structure are derived and can be plotted) were used for indirect gradient analysis of the 2009 benthic data from the survey areas. Data reduction prior to calculation of similarity coefficients consists of elimination of taxa that could not be identified to at least genus level. Exceptions include organisms regularly identified to the family level (due to taxonomic uncertainty of the genus and species) such as Cirratulidae, which would be included in the multivariate analyses. The Bray-Curtis coefficient (Bray and Curtis, 1957) was used to calculate similarity matrices for cluster analysis and ordination and is defined as:

$$S_{ij} = \left(1 - \frac{\sum_{j=1}^{n} \left| y_{ij} - y_{kj} \right|}{\sum_{j=1}^{n} \left(y_{ij} + y_{kj} \right)} \right) 100$$

where y_{ij} = the jth species of station i and y_{kj} = the jth species of station k. The Bray-Curtis coefficient is widely used in marine benthic studies. This coefficient is typically used with a square root, fourth root, or natural logarithmic transformation. In the context of multivariate analyses, strong transformations such as the fourth-root or *ln*(x+1) are commonly chosen for benthic data to reduce the influence that dominant species have on the similarity coefficient (Clarke and Gorley, 2006). For the present study, the Bray-Curtis coefficient was used to calculate similarity matrices using natural logarithm-transformed abundance data [*ln*(ind. m^{-2} +1)].

Cluster analysis is useful to summarize data by sorting entities into “natural groupings” based on their attributes and the results are summarized in a dendrogram (Johnson and Wichern, 1992). Similarity among station groups is inferred from a dendrogram by interpreting the joining of branches in the plot. Dendrograms were constructed using a group-average agglomerative hierarchical cluster analysis (Clifford and Stephenson, 1975). Normal cluster analysis, performed with stations as entities to be classified and species as their attributes, was utilized. The grouping of stations into patterns reflecting station similarities are interpreted as ecologically meaningful groupings.

Non-metric multidimensional scaling (nMDS: Kruskal and Wish, 1978; Clarke and Green, 1988) is used extensively for assessing species composition data from the marine environment for ecological patterns (e.g., Gray et al., 1988; Agard et al., 1993; Clarke, 1993). As described by Gray et al. (1988) ". . . nMDS attempts to construct a 'map' of the sites in which the more similar . . . samples, . . . in terms of species abundances, are nearer to each other on the 'map'." The extent to which the relations can be adequately represented in a two-dimensional map (rather than three dimensions or higher) is summarized by a 'stress' coefficient (should be ≤ 0.15 for a good fit (Clarke and Ainsworth, 1993)). Non-metric multidimensional scaling is perhaps the most statistically robust (unaffected by extreme values) ordination technique available, using only rank order information of the form "Sample 1 is more similar to Sample 2 than it is to Sample 3." Agreement in the groupings of stations in the cluster and nMDS ordination provides evidence that the station groupings represent a reasonable summary of the multidimensional relationships of the data. Cluster analysis and nMDS were performed using the multivariate statistical analysis software PRIMER v6 (Clarke and Gorley, 2006).

The average abundance of the numerically dominant taxa was calculated for each survey area. Organisms were ranked by their abundance and biomass and the top twenty organisms listed. The program SIMPER from PRIMER (Clarke and Gorley, 2006) was also used to demonstrate taxa with the greatest contribution to community structure in each survey area, based on the contribution of each taxon to the similarity coefficient used in the multivariate analyses.

To understand how benthic communities vary with respect to environmental gradients, canonical correspondence analysis (CCA) was applied to describe associations with the biotic community and environmental variables. CCA is one of the direct gradient analysis methods that can be used to directly evaluate relationships between environmental variables and community structure. This method uses correspondence analysis (an ordination technique based on methods for analysis of categorical data) to initially summarize faunal structure and create new multivariate "axes" but then regresses environmental variables against the results from the correspondence analysis (McCune and Grace, 2002). Thus, the CCA plot will reveal that portion of the structure of the biotic data accounted for by the environmental variables. Here, CCA was used to evaluate the community structure of infauna and epifauna associated with environmental variables, to document and understand baseline relationships between fauna and environmental gradients. Environmental variables included in the CCA were water depth, percent sand, phaeopigment concentration, and salinity. Water depth and sediment granulometric measures serve as proxies for larger environmental and oceanographic conditions. Phaeopigments reflect nutrient inputs and salinity was a measure of water characteristics associated with each survey area. The biotic data used was the abundance of dominant fauna (rare fauna excluded) from the Burger and Klondike survey areas. CCA was performed using the vegan library (Oksanen et al., 2007) on square-root transformed data in the statistical program R (R Development Core Team, 2009). The square-root transformation was applied to reduce the effect of much higher abundances of some taxa in the Burger survey area.

Geostatistical analyses of select biological and environmental variables were presented to evaluate spatial trends and were performed using geoR (Cressie, 1993; Ribeiro and Diggle, 2001). Geostatistical analysis provides an effective means of demonstrating overall trends while still recognizing lesser variability in localized areas (the "hotspots"). The results of the geostatistical analyses were presented as contour plots (kriging plots) of predicted values.

RESULTS

Infauna of Burger, Klondike, and Whale Feeding stations, 2009

Overall, average abundance, biomass, and the number of taxa (sample) were significantly higher ($\alpha = 0.05$) in Burger than in Klondike, as indicated by the lack of overlap at the 95% confidence interval (Table 3). Abundance of infauna at the whale feeding stations was significantly greater than in Klondike and but the number of taxa was higher in the feeding stations than in Burger and Klondike. Differences in Simpson dominance, Shannon diversity, and taxon richness were small to moderate between Burger and Klondike, with diversity values reflecting diverse communities in both survey areas. β diversity was relatively low, 4.9 and 7.5 for Burger and Klondike, as compared to the possible maximum value of 26 (the number stations sampled). The β diversity values suggested moderate replacement of taxa among stations within each survey area with a greater rate of taxa replacement at Klondike. Diversity measures in the whale feeding stations were different than the other survey areas but diversity is dependent on number of stations sampled. The low number of stations (n=6) in the whale feeding area makes direct comparisons of values difficult. Whale feeding stations had low total number of taxa, low Shannon and β diversity (3.28), and taxon richness and slightly inflated dominance.

Table 3. Summaries of biotic and environmental variables, and diversity indices for the fixed and random stations sampled for infauna during the 2009 CSESP. Ave. = average, SD = standard deviation, 95% CI = 95% confidence interval, Sample # Taxon = the average number of taxonomic categories based on all station data (fixed and random), Total # Taxon = the number of taxonomic categories found in each survey area, and -- = not calculated. Abundance was ind. m^{-2}, biomass was in g m^{-2}, depth was in meters, and chlorophyll-a and phaeopigment concentrations were mg m^{-2}.

	Burger			Klondike			Whale Feeding		
Variable	Ave.	SD	95% CI	Ave.	SD	95% CI	Ave.	SD	95% CI
Abundance	3979.1	2723.8	(3618.8, 4339.4)	1119.7	685.6	(1029, 1210.4)	8209.4	4466.2	(6979.6, 9439.2)
Biomass	283.7	109.5	(268.5, 297.5)	115.0	63.1	(106.7, 123.3)	196.8	64.6	(179, 214.6)
Sample # Taxa	58.3	7.6	(57.3, 59.3)	41.4	13.5	(39.6, 43.2)	63.0	8.5	(60.6, 65.4)
Total # Taxon	286	--	--	312	--	--	212	--	--
β diversity	4.91	--	--	7.54	--	--	3.37	--	--
Simpson dominance	0.06	--	--	0.02	--	--	0.17	--	--
Shannon diversity	3.76	--	--	4.50	--	--	3.06	--	--
Taxon Richness	34.38	--	--	44.30	--	--	23.41	--	--
Water Depth	41.9	1.5	(41.22, 42.66)	39.8	2.1	(38.8, 40.77)	50.7	0.9	(49.75, 51.59)
Chlorophyll-a	0.0018	0.0015	(0.001, 0.003)	0.0017	0.0015	(0.001, 0.002)	0.0067	0.0027	(0.003, 0.010)
Phaeopigment	0.0093	0.0093	(0.005, 0.014)	0.0149	0.0166	(0.007, 0.023)	0.0936	0.0377	(0.048, 0.139)
% H_2O Content	16.4	3.2	(14.9, 17.9)	17.1	4.0	(15.2, 18.9)	10.4	2.5	(7.3, 13.4)
% Total Organic Carbon	5.0	1.5	(4.3, 5.7)	2.6	1.1	(2.0, 3.1)	4.1	1.1	(2.8, 5.4)
% Sand	34.1	15.2	(27.0, 41.2)	45.5	15.4	(38.3, 52.6)	67.5	8.5	(57.2, 77.9)
% Mud	60.6	17.2	(52.6, 68.7)	47.4	17.6	(39.2, 55.6)	15.5	3.9	(10.9, 20.2)
% Gravel	5.2	9.7	(0.7, 9.7)	7.1	13.7	(0.7, 13.5)	16.9	8.9	(6.1, 27.7)

Environmental measures indicated significant differences among the survey areas (Table 3). Confidence intervals for chlorophyll, phaeopigment, and sediment grain-size measures overlap between the Burger and Klondike survey areas indicating no statistical differences. The whale feeding stations, however, had significantly lower percent water content and mud, but higher percent sand, chlorophyll-a, and phaeopigment concentrations compared to Burger and Klondike ($\alpha = 0.05$). Klondike was significantly shallower than Burger yet both survey areas were shallower than the whale feeding area. Kriging plots from geostatistical analyses for the Burger and Klondike survey areas indicated increasing abundance, biomass, percent mud, and depth from the southeast corner of Klondike to the northwest corner of Burger (Fig. 2). (Sampling of whale feeding stations was too limited for inclusion in geostatistical analyses.) The significant differences in abundance, biomass, and water depth between Klondike and Burger survey areas were reflected in the spatial trends demonstrated in the kriging plots. Whereas confidence intervals for percent mud did not indicate a significant difference at the 5% level of significance, the kriging plot did demonstrate a strong spatial trend of increasing percent mud to the northeast (Burger).

The numerically dominant fauna (the five most abundant) in Burger included the bamboo worm *Maldane glebifex*, the seed shrimp Ostracoda, smooth nutclam *Ennucula tenuis*, and marine scuds (amphipods) *Photis* sp. and *Paraphoxus* sp. (Table 4). In Klondike, the five taxa of greatest abundance were *Ennucula tenuis*, spaghetti worms of the family Cirratulidae, the bamboo worms *Maldane glebifex* and *Praxillella praetermissa*, and the polychaete worms from the Capitellid family. The whale feeding stations were dominated by the marine scuds (amphipods) *Byblis* sp., *Ischyrocerus* sp., and *Protomedeia* sp., and the polychaete families Cirratulidae and Ampharetidae. On the basis of biomass, the dominant taxa at Burger included the northern astarte clam *Astarte borealis*, *Ennucula tenuis*, chalky Macoma clam *Macoma calcarea*, the peanut worm *Golfingia margaritacea*, and *Maldane glebifex* (Table 4). In Klondike, the top-ranked taxa by biomass included *Astarte borealis*, the rayed nutclam *Nuculana radiata*, the Bering scallop *Chlamys behringiana*, and the bamboo worms *Axiothella catenata* and *Maldane glebifex* (Family Maldanidae). In the whale feeding area, the fauna with greatest biomass included *Byblis* sp. and other unidentified amphipods, the clam *Astarte borealis*, the blind worm *Nephtys caeca*, and barnacles *Balanus rostratus.*

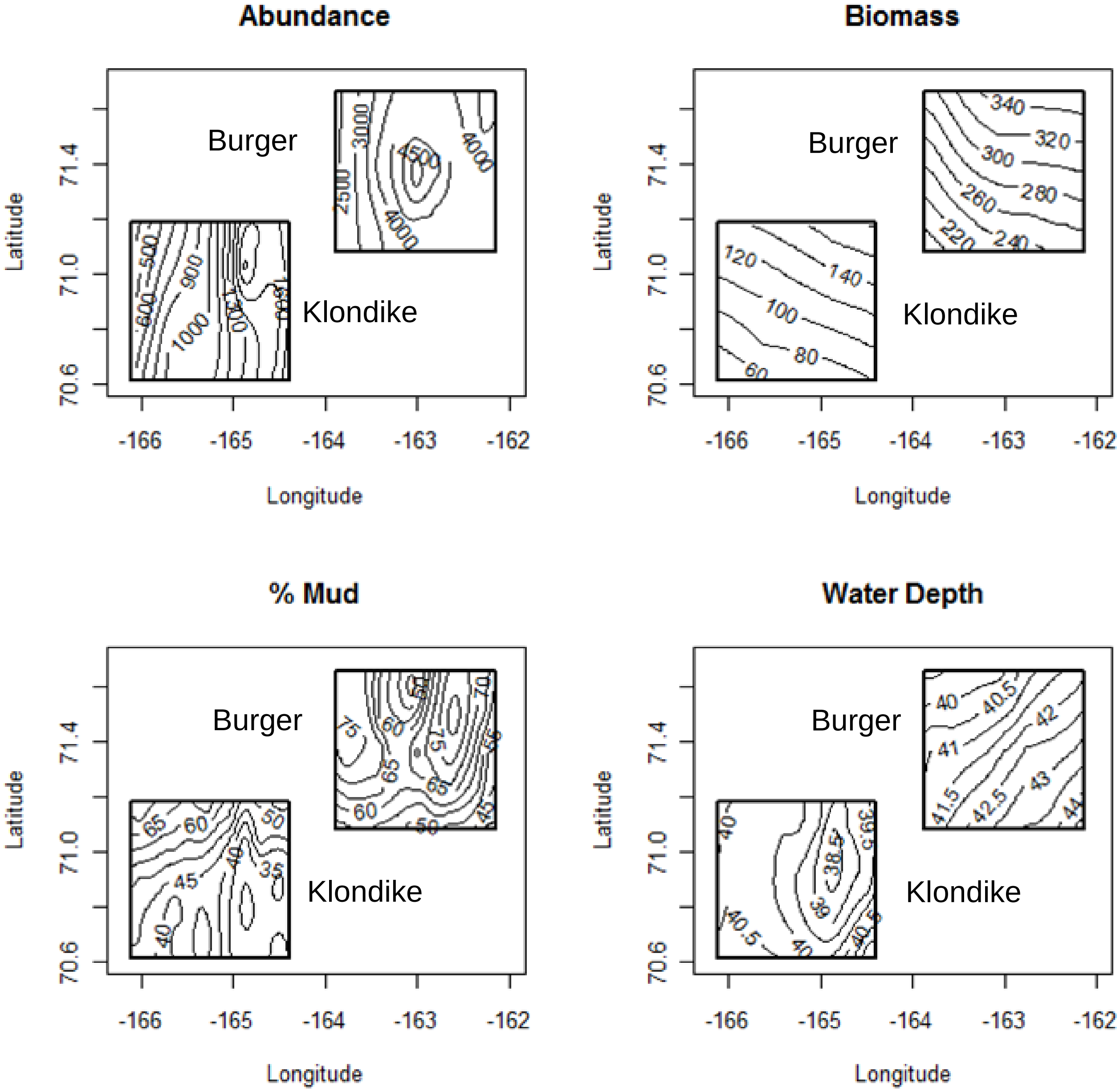

Figure 2. Kriging plots of abundance (ind. m^{-2}), biomass (g m^{-2}), percent mud, and water depth in Burger and Klondike in 2009.

Table 4. Rank average abundance (ind. m^{-2}) and rank wet biomass (g m^{-2}) of dominant infaunal taxa (first 20) by survey area in 2009.

Region	Taxon	Abundance	Taxon	Biomass
Burger	*Maldane glebifex*	750	*Astarte borealis*	57.5
	Ostracoda	289	*Macoma calcarea*	44.6
	Photis sp.	212	*Ennucula tenuis*	28.8
	Ennucula tenuis	189	*Maldane glebifex*	27.3
	Paraphoxus sp.	165	*Golfingia margaritacea*	11.4
	Lumbrineris sp.	152	*Astarte montagui*	11.3
	Brachydiastylis resima	142	*Cyclocardia crebricostata*	7.3
	Leitoscoloplos pugettensis	138	*Macoma moesta*	7.1
	Ampharetidae	129	*Yoldia myalis*	7.0
	Cirratulidae	121	*Axiothella catenata*	5.6
	Prionospio steenstrupi	73	*Terebellides stroemi*	4.1
	Anonyx sp.	71	*Onuphis parva*	4.0
	Cossura sp.	69	*Golfingia vulgaris*	3.9
	Pontoporeia femorata	62	*Lumbrineris* sp.	3.8
	Myriochele heeri	61	*Lumbrineris fragilis*	3.5
	Terebellides stroemi	55	*Euspira pallida*	3.5
	Dyopedos arcticus	51	*Ampelisca eschrichti*	3.4
	Praxillella praetermissa	41	*Priapulus caudatus*	3.1
	Ampharete acutifrons	40	*Liocyma fluctuosa*	2.9
	Onuphis parva	40	Rhynchocoela	2.3
Klondike	*Ennucula tenuis*	112	*Maldane glebifex*	16.2
	Cirratulidae	59	*Nuculana pernula*	9.8
	Maldane glebifex	47	*Astarte borealis*	7.6
	Praxillella praetermissa	41	*Chlamys behringiana*	6.9
	Capitellidae	32	*Axiothella catenata*	5.5
	Barantolla americana	29	*Euspira pallida*	4.7
	Cossura sp.	26	*Ennucula tenuis*	4.6
	Bathymedon sp.	22	*Golfingia vulgaris*	4.0
	Sternaspis fossor	21	*Astarte montagui*	3.7
	Paraphoxus sp.	20	*Macoma calcarea*	3.4
	Leitoscoloplos pugettensis	20	*Serripes laperousii*	3.2
	Leucon nasica	18	*Golfingia margaritacea*	3.1
	Arcteobia anticostiensis	18	*Yoldia myalis*	2.6
	Bivalvia	18	Musculus niger	2.4
	Thyasira flexuosa	17	*Praxillella praetermissa*	2.4
	Sabellidae	17	*Nephtys punctata*	2.0

Table 4. Continued.

Region	Taxon	Abundance	Taxon	Biomass
Klondike cont.	*Polycirrus* sp.	16	*Axiothella* sp.	2.0
	Byblis sp.	16	*Neoamphitrite groenlandica*	1.9
	Melita sp.	16	*Nicomache lumbricalis*	1.9
	Cistenides granulata	16	*Priapulus caudatus*	1.8
Whale Feeding	*Byblis* sp.	737	*Byblis* sp.	8.3
	Protomedeia sp.	155	*Balanus rostratus*	3.9
	Ischyrocerus sp.	126	*Astarte borealis*	3.4
	Cirratulidae	85	*Nephtys caeca*	3.0
	Ampharetidae	46	Amphipoda	2.2
	Amphipoda	44	*Byblis pearcyi*	1.9
	Syllidae	36	*Ophiopenia tetracantha*	1.8
	Sabellidae *Syllis* sp.	31	*Astarte montagui*	1.5
	Golfingia sp.	28	*Clinocardium ciliatum*	1.5
	Synidotea bicuspida	24	*Nicomache lumbricalis*	1.2
	Byblis pearcyi	24	*Golfingia margaritacea*	1.1
	Praxillella praetermissa	24	Colonial hydrozoa	0.9
	Ophiopenia tetracantha	23	*Chone mollis*	0.8
	Ennucula tenuis	23	*Priapulus caudatus*	0.7
	Chone mollis	16	*Astarte* sp.	0.7
	Photis sp.	15	*Synidotea bicuspida*	0.6
	Paraphoxus sp.	15	*Cistenides granulata*	0.6
	Melita sp.	14	*Protomedeia* sp.	0.6
	Corophium sp.	14	Terebellidae	0.6
	Orbiniidae	13	Sabellidae	0.5

Multivariate analyses of infaunal community composition data (abundance) indicated separate communities among Burger, Klondike, and the whale feeding areas. The cluster analysis and nMDS ordination separated stations into three groups with very little overlap of the respective areas (Figs. 3 and 4). The variability of the benthic communities of Klondike stations was reflected in the low similarities of stations as shown in the cluster analysis and nMDS ordination. In the cluster analysis, the Burger stations were grouped together at approximately 62% similarity. The Klondike stations were grouped together at about 52% similarity, and the whale feeding stations grouped at about 56% similarity (Table 5). Two stations, KF001 and

KF019, did not join a multivariate group. KF011 did not join a group in the MDS ordination while KF019 was closely associated with the whale feeding stations.

Fauna contributing to the separation of multivariate groupings can be identified using SIMPER, an analytical routine in the PRIMER package (Clarke and Gorley, 2006) (Table 5). This analytical routine determines the contribution of each taxon to within group similarity and between group dissimilarity. SIMPER results mirrored the abundance rankings for each survey area. The five taxa contributing to within survey area similarity for Burger ranked by abundance include the smooth nutclam *Ennucula tenuis*, the bamboo worm *Maldane glebifex*, the orbinid worm *Leitoscoloplos pugettensis*, lumbrinerid thread worm *Lumbrineris* spp., and the marine scud (amphipoda) *Paraphoxus* sp. (Tables 5). Within Klondike, the five taxa contributing most to similarity were *Ennucula tenuis*, spaghetti worms of the family Cirratulidae, the bamboo worms *Maldane glebifex* and *Praxillella praetermissa*, and the worm *Sternaspis fossor*, which, with the exception of *Sternaspis fossor*, were listed as numerical dominants in the taxa ranking. Taxa contributing to similarity of the whale feeding stations were the marine scuds (amphipods) *Byblis* sp., *Ischyrocerus* sp., and *Protomedeia* sp., the polychate family Cirratulidae, and *Praxillella praetermissa*. Taxa contributing most to the dissimilarity between Burger and Klondike were *Lumbrineris* spp., amphipods *Paraphoxus* sp., *Pontoporeia femorata*, and *Dyopedos arcticus*, as well as seed shrimps Ostracoda; all were more abundant in Burger (Table 6). Taxa separating Burger from the whale feeding area included *Byblis* sp., *Ischyrocerus* sp., *Protomedeia* sp., the polychaete worms *Cossura* sp. and *Syllis* sp., which, with the exception of *Cossura* sp., were more abundant in the whale feeding area. Taxa separating Klondike from the whale feeding area were *Byblis* sp., *Ischyrocerus* sp., *Protomedeia* sp., and *Syllis* sp., and *Golfingia* sp. These fauna were all more abundant in the whale feeding area. Overall, the whale feeding area was separated from Burger and Klondike survey areas by the dominance of amphipods and lack of polychaetes and bivalves in the whale feeding area (Table 6).

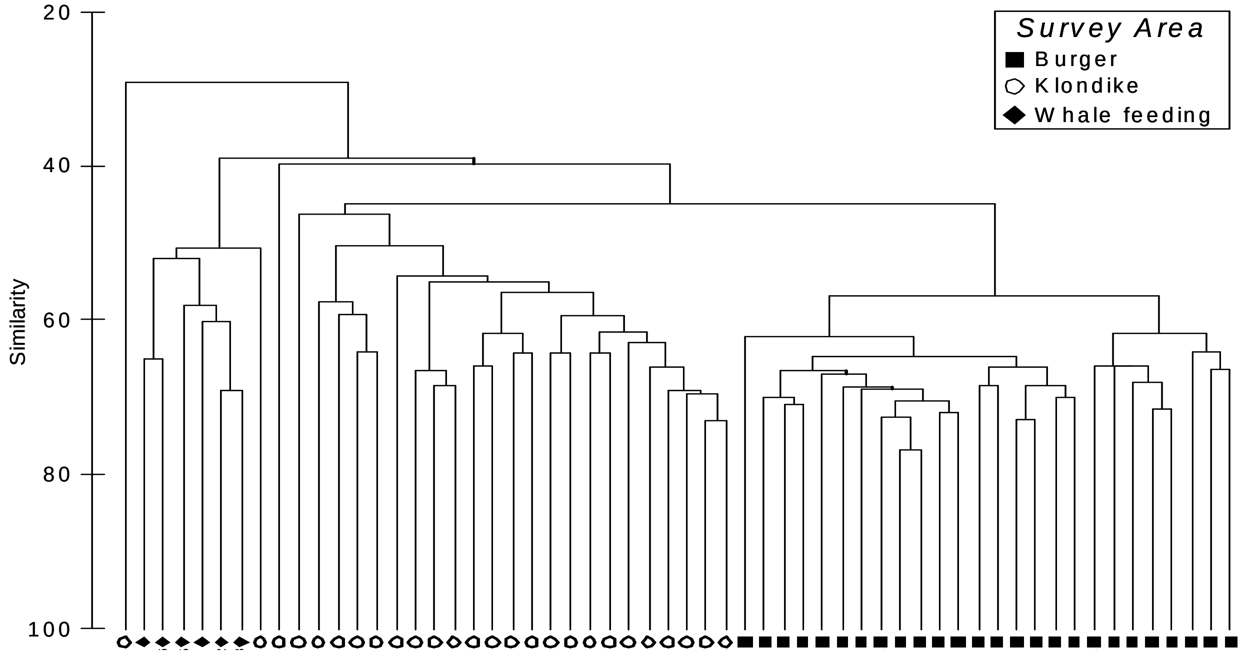

Figure 3. Cluster analysis of Bray-Curtis similarities based on *ln*(x+1)-transformed infaunal abundance data from the 2009 CSESP.

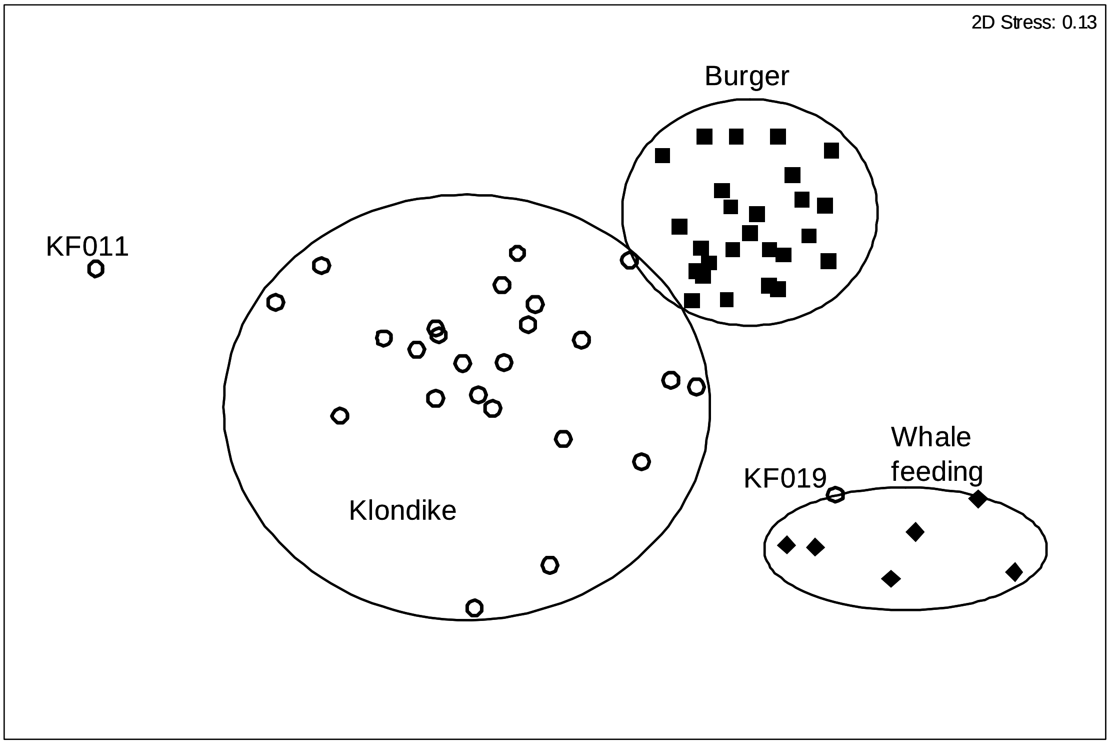

Figure 4. Nonmetric multidimensional scaling ordination plot of Bray-Curtis similarities for *ln*(x+1)-transformed infaunal abundance data from the 2009 CSESP.

Table 5. The five infaunal taxa contributing most to within survey area similarity (Sim). ln Abund = average *ln*(abundance+1), Sim = average similarity, % Contr = % contribution to similarity. Stations for each area are those included in the nMDS ordination plot (Fig. 4).

Burger: Average similarity = 61.75

Taxon	ln Abund	Sim	% Contr.
Ennucula tenuis	5.11	2.33	3.77
Paraphoxus sp.	4.93	2.16	3.54
Lumbrineris sp.	4.81	2.12	3.44
Leitoscoloplos pugettensis	4.52	1.91	3.09
Maldane glebifex	4.83	1.83	2.96

Klondike: Average similarity = 51.62

Taxon	ln Abund	Sim	% Contr.
Ennucula tenuis	4.62	3.30	6.38
Cirratulidae	3.76	2.52	4.87
Maldane glebifex	3.47	2.11	4.09
Praxillella praetermissa	3.27	2.10	4.07
Sternaspis fossor	3.21	1.87	3.62

Whale feeding: Average similarity = 56.30

Taxon	ln Abund	Sim	% Contr.
Cirratulidae	5.61	2.30	4.09
Byblis sp.	6.26	1.99	3.53
Praxillella praetermissa	4.45	1.83	3.25
Protomedeia sp.	5.12	1.73	3.07
Ischyrocerus sp.	5.05	1.61	2.86

Table 6. The five infaunal taxa contributing most to between survey area dissimilarity (Diss). ln Abund = average *ln*(abundance+1), Diss = average similarity, % Contr = % contribution to dissimilarity. Stations for each area are those included in the nMDS ordination plot (Fig. 4).

Burger & Klondike: Average dissimilarity = 56.18

Taxon	**Burger** ln Abund	**Klondike** ln Abund	Diss	% Contr.
Ostracoda	4.64	1.39	1.06	1.88
Lumbrineris sp.	4.81	1.45	1.03	1.84
Paraphoxus sp.	4.93	1.83	0.95	1.70
Pontoporeia femorata	3.33	0.13	0.94	1.67
Dyopedos arcticus	3.35	0.28	0.91	1.61

Burger & Whale feeding: Average dissimilarity = 58.95

Taxon	**Burger** ln Abund	**Whale feeding** ln Abund	Diss	% Contr.
Byblis sp.	1.68	6.26	1.15	1.95
Ischyrocerus sp.	1.54	5.05	0.95	1.61
Protomedeia sp.	1.33	5.12	0.89	1.51
Cossura sp.	3.96	0.24	0.87	1.48
Syllis sp.	0	3.67	0.85	1.44

Klondike & Whale feeding: Average dissimilarity = 64.53

Taxon	**Klondike** ln Abund	**Whale feeding** ln Abund	Diss	% Contr.
Byblis sp.	2.28	6.26	1.26	1.95
Ischyrocerus sp.	1.21	5.05	1.22	1.89
Golfingia sp.	0.41	4.10	1.06	1.65
Protomedeia sp.	1.75	5.12	0.99	1.54
Syllis sp.	0.25	3.67	0.97	1.51

Associations of infaunal community structure in relation to four environmental variables were demonstrated by canonical correspondence analysis (CCA), as shown in Figure 5. A CCA ordination presents only that portion of faunal variability associated with the environmental regressors, so the presence of a gradient in the faunal data are demonstrated by a spread of stations along the vertical and horizontal axes in the plot. Analysis of the 2009 data and the plot of the first two axes from the CCA analysis indicates that faunal community structure in these study areas was different, with the Burger stations located mostly in the upper right side of the plot, the Klondike stations spread out towards the bottom, and the whale feeding stations positioned in the upper left (Fig. 5). The separation of stations by survey area was similar to that demonstrated in the nMDS ordination (Figs. 3 and 4).

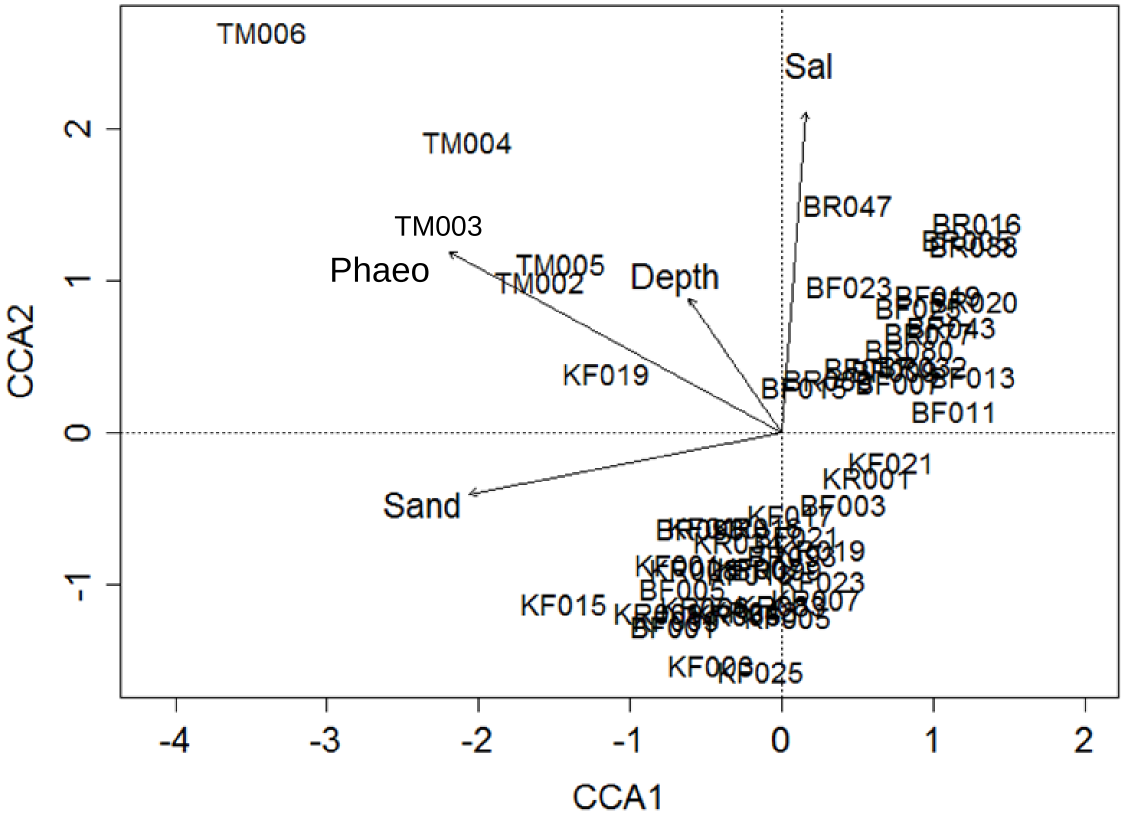

Figure 5. Plot of the first two axes from canonical correspondence analysis (CCA) for double square-root transformed infaunal abundance data from the 2009 CSESP. Fixed, random, and whale feeding stations are included here.

Associations of environmental variables with CCA axes are demonstrated by the overlay on the station plot of arrows representing the four environmental variables. Length of an arrow indicates the strength of the correlation and direction of an arrow indicates positive or negative associations between each variable and the CCA axes. The arrows for salinity (Sal), percent sand (Sand), and phaeopigments (Phaeo) are long, reflecting relatively strong correlations with the axes (Table 7 and Fig. 5). Percent sand and phaeopigments were negatively correlated with the horizontal (first CCA) axis accounting for 12% of overall variability in the ordination. Salinity was positively correlated with the vertical (CCA2) axis accounting for 8% of total variability (Table 7). Thus, the spread of stations along horizontal axis (CCA1) reflect a gradient in faunal community structure associated with sediment grain-size and phaeopigment concentrations. The spread of stations along the vertical axis reflect increasing salinity towards the top of the plot.

Table 7. Summary of correlations between CCA axes and four environmental variables sampled during the 2009 CSESP. Values in bold highlight moderate-sized correlations between environmental variables and CCA axes. Sign indicates direction of correlation.

CCA Label	Variable	CCA1	CCA2
Sand	% Sand	**-0.61**	-0.15
Phaeo	Phaeopigment (mg m^{-2})	**-0.62**	0.34
Depth	Depth (m)	-0.18	0.26
Sal	Salinity	0.09	**0.63**
	Cumulative % Variance Accounted for	12%	20%

Temporal Comparisons of Infauna

Analysis of variance comparisons of data between years and survey areas suggested differences, largely between survey areas as well as a few differences between years. The Area effect (comparing Burger and Klondike) was significant for abundance, biomass, number of taxa, percent mud, and percent sand (Table 8 and Fig. 6). Burger had higher abundance, biomass, number of taxa, and percent mud than Klondike, which had higher percent sand. There were differences between years for the number of taxa, % water content of sediments, and chlorophyll-a and phaeopigment concentrations. The Year differences for chlorophyll, phaeopigments, and % water content may reflect methodological refinements and taxonomic refinements for the number of taxa rather than real temporal changes in these variables. Confidence intervals for selected variables demonstrated that the 2009 whale feeding stations had a significantly higher average number of taxa, greater water depth, and lower percent mud than averages for Burger and Klondike survey areas in both years (Fig. 6). The average abundance of infauna in the whale feeding area was an order of magnitude higher than the average in Burger. However, the variance of average abundance in the whale feeding area was extremely high, resulting in overlapping confidence intervals. Average abundance of infauna was significantly higher in the whale feeding area compared to Klondike in both 2008 and 2009.

Table 8. Analysis of variance of data from the 2008 and 2009 CSESP. Comparisons were made for biological and environmental variables between the Burger and Klondike survey areas. Whale feeding sites are not included here due to the resulting unbalanced design. Bold values indicate significance at $\alpha = 0.05$.

Abundance	F	P-Value
Year	0.4	0.58378
Area	38.7	**<0.0001**
Year x Area	0.1	0.75849

% Gravel	F	P-Value
Year	1.1	0.29082
Area	1.1	0.30136
Year x Area	0.0	0.97467

Biomass	F	P-Value
Year	1.2	0.28299
Area	38.3	**<0.0001**
Year x Area	0.5	0.49123

% Sand	F	P-Value
Year	0.1	0.77556
Area	13.0	**0.00050**
Year x Area	0.1	0.80969

Taxa	F	P-Value
Year	7.1	**0.01110**
Area	48.3	**<0.0001**
Year x Area	0.6	0.48027

% Mud	F	P-Value
Year	0.2	0.67567
Area	15.4	**0.00016**
Year x Area	0.0	0.88393

Water Depth	F	P-Value
Year	0.4	0.55123
Area	39.8	**<0.0001**
Year x Area	0.1	0.74454

Chlorophyll-a	F	P-Value
Year	335.6	**<0.0001**
Area	1.4	0.23745
Year x Area	1.2	0.27235

% Water Content	F	P-Value
Year	253.1	**<0.0001**
Area	0.3	0.60624
Year x Area	0.4	0.55377

Phaeopigments	F	P-Value
Year	429.9	**<0.0001**
Area	0.0	0.90764
Year x Area	1.4	0.23719

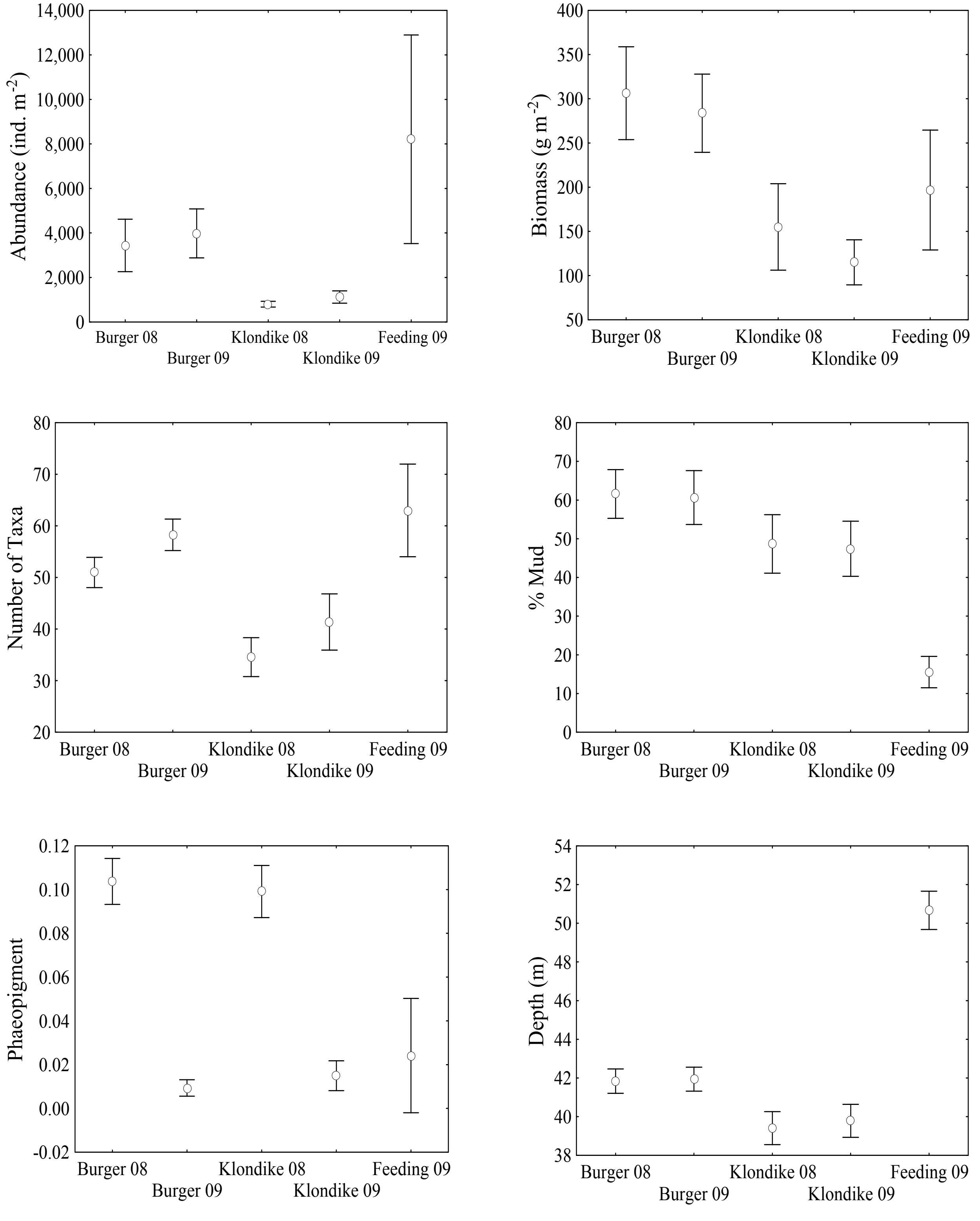

Figure 6. Averages and 95% confidence intervals of selected variables from the 2008 and 2009 CSESP in Burger, Klondike, and Whale feeding areas (2009 CSESP only).

Multivariate analyses was performed on the data collected in 1986 by Feder et al. (1994b) and the data from the Burger and Klondike survey areas in 2008 and 2009. The nMDS ordination of the data suggested groupings reflecting distance offshore (Fig. 7). Offshore stations of Burger and Klondike, sampled in 2008 and 2009, demonstrate that, for each area, there was no difference between years. However, each area was separated from the other, similar to the nMDS ordinations for 2009 data only (Figs. 4 and 7). The whale feeding stations, sampled in 2009, were separated from Burger and Klondike as were the ACW stations (under the influence of the Alaska Coastal Current) from 1986. The 1986 offshore stations (Feder et al., 1994b) were divided into two station groups (the dashed lines), which encompass Burger and Klondike stations along the horizontal axis. The 1986 ACW stations were scattered to the right. The whale feeding stations of 2009, also close enough to shore to be under the influence of the Alaska Coastal Current) were positioned closely to a set of ACW stations from 1986.

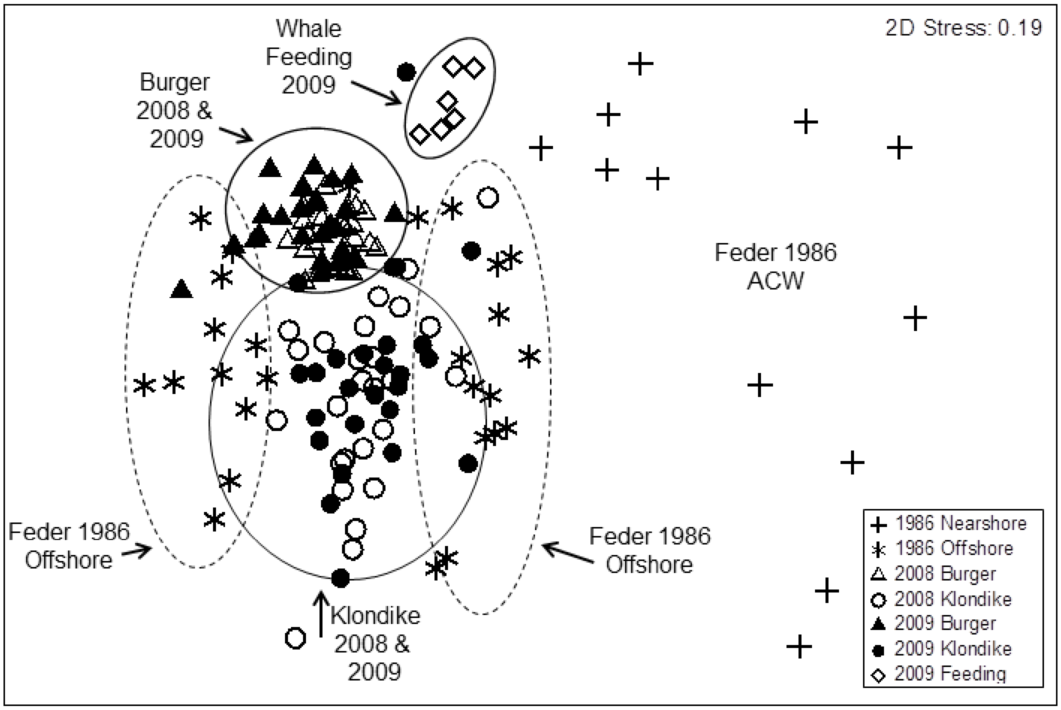

Figure 7. Nonmetric multidimensional scaling of abundance data from the northeastern Chukchi Sea. Data were ln(X+1)-transformed. This analysis included data from 1986 (Feder et al.,1994b) and the 2008 and 2009 CSESP studies at the Burger, Klondike, and Whale Feeding survey areas.

Numerically dominant fauna in 1986 (Table 9) was similar to that found in 2008 and 2009. At the ACW stations, amphipods dominated the abundance ranking although *Byblis*, the dominant genera in the whale feeding area, was not as abundant. Amphipods in the ACW stations sampled in 1986 included *Atylus bruggeni*, *Protomedeia* sp., *Ampelisca macrocephala*, and *Photis* sp. Numerically dominant taxa from offshore stations sampled in 1986 included a number of species found in the Burger and Klondike survey areas. They were the clam *Ennucula tenuis*, the polychaete worms *Leitoscoloplos pugettensis* and *Maldane glebifex*, and the amphipod genera *Byblis* sp., representing high similarity between the offshore stations sampled in 1986 and those sampled in 2008 and 2009.

Table 9. Average abundance of numerically dominant species from the northeast Chukchi Sea in 1986 as reported by Feder et al. (1994b). Species dominant at Burger and Klondike stations sampled in 2009 are highlighted in bold while those dominant at the 2009 whale feeding stations are underlined.

1986 ACW Species	Ave. Abund.	1986 offshore Species	Ave. Abund.
Atylus bruggeni	367	***Ennucula tenuis***	**123**
<u>*Protomedeia* sp.</u>	<u>291</u>	***Maldane glebifex***	**105**
Ampelisca macrocephala	199	<u>*Byblis* sp.</u>	<u>78</u>
Photis sp.	156	*Leitoscoloplos pugettensis*	50
<u>*Ischyrocerus* sp.</u>	<u>72</u>	*Byblis gaimardi*	49
Leitoscoloplos pugettensis	51	**Cirratulidae**	**48**
Ampelisca eschrichti	38	***Lumbrineris* sp.**	**44**
Paraphoxus nasutus	38	*Barantolla americana*	42
Scoloplos armiger	36	*Brachydiastylis resima*	41
Cirratulidae	36	*Echiurus echiurus alaskanus*	37

Epifauna of Burger and Klondike, 2009

Epifauna of the survey area were field-identified to 147 unique taxa, which were used in data analysis, but expanded to 294 taxa in a laboratory setting (Appendix II) for the purposes of creating an extensive voucher collection. (Abundance calculations and diversity indices do not include organisms that were assessed for presence such as colonial ascidians (tunicates), hydrozoa, bryozoa, and porifera (sponges). Thus, abundance and diversity estimates slightly underestimate the true numbers.) Of the total number of organisms, 89% were brittle stars, 4% were shrimp, 2% were barnacles, sea cucumbers, and bivalves, and <1% were gastropods and other taxa. Seventy percent of the biomass of the northeast Chukchi Sea was comprised of brittle stars, 6% crabs, 4-5% sea cucumbers and gastropods, 3% bivalves and colonial organisms such as ascidiaceans, sponges, hydrozoans, and bryozoans, 2% shrimp and sea anemones, and 1% of the biomass was hermit crabs and sea stars. By survey area, brittle stars comprised 74% of the biomass in Burger and 58% in Klondike. In Burger, sea cucumbers and crabs comprised 6% of the biomass; bivalves and gastropods comprised 4%; and sea anemones, shrimp, and sea stars comprised 1-2% of the biomass. The biomass in Klondike consisted of 10% tunicates, 7% crabs, 2-5% shrimp, gastropods, hermit crabs, bivalves, and echinoderms including sea stars, sea cucumbers, and sea urchins.

Biological summary measures did not vary significantly between the two cruises as indicated by the overlapping confidence intervals for biomass (Table 10). Diversity indices (which did not include colonial organisms or those assessed for presence) were very similar between Burger and Klondike for both cruises; however taxon richness was lower in Burger than in Klondike. In August (cruise WWW0902), β diversity was relatively low, 2.4 for Burger and 3.3 at Klondike as compared to the possible maximum value of 10 (the number of stations sampled). The β diversity values in October (cruise WW0904) were 2.3 at Burger and 2.9 at Klondike as compared to a possible maximum of 13 (number of stations sampled). These β diversity values suggest little replacement of taxa among stations within each survey area.

Table 10. Summaries of biotic variables and diversity indices[†] for the fixed stations sampled for epifauna during the 2009 CSESP. Ave. = average, SD = standard deviation, 95% CI = 95% confidence interval, Sample # Taxon = the average number of taxonomic categories based on all station data and Total # Taxon = the number of taxonomic categories found in each survey area and -- = not calculated.

WWW0902	Burger			Klondike		
Variable	Ave.	SD	95% CI	Ave.	SD	95% CI
Abundance (ind. 1000^{-1} m^{-2})[†]	135,382	155,216	(59,014; 251,419)	37,429	99,364	(37,779; 160,949)
Biomass (g 1000^{-1} m^{-2})	99,756.3	72,584.6	(27,597; 117,572.2)	36,127.4	45,387.9	(17,256.7; 73,519.1)
Sample # Taxa	30	9	(4; 15)	27	10	(4; 16)
Total # Taxa	73	--	--	90	--	--
β Diversity	2.43	--	--	3.33	--	--
Simpson Dominance	0.84	--	--	0.83	--	--
Shannon Diversity	0.24	--	--	0.24	--	--
SW Evenness	0.13	--	--	0.12	--	--
Taxon Richness	6.09	--	--	8.45	--	--

WWW0904	Burger			Klondike		
Variable	Ave.	SD	95% CI	Ave.	SD	95% CI
Abundance (ind. 1000^{-1} m^{-2})[†]	82,076	98,477	(44,945; 152,009)	19,814	59,178	(27,009; 91,346)
Biomass (g 1000^{-1} m^{-2})	55,326.5	51,832.5	(23,656.6; 80,008.5)	21,936.4	40,444.6	(18,459.1; 62,430.1)
Sample # Taxa	31	6	(3; 9)	26	8	(3; 12)
Total # Taxa	71	--	--	74	--	--
β Diversity	2.29	--	--	2.85	--	--
Simpson Dominance	0.75	--	--	0.73	--	--
Shannon Diversity	0.78	--	--	0.74	--	--
SW Evenness	0.18	--	--	0.17	--	--
Taxon Richness	6.19	--	--	7.38	--	--

[†] Abundance calculations and diversity indices do not include organisms that were assessed for presence such as colonial ascidians (tunicates), hydrozoa, bryozoa, and porifera (sponges).

For the two cruises combined, Burger had higher biomass and average number of taxa per station than Klondike (Table 11). However, Klondike had an overall higher total number of taxa. In general, diversity measures were also slightly higher in Klondike than in Burger, although the measures reflected diverse communities in both survey areas. β diversity was low for both survey areas (2.97 for Burger and 3.12 for Klondike) compared to the maximum possible value of 13 for both areas. These values suggested little replacement of taxa within each survey area, however Klondike had a slightly higher rate of replacement.

Table 11. Summaries of biotic variables and diversity indices† for the fixed stations sampled for epifauna averaged across sampling cruises from the 2009 CSESP. Ave. = average, SD = standard deviation, 95% CI = 95% confidence interval, Sample # Taxon = the average number of taxonomic categories based on all station data and Total # Taxon = the number of taxonomic categories found in each survey area, and -- = not calculated.

	Burger			Klondike		
Variable	Ave.	SD	95% CI	Ave.	SD	95% CI
Abundance (ind. 1000^{-1} m^{-2})†	106,796	103,894	(47,418; 160,371)	24,523	73,304	(33,456; 113,152)
Biomass (g 1000^{-1} m^{-2})	76,103.6	53,806.7	(24,557.6; 83,055.9)	25,743.5	40,272.8	(18,380.6; 62,164.9)
Sample # Taxon	30	5	(2; 8)	27	8	(4; 12)
Total # Taxon	89	--	--	103	--	--
β Diversity	2.97	--	--	3.12	--	--
Simpson Dominance	0.52	--	--	0.39	--	--
Shannon Diversity	0.67	--	--	0.83	--	--
SW Evenness	0.34	--	--	0.41	--	--
Taxon Richness	7.94	--	--	10.18	--	--

†Abundance calculations and diversity indices do not include organisms that were assessed for presence such as colonial ascidians (tunicates), hydrozoa, bryozoa, and porifera (sponges).

Dominant species based on biomass in both survey areas during both cruises were brittle stars, bivalves (clams), gastropods (marine snails), crab, and shrimp. The rankings, however, varied slightly in each area and cruise (Table 12). Brittle stars, crabs, sea cucumbers, bivalves, and basket stars were the five taxa that dominated the biomass in Burger for both cruises were. In Klondike, the biomass was dominated by brittle stars, tunicates (sea squirts), crabs, shrimp, and gastropods. Additionally, hermit crabs, amphipods, anemones, and moss animals such as hydrozoa, bryozoa, and sponge were among the dominant taxa by biomass in the survey areas (Table 12). Abundance and biomass rankings of dominant epifaunal taxa per station are included in Appendix III.

Table 12. Rank biomass (g 1000^{-1} m^{-2}) of epifauna by cruise and survey area from the 2009 CSESP.

	WWW0902		WWW0904	
Region	Taxon	Biomass	Taxon	Biomass
Burger	Brittle star	69,293.01	Brittle star	39,810.13
	Sea cucumber	7,366.03	Basket star	3,382.37
	Crab	5,667.45	Crab	3,075.57
	Bivalve	4,447.86	Sea cucumber	2,489.68
	Gastropod	4,031.16	Gastropod	1,840.20
	Anthozoa	2,919.59	Bivalve	1,232.83
	Tunicates	1,173.72	Shrimp	860.35
	Basket star	1,171.90	Sea star	596.98
	Shrimp	916.49	Anthozoa	470.42
	Sea star	663.88	Hydrozoa	458.21
	Amphipoda	517.44	Hermit crab	393.91
	Bryozoa	391.39	Bryozoa	345.13
	Hermit crab	372.57	Amphipoda	104.11
	Polychaeta	192.42	Polychaeta	78.42
	Sipunculida	163.14	Nemertea	56.29
Klondike	Brittle star	18,719.92	Brittle star	13,276.31
	Tunicate	4,471.91	Tunicate	1,366.89
	Crab	2,971.83	Crab	1,363.97
	Gastropod	1,633.15	Shrimp	1,345.38
	Hermit crab	1,626.71	Sponge	827.08
	Basket star	1,471.96	Gastropod	752.02
	Shrimp	1,356.29	Sea star	676.82
	Sea urchin	984.63	Sea cucumber	673.47
	Sea star	901.76	Hermit crab	438.04
	Bivalve	831.37	Anthozoa	354.75
	Anthozoa	505.42	Sea urchin	304.94
	Sea cucumber	426.40	Basket star	156.45
	Bryozoa	77.65	Barnacle	91.94
	Amphipoda	63.15	Bivalve	57.73
	Chiton	32.71	Bryozoa	57.04

Multivariate analysis of epifaunal biomass indicated somewhat different communities between the Burger and Klondike survey areas. The nMDS ordination largely separated the stations into their respective survey area with minor mixing between areas (Fig. 8). The two cruises clustered within their respective areas as well, indicating little seasonal difference between the cruises in 2009. Specifically, Klondike stations sampled during cruise WW0902 and WW0904 clustered together and separate from the Burger stations sampled during each cruise. Overall, the stations sampled in Burger clustered tightly together at about 41% similarity while the Klondike stations were more spread out and grouped at 26% similarity (Table 13).

Using the SIMPER analytical routine in PRIMER (Clarke and Gorley, 2006), the organisms contributing to the separation of the survey areas were identified. Ranking of the average biomass of faunal components by their differential contribution to the similarity between the Burger and Klondike survey areas demonstrated that brittle stars, shrimp, gastropods, bivalves, and tunicates largely define the epifauna of the two areas (Table 13). The fauna contributing to differences between the areas were largely the higher biomass of brittle stars, sea cucumbers, and basket stars at Burger and higher biomass of tunicates, hermit crabs, and shrimp at Klondike (Table 14).

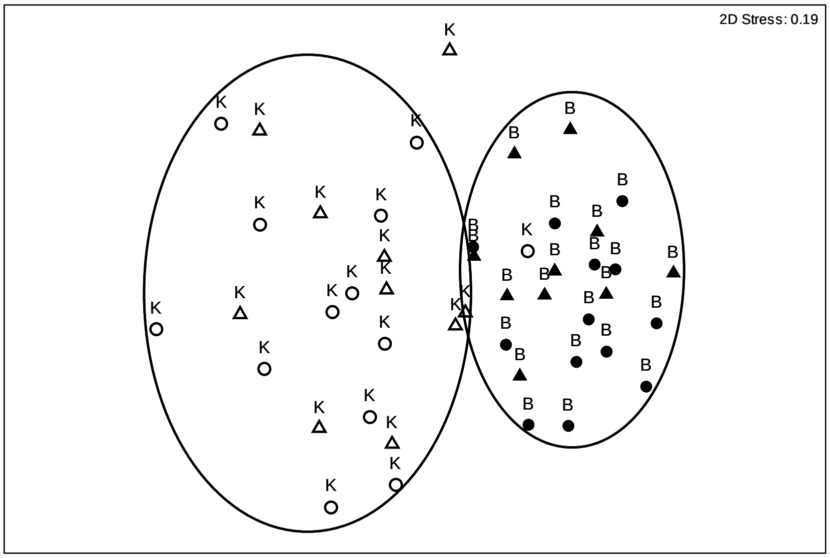

Figure 8. Nonmetric multidimensional scaling ordination plot of Bray-Curtis similarities based on log(X+1)-transformed biomass data of epifaunal invertebrates from the Burger and Klondike survey areas, 2009 CSESP. Open symbols indicate Klondike (K), filled symbols Burger (B), triangles indicate stations sampled in August (WW0902) and circles in October (WW0904).

Table 13. Epifaunal taxa contributing most to within survey area and cruise similarity (Sim). ln Biom = average ln(biomass+1) in g 1000^{-1} m^{-2}, Sim = average similarity, % Contr. = % contribution to similarity, and Cum. % = cumulative percent contribution. Stations for each area are those included in Figure 8.

WWW0902 Burger: Average similarity: 47.45

Taxon	ln Biom	Sim	% Contr.	Cum. %
Brittle star	69,293.01	35.20	74.19	74.19
Bivalve	4,447.86	2.85	6.01	80.19
Gastropod	4,031.16	2.84	5.99	86.19
Crab	5,667.45	2.71	5.71	91.89

Table 13. Continued.

WWW0902 Klondike: Average similarity: 21.99

Taxon	ln Biom	Sim	% Contr.	Cum. %
Crab	2,971.83	4.19	19.05	19.05
Tunicates	4,471.91	4.03	18.33	37.38
Sea star	901.76	2.80	12.72	50.10
Shrimp	1,356.29	2.65	12.05	62.15
Hermit crab	1,626.71	2.28	10.36	72.51

WWW0904 Burger: Average similarity: 37.95

Taxon	ln Biom	Sim	% Contr.	Cum. %
Brittle star	39,810.13	28.85	76.02	76.02
Crab	3,075.57	1.95	5.13	81.15
Sea cucumber	2,489.68	1.69	4.45	85.60
Gastropod	1,840.20	1.27	3.35	88.95
Shrimp	860.35	1.21	3.20	92.14

WWW0904 Klondike: Average similarity: 27.65

Taxon	ln Biom	Sim	% Contr.	Cum. %
Crab	1,363.97	7.55	27.29	27.29
Shrimp	1,345.38	5.61	20.29	47.58
Tunicates	1,366.89	3.87	14.00	61.58
Sea star	676.82	3.43	12.41	73.99
Hermit crab	438.04	2.22	8.03	82.02

Table 14. Epifaunal taxa contributing most to between survey area and cruise dissimilarity (Diss). ln Biom = average ln(biomass+1) in g 1000^{-1} m^{-2}, Diss = average dissimilarity, % Contr. = % contribution to (dis)similarity, and Cum. % = cumulative percent contribution. Stations for each area are those included in Figure 8.

WWW0902 Burger & Klondike: Average dissimilarity: 79.83

Taxon	Burger ln Biom	Klondike ln Biom	Diss	% Contr.	Cum. %
Brittle star	69,293.01	18,719.92	48.71	61.02	61.02
Sea cucumber	7,366.03	426.40	6.72	8.42	69.44
Tunicates	1,173.72	4,471.91	4.27	5.35	74.79
Crab	5,667.45	2,971.83	4.25	5.32	80.11
Bivalve	4,447.86	831.37	3.65	4.57	84.69

WWW0904 Burger & Klondike: Average dissimilarity: 81.73

Taxon	Burger ln Biom	Klondike ln Biom	Diss	% Contr.	Cum. %
Brittle star	39,810.13	13,276.31	47.70	58.36	58.36
Sea cucumber	2,489.68	673.47	5.19	6.35	64.71
Crab	3,075.57	1,363.97	5.06	6.19	70.90
Basket star	3,382.37	156.45	4.37	5.34	76.24
Tunicates	2.74	1,366.89	3.20	3.92	80.16

WWW0902 Burger & WWW0904 Klondike: 83.41

Taxon	WW0902 Burger ln Biom	WW0904 Klondike ln Biom	Diss	% Contr.	Cum. %
Brittle star	69,293.01	13,276.31	53.49	64.13	64.13
Sea cucumber	7,366.03	673.47	7.66	9.18	73.32
Bivalve	4,447.86	57.73	4.65	5.58	78.89
Crab	5,667.45	1,363.97	3.69	4.43	83.32
Gastropod	4,031.16	752.02	3.24	3.89	87.21

WWW0902 Klondike & WWW0904 Burger: Average dissimilarity: 80.81

Taxon	WW0902 Klondike ln Biom	WW0904 Burger ln Biom	Diss	% Contr.	Cum. %
Brittle star	18,719.92	39,810.13	43.76	54.16	54.16
Tunicates	4,471.91	2.74	6.14	7.60	61.75
Crab	2,971.83	3,075.57	5.75	7.12	68.87
Basket star	1,471.96	3,382.37	4.62	5.72	74.59
Sea cucumber	426.40	2,489.68	4.10	5.07	79.66

Evaluation of the 2009 epifaunal abundance and environmental data in the CCA analysis indicated moderate associations with environmental gradients. Stations were separated by survey area with the Burger stations located mostly in the lower left side of the plot and the majority of the Klondike stations located in the upper right, indicating differences in faunal community structure (Fig. 9). Five Klondike stations (two stations from cruise WW0902 and three from WW0904) were spread out in the lower right quadrant. The separation of survey areas was similar to that demonstrated by the nMDS ordination (Fig. 8). Three variables were moderately associated with faunal community structure. The arrow for water depth was long and pointed left indicating a strong negative correlation with the horizontal (CCA1) axis and a weaker correlation with the vertical (CCA2) axis (Table 15 and Fig. 9). Percent sand (Sand) and phaeopigment concentration (Phaeo) were positively correlated with the CCA1 axis while percent sand was positively correlated and phaeopigment concentration negatively correlated with the CCA2 axis. The spread of stations along CCA1, from left to right, reflected an association of the benthic communities with water depth and sediment grain-size such that stations were oriented with deeper and muddier stations positioned in the lower left corner (Burger stations) and shallower, sandier stations in the upper right (Klondike stations) (Fig. 9). The spread of stations in relation to the axes was also associated with phaeopigment concentrations. There were five Klondike stations in the lower right corner of the plot (the shallowest Klondike stations) that were associated with greater phaeopigment concentrations. It is presumed that, at shallower stations, phaeopigments could reach the benthos faster without being consumed in the water column. The strongest correlations of environmental variables were between the CCA1 and water depth (which was negatively correlated to CCA1) and phaeopigment concentration (positively correlated to CCA1) accounting for 14% of overall variability in the ordination (Table 15). The second CCA axis accounted for 20% of total variability but correlations to this axis were weaker, suggesting weaker relationships with fauna.

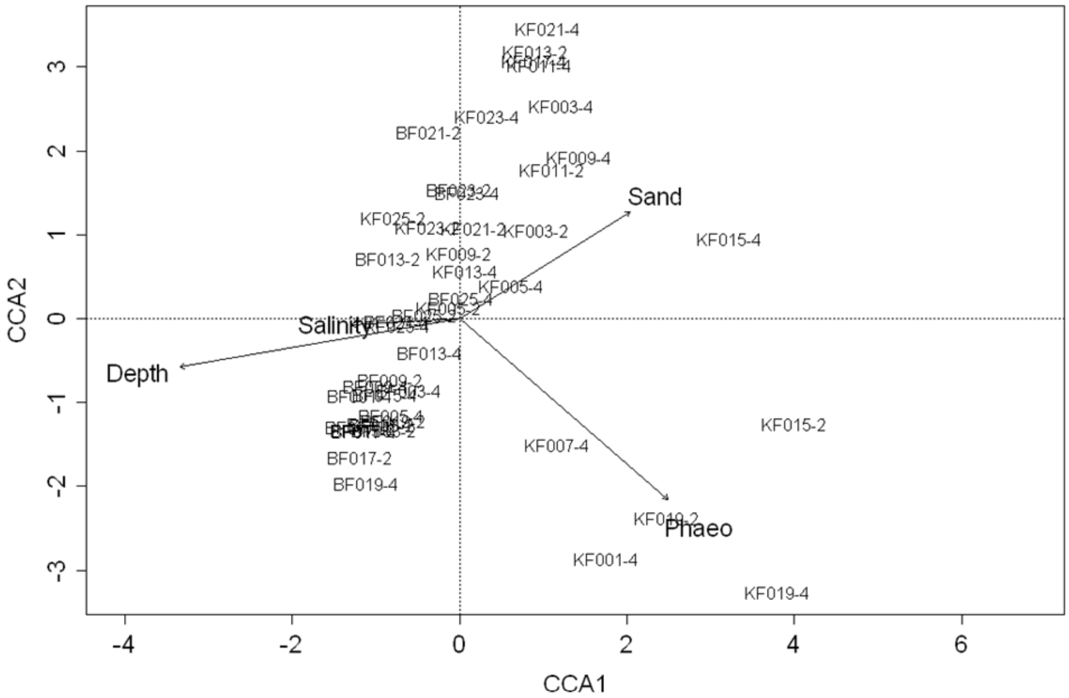

Figure 9. Plot of the first two axes from canonical correspondence analysis (CCA) for log(X+1)-transformed epifaunal abundance data from the 2009 CSESP. Cruise WWW0902 stations are denoted by the -2 and WWW0904 stations are denoted by the -4 after each station number.

Table 15. Summary of correlations between CCA axes and environmental variables for 2009 CSESP. Values in bold highlight moderate correlations between environmental variables and CCA axes. Sign indicates direction of correlation.

CCA Label	Variable	CCA1	CCA2
Sand	% Sand	0.41	0.18
Phaeo	Phaeopigment concentration	**0.57**	-0.44
Depth	Water depth	**-0.75**	-0.03
Salinity	Salinity	-0.29	0.03
	Cumulative % Variance Accounted for	14.3%	19.6%

Kriging plots from geostatistical analyses indicate a general trend of increasing abundance and biomass from the southeast corner of Klondike to the northwest corner of Burger (Fig. 10) during both cruises. Abundance and biomass appeared to be higher in the southeast corner of Burger. The area of sharpest increase of abundance and biomass is probably between the two survey areas, an area that was not sampled during either cruise in 2009.

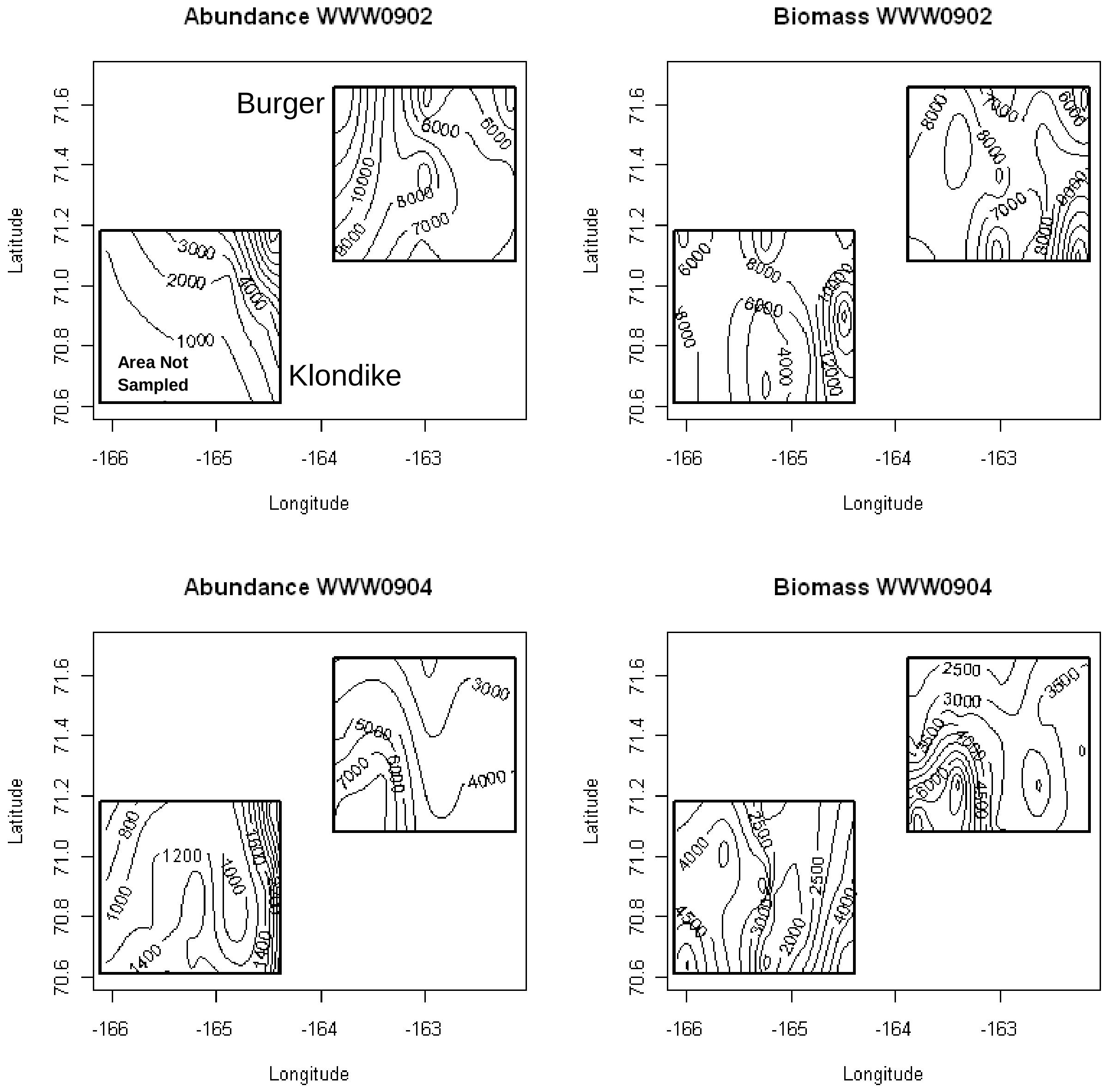

Figure 10. Kriging plots of abundance (ind. 1000^{-1} m^{-2}) and biomass (g m^{-2}) of epifauna during both 2009 CSESP cruises to Burger and Klondike.

DISCUSSION

Benthos of the Burger and Klondike Survey areas

The benthic fauna of Burger and Klondike are diverse, very abundant, and representative of northern Pacific benthic assemblages found throughout the Bering and Chukchi seas (Feder et al., 1994b, 2005, 2007; Blanchard et al., 2010). Water masses of southern origin transport heat, nutrients, carbon, and animals to the Chukchi Sea and Arctic Ocean and are vitally important for maintenance of the ecological structure of the region (Weingartner et al., 2005; Grebmeier et al., 2006; Hopcroft et al., in submission). The high abundance and biomass values of the communities in the survey areas indicate high productivity in the nutrient-rich waters (Grebmeier et al., 2006). As shown in 2008 and 2009, descriptive measures for infauna (abundance, biomass, and number of taxa) were significantly higher at Burger than at Klondike although the faunal assemblages in both survey areas were generally similar (containing most of the same species). This was indicated by the low β diversity values (Table 3) (Blanchard et al., 2010). The differences in the multivariate analyses for infauna between the two survey areas reflected lower abundances and more restricted distributions of animals at Klondike. For the epifauna, averages of biotic measures were not significantly different between the survey areas in 2009, although there were differences in types of organisms found in each survey area. As with infauna, most epifaunal species were common to both Burger and Klondike.

Associations of Fauna with Environmental Characteristics

Feder et al. (1994b) reported high infaunal abundance and biomass in the northeastern Chukchi Sea including at stations adjacent to our study areas. Factors associated with the structure and abundance of infaunal communities in the northeastern Chukchi Sea include sediment grain-size, sediment organic carbon concentrations, and the nutrient rich waters (Feder et al., 1994b; Grebmeier et al., 2006). The physical variables examined are not the only driving factors for benthic community structure as they reflect the broader environmental characteristics and gradients in the study area. Gradients include changes in physical dynamics with distance offshore and water depth, differences in organic carbon (food) sources, and nutrient availability (Lenihan and Micheli, 2001; Grebmeier et al., 2006; Cusson et al., 2007; Bluhm and Gradinger, 2008). In the present study, differences in benthic community structure are associated with sediment grain-size, phaeopigment concentration, and salinity, which again, reflect the natural influence of larger physical processes on biological production (Hopcroft et al., 2009; in preparation; Weingartner 2009, 2010).

Faunal composition in the whale feeding area was different from that in Burger and Klondike. The whale feeding area were deeper and sandier reflecting differences most likely associated with coastal currents. The physical characteristics in this area (presumably under the Alaska Coastal Current) are presently not well defined although they are reflected by the dominance of amphipods (particularly *Byblis* sp.) instead of the bivalves and polychaete worms, both of which were more abundant in Burger and Klondike. Amphipods are a preferred prey of gray whales in the northern Bering and Chukchi seas (Highsmith and Coyle, 1992; Highsmith et al., 2006; Bluhm and Gradinger, 2008). Such an abundance of amphipods were not found in Burger and Klondike in either 2008 or 2009 (Blanchard et al., 2010).

Factors associated with the distributions and community structures of epifauna in the Chukchi Sea are inadequately known. Feder et al. (2005) related distributions of epifauna of the southeastern Chukchi Sea to varying environmental characteristics including water masses (Alaska Coastal vs. Bering Shelf/Anydyr water) and associated nutrient concentrations. Feder et al. (1994a) reported higher abundance of epifaunal mollusks to also be associated with water mass characteristics in the northeastern Chukchi Sea. Bluhm et al. (2009) found little correlation between epifaunal community structure and measured environmental variables in the broader Chukchi Sea although their sample size was small and sampling locations were not inclusive of all habitats and gradients. A limitation of the past studies may be that epifaunal communities demonstrate high local and regional variability and sampling programs were not designed to sample along environmental gradients. With appropriate designs for sampling gradients, as in the epifaunal surveys undertaken in the CSESP, it is possible to demonstrate strong correlations of biota with environmental gradients in the northern Chukchi Sea. The associations of epifaunal community structure and percent sand, water depth, and phaeopigment concentration reflect the significant influence that general physical processes have on biological communities in the northeastern Chukchi Sea.

Temporal comparisons

The faunal communities found in the northeastern Chukchi Sea in 1986 and those sampled in 2008 and 2009 are very similar. The multivariate analyses and faunal rankings demonstrate that the faunal communities of 1986 separate into a few multivariate groups, which, in our study, are related to distance from shore (under the nearshore, Alaska Coastal Current vs. offshore). The environmental factors associated with the ACW/offshore categories of the 1986 dataset were identified as sediment grain-size characteristics and sediment organic carbon reflecting the changing physical environment with greater distance offshore (Feder et al., 1994b). The offshore groupings reported by Feder et al. (1994b) were similar to those found in the Burger and Klondike survey areas in 2008 and 2009, and were dominated by similar fauna. One cluster of ACW stations sampled in 1986 was grouped closely to the whale feeding stations sampled in 2009. Amphipods were abundant in the ACW stations of 1986 and the whale feeding stations of 2009. The species composition of amphipods found in 1986 was different that found in 2009 but the difference most likely represents the spatial variability of amphipod communities, rather than a temporal change. Specific sites known to be hot spots for whale feeding were not sampled in 1986 so a direct comparison to this study can not be made.

Although there have been suggestions of ecologically-significant environmental changes affecting faunal communities of the Chukchi Sea over the last few decades (Sirenko and Kolutin, 1992), the data that we analyzed for infauna from 1986, 2008, and 2009 indicate that such changes have not had an impact on the benthos in our study area. The communities found at Burger and Klondike in 2008 and 2009 were comparable to offshore areas of the northeastern Chukchi Sea in 1986.

CONCLUSIONS

Benthic communities in the Burger and Klondike survey areas reflected the high production in the nutrient-rich water and short food chains in the relatively shallow water of the Chukchi Sea (Grebmeier et al., 2006). Although infaunal abundance, biomass, and number of taxa per station were higher in Burger than in Klondike, the assemblages at both survey areas were generally similar (containing most of the same species). Similary, epifauna were abundant, the epifaunal communities were diverse, and most species were present in both survey areas. Both the infaunal and epifaunal communities sampled in 2009 demonstrated differences (though not always statistically significant) between the two study areas. Environmental gradients in our study area were moderate in 2008 and 2009 and driven by a number of factors co-varying with sediment grain-size, salinity, and phaeopigment concentrations. Environmental gradients were moderately associated with trends in benthic community structure. The infaunal assemblages of 2008 and 2009 were characteristic of species found throughout the Bering and Chukchi seas and were similar to those found in 1986 in the northeastern Chukchi Sea by Feder (1994 a, b, 2005, 2007). The infaunal community at the whale feeding sites was dominated by ampeliscid amphipods (the preferred food resource of gray whales).

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Appendix I

Ranking of Infauna by Abundance and Biomass for each Station for the 2009 Chukchi Sea Environmental Studies Program

Table AI. Ranking of top five infaunal taxa by abundance (ind. m^{-2}) and biomass (g m^{-2}) for fixed and random stations sampled in the Chukchi Sea, 2009.

Station	Taxon	Abundance	Taxon	Biomass
BF001	Ostracoda	507	*Astarte borealis*	55.11
	Paraphoxus sp.	263	*Axiothella catenata*	26.51
	Brachydiastylis resima	203	*Maldane glebifex*	21.26
	Praxillella praetermissa	180	*Cyclocardia crebricostata*	15.32
	Maldane glebifex	87	*Astarte montagui*	13.76
	Photis sp.	87		
BF003	*Maldane glebifex*	130	*Golfingia margaritacea*	90.01
	Paraphoxus sp.	120	*Maldane glebifex*	50.20
	Ennucula tenuis	117	*Astarte borealis*	44.79
	Ostracoda	110	*Cyclocardia crebricostata*	19.57
	Lumbrineris sp.	100	*Macoma calcarea*	16.65
	Leitoscoloplos pugettensis	100		
BF005	*Brachydiastylis resima*	233	*Astarte borealis*	134.51
	Photis sp.	193	*Macoma calcarea*	63.74
	Cirratulidae	147	*Yoldia myalis*	22.16
	Ennucula tenuis	137	*Ennucula tenuis*	19.54
	Praxillella praetermissa	107	*Axiothella catenata*	15.54
BF007	Ostracoda	583	*Astarte borealis*	42.48
	Brachydiastylis resima	320	*Ennucula tenuis*	21.75
	Pontoporeia femorata	300	*Axiothella catenata*	13.45
	Ennucula tenuis	207	*Terebellides stroemi*	13.08
	Ampharete acutifrons	77	*Lumbrineris fragilis*	12.65
BF009	*Maldane glebifex*	687	*Astarte borealis*	45.72
	Ostracoda	557	*Ennucula tenuis*	26.49
	Photis sp.	450	*Yoldia myalis*	25.16
	Ennucula tenuis	337	*Lumbrineris fragilis*	19.18
	Brachydiastylis resima	250	*Astarte montagui*	17.49
BF011	Ostracoda	400	*Ampelisca eschrichti*	33.92
	Ampelisca eschrichti	170	*Euspira pallida*	13.31
	Ennucula tenuis	123	*Ennucula tenuis*	13.27
	Brachydiastylis resima	83	*Lumbrineris fragilis*	6.31
	Praxillella praetermissa	83	*Yoldia myalis*	5.95
	Paraphoxus sp.	70		

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
BF013	*Maldane glebifex*	6840	*Maldane glebifex*	101.42
	Anonyx sp.	1437	*Ennucula tenuis*	43.31
	Ostracoda	1003	*Astarte montagui*	25.48
	Orchomene sp.	527	*Lumbrineris fragilis*	10.41
	Brachydiastylis resima	387	*Anonyx* sp.	8.73
BF015	*Ennucula tenuis*	560	*Macoma calcarea*	137.65
	Brachydiastylis resima	523	*Ennucula tenuis*	70.69
	Ostracoda	420	*Astarte borealis*	49.60
	Lumbrineris sp.	163	*Terebellides stroemi*	14.70
	Leitoscoloplos pugettensis	163	*Maldane glebifex*	8.82
	Paraphoxus sp.	147		
BF017	*Paraphoxus* sp.	407	*Astarte borealis*	173.19
	Lumbrineris sp.	197	*Musculus niger*	41.11
	Prionospio steenstrupi	133	*Macoma calcarea*	29.30
	Leitoscoloplos pugettensis	130	*Astarte montagui*	20.82
	Owenia fusiformis	110	*Ennucula tenuis*	19.18
	Terebellides stroemi	110		
BF019	*Maldane glebifex*	1957	*Macoma calcarea*	118.43
	Myriochele heeri	767	*Maldane glebifex*	58.38
	Lumbrineris sp.	380	*Ennucula tenuis*	43.74
	Owenia fusiformis	350	*Macoma* sp.	15.03
	Paraphoxus sp.	300	*Euspira pallida*	9.80
BF021	*Prionospio steenstrupi*	217	*Ennucula tenuis*	37.66
	Leitoscoloplos pugettensis	217	*Maldane glebifex*	34.15
	Paraphoxus sp.	157	*Onuphis parva*	7.35
	Lumbrineris sp.	143	Rhynchocoela	6.85
	Ennucula tenuis	127	*Macoma moesta*	6.80
	Cossura sp.	93		
	Cirratulidae	93		
BF023	Cirratulidae	880	*Astarte borealis*	84.75
	Lumbrineris sp.	273	*Macoma calcarea*	79.92
	Leitoscoloplos pugettensis	263	*Priapulus caudatus*	51.32
	Prionospio steenstrupi	157	*Macoma moesta*	28.03
	Ennucula tenuis	140	*Ennucula tenuis*	21.68

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
BF025	Cirratulidae	380	*Macoma calcarea*	239.45
	Macoma calcarea	257	*Nephtys paradoxa*	38.96
	Lumbrineris sp.	220	*Macoma moesta*	24.40
	Prionospio steenstrupi	117	*Yoldia myalis*	11.45
	Leitoscoloplos pugettensis	110	*Ennucula tenuis*	10.59
BR005	*Leitoscoloplos pugettensis*	357	*Astarte borealis*	302.98
	Cirratulidae	313	*Astarte montagui*	63.55
	Paraphoxus sp.	290	*Cyclocardia crebricostata*	62.83
	Lumbrineris sp.	290	*Yoldia myalis*	46.55
	Byblis sp.	237	*Golfingia vulgaris*	19.80
	Cossura sp.	170		
BR016	*Leitoscoloplos pugettensis*	420	*Macoma calcarea*	64.48
	Cirratulidae	347	*Ennucula tenuis*	63.95
	Lumbrineris sp.	230	*Macoma moesta*	35.66
	Ennucula tenuis	230	*Astarte borealis*	29.05
	Paraphoxus sp.	140	*Maldane glebifex*	9.01
	Yoldia sp.	140		
	Byblis sp.	120		
BR020	*Lumbrineris* sp.	243	*Macoma calcarea*	160.41
	Byblis sp.	230	*Ennucula tenuis*	36.75
	Cirratulidae	210	*Macoma moesta*	13.55
	Ennucula tenuis	133	*Yoldia myalis*	9.83
	Macoma calcarea	103	*Maldane glebifex*	8.33
BR032	*Paraphoxus* sp.	280	*Astarte borealis*	91.43
	Leitoscoloplos pugettensis	257	*Golfingia margaritacea*	58.50
	Lumbrineris sp.	207	*Macoma calcarea*	33.80
	Cossura sp.	153	*Ennucula tenuis*	32.24
	Ennucula tenuis	147	*Cyclocardia crebricostata*	32.21
BR038	*Maldane glebifex*	637	*Macoma calcarea*	116.53
	Myriochele heeri	510	*Ennucula tenuis*	97.62
	Ennucula tenuis	287	*Maldane glebifex*	34.65
	Leitoscoloplos pugettensis	277	*Liocyma fluctuosa*	11.98
	Lumbrineris sp.	240	*Terebellides stroemi*	6.21

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
BR043	*Maldane glebifex*	4493	*Maldane glebifex*	88.47
	Ostracoda	657	*Golfingia vulgaris*	77.93
	Brachydiastylis resima	270	*Ennucula tenuis*	25.88
	Pontoporeia femorata	220	*Macoma moesta*	14.16
	Ennucula tenuis	213	*Lumbrineris fragilis*	13.95
BR047	*Maldane glebifex*	3303	*Macoma calcarea*	78.49
	Ostracoda	667	*Maldane glebifex*	65.85
	Prionospio steenstrupi	437	*Ennucula tenuis*	56.06
	Paraphoxus sp.	343	*Euspira pallida*	29.11
	Leitoscoloplos pugettensis	337	*Cyclocardia crebricostata*	26.01
BR077	Ostracoda	753	*Astarte borealis*	38.60
	Ennucula tenuis	267	*Astarte montagui*	21.68
	Dyopedos arcticus	193	*Maldane glebifex*	21.16
	Brachydiastylis resima	187	*Ennucula tenuis*	18.18
	Paraphoxus sp.	163	*Nephtys paradoxa*	12.90
BR080	*Photis* sp.	1910	*Cyclocardia crebricostata*	16.86
	Ostracoda	633	*Maldane glebifex*	15.39
	Maldane glebifex	393	*Liocyma fluctuosa*	12.21
	Brachydiastylis resima	297	*Ennucula tenuis*	12.16
	Ennucula tenuis	277	*Lumbrineris* sp.	3.62
BR086	*Paraphoxus* sp.	230	*Golfingia margaritacea*	87.16
	Ennucula tenuis	130	*Astarte borealis*	50.08
	Ostracoda	127	*Maldane glebifex*	26.00
	Maldane glebifex	103	*Astarte montagui*	21.55
	Lumbrineris sp.	103	*Ennucula tenuis*	20.03
	Ampharete acutifrons	97		
BR093	*Ennucula tenuis*	233	*Astarte borealis*	70.53
	Ostracoda	227	*Golfingia margaritacea*	47.72
	Paraphoxus sp.	153	*Maldane glebifex*	46.27
	Brachydiastylis resima	150	*Ennucula tenuis*	19.05
	Maldane glebifex	97	*Praxillella gracilis*	9.59
BR098	*Photis* sp.	200	*Astarte borealis*	85.20
	Ostracoda	177	*Maldane glebifex*	27.14
	Brachydiastylis resima	143	*Axiothella catenata*	23.76
	Paraphoxus sp.	143	*Astarte montagui*	13.39
	Lumbrineris sp.	117	*Terebellides stroemi*	7.78
	Maldane glebifex	103		

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
BR099	*Photis* sp.	2140	*Astarte borealis*	193.40
	Ostracoda	213	*Nephtys punctata*	31.96
	Brachydiastylis resima	197	*Maldane glebifex*	21.88
	Paraphoxus sp.	187	*Yoldia myalis*	19.28
	Praxillella praetermissa	153	*Astarte montagui*	15.63
KF001	*Maldane glebifex*	93	*Hyas coarctatus*	33.73
	Cirratulidae	87	*Proclea emmi*	7.03
	Lepeta caeca	60	*Boltenia villosa*	6.19
	Ennucula tenuis	57	*Maldane glebifex*	4.90
	Paraphoxus sp.	40	*Yoldia myalis*	3.28
KF003	*Ennucula tenuis*	107	*Maldane glebifex*	30.10
	Maldane glebifex	83	*Macoma calcarea*	21.48
	Cirratulidae	47	*Praxillella praetermissa*	4.91
	Barantolla americana	40	*Proclea emmi*	2.23
	Praxillella praetermissa	37	*Ampelisca eschrichti*	1.61
KF005	*Ennucula tenuis*	160	*Maldane glebifex*	36.64
	Maldane glebifex	103	*Astarte montagui*	13.86
	Cirratulidae	57	Rhynchocoela	11.49
	Cossura sp.	50	*Ennucula tenuis*	8.30
	Bathymedon sp.	43	*Nephtys punctata*	3.18
KF007	*Ennucula tenuis*	173	*Astarte montagui*	28.51
	Cirratulidae	103	*Nicomache lumbricalis*	24.91
	Barantolla americana	90	*Maldane glebifex*	14.88
	Capitellidae	87	*Axiothella catenata*	10.53
	Maldane glebifex	60	*Ennucula tenuis*	6.69
KF009	*Maldane glebifex*	67	*Maldane glebifex*	22.45
	Ennucula tenuis	60	*Lumbrineris fragilis*	5.88
	Praxillella praetermissa	40	*Nephtys paradoxa*	4.66
	Bathymedon sp.	33	*Axiothella catenata*	2.68
	Monoculodes sp., Cirratulidae	30	*Macoma* sp.	2.63

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
KF011	*Ennucula tenuis*	67	*Euspira pallida*	9.84
	Cirratulidae	27	*Nephtys* sp.	8.15
	Nephtys punctata	23	*Astarte montagui*	6.21
	Barantolla americana	16	*Maldane glebifex*	6.16
	Maldane glebifex	16	*Macoma calcarea*	5.37
	Magelona longicornis, *Euspira pallida*	10		
KF013	*Ennucula tenuis*	117	*Euspira pallida*	49.80
	Maldane glebifex	57	*Golfingia vulgaris*	41.05
	Anonyx sp.	53	*Maldane glebifex*	16.59
	Cirratulidae	47	*Axiothella* sp.	15.16
	Praxillella praetermissa	40	*Chone mollis*	15.06
KF015	*Cistenides granulata*	70	*Macoma calcarea*	11.71
	Ennucula tenuis	67	*Liocyma fluctuosa*	6.22
	Protomedeia sp.	53	*Anonyx* sp.	5.58
	Axinopsida serricata	53	*Nephtys punctata*	3.50
	Bathymedon sp.	37	*Solariella obscura*	2.81
	Byblis sp.	37		
	Leitoscoloplos pugettensis	33		
KF017	*Ennucula tenuis*	87	*Macoma calcarea*	6.30
	Bathymedon sp.	67	*Maldane glebifex*	5.95
	Cistenides granulata	50	*Nuculana pernula*	4.00
	Polycirrus sp.	27	*Ennucula tenuis*	2.23
	Retusa obtusa	23	*Periploma aleuticum*	2.18
	Cirratulidae	23		
KF019	Cirratulidae	413	*Serripes laperousii*	81.13
	Leitoscoloplos pugettensis	200	*Astarte montagui*	17.34
	Polydora sp.	187	*Anonyx* sp.	6.60
	Capitellidae	160	*Nephtys paradoxa*	5.85
	Bathymedon sp.	130	*Nephtys punctata*	3.98
KF021	*Nuculana pernula*	90	*Nuculana pernula*	82.28
	Ennucula tenuis	73	*Axiothella catenata*	9.03
	Sternaspis fossor	63	*Sternaspis fossor*	3.57
	Cirratulidae	43	*Yoldia myalis*	1.95
	Bathymedon sp.	30	*Nephtys punctata*	1.68

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
KF023	*Ennucula tenuis*	150	*Golfingia margaritacea*	62.69
	Sternaspis fossor	53	*Maldane glebifex*	22.76
	Maldane glebifex	53	*Axiothella catenata*	14.94
	Thyasira flexuosa	47	*Yoldia myalis*	13.91
	Praxillella praetermissa	40	*Ennucula tenuis*	11.68
	Arcteobia anticostiensis	33		
KF025	*Ennucula tenuis*	143	*Astarte borealis*	49.14
	Paraphoxus sp.	127	*Maldane glebifex*	38.65
	Maldane glebifex	90	*Axiothella catenata*	23.00
	Ostracoda	73	*Praxillella gracilis*	15.28
	Cossura sp.	63	*Astarte montagui*	7.84
KR001	*Nuculana pernula*	87	*Nuculana pernula*	84.13
	Ennucula tenuis	77	*Maldane glebifex*	11.45
	Sternaspis fossor	63	*Ampelisca eschrichti*	2.59
	Cirratulidae	37	*Sternaspis fossor*	2.18
	Bathymedon sp.	20	*Solariella obscura*	1.33
KR007	*Ennucula tenuis*	97	*Astarte borealis*	48.22
	Maldane glebifex	53	*Maldane glebifex*	28.63
	Cirratulidae	40	*Yoldia myalis*	20.44
	Sternaspis fossor	37	*Axiothella* sp.	14.53
	Praxillella praetermissa	33	*Euspira pallida*	13.94
KR008	*Cossura* sp.	130	*Priapulus caudatus*	33.80
	Cirratulidae	127	*Astarte borealis*	29.93
	Ennucula tenuis	103	*Axiothella catenata*	29.63
	Leitoscoloplos pugettensis	73	*Maldane glebifex*	16.06
	Maldane glebifex	73	*Astarte montagui*	13.35
	Paraphoxus sp.	73		
	Melita sp., *Leucon nasica*, *Polycirrus* sp.	60		
KR009	*Praxillella praetermissa*	1320	*Astarte borealis*	70.71
	Paraphoxus sp.	120	*Golfingia vulgaris*	55.32
	Capitellidae	97	*Maldane glebifex*	30.45
	Maldane glebifex	93	*Neoamphitrite groenlandica*	10.84
	Phascolion strombi	70	*Axiothella catenata*	9.33

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
KR016	*Ennucula tenuis*	177	*Maldane glebifex*	26.89
	Barantolla americana	67	*Periploma aleuticum*	12.47
	Maldane glebifex	47	*Yoldia myalis*	9.03
	Cirratulidae	37	*Ennucula tenuis*	8.34
	Praxillella praetermissa	33	*Macoma calcarea*	1.95
KR019	*Maldane glebifex*	97	*Musculus niger*	46.65
	Ennucula tenuis	57	*Maldane glebifex*	42.94
	Capitellidae, Cirratulidae, *Cylichna alba*	33	*Axiothella catenata*	16.11
	Ostracoda	27	*Axiothella* sp.	3.72
	Thyasira flexuosa	23	*Sternaspis fossor*	2.46
KR034	*Praxillella praetermissa*	60	*Nephtys punctata*	9.55
	Retusa obtusa	50	*Maldane glebifex*	8.64
	Thyasira flexuosa, *Maldane glebifex*	40	*Macoma calcarea*	7.63
	Sternaspis fossor	37	*Axiothella* sp.	5.81
	Cistenides granulata, *Bathymedon* sp.	33	*Praxillella praetermissa*	3.17
KR043	*Ennucula tenuis*	157	*Praxillella praetermissa*	5.00
	Melita sp.	100	*Ennucula tenuis*	4.08
	Harpinia kubjakovae	47	*Nuculana pernula*	3.89
	Thyasira flexuosa	40	*Sternaspis fossor*	3.06
	Nuculana sp.	37	*Nephtys punctata*	2.99
KR045	*Ennucula tenuis*	123	*Macoma calcarea*	12.04
	Praxillella praetermissa	40	*Maldane glebifex*	10.21
	Retusa obtusa	30	*Nephtys paradoxa*	9.70
	Maldane glebifex	23	*Neoamphitrite groenlandica*	9.11
	Barantolla americana	23	Rhynchocoela	4.25
	Arcteobia anticostiensis	20		
	Cirratulidae	20		
KR056	*Ennucula tenuis*	200	*Maldane glebifex*	12.04
	Barantolla americana	47	*Ennucula tenuis*	9.25
	Byblis sp.	37	*Nuculana pernula*	3.63
	Praxillella praetermissa	37	*Nephtys punctata*	2.31
	Maldane glebifex	33	*Praxillella praetermissa*	1.75
	Cirratulidae	27		
	Leucon nasica	27		

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
KR066	*Ennucula tenuis*	167	*Maldane glebifex*	15.86
	Cirratulidae	60	Rhynchocoela	11.24
	Byblis sp.	50	*Axiothella catenata*	9.59
	Bathymedon sp.	40	*Ennucula tenuis*	9.32
	Arcteobia anticostiensis	37	*Nuculana pernula*	7.15
KR083	*Ennucula tenuis*	157	*Chlamys behringiana*	179.93
	Cirratulidae	73	*Macoma calcarea*	10.83
	Phascolion strombi	67	*Maldane glebifex*	8.69
	Maldane glebifex	47	*Nicomache lumbricalis*	6.55
	Orchomene sp.	37	*Ennucula tenuis*	6.54
KR095	*Ennucula tenuis*	70	*Nuculana pernula*	40.71
	Cirratulidae	40	*Euspira pallida*	37.28
	Bathymedon sp., *Nuculana pernula*, *Leucon nasica*	37	*Maldane glebifex*	9.28
	Barantolla americana	30	*Axiothella catenata*	8.12
	Sternaspis fossor	27	*Anaitides groenlandica*	7.82
TM001	Cirratulidae	530	*Astarte borealis*	66.72
	Ennucula tenuis	227	*Nicomache lumbricalis*	18.57
	Phascolion strombi	200	*Priapulus caudatus*	18.49
	Synidotea bicuspida	160	*Ophiopenia tetracantha*	10.04
	Ophiopenia tetracantha	133	*Cistenides granulata*	9.77
TM002	*Byblis* sp.	5880	*Byblis* sp.	84.24
	Protomedeia sp.	1277	*Byblis pearcyi*	10.39
	Ischyrocerus sp.	937	*Protomedeia* sp.	5.52
	Golfingia sp.	180	*Lumbrineris* sp.	3.82
	Corophidae	170	*Nephtys caeca*	3.73
TM003	*Byblis* sp.	7867	*Byblis* sp.	89.79
	Protomedeia sp.	2360	*Astarte borealis*	22.82
	Ischyrocerus sp.	817	*Nephtys caeca*	14.49
	Golfingia sp.	260	*Byblis pearcyi*	11.05
	Corophium sp.	250	*Astarte montagui*	10.79
TM004	*Byblis* sp.	2510	*Balanus rostratus*	101.93
	Cirratulidae	667	*Nephtys caeca*	40.03
	Ischyrocerus sp.	483	*Byblis* sp.	23.74
	Protomedeia sp.	280	*Byblis pearcyi*	15.43
	Byblis pearcyi	220	*Nephtys* sp.	7.47

Table AI. Continued.

Station	Taxon	Abundance	Taxon	Biomass
TM005	*Byblis* sp.	2890	*Clinocardium ciliatum*	38.10
	Ischyrocerus sp.	1010	*Byblis* sp.	18.64
	Photis sp.	285	*Chone mollis*	14.74
	Chone mollis	255	*Byblis pearcyi*	12.93
	Byblis pearcyi	145	*Astarte montagui*	8.80
TM006	Cirratulidae	653	*Ophiopenia tetracantha*	36.10
	Ophiopenia tetracantha	477	*Astarte* sp.	14.58
	Synidotea bicuspida	457	*Synidotea bicuspida*	11.61
	Ampharete acutifrons	120	*Astarte montagui*	6.46
	Capitellidae	117	*Nicomache lumbricalis*	4.87

Appendix II

List of epifaunal taxa collected during the 2009 CSESP
(Taxon in bold were classifications used in the field)

CNIDARIA
- **Anthozoa**
  - Actiniaria (possibly 3 additional species)
    - ***Stomphia* sp.**
  - **Gersemia rubiformis**
- **Hydrozoa (aka "Colonial organisms")**
  - *Abietinaria* sp.
  - *Lafoeina maxima*

BRYOZOA (aka "Colonial organisms")
- Alcyonidiidae
  - ***Alcyonidium* spp.**
  - *Alcyonidium gelatinosum*
  - *Alcyonidium vermiculare*
- Vesiculariidae
  - *Bowerbankia composita*
- Bugulidae
  - *Dendrobeania* sp.
- Scrupariidae
  - *Eucratea loricata*

BRYOZOA – upright
BRYOZOA – encrusting
BRYOZOA – foliose

RHYNCHOCOELA

PLATYHELMINTHES
- **Turbellaria**

CRUSTACEA
- **Amphipoda**
  - Ampeliscidae
    - ***Ampelisca* spp.**
    - *Ampelisca eschrichti*
    - *Haploops laevis*
  - Uristidae
    - ***Anonyx nugax***
  - Oedicerotidae
    - *Bathymedon* sp.
    - *Monoculodes* sp.
  - Caprellidae
    - *Caprella* sp.
  - Podoceridae
    - *Dyopedos arcticus*
  - Lysianassidae
    - *Hippomedon* sp.

        - *Orchomene* sp.
    - Ischyroceridae
        - *Ischyrocerus* sp.
    - Melitidae
        - *Melita* sp.
    - Epimeriidae
        - ***Paramphithoe polyacantha***
    - Phoxocephalidae
        - *Paraphoxus* sp.
    - Isaeidae
        - *Photis* sp.
        - *Protomedeia* sp.
    - Pleustidae (possibly 2 species)
    - Pontoporeiidae
        - *Pontoporeia femorata*
    - Eusiridae
        - *Rhachotropis aculeata*
        - cf. *Rhachotropis oculata*
    - Stegocephalidae
        - *Stegocephalopsis ampulla*
        - ***Stegocephalus inflatus***
    - Hyperiidae
        - *Themisto libellula*
    - Stenothoidae
- Amphipoda (juveniles)
- **Isopoda**
    - Idoteidae
        - ***Synidotea* spp.**
        - *Synidotea bicuspida*
        - *Synidotea muricata*
- **Caridea**
    - Crangonidae
        - *Argis* sp.
        - ***Argis lar***
        - *Crangon communis*
        - *Crangon dalli*
        - *Sabinea septemcarinata*
        - *Sclerocrangon boreas*
    - Hippolytidae
        - *Eualus* spp.
        - *Eualus fabricii*
        - *Eualus gaimardii*
        - *Eualus macrophthalmus*
        - *Eualus suckleyi*
        - *Spirontocaris arcuata*
        - *Spirontocaris lamellicornis*

Pandalidae
    Pandalopsis spp.
    Pandalopsis ampla
    Pandalopsis dispar
Cumacea
  Diastyliidae
    Brachydiastylis resima
    Diastylis bidentata
  Leuconiidae
    Leucon nasica
Balanomorpha
  Balanidae
    ***Balanus* spp.**
    Balanus crenatus
    Balanus glandula
Anomura
  Paguridae
    Labidochirus splendescens
    ***Pagurus* spp.**
    Pagurus rathbuni
    Pagurus trigonocheirus
    Pagurus capillatus
Decapoda
  Oregoniidae
    Chionoecetes opilio
    Hyas coarctatus
Ostracoda
Tanaidacea

MOLLUSCA
  Bivalvia
    Astartidae
      ***Astarte* spp.**
      Astarte borealis
      Astarte montagui
    Pectinidae
      ***Chlamys* spp.**
      Chlamys behringiana
      Chlamys rubida
    Cardiidae
      Clinocardium ciliatum
      Serripes sp.
      Serripes groenlandicus
    Carditidae
      ***Cyclocardia* spp.**
      cf. *Cyclocardia ovata*

Cyclocardia crassidens
Cyclocardia crebricostata
cf. *Cyclocardia borealis*
Nuculidae
Ennucula tenuis
Hiatellidae
Hiatella arctica
Veneridae
Liocyma fluctuosum
Lyonsiidae
Lyonsia arenosa
Tellinidae
***Macoma* spp.**
Macoma calcarea
Macoma moesta
Mytilidae
***Musculus* spp.**
Musculus discors
Musculus niger
Myidae
Mya sp.
Nuculanidae
***Nuculana* spp.**
Nuculana minuta
Nuculana pernula
Nuculana radiata
Yoldiidae
***Yoldia* spp.**
Yoldia hyperborea
Brachiopoda
Hemithyrididae
Hemithiris psittacea
Cephalopoda
Octopodidae
Benthoctopus sibiricus
Polyplacophora
Ischnochitonidae
Ischnochiton albus
Amicula vestita
Gastropoda
Nudibranchia (possible 3 additional species)
Adalaria sp.
Dendronotus sp.
Dendronotus dalli
Cancellariidae
Admete spp.

- *Admete middendorffii*
- *Admete regina*
- *Admete viridula*

Buccinidae

- *Beringius* sp.
- ***Buccinum* sp.**
- *Buccinum angulosum*
- *Buccinum plectrum*
- *Buccinum polaris*
- *Buccinum scalariforme*
- *Buccinum transliratum*
- ***Colus* spp. (possibly 2 additional species)**
- *Colus esychus*
- *Colus herendeenii*
- *Colus hypolispus*
- ***Neptunea* spp.**
- *Neptunea borealis*
- ***Neptunea heros***
- *Neptunea lyrata*
- ***Neptunea magna***
- ***Plicifusus* spp. (possibly 2 additional species)**
- ***Plicifusus kroyeri***
- *Pyrulofusus* sp.
- *Pyrulofusus deformis*
- *Volutopsius* sp.

Muricidae

- ***Boreotrophon* spp.**
- *Boreotrophon clathratus*
- *Boreotrophon coronatus*
- *Boreotrophon pacificus*

Cerithiidae

Conidae (possibly 3 additional species)

- *Curtitoma incisula*
- *Curtitoma novajasemljensis*
- *Obesotoma simplex*
- cf. *Oenopota elegans*
- *Oenopota excurvata*
- *Oenopota harpa*
- *Oenopota impressa*
- *Oenopota nobilis*
- cf. *Propebela turricula*

Naticidae

- *Cryptonatica* spp.
- ***Cryptonatica affinis***
- *Cryptonatica russa*
- ***Euspira pallida***

- Cylichnidae
  - ***Cylichna alba***
- Bodotriidae
  - ***Iphinoe coronata***
- Lepitidae
  - *Lepeta caeca*
- Trochidae
  - ***Margarites* spp.**
  - *Margarites costalis*
  - *Margarites helicinus*
  - ***Solariella* sp.**
  - *Solariella obscura*
- Lamellariidae
  - ***Onchidiopsis* sp.**
- Retusidae
  - ***Retusa obtusa***
- Turritellidae
  - ***Tachyrhynchus* spp.**
  - *Tachyrhynchus erosus*
  - *Tachyrhynchus reticulatus*
  - *Trichotropis borealis*
  - *Trichotropis kroyeri*
- Velutinidae
  - *Velutina undata*

Gastropoda (juveniles)

ECHINODERMATA

Asteroidea

- Solasteridae
  - ***Crossaster papposus***
- Goniopectinidae
  - *Ctenodiscus crispatus*
- Echinasteridae
  - ***Henricia* sp.**
  - *Henricia tumida*
- Asteriidae
  - ***Leptasterias* spp.**
  - *Leptasterias groenlandica*
  - *Leptasterias arctica*
  - ***Leptasterias polaris***
  - ***Urasterias lincki***
- Pterasteridae
  - ***Pteraster obscurus***

Asteroidea (juveniles)

Echinoida

- Strongylocentrotidae

            - ***Strongylocentrotus* sp.**
    - **Holothuroidea**
        - Myriotrochidae
            - ***Myriotrochus rinkii***
        - Cucumariidae
            - **cf. *Ocnus glacialis***
        - Psolidae
            - ***Psolus* sp.**
            - *Psolus fabricii*
    - Ophiuroidea
        - Ophiuridae
            - **cf. *Amphiophiura pachyplax***
            - ***Ophiura sarsi***
        - Amphiuridae
            - *Diamphiodia craterodmeta*
            - cf. *Unioplus macraspis*
        - Ophiactidae
            - *Ophiopholis aculeata*
        - Gorgonocephalidae
            - ***Gorgonocephalus* spp.**
            - *Gorgonocephalus arcticus* (or *G. caryi*)
            - *Gorgonocephalus eucnemis*
- Ophiuroidea (juveniles)

- ANNELIDA
    - **Polychaeta**
        - **Ampharetidae**
            - *Ampharete finmarchia*
            - *Ampharete goesi goesi*
        - **Phyllodocidae**
            - *Anaitides groenlandica*
        - **Polynoidae**
            - *Antinoella* sp.
            - *Antinoella macrolepida*
            - *Arcteobea anticostiensis*
            - *Arctonoe vittata*
            - *Eunoe* spp.
            - *Eunoe depressa*
            - *Eunoe nodosa*
            - *Gattyana* spp.
            - *Gattyana cilliata*
            - cf. *Gattyana cirrosa*
            - *Gattyana treadwelli*
            - *Harmothoe* spp.
            - *Harmothoe extenuata*
            - *Harmothoe imbricata*

Flabelligaridae
    Brada granulata
Cirratulidae
Amphictenidae
    Cistenides granulata
Hesionidae
Lumbrineridae
    Lumbrineris sp.
Maldanidae
Oweniidae
    Myriochele heeri
Siglionidae
    Pholoe minuta
Spionidae
    Polydora sp.
Sabellidae
Sphaerodoridae
    Sphaerodorum papillifer
Spirorbidae
    ***Spirorbis* sp.**
Syllidae
    Typosyllis armillaris bilineata
Terebellidae

PORIFERA
    Choanitidae
        Choanites luetkeni
    Halichondriidae
        Halichondria sp.
    Grantiidae
        Leucandra sp.
    Axinellidae
        cf. *Phakellia cribrosa*
    Suberitidae
        Suberites sp.

CHORDATA
    Ascidiacea (aka "Colonial organisms")
        Pyuridae
            ***Boltenia* spp.**
            Boltenia echinata
            Boltenia ovifera
            Boltenia villosa
            Halocynthia aurantium
        Corellidae
            ***Chelyosoma* sp.**

        - *Chelyosoma orientale*
    - Didemnidae
    - Styelidae
        - *Cnemidocarpa* sp.
        - *Styela* sp.
        - *Styela coriacea*
        - *Styela rustica*
        - ***Pelonaia corrugata***
    - **Styelidae – thick-skin, black**
    - Styelidae – fuzzy
    - Styelidae (juveniles)
    - Styelidae – scaly
- Ascidiacea – compound
- Ascidiacea – compound, orange
- Ascidiacea – compound, with visible zoids
- Ascidiacea – gelatinous
- Ascidiacea – gravel-covered
- Ascidiacea – on shell
- Ascidiacea – on shell, dark brown
- Ascidiacea – small, flat
- Ascidiacea – thick veins
- Ascidiacea – transparent, bumpy
- Ascidiacea – transparent, spiky

PYCNOGONIDA (possibly 3 species)

SIPUNCULA

- Golfingiidae
    - ***Golfingia* sp.**
    - ***Golfingia margaritacea***
- Phascoliidae
    - ***Phascolion strombi***

Appendix III

Ranking of Epifauna by Abundance and Biomass
for each Station for the
2009 Chukchi Sea Environmental Studies Program

Table AIII. Ranking of top five epifaunal taxa by Abund. (Abundance ind. m^{-2}) and biomass (g m^{-2}) for fixed stations sampled in the Chukchi Sea, 2009.

August - WW0902

Area	Station	Taxon	Abund.	Taxon	Biomass
Burger	BF001	Not sampled in August 2009			
	BF003	*Ophiura sarsi*	29,516	*Ophiura sarsi*	26,746.23
		Caridae	626	*Leptasterias* sp.	569.07
		Solariella sp.	228	*Astarte* sp., *Chionoecetes opilio*	474.22
		Myriotrochus rinkii	190	Caridae	379.38
		Astarte sp., *Margarites* sp.	152	*Margarites* sp.	322.47
	BF005	*Ophiura sarsi*	37,771	*Psolis fabricii*	44,901.50
		Caridae	2,233	*Ophiura sarsi*	25,840.30
		Myriotrochus rinkii	893	*Gorgonocephalus* sp.	3,987.70
		Psolis fabricii	702	Caridae	1,250.14
		Liocyma fluctuosum	479	Anthozoa	1,060.73
	BF007	Not sampled in August 2009			
	BF009	*Ophiura sarsi*	21,1577	*Ophiura sarsi*	105,087.27
		Astarte sp.	5,549	*Astarte* sp.	5,903.37
		Gastropoda	2,243	*Gorgonocephalus arcticus*	4,132.36
		Boreotrophon sp.	945	*Cyclocardia* sp.	2,361.35
		Cyclocardia sp.	826	*Chionoecetes opilio*	1,771.01
				Gersemia rubiformis, *Leptasterias* sp., *Neptunea heros*, *Plicifusus koyeri*	1,771.01
	BF011	Not sampled in August 2009			
	BF013	*Ophiura sarsi*	203,518	*Ophiura sarsi*	108,998.61
		Gastropoda	1,516	Anthozoa	10,430.25
		Astarte sp.	967	*Chionoecetes opilio*	2,418.61
		Caridae	322	*Astarte* sp.	1,934.89
		Hyas coarctatus	258	*Gorgonocephalus arcticus*	1,773.65
	BF015	*Ophiura sarsi*	122,664	*Ophiura sarsi*	85,657.15
		Ennucula tenuis	2,108	*Astarte borealis*	8,681.99
		Solariella sp.	1,426	*Chionoecetes opilio*	7,306.05
		Gastropoda	1,302	*Gorgonocephalus arcticus*	1,724.77
		Ocnus glacialis	1,178	*Ocnus glacialis*	1,552.29

Table AIII. August – WW0902 Continued.

Area	Station	Taxon	Abund.	Taxon	Biomass
Burger	BF017	*Ophiura sarsi*	108,082	*Ophiura sarsi*	72,852.08
		Myriotrochus rinkii	8,658	*Chionoecetes opilio*	7,458.50
		Solariella sp.	1,522	*Psolis fabricii*	5,589.63
		Astarte sp.	1,482	*Myriotrochus rinkii*	2,480.51
		Gastropoda	1,359	*Astarte* sp., *Ocnus glacialis*	1,987.80
	BF019	*Ophiura sarsi*	22,518	*Ophiura sarsi*	30,827.76
		Myriotrochus rinkii	10,750	*Myriotrochus rinkii*	7,773.96
		Ocnus glacialis	3,351	*Ocnus glacialis*	5,964.50
		Gastropoda	3,136	*Chionoecetes opilio*	3,216.81
		Ennucula tenuis	2,520	*Astarte* sp.	1,608.41
	BF021	*Ophiura sarsi*	499,459	*Ophiura sarsi*	207,121.43
		Astarte sp.	2,367	*Hyas coarctatus*	14794.78
		Oenopota sp.	2,367	*Gersemia rubiformis*	13,611.20
		Caridae, *Hyas coarctatus*	1,479	*Chionoecetes opilio*	10,356.35
		Gersemia rubiformis	1,184	*Astarte* sp.	3,550.75
		Amphipoda, *Chionoecetes opilio*, *Cryptonatica affinis*, Paguridae	888		
	BF023	*Ophiura sarsi*	4,591	*Ophiura sarsi*	19,043.30
		Chionoecetes opilio	827	*Chionoecetes opilio*	4,133.43
		Astarte sp.	399	*Astarte* sp.	1,107.17
		Gastropoda	325	*Buccinum* sp.	930.02
		Solariella sp.	236	*Cyclocardia* sp.	590.49
	BF025	*Ophiura sarsi*	2,586	*Ophiura sarsi*	10,660.32
		Macoma sp.	1,162	*Chionoecetes opilio*	2,034.00
		Gastropoda	843	*Macoma* sp., *Yoldia* sp.	1,017.00
		Caridae	552	*Leptasterias* sp.	944.36
		Nuculana sp.	523	*Nuculana* sp., *Ocnus glacialis*	871.71
Klondike	KF001	Not sampled in August 2009			
	KF003	Caridae	185	*Leptasterias polaris*	353.22
		Styelidae	51	*Chionoecetes opilio*	214.60
		Pagurus trigonocheirus	46	*Gorgonocephalus* sp.	184.83
		Argis lar	25	*Argis lar*	74.96
		Amphipoda	24	*Pagurus trigonocheirus*	69.82

Table AIII. August – WW0902 Continued.

Area	Station	Taxon	Abund.	Taxon	Biomass
Klondike	KF005	Caridae	3,885	*Gorgonocephalus arcticus*	7,859.59
		Ophiura sarsi	726	*Hyas coarctatus*	3,788.73
		Gorgonocephalus arcticus	548	*Ophiura sarsi*	3,224.45
		Hyas coarctatus	443	Neptunea sp.	2,498.95
		Paguridae	347	*Chionoecetes opilio*, Paguridae	2,257.11
	KF007	Not sampled in August 2009			
	KF009	Caridae	1,420	*Chionoecetes opilio*	2,611.21
		Amphiophiura pachyplax	751	Paguridae	2,137.93
		Paguridae	465	Stomphia sp.	1,958.41
		Solariella sp.	237	*Leptasterias* sp.	1,713.61
		Chionoecetes opilio	163	*Argis lar*	571.20
	KF011	Paguridae	1,109	*Chionoecetes opilio*	15,173.80
		Chionoecetes opilio	793	Paguridae	7,009.22
		Caridae	408	Neptunea sp.	2,541.80
		Nuculana sp.	354	*Leptasterias polaris*	1,771.56
		Labidochirus splendescens	146	*Boltenia ovifera*, *Labidochirus splendescens*	847.27
	KF013	Caridae	1,415	*Chionoecetes opilio*	2,128.22
		Balanus sp.	1,262	*Leptasterias polaris*	1,137.80
		Amphiophiura pachyplax	684	Styelidae	766.39
		Nuculana sp.	330	*Hyas coarctatus*	453.94
		Paguridae	318	*Amphiophiura pachyplax*	418.57
				Pagurus trigonocheirus	418.57
	KF015	Caridae	1,393	*Strongylocentrotus droebachiensis*	7,802.56
		Strongylocentrotus droebachiensis	116	*Boltenia ovifera*	4,351.85
		Amphiophiura pachyplax	99	*Halocynthia aurantium*	3,538.63
		Hyas coarctatus	84	Caridae	2,219.88
		Boltenia ovifera	81	*Psolis fabricii*	1,318.74
	KF017	Not sampled in August 2009			

Table AIII. August – WW0902 Continued.

Area	Station	Taxon	Abund.	Taxon	Biomass
Klondike	KF019	Caridae	1,979	Caridae	3,240.06
		Leptasterias sp.	90	*Psolis fabricii*	2,517.28
		Argis lar	75	*Strongylocentrotus droebachiensis*	2,043.73
		Gersemia rubiformis	70	*Halocynthia aurantium*	1,370.79
		Paguridae	45	*Stomphia* sp.	1,370.79
				Leptasterias sp.	1,096.64
	KF021	*Nuculana* sp.	391	*Chionoecetes opilio*	1,600.51
		Caridae	85	*Nuculana* sp.	394.93
		Paguridae	69	Paguridae	360.29
		Chionoecetes opilio	54	*Urasterias linckii*	256.36
		Argis lar	19	*Leptasterias* sp.	173.22
	KF023	*Ophiura sarsi*	23,126	*Ophiura sarsi*	40,883.11
		Caridae	1,505	*Gorgonocephalus* sp.	6,292.64
		Solariella sp.	1,342	*Leptasterias* sp.	1,779.74
		Gastropoda	1,139	Caridae	1,754.31
		Paguridae	305	*Chionoecetes opilio*, Paguridae	610.20
	KF025	*Ophiura sarsi*	316,147	*Ophiura sarsi*	141,975.33
		Astarte sp.	621	*Volutopsius fragilis*	3,568.78
		Cyclocardia sp.	543	*Astarte* sp.	2,172.30
		Solariella sp.	465	*Cyclocardia* sp.	1,396.48
		Cryptonatica affinis	233	*Margarites* sp.	465.49
		Leptasterias polaris	233	*Neptunea communis*	465.49
		Oenopota sp.	233		

October - WW0904

Area	Station	Taxon	Abund.	Taxon	Biomass
Burger	BF001	*Ophiura sarsi*	43,077	*Ophiura sarsi*	22,376.01
		Caridae	720	*Psolis fabricii*	7,720.38
		Myriotrochus rinkii	249	*Pteraster obscurus*	601.93
		Astarte sp.	183	Caridae	287.88
		Astarte montegui	170	*Argis lar*	196.28
	BF003	*Ophiura sarsi*	19,140	*Ophiura sarsi*	15,564.43
		Caridae	4,775	*Gorgonocephalus arcticus*	4,382.02
		Myriotrochus rinkii	1,178	*Chionoecetes opilio*	2,480.39
		Amphipoda	579	Caridae	992.16
		Solariella sp.	248	*Gersemia rubiformis*	413.40

Table AIII. October – WW0904 Continued.

Area	Station	Taxon	Abund.	Taxon	Biomass
Burger	BF005	*Ophiura sarsi*	54,773	*Ophiura sarsi*	37,198.80
		Caridae	12,058	*Psolis fabricii*	6,590.34
		Myriotrochus rinkii	3,222	Caridae	3,319.58
		Amphipoda	488	*Argis lar*	1,025.16
		Gastropoda	488	*Myriotrochus rinkii*	488.17
		Boreotrophon sp.	342		
	BF007	*Ophiura sarsi*	79,169	*Ophiura sarsi*	42,000.66
		Amphipoda	1,796	*Gorgonocephalus arcticus*	13,915.88
		Solariella sp.	810	*Astarte borealis*	657.84
		Caridae	784	*Buccinum scalariforme*	556.64
		Cylichna alba	531	*Astarte montegui*	531.33
	BF009	*Ophiura sarsi*	318,307	*Ophiura sarsi*	100,307.69
		Gastropoda	1,798	*Gorgonocephalus arcticus*	22,179.59
		Asteroidea, Caridae, *Liocyma fluctuosum*	1,199	*Buccinum polare*	3,396.87
		Amphipoda	999	*Chionoecetes opilio*	3,396.87
		Buccinum polare	799	*Gersemia rubiformis*	1,798.35
		Gorgonocephalus arcticus	799	*Astarte montegui*	1,298.81
	BF011	*Ophiura sarsi*	210,993	*Ophiura sarsi*	142,767.85
		Ennucula tenuis	1,805	*Chionoecetes opilio*	9,926.97
		Caridae	1,624	*Astarte montegui*	2,346.37
		Colus sp.	1,263	*Gersemia rubiformis*	1,985.39
		Chionoecetes opilio	902	*Hyas coarctatus*	1,985.39
				Gorgonocephalus arcticus	1,804.90
	BF013	*Ophiura sarsi*	7,467	*Ophiura sarsi*	3,418.59
		Caridae	1,542	*Stomphia* sp.	1,339.80
		Hyas coarctatus	174	*Psolis fabricii*	758.26
		Pycnogonida	167	Caridae	532.07
		Amphipoda	116	*Gorgonocephalus arcticus*	526.93

Table AIII. October – WW0904 Continued.

Area	Station	Taxon	Abund.	Taxon	Biomass
	BF015	*Ophiura sarsi*	3,968	*Ophiura sarsi*	3,434.85
		Caridae	1,509	*Gorgonocephalus arcticus*	1,137.12
		Amphipoda	164	Caridae	436.07
		Ennucula tenuis	141	*Chionoecetes opilio*	362.27
		Asteroidea	77	*Leptasterias groenlandica*	231.45
	BF017	*Ophiura sarsi*	15,820	*Ophiura sarsi*	8,514.53
		Caridae	1,234	*Myriotrochus rinkii*	1,717.42
		Myriotrochus rinkii	1,234	Caridae	483.78
		Amphipoda	278	*Chionoecetes opilio*	278.17
		Ocnus glacialis, *Solariella* sp.	145	*Ocnus glacialis*	217.70
		Anonyx nugax	121		
	BF019	*Ophiura sarsi*	31,192	*Ophiura sarsi*	21,014.27
		Myriotrochus rinkii	23,182	*Chionoecetes opilio*	11,873.53
		Solariella sp.	2,262	*Myriotrochus rinkii*	8,763.80
		Gastropoda	2,167	*Leptasterias groenlandica*	3,863.61
		Caridae, *Ennucula tenuis*	2,073	*Ocnus glacialis*	2,261.63
	BF021	*Ophiura sarsi*	133,052	*Ophiura sarsi*	97,756.28
		Myriotrochus rinkii	4,019	*Myriotrochus rinkii*	1,198.23
		Gastropoda	1,955	*Chionoecetes opilio*	1,086.14
		Solariella sp.	1,412	*Ocnus glacialis*	868.91
		Caridae	760	*Solariella* sp.	543.07
	BF023	*Ophiura sarsi*	2,052	*Ophiura sarsi*	8,843.88
		Gastropoda	991	*Chionoecetes opilio*	2,311.20
		Balanus sp.	920	*Ocnus glacialis*	660.34
		Solariella sp.	495	*Buccinum polare*	613.18
		Ennucula tenuis	448	*Neptunea heros*	377.34
	BF025	Caridae	6,555	*Ophiura sarsi*	14,302.07
		Ophiura sarsi	3,289	*Pagurus trigonocheirus*	3,766.21
		Ennucula tenuis	810	*Chionoecetes opilio*	3,480.17
		Hyas coarctatus	691	*Hyas coarctatus*	1,287.19
		Chionoecetes opilio	667	Caridae	1,203.76

Table AIII. October – WW0904 Continued.

Area	Station	Taxon	Abund.	Taxon	Biomass
Klondike	KF001	Caridae	981	*Chionoecetes opilio*	1,526.61
		Chionoecetes opilio	38	Caridae	544.74
		Argis lar	27	*Hyas coarctatus*	471.59
		Polynoidae	15	*Crossaster papposus*	149.64
		Gastropoda	11	*Chlamys berhingiana*	116.54
	KF003	Caridae	750	Caridae	238.89
		Balanus sp.	44	*Leptasterias* sp.	231.87
		Argis lar	37	*Stomphia* sp.	221.33
		Gorgonocephalus arcticus	16	*Argis lar*	144.04
		Amphipoda	11	*Gersemia rubiformis*	129.99
		Chionoecetes opilio	11		
	KF005	Caridae	2,902	*Boltenia ovifera*	2,558.58
		Gorgonocephalus arcticus	330	*Gorgonocephalus arcticus*	1,932.69
		Argis lar	303	Caridae	1,568.85
		Gersemia rubiformis	220	*Argis lar*	1,224.27
		Amphipoda	179	*Stomphia* sp.	763.45
	KF007	Caridae	1,077	*Chionoecetes opilio*	1,696.50
		Argis lar	140	Caridae	773.14
		Paguridae	78	*Leptasterias* sp.	701.91
		Stegocephalus inflatus	70	*Stomphia* sp.	572.41
		Amphipoda	57	*Neptunea* sp.	533.56
	KF009	Caridae	1,352	*Leptasterias* sp.	1,712.53
		Paguridae	258	Styelidae	1,339.98
		Ophiura sarsi	210	*Chionoecetes opilio*	1,051.55
		Argis lar	72	*Strongylocentrotus droebachiensis*	835.24
		Buccinum scalariforme	54	Caridae	721.07
	KF011	Caridae	729	*Chionoecetes opilio*	4,340.89
		Paguridae	212	Paguridae	787.62
		Balanus sp.	180	*Buccinum scalariforme*	353.30
		Chionoecetes opilio	178	Caridae	334.40
		Argis lar, *Nuculana* sp.	68	*Leptasterias* sp.	315.05

Table AIII. October – WW0904 Continued.

Area	Station	Taxon	Abund.	Taxon	Biomass
	KF013	Caridae	1,903	*Chionoecetes opilio*	1,982.78
		Ophiura sarsi	152	*Leptasterias* sp.	1,621.23
		Argis lar	114	Caridae	1,012.32
		Chionoecetes opilio	103	*Pagurus trigonocheirus*	437.66
		Paguridae	84	*Hyas coarctatus*	372.96
	KF015	Caridae	1,450	*Boltenia ovifera*	4,342.58
		Balanus sp.	390	*Halocynthia aurantium*	2,091.13
		Argis lar	160	Caridae	1,709.15
		Boltenia ovifera	98	*Strongylocentrotus droebachiensis*	1,338.32
		Hyas coarctatus	77	*Psolis fabricii*	1,115.27
	KF017	Caridae	1,030	*Ophiura sarsi*	4,682.51
		Ophiura sarsi	779	*Chionoecetes opilio*	1,344.55
		Balanus sp.	258	*Leptasterias* sp.	785.99
		Paguridae	177	*Neptunea* sp.	675.62
		Nuculana sp.	114	Paguridae	448.18
	KF019	Caridae	4,216	*Psolis fabricii*	6,690.32
		Psolis fabricii	249	Caridae	2,393.84
		Gersemia rubiformis	187	Styelidae	1,877.77
		Amphipoda	174	*Strongylocentrotus droebachiensis*	1,790.72
		Argis lar	87	*Stomphia* sp.	609.34
	KF021	Caridae	246	*Chionoecetes opilio*	2,325.92
		Balanus sp.	147	*Leptasterias* sp.	542.41
		Chionoecetes opilio	110	Paguridae	248.22
		Nuculana sp., Paguridae	39	Caridae	114.00
		Argis lar	18	*Nuculana* sp.	36.77
	KF023	*Ophiura sarsi*	10,531	*Ophiura sarsi*	21,738.56
		Caridae	2,343	*Leptasterias* sp.	1,545.85
		Paguridae	411	Paguridae	917.85
		Solariella sp.	217	Caridae	869.54
		Balanus sp.	145	*Gersemia rubiformis*	628.00
	KF025	*Ophiura sarsi*	206,690	*Ophiura sarsi*	145,898.91
		Caridae	3,095	*Neptunea heros*	3,315.88
		Gastropoda	2,211	Caridae	2,763.24
		Bivalvia	1,216	Gastropoda	442.12
		Solariella sp.	1,216	*Chionoecetes opilio*	341.32
		Anonyx nugax	553		