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Zooplankton Data Report: Distribution of Zooplankton in the Western Arctic During Spring 2004

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Introduction

The data reported here are the results of zooplankton sampling conducted in 2004 during the second phase of the National Science Foundation's Shelf Basin Interactions (SBI) program. The SBI program was developed to explore the effects of climate change on biogeochemical processes in the Arctic. Phase two of SBI emphasized fieldwork in the western Arctic, specifically the Chukchi and Beaufort Seas. Further background information may be found on the SBI website at http://sbi.utk.edu/. Users of this report are encouraged to consult the zooplankton data resulting from the 2002 fieldwork (Lane *et al.*, 2006; 2008).

Methods

Zooplankton samples were collected from the USCGC *Healy* between 24 May and 21 June 2004 (cruise designation HLY0402). Sampling focused on the shelf and slope regions in the northeastern Chukchi Sea and western Beaufort Sea (Figure 1). Samples were collected with vertically hauled Bongo nets with a 60 cm diameter net-mouth and 150 μm and 335 μm mesh nets (Sea-Gear Corporation), or with a Hydro-Bios MultiNet plankton sampler with a 0.25 m^2 net mouth fitted with 150 μm mesh nets, pressure sensor and flowmeter. Nets were generally lowered at 20 m min^{-1} and retrieved at 30 m min^{-1}. Maximum depths sampled with the Bongo net were measured with a Wildlife Computers Mk9 depth recorder that was attached to the top of the Bongo frame. The volume filtered by the Bongo net was measured by a TSK flowmeter placed off-center in the net mouth. Locations, bottom depth and sampling depths of collections in this report are listed in Table 1. Samples were preserved immediately after collection in either 95% ethanol or 4% buffered formaldehyde/seawater solution.

Laboratory analyses were performed at the University of Miami's Rosenstiel School of Marine and Atmospheric Science. Samples selected for taxonomic enumeration were split several times in a Folsom splitter (Van Guelpen *et al.*, 1982). In general, three or four aliquots were counted for each taxonomic category identified. Usually the first counted aliquot contained approximately 200-400 individuals. The size of the second through fourth aliquots varied depending on the composition and number of species present. Abundance in terms of individuals per cubic meter (ind m^{-3}) was estimated for each category by dividing the number counted by the fraction of the sample counted for that category and dividing that result by the volume of water filtered. The use of 150 μm mesh Bongo nets precludes quantitative estimates

of certain categories including copepod nauplii and copepodites of smaller calanoid, cyclopoid, and harpacticoid species, such as *Pseudocalanus* spp., *Oithona similis*, and *Microsetella* sp. respectively. Nonetheless, these groups were counted to indicate their presence and to estimate their relative abundances.

Species enumeration and identification were conducted with the aid of Leica Wild M10 and Wild M5 dissecting microscopes and a Wild M20 compound microscope following the methods reported in Lane *et al*. (2006; 2008). The following methods, including all size measurements, were completed during analysis of samples collected in 2002. The same methods were applied to samples collected in 2004. Prosome length measurements of selected copepods were made with a calibrated ocular micrometer at 12X magnification and converted to mm (1 division = 0.037mm). Table 2 lists species and categories enumerated during the present study. Copepod species were identified by the following criteria.

Calanus hyperboreus and *C. glacialis*. These large calanoid copepod species were the most thoroughly analyzed in this work. Prosome length (PL), distance from the anterior tip of the cephalosome to the distal posterio-lateral end of the last thoracic segment and morphological characteristics were used to distinguish adults for both species (Brodsky, 1950; Frost, 1974). The PL of randomly sorted copepodite stages C1 (781 individuals), C2 (564 individuals) and C3 (360 individuals) from several stations sampled in 2002 (EB7, EB1, EHS1, EHS11, WHS7, HV4 and HV3) were measured and length-frequency plots were constructed for each stage (Figure 2). Additional PL measurements were then made of these three copepodite stages (153 C1, 69 C2 and 53 C3) for subsequent molecular analyses to determine which PL ranges were associated with *C. hyperboreus* as opposed to *C. glacialis*. Length-frequency plots were again constructed for the specimens used in the molecular analysis performed using the mitochondrial 16s rRNA gene. The universal primer 16SASR (5'-CGCCTGTTTAACAAAAACAT-3') and the recently modified primer 16SB3R (5'-TAATTCAACATCGAGGTCACAA-3') were used to amplify the 16s rRNA gene. PCR conditions consisted of 40 cycles of denaturing at 94°C for 1 minute, annealing at 50°C for 2 minutes and extending at 72°C for 3 minutes. The last cycle was followed by an extension period of 7 minutes at 72°C. Nucleotide sequences were determined using an Applied Biosystems 3730 DNA Analyzer. Individuals were identified by comparing nucleotide sequences of the mitochondrial 16S rRNA gene with the previously described sequences of *C. glacialis* and *C. hyperboreus* collected in the Norwegian Sea (Lindeque *et al*., 1999). A bimodal distribution of PL is clear for stage C3 and is supported by the genetic

analyses; however, the C2 and C1 data present some overlap (Figure 2A, B). In the case of C2s, genetic analyses verified that 6 of 69 specimens (<10%) were *C. hyperboreus*, however the size frequency was not clearly bimodal (Figure 2B). Therefore, we chose the upper size limit of 1.5 mm given by Grainger (1963) for routine sample analyses. In the case of C1s, the genetic identification verified that only two of the 153 C1 individuals (<2%) were *C. hyperboreus* and the prosome lengths of those two specimens were both 1.03 mm. However, there were several specimens of *C. glacialis* identified genetically that had prosome lengths greater than 1.03 mm. Therefore, we used the maximum prosome length of *C. glacialis* C1 found in the literature, 1.07 mm (Grainger, 1963), so as not to underestimate the abundance of *C. glacialis* copepodites, which were far more abundant than *C. hyperboreus* copepodites in our samples. *Calanus* spp. copepodite stages C4 and C5 were distinguished following the size criteria given in Madsen *et al*. (2001) in addition to the presence or absence of the acute terminal process of the fifth metasomal segment. Size ranges of *Calanus* spp. prosome lengths are summarized in Table 3.

Metridia longa. Adults of this species were identified following the descriptions of Brodsky (1950) and Thorp (1980). Copepodite stages were identified by their body shape and presence of terminal spines on the last thoracic segment and grouped.

Pseudocalanus spp. Frost (1989) recognized seven species of *Pseudocalanus* and reported at least four species co-occurring in the SBI study region. In the present study, adult females of *P. minutus* were differentiated from other species by their anterior cephalosome shape (Frost, 1989). Adult males and adult females other than *P. minutus*, and copepodite C5s of this genus, were counted as *Pseudocalanus acuspes* or *Pseudocalanus* sp. Copepodites less than C4 were grouped with unidentified calanoid copepodites, which included the *Microcalanus pygmaeus* C1, C2 and C3 stages (Table 2).

Acartia longiremis. Adult males and females of this species were distinguished following the descriptions of Brodsky (1950) and Bradford (1976). All copepodite stages of this species were grouped.

Microcalanus sp. All adults were identified as *Microcalanus pygmaeus* and sex was listed separately. Copepodite stages C4 and C5 of this species were grouped together and C1, C2, and C3 were grouped with unidentified calanoid copepodites C1-C3.

Oithona similis. Adult males and females of this species were listed separately and all copepodite stages were counted as a single group. Identification was done according to Nishida (1985).

Oncaea spp. Two species of *Oncaea, O. borealis* and *O. parila*, were observed in our samples and they were grouped for the present study. All copepodite stages were counted as a single group, and males and females of this genus were distinguished by body size and shape of the genital segment (Heron *et al*., 1984).

Less abundant copepods. Adults and copepodite stages C4 and C5 of some less abundant copepods were easily identified to the species level by morphology. In general these species were found in deep MultiNet samples. The following briefly lists the references used in identifying these species. *Paraeuchaeta* spp. were identified following Park (1978, 1995) and Brodsky (1950). *Aetideopsis* spp. *Chiridius obtusifrons*, *Chiridiella abyssalis* and *Gaetanus* spp. were identified following Markhaseva (1996). *Scaphocalanus magnus* was identified following Park (1982) and Sars (1903). *Spinocalanus* spp. were identified following Damkaer (1975) and Brodsky (1950). *Undinella oblonga* was identified following Brodsky (1967). *Lucicutia polaris* was identified following Hulsemann (1966) and Brodsky (1950). *Heterorhabdus norvegicus* and *Paraheterorhabdus compactus* were identified following Park (2000) and Sars (1903). *Temorites brevis* was identified following Sars (1900) and Vervoot (1957). *Haloptilus acutifrons* was identified following Bradford-Grieve (1999) and Sars (1925). *Augaptilus glacialis* was identified following Brodsky (1950) and Sars (1925). *Neomormonilla minor* was identified following Giesbrecht (1982).

Other zooplankton. Identification of other zooplankton such as chaetognatha, appendicularia, and various meroplanktonic taxa was carried out only to general taxonomic groupings. Chaetognaths were divided into size categories to offer some indication of their relative contribution to zooplankton biomass (Table 2).

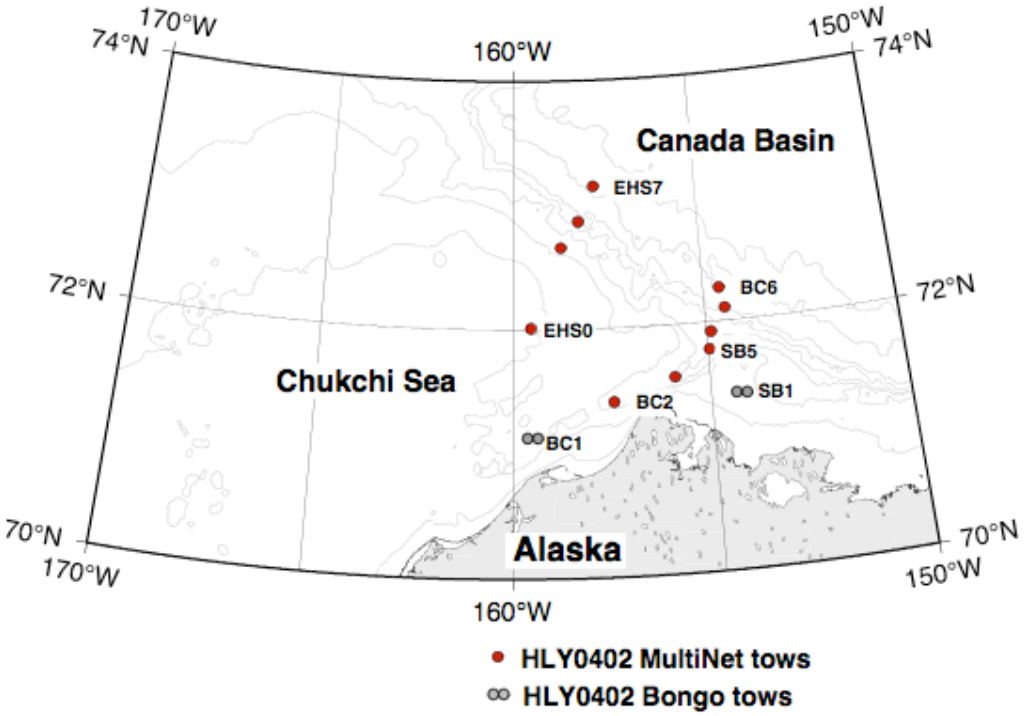

Figure 1. Station map showing zooplankton sampling locations for the present report. See Table 1 for position listings and station abbreviations.

Table 1.
Summary of net tow locations during cruise HLY0402. Stations are listed in the chronological order in which they were sampled during the cruise. Positions are listed as degrees and decimal minutes.

Date	Latitude (°N)	Longitude (°W)	Sonic depth (m)	Station	Master Station[a]	Gear	Sample depth(s) (m)
24-May-04	72 00.38	159 41.05	42	9	EHS0	MultiNet	42-22-0
30-May-04	72 39.23	158 42.98	149	16	EHS4	MultiNet	132-99-50-0
3-Jun-04	72 51.81	158 14.31	1043	19	EHS6	MultiNet	850-600-200-100-50-0
4-Jun-04	73 08.69	157 47.37	2388	20	EHS7	MultiNet	1500-1000-600-300-100-0
8-Jun-04	71 26.40	154 18.30	36	22	SB1	Bongo	32-0
12-Jun-04	71 46.75	154 57.08	260	24	SB5	MultiNet	250-200-150-100-50-0
14-Jun-04	72 06.27	154 28.03	1522	26	BC5	MultiNet	1450-1000-600-300-100-0
15-Jun-04	72 16.19	154 34.27	1767	27	BC6	MultiNet	1500-1000-600-300-100-0
16-Jun-04	71 55.32	154 52.50	572	28	BC4	MultiNet	550-300-200-100-50-0
19-Jun-04	71 34.73	155 52.90	193	31	BC3	MultiNet	180-150-100-50-0
20-Jun-04	71 24.25	157 27.23	122	34	BC2	MultiNet	110-50-0
21-Jun-04	71 07.07	159 21.40	87	35	BC1	Bongo	75-0

[a] EHS = East Hanna Shoal; SB = Shelf Basin; BC = Barrow Canyon

Table 2. Species and groups targeted in the laboratory enumerations.

Large-bodied copepoda	Small-bodied copepoda	Miscellaneous unidentified copepoda	Other zooplankton
Calanus hyperboreus, C1, C2, C3, C4, C5, Adults	*Pseudocalanus* sp., C4-C5 grouped, Adults	Copepod nauplii	Amphipods
Calanus glacialis, C1, C2, C3, C4, C5, Adults	*Pseudocalanus minutus,* Adult female	Calanoid Copepodites, unidentified C1-C3 grouped	Barnacle nauplii
Metridia longa, C1-C5 grouped, Adults	*Pseudocalanus acuspes,* Adult female	Cyclopoid Copepodites, unidentified	Barnacle cypris
Metridia pacifica, C1-C5 grouped, Adults	*Microcalanus pygmaeus,* C4-C5 grouped, Adults	*Microsetella* sp., All grouped	Bivalve larvae
Eucalanus bungi bungi, C4-C5 grouped, Adults	*Scolecithricella minor,* C4-C5 grouped, Adults	Harpacticoids, unidentified	Chaetognaths 0-10 mm
Paraeuchaeta glacialis, Adults	*Acartia longiremis* C1-C5 grouped, Adults		Chaetognaths 10-15 mm
Paraeuchaeta barbata, Adults	*Oithona similis* C1-C5 grouped, Adults		Chaetognaths 15-20 mm
Paraeuchaeta spp., C4-C5 grouped	*Oncaea* spp. C1-C5 grouped, Adults		Chaetognaths 20-25 mm
Aetideopsis rostrata, C4-C5 grouped, Adults	*Neomormonilla minor,* all grouped		Chaetognaths >25 mm
Aetideopsis armata, C4-C5 grouped, Adults	*Lubbockia* spp., all grouped		Cnidaria
Chiridius obtusifrons, C4-C5 grouped, Adults			Decapod larvae
Gaetanus brevispinis, C4-C5 grouped, Adults			Echinoderm larvae
Gaetanus tenuispinus, C4-C5 grouped, Adults			Euphausiids
Chiridiella abyssalis, C4-C5 grouped, Adults			Gastropod larvae
Scaphocalanus magnus, C4-C5 grouped, Adults			Larvaceans
Spinocalanus longicornis, Adults			Ostracods
Spinocalanus elongatus, Adults			Polychaete larvae
Spinocalanus horridus, Adults			Actinia larvae
Spinocalanus spp., C4-C5 grouped			Ascidia larvae
Spinocalanus antarcticus, C4-C5 grouped, Adults			Briozoo larvae
Undinella oblonga, C4-C5 grouped, Adults			Facetotecta
Lucicutia polaris, C4-C5 grouped, Adults			Foraminifera
Heterorhabdus norvegicus, C4-C5 grouped, Adults			Nematode
Parahetorhabdus compactus, C4-C5 grouped, Adults			Parasitic isopod
Temorites brevis, C4-C5 grouped, Adults			Planaria
Haloptilus acutifrons, C4-C5 grouped, Adults			Siphonophora
Augaptilus glacialis, C4-C5 grouped, Adults			Tharybis
			Unidentified zooplankton

Table 3. Size range of prosome lengths and distinguishing characteristics of copepodite and adult stages of *Calanus glacialis* and *C. hyperboreus*.

Stage	Number of urosome segments	Number of swimming legs	Prosome length (mm)		
			C. glacialis	*C. hyperboreus*	
C1	2	2	0.750 – 1.070	>1.070	Our results; Grainger, 1963
C2	2	3	1.100 – 1.500	>1.500	Our results; Grainger, 1963
C3	2	4	1.600 – 2.000	>2.000	Our results
C4	3	5	2.025 – 2.925	>2.925 5th metasome segment with acute process	Madsen *et al.*, 2001
C5	4	5	2.725 – 3.900	>3.900 5th metasome segment with acute process	Madsen *et al.*, 2001
AF	4	5	> 3.000	>4.500 5th metasome segment with acute process	Madsen *et al.*, 2001
AM	5	5	> 3.000	>4.500	Madsen *et al.*, 2001

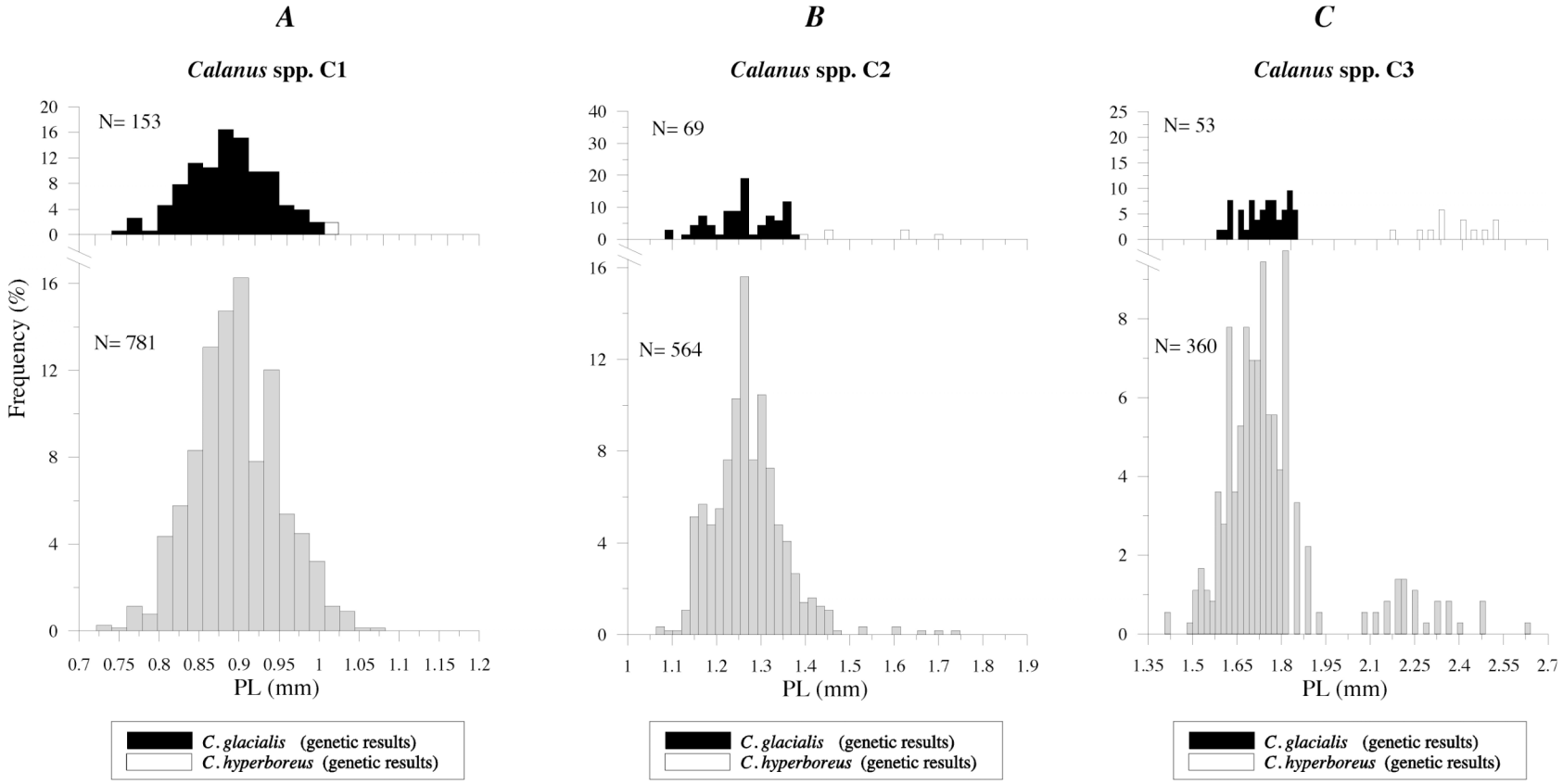

Figure 2. Length-frequency plots of prosome length of randomly sorted *Calanus* spp. copepodite stages C1 (panel A), C2 (panel B) and C3 (panel C) collected in 2002 from stations EB7, EB1, EHS1, EHS11, WHS7, HV4 and HV3. The top plot in each panel represents only those specimens that were examined by molecular methods (these specimens were preserved in ethyl alcohol). The lower plot in each panel represents a larger sampling of the population for which no molecular analyses were done (these specimens were preserved in buffered formalin seawater). A bimodal size distribution among the genetic results was clear only for the C3 stages, therefore the size criteria published by Grainger (1963) were used to separate the two species in the C1 and C2 stages. Size ranges of all *Calanus* spp. stages distinguished in the present study are listed in Table 3.

Data

The taxonomic abundance data are listed for each station (in chronological order; Table 1) in Excel worksheets. Each page includes header information describing the cruise, ship, date and time in UTC, latitude and longitude in degrees and decimal minutes, net type (Bongo or MultiNet) and net mesh, tow depth interval (m), and volume of water filtered (m^3). The copepod taxa are listed first and are followed by the more general other zooplankton categories. For each taxon counted, the total number of individuals counted in subsamples is listed in columnar format followed by the percent of the sample sorted for that category and the estimated abundance in number of individuals per cubic meter. Note that abundance calculations are formatted to report one decimal place (i.e., tenths of individuals per cubic meter). Therefore if the abundance of a given category was calculated to be less than 0.05 individuals m^{-3} then the report lists that abundance as 0.0. The user of the report may calculate the actual value using the method described above, or by selecting (clicking on) the abundance cell of the corresponding organism in the electronic worksheet, which is available for download at the SBI data archive (http://www.eol.ucar.edu/projects/sbi/). The total number of specimens counted and the total zooplankton per cubic meter are given at the bottom of each list. Any comments made by the person counting the sample, for example presence of dense algae or cnidaria, are typed at the end of the list.

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