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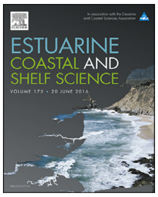

A seasonal comparison of zooplankton communities in the Kara Sea — With special emphasis on overwintering traits

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ABSTRACT

Siberian marginal seas cover large parts of the marine Arctic and host unique zooplankton communities. Detailed knowledge of their community structure and life history traits is a prerequisite to predict their response to ongoing and future climate and anthropogenic changes although winter data is extremely rare. Here data are presented from winter samples (February and April) in four biogeographic regions of the Kara Sea. Comparison of community composition and zooplankton abundance/biomass with data collected during summer showed lower diversity in winter, mainly due to the absence of freshwater species. In contrast to many other northern regions, seasonal biomass differences were relatively small. Year-round high biomass is maintained through a large share of small copepod species and constantly high share of the chaetognath *Parasagitta elegans*. An advanced state of gonad maturation and reproduction was observed in winter in herbivorous, omnivorous, and carnivorous species, e.g. the copepods *Calanus glacialis*, *Drepanopus bungei*, *Limnocalanus macrurus*, *Oithona similis*, *Pseudocalanus major*, *Pseudocalanus minutus/acuspes*, *Paraeuchaeta glacialis*, *Microcalanus pygmaeus*, and euphausiids, hydromedusae, and pteropods. Meroplanktonic larvae of nudibranchia, polychaeta and bivalvia were also registered. Close to the Yenisei mouth, abundance of eggs and larvae of various taxa exceeded older stages. Our data show that the brackish-water zone of the Kara Sea hosts specific communities with omnivorous species efficiently exploiting local resources during the winter and utilizing them for winter reproduction.

1. Introduction

According to a classical paradigm, life history traits of zooplankton in the Arctic are strongly coupled to the light cycle and its control of primary production (Østvedt, 1955; Conover, 1988; Smith and Sakshaug 1990; Grebmeier et al., 1995). Recent observations of ongoing reproduction in several zooplankton species under a solid ice cover (Hirche and Kosobokova, 2011) and studies on various aspects of polar night ecology in Svalbard fjords (Berge et al., 2015) challenge this paradigm. Unfortunately, seasonal comparisons of zooplankton composition in the Arctic are mainly restricted to fjords around Svalbard (Weslawski et al., 1991, 1993; Walkusz et al., 2009; Hirche and Kosobokova, 2011; Weydmann et al., 2013), western Greenland (Madsen et al., 2008) and the White Sea (Kosobokova and Pertsova, 2005). Knowledge on reproductive traits in zooplankton during the winter is even more limited. Due to the difficult access, seasonal observations from the Siberian Arctic seas, which occupy approx. 30% of the Arctic, are restricted to a few shallow locations in the Kara Sea (Chislenko, 1972a,b) and near-shore waters of the Laptev Sea (Abramova, 2000). Climate induced changes in ice cover and precipitation and, consequently, river runoff together with increasing human impact may strongly affect the pelagic system of these large seas and make a better understanding of their ecology necessary. Extrapolation of observations from other regions is difficult due to the specifics of these seas, namely a strong regionality of communities due to strong salinity gradients caused by river runoff and advection of water masses from the Arctic Ocean and neighboring seas (Carmack and Wassmann, 2006).

The Kara Sea, due to its heterogeneous topography and greatly varying hydrographic regimes hosts several zooplankton communities differing in composition, structure and function (Hirche et al., 2006; Flint et al., 2010). Advection of Barents Sea water, strong

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riverine freshwater input, seasonal variation of water temperature in the upper water layer, and sea ice are major factors structuring the pelagic environment and marine fauna. Ice formation in the Kara Sea begins at the end of September or early October. The breakup usually begins in the estuaries in early to late June, followed by an advancing arc of open water further seaward (Mironov et al., 1994). The only annual observations on the Kara Sea zooplankton were carried out in the coastal zone near Dikson Island by Chislenko (1972b). Winter zooplankton collections were obtained recently, between February and April 2000, at four locations near Dikson (Vinogradov et al., 2001) and five other locations in February 2002 (Dvoretsky and Dvoretsky, 2009).

Here we present data on the zooplankton composition and winter reproduction of common taxa in four previously defined biogeographic zones of the Kara Sea (Fetzer et al., 2002; Deubel et al., 2003; Hirche et al., 2006), (1) the estuaries of the southern Kara Sea, (2) the coastal zone outside estuaries, (3) the central open Kara Sea, and (4) the south-western (SW) Kara Sea, based on material collected during the winters 2001 to 2002, and compare them with data from late summer expeditions to the same zones. Additionally, samples from two sediment trap moorings deployed during two year cycles are used to complement observations on the winter state of zooplankton. The goals of our study were 1) to establish an inventory of invertebrates present in the pelagic of the Kara Sea during the winter season and compare it with summer data, and 2) to describe the population structure and reproductive state of different trophic groups of plankton during the winter months, using developmental stage structure, gonad maturity and presence of eggs and larvae.

2. Material and methods

Zooplankton were collected during five surveys to the Kara Sea. The winter collections include 10 samples from 8 locations obtained in April 2001 and February 2002 from the Russian nuclear icebreakers “Taimyr”, “Rossiya” and “Yamal” (Table 1, Fig. 1). In April 2001 sampling sites were located along a transect from the Yenisei estuary to the central Kara Sea. In 2002 they were located along the western coast of the Taymyr peninsula from the Yenisei estuary to the northwestern tip of the peninsula, plus one station in the SW Kara Sea (Fig. 1, Table 1). Samples were collected using a Juday net (0.1 m^2 catching area; 180 μm mesh size) towed vertically from the bottom to the surface (2001), or at deeper stations from 60 m to the surface (2002). The surface salinity and temperature were measured using a Salinometer (GM-65) and a digital thermometer.

For faunistic and abundance/biomass comparison, samples collected during the ice-free seasons in the same regions were used, including collections from two late summer cruises with R/V ‘Akademik Boris Petrov’ (ABP) in September 2000 and August 2001 to the southern and central Kara Sea (the German-Russian Project SIRRO), and two stations from a cruise with RV ‘Dalnye Zelentsy’ (DZ) to the southwestern Kara Sea (Hirche et al., 2006). The ABP samples were collected using vertical tows of a Nansen net (0.44 m^2 catching area, 150 μm mesh size) from close to the bottom to the surface (Table 1). Samples from DZ were collected by the same net design as the winter samples. CTD profiles were taken over the entire water column with an OTS-116 Probe (Meerestechnik Electronic GmbH). Salinity was measured according to the Practical Salinity Scale.

All mesozooplankton organisms in the samples were counted and measured under a stereo microscope. Most taxonomic groups including Copepoda (Calanoida and Cyclopoida), Amphipoda, Pteropoda, Chaetognatha, Larvacea, and Hydromedusae were identified to the species level. Prosome length was used to distinguish the closely related copepod species *Calanus finmarchicus* (Females $<$ 3.1 mm, CV $<$ 2.9 mm, CIV $<$2.2), *Calanus glacialis* (Females $>$ 3.1 mm, C5 $>$ 2.9 mm, C4 $>$ 2.2), and *Calanus hyperboreus* (C4 $>$ 3.0), according to Hirche et al. (1994). For most copepod species all copepodite stages were distinguished, but for two congeners *Pseudocalanus minutus* and *P. acuspes* copepodids C1 to C3 were pooled (Table 2). In contrast, all copepodite stages of *Pseudocalanus major* were distinguished and identified to the species level. *Oithona similis* and *Triconia borealis* copepodids C1 to C3 were pooled for each species, but adult females and males were distinguished. Calanoida eggs were assigned to *C. glacialis* and *P. major* based on their size and morphology, in conjunction with

Table 1
Sampling dates, station positions, surface temperature and salinity. n.d. = no data.

	Date	Bottom depth, m	Sampling depth, m	Latitude, °N	Longitude °E	T°C	Salinity
Winter							
2001	April						
W3	23	20	18	72°36′	80°08′	−0.2	4.6
W4	23	40	38	74°00′	78°02′	−1.3	26.5
W5	28	32	30	75°02′	77°08′	−1.8	28.9
W6	21	125	120	76°03′	76°38′	−1.7	34.2
2002	Feb						
W7	6	22	21	72°35′	80°05′	−1.8	28.3
W8	13	28	23	72°59′	79°51′	−0.5	27.4
W9	21	21	20	73°32′	80°22′	−1.6	30.5
W10	16	107	60	71°14′	61°52′	−1.6	29.0
Summer/fall							
2000	Sept						
S13	9	13	10	72°56′	80°33′	3.6	22.7
S23	14	33	30	73°29′	79°51′	0.6	28.2
S24	14	31	28	74°01′	80°00′	1.4	22.8
S26	15	68	60	75°43′	77°58′	4.2	18.9
S27	15	78	75	76°18′	78°56′	2.5	22.4
2000	Oct						
DZ41	12	113	100	71°19′	60°11′	n.d.	n.d.
DZ42	12	135	100	12°44′	61°34′	n.d.	n.d.
2001	Aug						
S1	14	38	35	74°59′	76°23′	6.3	37.9
S19	21	28	24	72°36′	80°06′	9.8	6.0
S26a	23	33	32	74°00′	80°01′	8	12.3
S58	02 Sep	94	75	76°48′	78°21′	5.3	22.0