COMPOSITION AND STRUCTURE OF MACROZOOBENTHOS OF EXPOSED SANDY LITTORAL ON BERING ISLAND

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This paper presents key primary data from the initial phase of a longitudinal ecological monitoring project on the composition and spatial structure, and temporal change of the macrozoobenthos species on an exposed sandy beach on Bering Island (Commander Islands, northwestern Pacific Ocean) collected during May 2016 – April 2017. Five species are found (in order of decreasing of occurrence): *Eogammarus schmidti* (Amphipoda, Crustacea), *Archaeomysis grebnitzkii* (Mysidacea, Crustacea), *Microspio theeli* (Spionidae, Annelida), *Eteone longa* (Phyllodocidae, Annelida), and *Locustogammarus locustoides* (Amphipoda, Crustacea). Thus, this work builds upon and extends the list of species previously reported in literature. The mean biomass varied from 1.85 g/m^2 in April to 78.47 g/m^2 in November with an annual mean of 36.98 g/m^2 (standard error of the mean = 7.02). The mean abundance varied from 43 individuals/m^2 in April to 2257 individuals/m^2 in November with an annual mean of 1013 individuals/m^2 (standard error of the mean = 187), which is relatively low compared to literature data for other sites in the North Pacific. The abundance is higher in the lower littoral and remarkably lower in the middle and higher littoral. The ecological relationships between these described species could not be elucidated yet. Within the population of *A. grebnitzkii* the number of females significantly exceeds the number of males (the percentage of females varies from 53% in September to 98.7% in June with an overall mean of 75%). In the study area, *A. grebnitzkii* breeds from May to August. The diurnal dynamics previously espoused in literature have been affirmed in that *A. grebnitzkii* and *E. schmidti* presides during the night, unlike at day. Additionally, the distribution of the two key dominant benthic species in the intertidal zone are shown here to prefer the lower littoral regardless of high or low tide, in good agreement with previous literature findings.

Key words: abundance, Bering Sea, biomass, nature reserve, North Pacific

Introduction

Bering Island is situated in an area of low pressure (Aleutian low), and subject to strong winds, storm waves and swell. Most of the seashore on the island consists of cliffs and features the archetypal products of weathering (gravel, cobble or boulder) along the cliff bases and rocky platforms, girt by rocky reefs, which partially dampen wave action. The local environment features numerous littoral puddles. Regardless of the relatively few hydrobiological studies carried out on the island (Isaychev, 2016), both the rocky littoral and the subtidal zone have been described thoroughly (Ivanyushina et al., 1991; Oshurkov, 2000), unlike the sandy littoral and the subtidal zone. Tarakanova (1978) firstly described the exposed sandy and cobble littoral of Bering Island as a “dead zone” and noticed two species in the sheltered sandy littoral: the mysid *Archaeomysis grebnitzkii* Czerniavsky, 1882 and the amphipod *Anisogammarus kygi* Derzhavin, 1923. Rzhavsky (1997) mentioned the polychaete *Microspio theeli* Soderstrom, 1920 in sandy littoral.

The biology of another intertidal mysid from the genus *Archaeomysis – A. articulata* Hanamura, 1997 – has been described for the western coast of Hokkaido (Hanamura, 1999). *Archaeomysis grebnitzkii* is known as a common northern Pacific species, which thrives across a range of high and low salinity environments in the upper subtidal and intertidal zones; these mysids burrow in the sand during the day and ascend to the surface of the sand or to the top of the water column at night (Banner, 1948). Mysids are widely used as an indicator of anthropogenic pollution (Verslycke et al., 2004).

Anisogammarus kygi (recently moved to the genus *Eogammarus* (Tomikawa et al., 2006)), is a widely distributed boreal Asian amphipod and was mentioned for Bering island by Tarakanova (1978). Another species of the genus *Anisogammarus – A. (Spinulogammarus) spasski* (Bulycheva, 1952) – was described on the Commander Islands by Tzvetkova (1975) albeit without a description of the environment from which the organism was isolated.

Bering Island is a unique territory with special hydrological and weather conditions. Due to substantial upwelling bringing nutrients to the coast, proximal ocean waters are very productive. Though the Nature Reserve on Bering Island was only recently established, in 1993, Bering Island still experiences anthropogenic influence from the island's native inhabitants as well as from global environmental change.

The present study provides primary data for longitudinal ecological monitoring of the sandy beaches on Bering Island. The proximity of the study area to research settlement, and the relative simplicity of the sampling and sorting methods employed, makes the present data easy to actualise in future studies.

Material and Methods

Study area

The sampling site was situated on a sandy beach of Gavanskaya bay (N 55°12′, E 166°00′) of Bering Island (Commander Islands, Russia) (Fig. 1).

Topographically, the slope ratio of the study area is 4:100 and the substrate in the study area is well sorted (grain size inclusive standard deviation parameter (Folk & Ward, 1957) $\sigma_I = 0.41$) medium (mean grain size in φ scale = 1.47) sand. The littoral is exposed to wave action (surf-scaling parameter (Sherman, 2006) ε = 35) and may be designated as a littoral of the second bionomical type in the Kussakin's (1956, 1961) classification system. Storms occur regularly during the year (wind velocity exceeds 15 mps for 80 days a year with annual mean 7.1). The temperature of coastal waters in the study area varies from -1°C to 9°C throughout the year. Tides are semi-diurnal and uneven. The amplitude of tides in the study area ranges from 0.2 m to 2.2 m above the lowest astronomical tide. The shore is normally iceless throughout the year. There are six established research stations along the shore from which samples are taken.

Sampling and analysis

A total of 75 samples were taken. Samples were collected with a hand-held ground sampler with a mouth square of 0.025 m^2, then washed gently and passed through a fine mesh (pore size 0.5 mm^2) to remove debris. Samples were taken once per month from May 2016 to April 2017 except for December and February. Each sample was obtained from the same six research points along the shoreline in spring (syzygial) low water. Samples were collected from the water's edge every two hours from low to high tide in a transect perpendicular to the coast to examine the temporal distribution of benthos in rising and falling tide.

In order to study the diurnal migration of zoobenthos, samples were taken at the same site before and after dusk on the same day. Samples were fixed with 10% formalin diluted in sea water, then fixed with 70% ethyl alcohol after sorting. The sex has been determined for *Archaeomysis grebnitzkii* when the specimen size was more than 5 mm. The sorted animals were counted and then weighted with scale *Cas*^{TM} *MWP* with an accuracy 0.005 g. The data were analysed with R software (R Core Team, 2017).

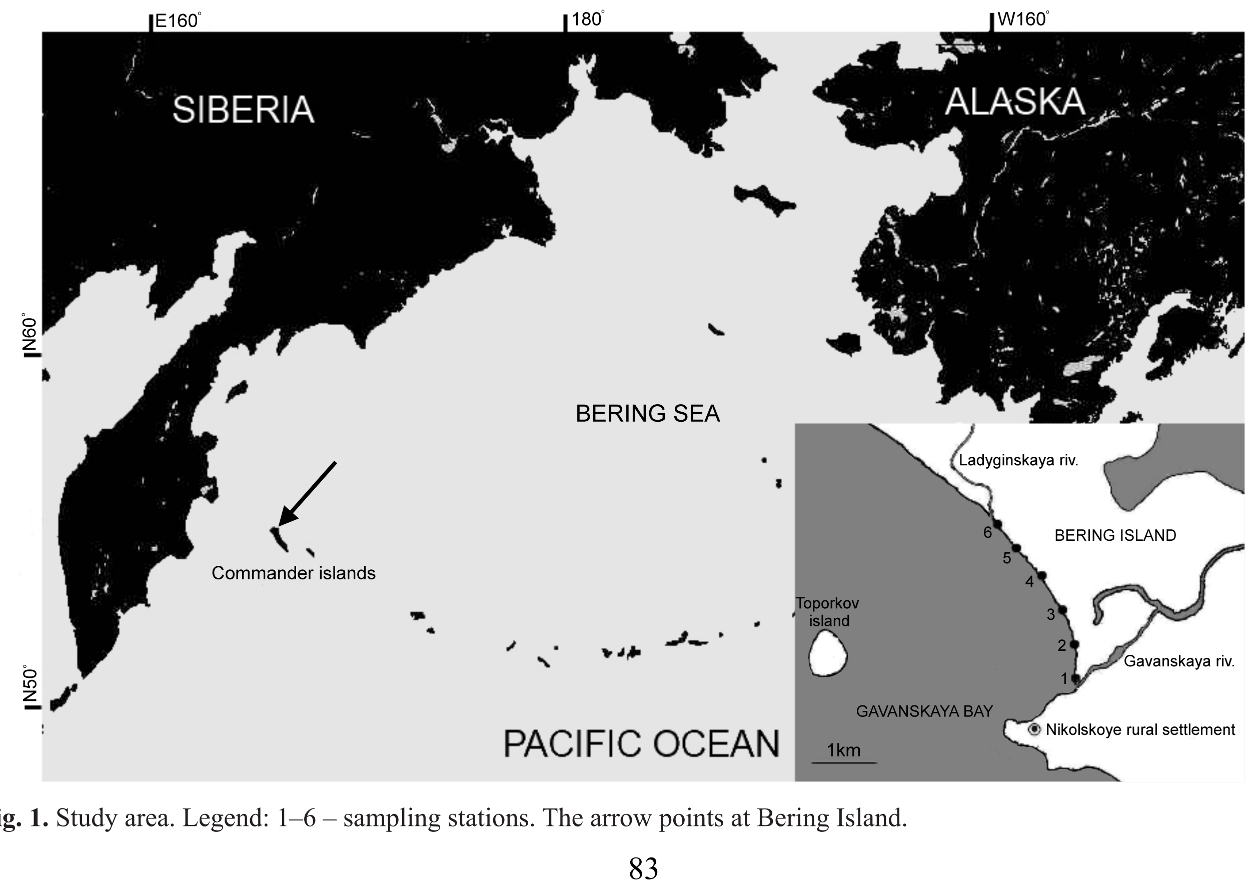

Fig. 1. Study area. Legend: 1–6 – sampling stations. The arrow points at Bering Island.

Results

The following species have been found in the samples (occurrence of species in samples are given in brackets): *Eogammarus schmidti* (Derzhavin, 1923) (66%), *Archaeomysis grebnitzkii* (42%), *Microspio theeli* (14%), *Eteone longa* (Fabricius, 1780) (< 3%) and *Locustogammarus locustoides* Brandt, 1851 (occurred once, < 1%). 19% of samples were empty.

The overall abundance of macrozoobenthos on the selected research stations varied from 0 to 9320 individuals/m^2. The Q1 value of the annual abundance was 40, the median was found to be 320 and the Q3 value was found to be 1560 individuals/m^2. The minimal monthly median abundance was determined to be in April (20 individuals/m^2) and the maximal monthly median abundance was found to occur in November (1700 individuals/m^2) (Fig. 2). The maximal abundance of the species *Eogammarus schmidti*, *Archaeomysis grebnitzkii* and *Microspio theeli* were respectively determined to be 4200, 21040 and 440 individuals/m^2 respectively.

The biomass of macrozoobenthos in the only sample collected during the whole period of study varied from 0 to 251 g/m^2 with the annual Q1 value = 0.97, median = 7.75, Q3 = 46.2. The monthly median biomass varied from 0.25 g/m^2 in April to 71.8 g/m^2 in November (Fig. 3).

During a tidal rise, the abundance and biomass of macrozoobenthos on the shoreline drastically decreased as it moved shoreward (Fig. 4). A correlation between the biomass of the two predominating species on the station and the distance from the station to the nearest river mouth has not been observed ($r = 0.34$, $p = 0.16$ for *Archaeomysis grebnitzkii*; $r = 0.13$, $p = 0.56$ for *Eogammarus schmidti*). *Archaeomysis grebnitzkii* occurred in samples taken from May to November. The ratio of females to males is 3:1 precisely. The proportion of females varied from 53% in September to 98% in June. The ratio of ovigerous females to the total number of females peaked (93%) in June and decreased to 0 in September (Fig. 5). The abundance of *A. grebnitzkii* in samples taken at night eclipsed those of samples taken during the day at the same site and equal height during low tide (> 20 000 individuals/m^2 and ~2500 individuals/m^2 respectively).

Discussion

Diversity

The diversity of species living in the area of study is very low. Nevertheless, this data expands the list of species given by Tarakanova (1978). The two most abundant species found in this study were the mysid *Archaeomysis grebnitzkii* and the amphipod *Eogammarus schmidti*.

The polychaete *Microspio theeli* was found in samples only sporadically (24 specimens in total). *Eteone longa* occurred only twice, and *Locustogammarus locustoides* only once in 75 samples.

Eogammarus schmidti can be distinguished from other Far-Eastern amphipods by numerous long chaetae on each pereopod (Gurjanova, 1951). Previous literature has reported the presence of *Anisogammarus kygi* on the sandy littoral of Bering Island (Tarakanova, 1978). *Anisogammarus kygi* is known as a common inhabitant of the intertidal zone, and can be found on the rivers of Western Kamchatka. However, this study was unable to find neither *Anisogammarus kygi*, nor any species of freshwater amphipods in the study area at all. Perhaps the species *E. schmidti*, found in this study, has previously been confused with *A. kygi*.

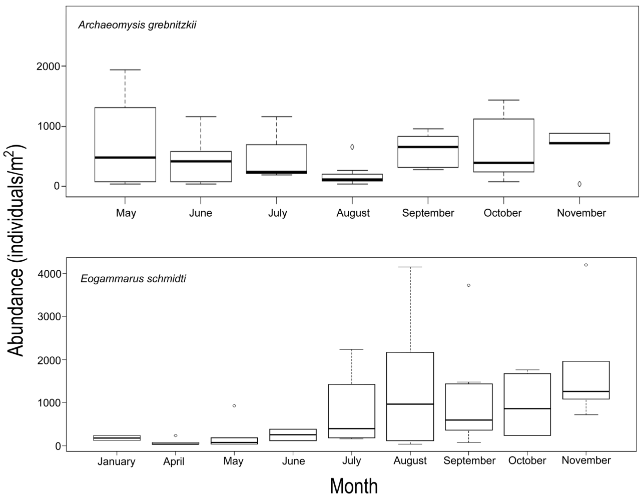

Fig. 2. The monthly abundance of two mass species of sampled macrozoobenthos.

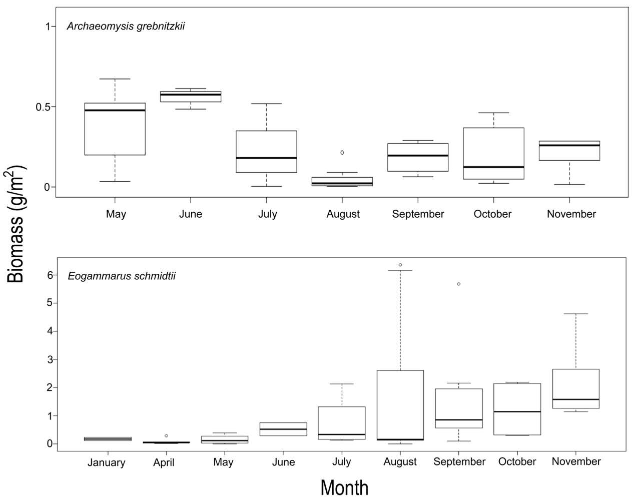

Fig. 3. The monthly biomass of two mass species of sampled macrozoobenthos.

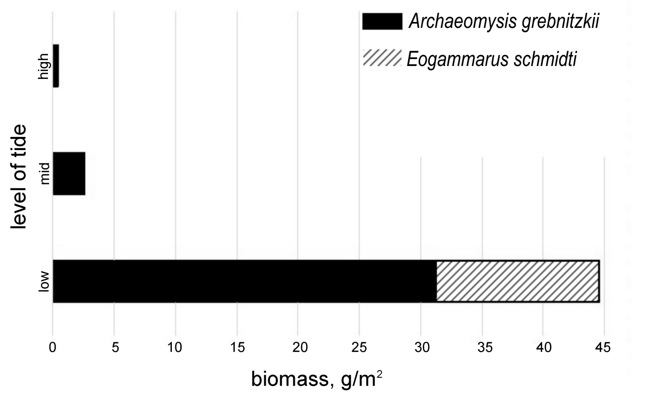

Fig. 4. The net biomass in samples taken sequentially from the water's edge at different phases of tide.

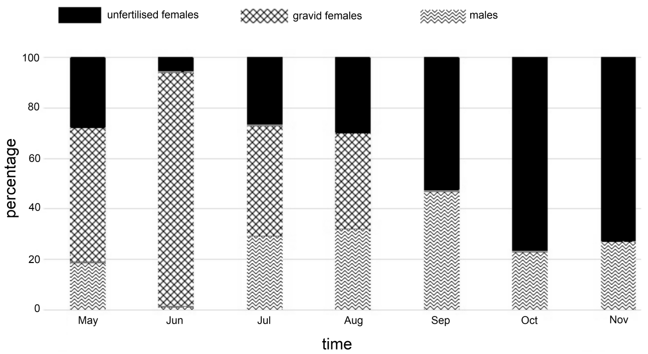

Fig. 5. Sex ratio within population of *Archaeomysis grebnitzkii.*

Abundance and biomass

Though the density of macrozoobenthos fluctuated remarkably from one sample to another, it is clear that the average density is lower in winter and early spring, then increases in May and peaks from September to November.

Data obtained during the months of October and November may be skewed by seasonal interference as samples were taken after dusk in these months specifically. These samples were taken after dusk in order to accurately reflect spring (syzygial) tide, which occurs later in the sampling day of each calendar month. This leads to a degree of confounding, as it has been shown that the dominant species thrive much more after dusk in the littoral. Despite the generally observed trend that zoobenthos density decreased with increasing tide, the data from October and November may be disproportionately high due to these organisms thriving in darker conditions when these samples were taken. Additionally, literature data indicating that *Archaeomysis grebnitzkii* is particularly sensitive to oxygen deprivation (Green, 1968) is in excellent agreement with the observed trend in this study for the abundance of *Archaeomysis grebnitzkii* to decrease significantly with an increase in tide.

Samples have been collected in the area between the mouths of the two key rivers located proximally to the research stations. The abundance and biomass of the dominant species do not rely on the distance between the river mouth and the sampling point, which confirms that *Archaeomysis grebnitzkii* thrives across a wide salinity range (0–34 practical salinity units – euryhaline) as reported by Banner (1948). Even though *Eogammarus schmidti* is known as an exclusively marine intertidal species (Lowry, 2010), we suppose that it may overcome minor shifts of salinity as intertidal species usually do (Dorgelo, 1976).

The high abundance of *A. grebnitzkii* in the lower littoral, and the remarkable flux in abundance between samples taken during the day and those during the night, are in excellent agreement with previous data (Marin Jarrin & Shanks, 2011).

Population structure of Archaeomysis grebnitzkii

Females outnumber the males (mean sex ratio is precisely 3:1) by a substantial margin. The incidence of females in the present study is higher compared to other mysid species, e.g. (54% for *Archaeomysis articulata* (Hanamura, 1999); 50–72% for *Neomysis americana* (S.I. Smith, 1873) (Pezzack & Corey, 1979); and 50–66% depending on range of wave action for *Schistomysis spiritus* (Norman, 1860) (Mauchline, 1967)).

Mauchline (1967) suggested that the greater the impact of wave action on a given site, the greater will be the incidence of females in the population. This is a surrogate for population productivity, and is of significant importance in harsh environments such as exposed sandy littoral, due to the relatively high mortality expected for these species. For as long as the sampling sites on Bering Island experience huge wave action, it is likely that the mean sex ratio will remain biased towards females.

Conclusions

Bering Island experiences some of the strongest wave action in the North Pacific. This strong wave action is correlated with the relatively low biomass, diversity, and abundance of macrozoobenthos on the sandy beach in this investigation, in tandem with the predominance of females in the population of *Archaeomysis grebnitzkii*.

Further research is needed to elucidate the dependence of the distribution of macrozoobenthos found on exposed sandy beaches of Bering Island, on parameters such as the grain size, temperature, salinity, wave height and period. We assume this study to be a background for regular ecological monitoring on the sampling site described above.

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СОСТАВ И СТРУКТУРА МАКРОЗООБЕНТОСА НЕЗАЩИЩЕННОЙ ПЕСЧАНОЙ ЛИТОРАЛИ ОСТРОВА БЕРИНГА

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Состав и временная и пространственная структура сообщества макрозообентоса незащищённой песчаной литорали острова Беринга (Командорские острова, северо-западная Пацифика) была изучена с целью получения первичных данных для многолетнего экологического мониторинга на основе проб, отобранных с мая 2016 г. по апрель 2017 г. Обнаружено пять видов (в порядке убывания встречаемости): *Eogammarus schmidti* (Amphipoda, Crustacea), *Archaeomysis grebnitzkii* (Mysidacea, Crustacea), *Microspio theeli* (Spionidae, Annelida), *Eteone longa* (Phyllodocidae, Annelida) и *Locustogammarus locustoides* (Amphipoda, Crustacea). Таким образом, список видов, имеющийся по литературным данным, расширен. Средняя биомасса варьирует от 1.85 г/м^2 в апреле до 78.47 г/м^2 в ноябре с годовым средним 36.98 г/м^2 (стандартная ошибка среднего = 7.02). Средняя численность варьирует от 43 особей/м^2 в апреле до 2257 особей/м^2 в ноябре с годовым средним 1013 особей/м^2 (стандартная ошибка среднего = 187), что относительно мало по сравнению с литературными данными, полученными из других местоположений в северной Пацифике. Обилие выше в нижнем горизонте литорали и значительно ниже в среднем и верхнем горизонтах. Связи между доминирующими видами не ясны. В литоральной популяции *A. grebnitzkii* доля самок значительно превышает долю самцов (доля самок варьирует от 53% в сентябре до 98.7% в июне с годовым средним 75%). В районе исследований *A. grebnitzkii* размножается с мая по август. Суточная динамика обилия доминантных видов бентоса и их пространственное распределение на литорали по оси направления прилива подтверждают имеющиеся литературные данные.

Ключевые слова: Берингово море, биомасса, заповедник, обилие, северная Пацифика