RUSALCA Meeting summary: Benthic systems session
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Summary of presentations by
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High-latitude western Arctic shelf systems are highly productive under the influence of nutrient-rich Pacific water. Seasonal sea ice duration and extent, seawater temperature, and current dynamics are also critical for water column production, carbon cycling, and pelagic-benthic coupling. Short food chains are characteristic of high productivity areas in this region, so changes in lower trophic levels can affect higher trophic organisms such as diving ducks, walruses, bearded seals and gray whales rapidly. Subsistence harvesting of these animals are locally important for human consumption and the vulnerability of this ecosystem to environmental change is therefore high.

Historic perspective of benthic sampling in the Chukchi Sea

Benthic infaunal and epifaunal communities were samples during leg 2 of the 2004 RUSALCA cruise. This cruise provided a strategic opportunity to continue previous studies in both U.S. and Russian waters. Early exploration of the Chukchi Sea benthos, little of which was published in English, is summarized in Table 1.

Table 1. Early exploration of benthic communities of the Chukchi Sea area.

Year	Location sampled	No of samples	Country	Vessel
1878-79	Chukchi Sea along Russian coast	13	Sweden	Vega [(1)]
1910-1914	Southcentral Chukchi Sea and Russian coast and Wrangel Island	50	Russia	Taimyr and Waigatsch [(2)]
1913	Chukchi Sea along Alaskan coast	4	Canada	? [(3)]
1922	North of Wrangel Island	10	Norway	Maud [(4)]
1929	Herald Canyon, central Russian Chukchi shelf, Bering Strait	>40	Russia	Fedor Litke [(5)]
1932	South eastern Chukchi Sea, Bering Strait	17	Russia	Dalnevostochnik[(5)]
1933	Bering Strait, central Chukchi shelf	34	Russia	Krasnoarmeetz [(6)]
1935	Russian Chukchi Sea, Herald Canyon	50	Russia	Krasin [(7)]
1938	Bering Strait, Cape Serdtse Kamen - Point Hope transect	6 (BS), 7 (PH)	Russia	Okhotsk [(8)]

References: **(1)** Vega expeditionens vetens kapliga rakttagelser bearbetade af deltagare i resan och andra forskare utgifna af A.E. Nordenskiold. Bd. 1-5, Stockholm F. & G. Beijer, 1882-1887. **(2)** Arngold E. 1915. Short observation of voyage and wintering of vessel Waigatsch in the Arctic Ocean in 1914-1915 // Marine doctor. (In Russian); Starokadomsky L.H. 1915. Zoological stations of vessel Taimir in 1912 in Arctic Ocean and seashore collections during the expedition. // Annual reports of the Zoological museum of Russian Academy of sciences. 19. (In Russian); Starokadomsky L.M. 1917. Zoological stations of vessel Taimir in 1913. // Annual reports of the Zoological Museum of Russian Academy of Sciences. 21 (In Russian). **(3)** Report of the Canadian Arctic Expedition. Volume 1-8. 1919-1925. **(4)** The Norwegian North Polar Expedition with the "Maud" 1918-1925, Scientific results. **(5, 7)** Ushakov P.V. 1952 The Chukchi Sea and its bottom fauna / Extreme Northeast of the Soviet Union 2. Fauna and flora of the Chukchi Sea. Academy of Sciences Publishing House: 5-82. **(6)** Makarov V.V. 1937. Materials on the quantitative inventory-making of bottom fauna in the northern Bering and Chukchi Seas// Explorations of the seas of Soviet Union. Gydromet 260-291 (In Russian). **(8)** Koshkin V.H. 1939. Hydrographical investigations onboard vessel Okhotsk during the navigation of 1938// Problem of Arctic.1 (In Russian).

Interrupted by World War II and its aftermath, sampling of the Chukchi Sea region commenced again in the 1970's. In 1970-1974 American scientists sampled close to 50 stations across most of the Chukchi Sea with about half of the stations in the northern area between Point Barrow and Wrangel Island (Stoker, 1981). Feder and co-workers sampled over 70 locations in Kotzebue Sound and in the US sector of the southern Chukchi Sea in 1976 (Feder et al., 2005). In the same year, Russian scientists sampled near Cape Shmidt and at the southern and eastern coast of Wrangel Island (38 stations, Golikov et al., 1978). Joint Russian-American expeditions (BERPAC) collected benthic materials from the southern Chukchi Sea (onboard *Ac. Korolev,* 1988, about 30 stations; Sirenko and Koltun, 1992) and from the western and central parts of the Chukchi Sea in 1995 onboard *Alpha Helix* (16 stations). In 1989, Russian researchers sampled Herald Bank, Koljuchinskaya Inlet, and the area off Serdtse Kamen (Golikov et al., 1991, 1998). Later American-led expeditions followed in 1980, 1986, 1987 and 1998 (Grebmeier et al., 2006). The two RUSALCA expeditions in 2004 and 2005 investigated Bering Strait and the southern Chukchi (2004, 2005) and Herald Canyon (2004) and provided a link with other current work of the Western Arctic Shelf-Basin Interactions (SBI) project (http://sbi.utk.edu), the Bering Strait Environmental Observatory (http://arctic.bio.utk.edu), and benthic work in the adjacent Canada Basin. The listed collections comprise different compartments of the benthos, infaunal macrofauna, epifaunal megafauna and infaunal meiofauna.

Table 2. Benthic materials collected in the Chukchi Sea during recent expeditions and kept in the Zoological Institute, RAS, St. Petersburg.

Vessel/ expedition, year	Number of		Status of processing
	St.	lots	
Third Arctic exp. of Zool. Inst., 1976	38	157	partly
Academic Korolev, 1988	30	63	partly
Dmitry Laptev, 1989	24	101	partly
Georgy Maximov, 1990	4	4	yes
Alpha Helix, 1995	16	48	partly
Professor Khromov/RUSALCA, 2004	17	54	partly
Sever/RUSALCA, 2005	8	24	no
Total	**134**	**451**	

So far, these expeditions have shown that the Chukchi Sea has low species richness relative to other Eurasian Arctic shelf seas: 1170 free-living invertebrates have been recorded from this area compared to 3245 in the Barents Sea, 1817 in the White Sea, 1671 in the Kara Sea, 1472 in the Laptev Sea, 1011 in the East Siberian Sea and 837 in the Central Arctic Basin. Among the 1170 listed species, crustaceans dominate by far (414 species), followed by mollusks (187), polychaetes (182) and bryozoans (109).

Benthic infaunal sampling

The RUSALCA sampling program for benthic infauna studies included replicate sediment samples using a $0.1 m^2$ van Veen grab and at some stations additionally an Ocean grab ($0.25 m^2$). In total, 122 grab samples were taken at 17 stations in 2004 and 24 grab samples were taken at 8 stations in 2005. One replicate grab was sub-sampled for meiofauna at each major station. One replicate grab was used for surface sediment sampling of total organic carbon (TOC) and nitrogen, sediment grain size, sediment chlorophyll *a* concentration, organic matter $\delta^{13}C$ and $\delta^{15}N$ ratios, and ^{7}Be, a short-lived atmospherically-derived cosmogenic isotope that provides an indication of where sedimentation has recently occurred (see also Cooper et al. summary). The remaining grabs were sieved separately through a 1 mm stainless steel mesh screen, preserved in

10% buffered formalin, and analyzed for macrofaunal species and biomass. Meiofauna samples were rinsed over 100 µm mesh.

Because of additional simultaneous sampling by the SBI project, the RUSALCA sediment chemistry data can be interpreted in the context of the larger data set available from the wider Chukchi shelf and slope. The majority of benthic stations sampled during the RUSALCA cruise were composed of silt and clay grain size fractions, although stations along the coast were dominated by coarse sediments (gravel and pebbles).

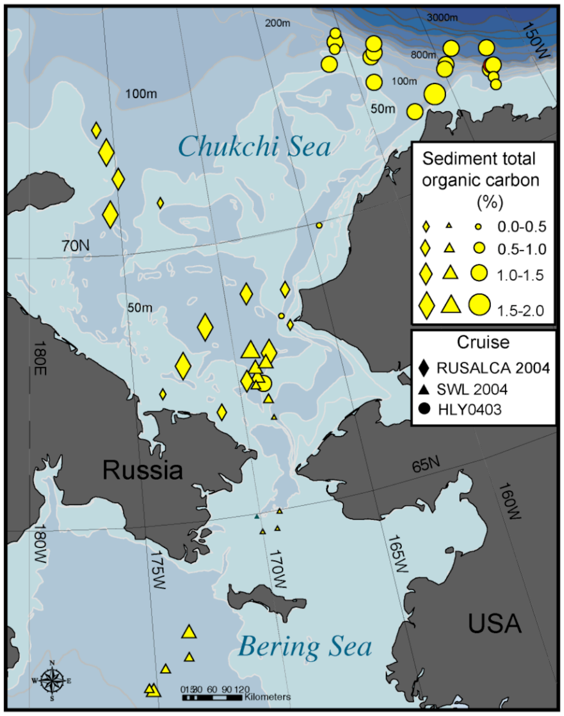

Figure 1a. Total organic carbon (%) in surface sediments in the northern Bering, Chukchi and western Beaufort Seas and Arctic Ocean.

Surface sediment TOC values were highest at the head of Hope Valley and downstream in Herald Valley as well as on the outer shelf/slope of the Chukchi Sea, the slope area of the Beaufort Sea, and in upper Barrow Canyon (Fig. 1a). There is a significant relationship between surface sediment TOC and silt and clay fraction (≥5 phi; Fig. 1b).

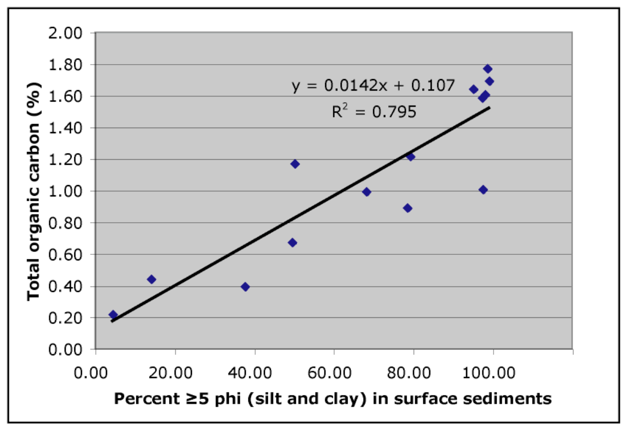

Figure 1b. Total organic carbon (TOC) vs. silt and grain content (≥5 phi) in the RUSACLA stations (diamonds in Fig. 1a).

Surface sediment activities of the particle-reactive, atmospherically- derived radioisotope ^{7}Be (half-life 53d) indicate activities are highest in sediments immediately north of Bering Strait, and in down-slope portions of Herald and Barrow Canyons where Pacific-origin waters flow off the continental shelf. These data suggest areas of tight pelagic-benthic coupling of organic carbon. Chlorophyll *a* concentrations in surface sediments show similar high concentrations on the shelf, with low concentrations in deep basin sediments. C/N ratios and $\delta^{13}C$ values of bulk organic carbon in sediments co-vary with lower C/N ratios and less depleted $\delta^{13}C$ values on the Russian shelf, consistent with less refractory and more readily usable, recently deposited organic materials (see Fluxes section of meeting summary).

The infaunal community at the two most southern transect lines (st 11-15, 22-25) was dominated by the bivalve *Macoma calcarea*, (Fig. 2b, Table 3) which was also dominant in that area at the beginning of the last century. Macrobenthic community wet weight biomass at these stations averaged 1000-2000g/m^2 and exceeded 4000 g/m^2 at st. 13 (Table 3, Figure 3 for biomass in g C/m^2). The results of the second RUSALCA expedition in 2005 confirmed the 2004 data regarding the abundance of *Macoma calcarea* in this region. The infauna along the northernmost transect line (st. 58B, 62B, 73B, 85B, 106 and 107) in Herald Canyon and its vicinity was

Table 3: Abundance, biomass and dominant species of infaunal macrofrauna communities in the Chukchi Sea in August 2004.

Station	Individuals per m^2	Wet weight per m^2	Community
11	3060	1291.2	*Yoldia hyperborea+Macoma calcarea+Leionucula tenuis +(Ampelisca sp.)*
13	8190	4231.7	*M. calcarea*
15	1670	1081.7	*M. calcarea*
17	310	248.8	*Cheliosoma orientalis+Nephtys ciliata*
18	60	86.3	*Polychaeta varia*
20	320	156.1	*Ophiura sarsi+Nephtys spp.*
22	640	260	*M. calcarea+L. tenuis*
23	1350	612.8	*L. tenuis*
24	350	491.4	*M. calcarea*
25	1150	934.6	*M. calcarea+Y. hyperborea*
27	680	12.2	*Gammaridea+Polychaeta*
106	110	116.9	*Maldane sarsi+O.sarsi*
85B	340	231.4	*M. sarsi+Astarta borealis+Ct. crispatus*
73B	5500	380	*M. sarsi*
62B	510	343.1	*Golfingia margaritacea+Nicomache lumbricalis*
58B	170	134.6	*N. ciliata+M. sarsi+Actiniaria*

dominated by polychaetes (*Maldane sarsi*, *Nicomache lumbricalis, Nephtys ciliata*), brittle stars (*Ophiura sarsi*) and sipunculids (*Golfingia margaritacea*) with a wet weight biomass ranging from 102 to 343 g/m^2 (Table 3). Species composition does not appear to have changed dramatically in community composition from previous sampling in this productive area.

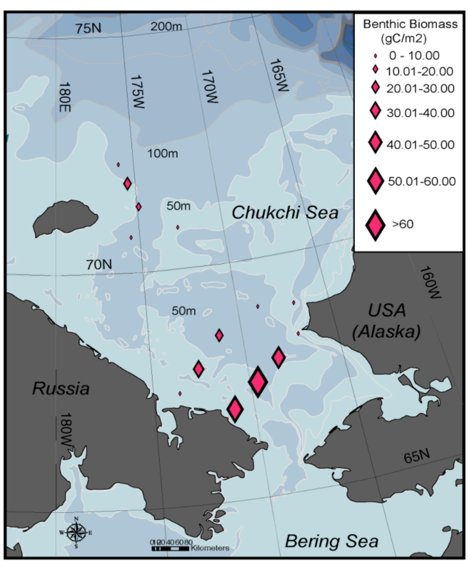

Figure 2a. Benthic biomass (g C/m^2) in the Chukchi Sea collected during RUSALCA 2005.

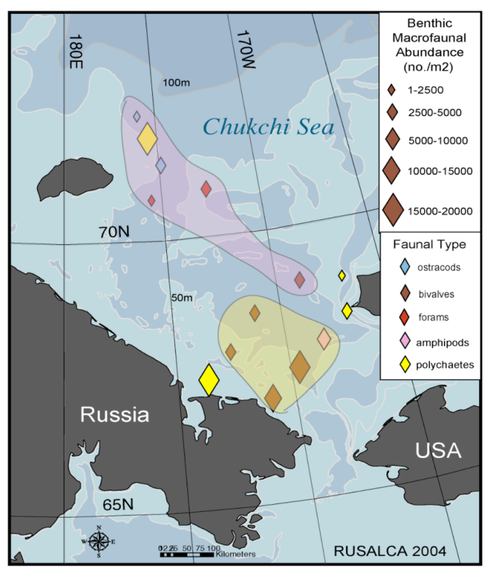

Figure 2b. Benthic community structure, based on macroinfaunal abundance (number/m^2), along with identification of dominant faunal type.

Wet weight benthic biomass was also converted to carbon benthic biomass, which allows removal of heavy carbonate test value. Macrobenthic infaunal biomass in the south-central

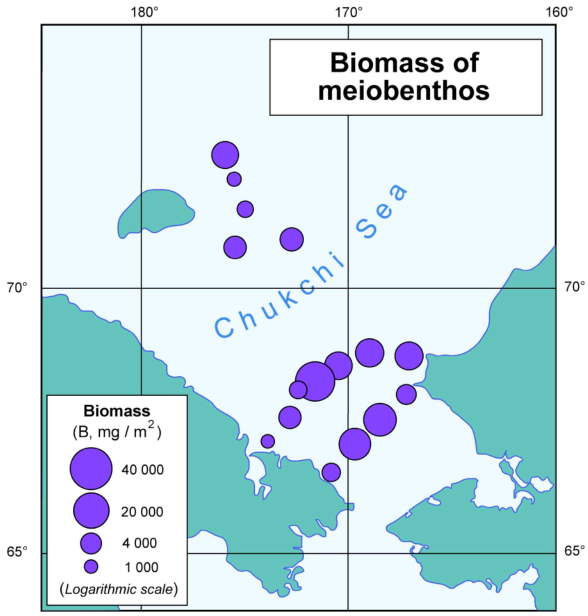

Figure 3. Meiofauna biomass (mg / m2) at 2004 RUSALCA stations.

Chukchi Sea stations ranged from 24-59 g C/m^2 (500-1400 g wet wt./m^2), exceeding 117 g C/m^2 (>3000 g wet wt./m^2) at st 13, which is extremely high for the world's oceans.

Benthic meiofauna biomass ranged from about 1-40 g wet weight / m^2 with highest values also at the southern Chukchi sea hot spot (Figure 3).

The northwestward transit of Pacific water through Bering Strait and northward into the Chukchi Sea, loaded with high nutrients and carbon content, seems to be a driving factor for the high productivity of the underlying infaunal benthos in the southcentral Chukchi Sea.

Benthic epifaunal sampling

Epibenthic megafauna, the larger seafloor animals living on top of the sediment, tend to be longer-lived (years to decades) and are, therefore, indicators of oceanographic conditions integrating over seasonal and other short-term 'noise'. This size-class of the benthos accounts for a quarter or more of benthic community remineralization (release of nutrients from degrading organic matter into the water column) on Arctic shelves. Epibenthic filter-feeding and deposit-feeding organisms are linking water column to benthic production, especially in highly productive waters, creating a long-term imprint of the transient oceanographic conditions. Epibenthic megafauna includes species of potential commercial and subsistence use (e.g., crabs, urchins), and range extensions due to warming trends may, therefore, be of economical interest.

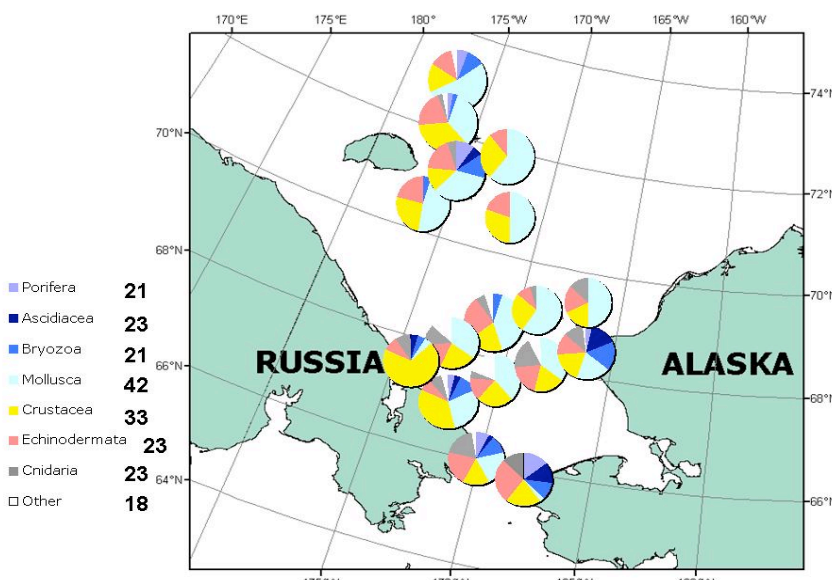

Figure 4: Epibenthic community composition at RUSALCA 2004 stations. The numbers behind the taxonomic group names indicate species richness.

Epibenthic communities were sampled with a beam trawl, or when unavailable, from benthic dredge or Otter trawl. Organisms were sorted by species / taxon, counted and wet weight was determined by species or taxon group. Voucher specimens were preserved in buffered formaldehyde solution. Taxonomic identifications were kindly assisted by Coyle and Foster (UAF), and Mah and Fautin (SI).

Epibenthic species richness ranged from 18 to 53 species per station with mollusks and crustaceans contributing 42 and 33 species, respectively, followed by echinoderms, cnidarians and ascidians (23 species each), bryozoans (21 species) and sponges (18 species) (Fig. 4). Locations with hard substrate housed more epifaunal species than soft bottom stations. Preliminary total species richness for the RUSALCA area was around 180 species.

Northern range extensions included two crabs, *Telmessus cheiragonus*, and *Oregonia gracilis,* and the bivalve *Pododesmus macrochisma*. These species usually inhabit the North Pacific along the Asian and American coasts. The crab *T. cheiragonus* is widely distributed from Hokkaido and California to the northern Bering Sea. Arctic records include the south-central Chukchi Bight (1976, 1988, 1998) and Kotzebue Sound (1976, 1998). *T. cheiragonus* was recorded further north in the RUSALCA trawl hauls in 2004 near Point Hope. The crab, *O. gracilis,* occurs from North Japan to the Commander Islands and from California to Nunivak Island in the Bering Sea. A first Arctic record from the Chukchi Sea was found during RUSALCA near Point Hope. The bivalve *P. macrochisma* occurs from northern Honshu to the Commander Islands and from California to the Pribilof Islands (Bering Sea). Two living specimens and one empty shell were collected further north in 2004 during in a RUSALCA trawl near Point Hope (Chukchi Sea). None of those species were recorded during the detailed trawling investigations in the eastern Chukchi Sea in the 1970s (Feder et al. 2005). We, therefore, presume that they penetrated into that area after 1976. We suggest that the invasion of these warmer water species are a consequence of warming in the southern Chukchi Sea.

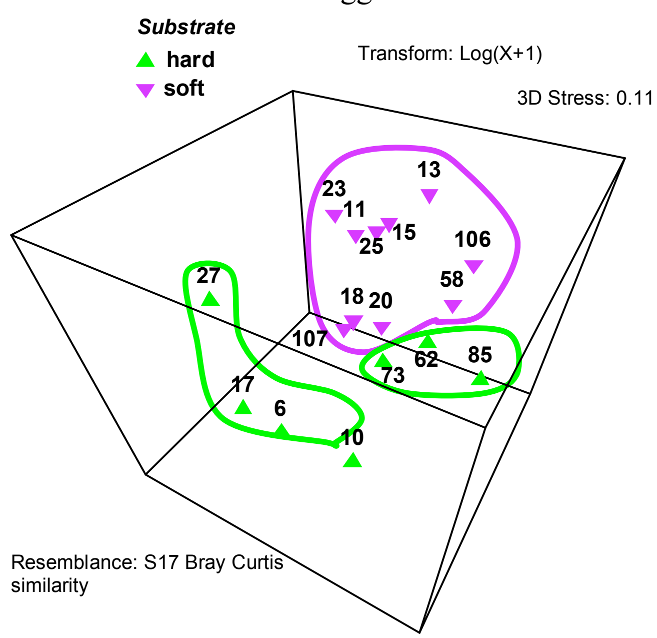

Figure 5: Similarity of RUSALCA 2004 epibenthic megafauna stations depicted in a multi-dimensional scaling plot based on complete species-stations matrix.

Gross abundance and biomass estimates ranged from 800-40,000 individuals 1000 m^{-2} and 1.6-69 kg wet weight 1000 m^{-2}, respectively [(1)]. Interestingly, biomass was highest on the Alaska Coastal Current side and at some of the Herald Canyon stations. This trend is apparently opposite to patterns observed for infauna (see above). At several stations, biomass and abundance were dominated by a single or few species, mainly echinoderms, namely the brittle star *Ophiura sarsi*, the sea urchin *Strongylocentrotus* sp., the sea star *Ctenodiscus crispatus* and the sea cucumber *Myriotrochus rinkii*. The dominance of echinoderms was also recorded in previous studies of Arctic shelf epifauna.

[(1)] Note that trawl assessments of abundance and biomass are estimated based on trawl time and trawled area, which cannot always be determined accurately. Resulting values are therefore termed 'gross' abundance and biomass.

Chionoecetes opilio, a commercially harvested species in the Bering Sea, occurred in considerable numbers at several stations at sub-legal size. Similarities between epifaunal communities were primarily based on substrate type (hard versus soft bottom); similar stations are close together in Fig. 5. Typical hard bottom fauna, found in Bering Strait, along the coasts and in the center of Herald Valley, included bryozoans, ascidians and sponges. Characteristics of the main water masses appeared to have less influence on epibenthic community composition although a more thorough analysis with a complete oceanographic dataset has yet to be performed. Herald Canyon stations contained more Arctic species than the southern stations. As a preliminary conclusion, we suggest that major changes in current regime, and therefore sea floor substrate structure, should be reflected in epifaunal composition, especially in the ratio of filter-feeding versus deposit-feeding taxa.

<u>Chukchi Sea Food web</u>

Epibenthic trawl, Van Veen grab, and CTD rosette water samples from 14 stations were processed for stable carbon and nitrogen isotope analysis to elucidate food web structure and relate it to water mass characteristics. Plankton samples were available only sporadically. A total of 62 water samples, 40 surface sediment samples, 143 plankton samples and 2165 tissue samples of infaunal and epibenthic organisms were collected. Samples were dried at 60ºC, HCl-treated to remove inorganic carbonates and measured using continuous-flow isotope ratio mass spectrometry (IRMS) at the Alaska Stable Isotope Facility.

Particulate organic matter (POM), the major food base, showed isotopically distinct trends in the southern Chukchi Sea region: POM from western stations under nutrient rich Anadyr Water (AW) influence was enriched in $\delta^{13}C$ (average -21‰) compared to stations on the eastern side under nutrient poor Alaska Coastal Current (ACC) influence (average -24‰). POM values for Herald Canyon are not available because of IRMS instrument failure. Coupling between POM and benthic consumers was tighter at stations under AW conditions than at ACC locations as indicated by the short isotopic distance between POM and consumers (Fig. 6). This resulted in comparatively longer overall food webs at ACC locations (3-4 TL for the fauna sampled) than at AW locations (2-3 TL). We suggest that benthic organisms under AW influence receive fresher, less reworked food while those under ACC influence receive more refractory material. We suggest that more extensive reworking and recycling of POM

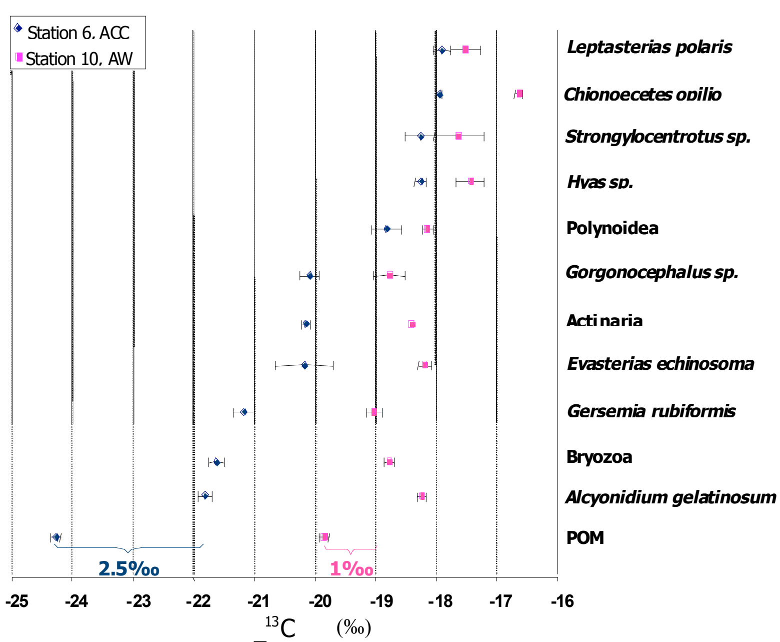

Figure 6: Benthic food web structure ($\delta^{13}C$) at stations six and ten as described by stable isotope signatures (sample subset).

in the pelagic ACC food web may be responsible for this difference. Our results indicate that stable isotope composition of POM and benthic fauna at different locations mirror local water mass characteristics. These isotopic signatures are, therefore, a valuable link between physical oceanography and its biological consequences as well as indicators of ecosystem functioning. A change in water mass characteristics (e.g., productivity) would likely be reflected in food web structure and expressed in isotopic composition.

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