ISSN 0012-4966, Doklady Biological Sciences, 2007, Vol. 414, pp. 231–234. © Pleiades Publishing, Ltd., 2007.
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GENERAL BIOLOGY

Benthos Elimination by Juvenile Red King Crabs *Paralithodes camtschaticus* (Tilesius, 1815) in the Barents Sea Coastal Zone: Experimental Data

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Presented by Academician G.G. Matishov August 31, 2006

Received December 11, 2006

DOI: 10.1134/S0012496607030180

Study of the effect of the red king crab *Paralithodes camtschaticus* (Tilesius, 1815) on the local benthic biota is one of the main lines of research in the ecological consequences of its introduction to the Barents Sea from the northern Pacific region. The conditions of the new habitat proved suitable for the crab reproduction and growth. Food resources are believed to be the main limiting factor of the red king crab numbers in the Barents Sea [2].

Adult red king crabs inhabit the southern Barents Sea to a depth of 300 m, whereas juvenile crabs are most abundant in the coastal zone. Undoubtedly, both adult and juvenile crabs affect benthic communities. However, the details of this effect, especially regarding juvenile crabs, have not been studied. The numbers of immature (juvenile) crabs off the Murman coast at depths less than 40 m was estimated at 55×10^6 in 2003 [10]. These crabs inhabit communities of hard and soft grounds with benthos biomasses of 500–3500 g/m^2 [1] and 40–150 g/m^2 [8, 12, 13], respectively. The main food of juvenile *P. camtschaticus* is bivalves, gastropods, echinoderms, and polychaetes [5, 7, 9, 11]. To estimate the elimination of benthos by juvenile *P. camtschaticus,* quantitative data on their feeding are necessary, but these data are very few in the available literature. The traditional quantitative analysis of the contents of the crab gastrointestinal tract, which contains only crushed and considerably digested remnants of the food does not allow the number of the eaten representatives of zoobenthos or their weight to be determined. The calculation of the crab ration or the elimination of benthos by crabs based on these data yields incorrect results [3, 9]. Therefore, experimental study of the quantitative parameters of *P. camtschaticus* feeding is necessary, because this approach more completely reflects the actual consumption of elimination of benthic invertebrates.

The purpose of this study was to estimate quantitatively the effect of juvenile *P. camtschaticus* on benthos with the use of experimental data. We estimated the consumption (ration) and elimination of benthos by immature crabs from different size–age groups, studied their feeding selectivity, and theoretically calculated the elimination of benthos by the total population of juvenile crabs.

The studies were performed at the Seasonal Biological Station of the Murmansk Marine Biological Institute of the Kola Research Center of the Russian Academy of Sciences (Dal'nie Zelentsy, Murmansk oblast, Russia) in collaboration with the Severtsov Institute of Ecology and Evolution of the Russian Academy of Sciences. Juvenile *P. camtschaticus* were collected by divers in Dal'nezelenetskaya and Yarnyshnaya bays. We performed experiments with eight size–age groups of juvenile crabs. Each size group was kept in a separate plastic tank containing running seawater. The population density and the tank volume were varied (Table 1). The elimination of benthos for one day was determined for all size groups; the consumption of benthos, in crabs with carapace widths (CWs) of 35, 40, 70, and 80 mm. The water temperature was varied from 8.5 to 13.0°C.

The daily ration of the juvenile crabs consisted of small invertebrates from six taxa: polychaetes, bivalves, gastropods, ophiuroids, echinoids, and asteroids. The relative biomasses of these animals in the food were different; the biomass was excessive, according to the results of preliminary observations of crab feeding. The weight of one group of invertebrates varied, depending on the size of the crabs, from 6 to 30 g. Before the experiment, food objects were counted and weighed. One day later, we recorded the amounts of live, undamaged animals that had left in the food. We

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Table 1. Size–age groups and the density of red king crabs in experimental tanks

Size group, mm	Age, years	Density, specimens per tank	Water volume, l
20	1	3	20
30	2	5	40
35	2	5	20
40	3	5	40
45	3	3	40
55	3	3	40
70	4	3	50
80	4	2	40

also weighed lost food, including the invertebrates that had been injured by the crabs and therefore died, soft tissues and fragments of the animals, fragments of shells, etc. The amount of crabs' feces was also determined. The elimination of benthos was calculated as the difference between the amount of food given to the juvenile crabs and the amount of the remaining live, undamaged food. The consumption was calculated as the difference between the elimination and the lost food. The feeding selectivity was estimated from the frequency of consumption of each of the six benthos-animal groups (the ratio of the number of days when the crabs consumed representatives of a given taxon to the total duration of the experiment). The data on the feeding of all *P. camtschaticus* in each tank were averaged. The duration of the experiments was between 5 and 16 days. When calculating the annual damage, we took into account that the crab feeding activity is known to decrease by a factor of about 5 during hydrological winter [3] and by a factor of 2.5 in spring and autumn

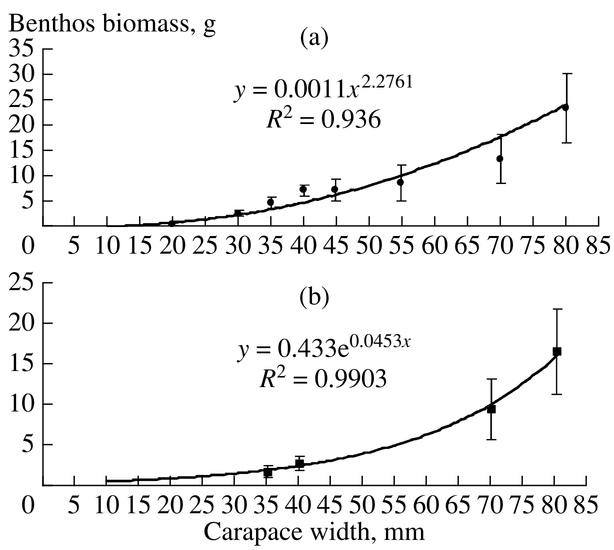

Fig. 1. (a) Elimination and (b) consumption of benthos by juvenile red king crabs in the experiment.

compared to summer. We also assumed that juvenile crabs fed no more than 340 days a year, because they starved during molting periods.

The daily elimination of benthos by juvenile crabs varied from 0.7 to 26.0 g/specimen; daily consumption, from 1.9 to 20.0 g/specimen. Both parameters increased with increasing size of the crabs (Fig. 1). The consumption was always lower than the elimination, because the food was never eaten completely. However, the amount of lost food was smaller in older *P. camtschaticus.* The younger group (with a CW of 35–40 mm) lost 60% of the biomass of the eliminated food, whereas the older group (with a CW of 70–80 mm) lost only 25% of it. The amount of food lost was the smallest when polychaetes and asteroids were eaten. When eating bivalves, gastropods, and sometimes echinoids, the crabs ate only soft tissues, rejecting hard parts (fragments of shells). Mollusk shell fragments often accounted for 80–90% of food remnants.

Juvenile crabs also exhibited feeding selecting when choosing the food object. The frequency of consumption of polychaetes and ophiuroids was 100%; that of bivalves and gastropods was 97%; and those of asteroids and echinoids were 65 and 48%, respectively.

In addition, *P. camtschaticus* eliminated different groups of benthos depending on the sizes of the crabs. Small crabs eliminated mainly (in terms of biomass) ophiuroids and polychaetes; large crabs, mainly bivalves and gastropods (Fig. 2). If the ration contained ophiuroids, only small amounts of other echinoderms were consumed.

We used literature data on the numbers of juvenile crabs in coastal zone and relative sizes of their size–age groups [10] and our quantitative data on crab feeding to calculate the annual elimination of benthos (Table 2). Missing data on the feeding of other size groups of *P. camtschaticus* were calculated on the basis of the aforementioned relationships between the quantitative parameters studied and the size of juvenile crabs (Fig. 1). We preliminarily estimated the elimination of benthos by the total population of juvenile crabs at 67×10^3 t. Of this amount, juvenile crabs can consume 37×10^3 t (55%), about 25.5×10^3 t (38%) will be lost in the form of inedible fragments, and the remaining 4.5×10^3 t (7%) will be accounted for by the loss of soft tissues, which may be utilized by consumers of the next order and destructors. Apparently, predatory invertebrates have additional advantage in region of the aggregation and feeding of *P. camtschaticus* due to an increase in food resources; hence, their numbers are expected to increase there.

Collating the data on benthos elimination with the benthos biomass (g/m^2) in hard-ground communities of crab habitats [8, 12, 13], we obtain that a crab with a CW of 20 mm needs 0.1–0.6 m^2 of the ground (depending on the community productivity) to feed on benthic animals for one year. These values for crabs with CWs of 40, 55, and 80 mm are 0.8–5.0, 2.0–8.0, and 4.0–

24.0 m^2, respectively. On soft grounds, the density and biomass of benthos are lower; therefore, each crab needs food resources of an area 10 to 20 times larger. In fact, crabs need animals from even larger areas of the bottom to feed on, because not all species of benthic invertebrates are accessible for them.

Juvenile crabs live in the upper sublittoral zone and the lower littoral layer, which is the most densely populated zone of the sea, with rich food resources [6]. As in our experiments, food is available in excess under natural conditions, especially in communities on hard grounds. This allows us to extrapolate the obtained data to the natural habitats of crabs.

The daily food consumption by juvenile *P. camtschaticus* estimated in our experiments is 1.5–2 times higher compared to literature data [4]. This may be explained by the fact that, unlike other researchers, we performed experiments with natural live food without any preliminary treatment (such as removing shells off mollusks). The feeding selectivity of the crabs under experimental conditions somewhat differed from that in natural habitats. For example, the ration of juvenile *P. camtschaticus* under natural conditions is dominated by mollusks [5, 7, 9, 11]. The intense consumption of ophiuroids in the experiment was a temporary phenomenon; its most probable explanation is that the experiments coincided in time with the period of juvenile crabs' molting under natural conditions, when the crabs need more calcium. The preference for polychaetes was apparently related to the high caloric content of this food object [2].

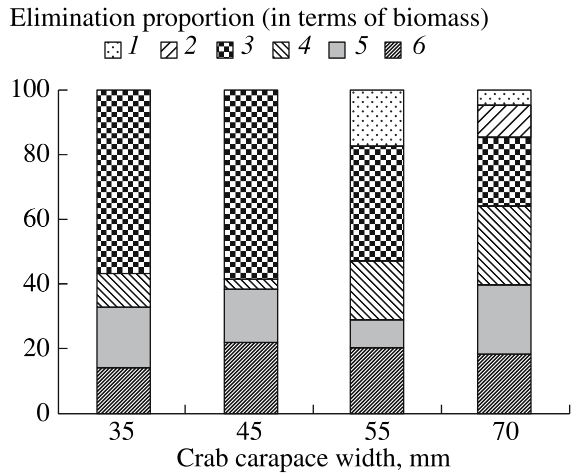

Fig. 2. Elimination of different groups of zoobenthos by juvenile crabs of different ages in the experiment: (*1*) Asteroidea, (*2*) Echinoidea, (*3*) Ophiuroidea, (*4*) Gastropoda, (*5*) Bivalvia, (*6*) Polychaeta.

Thus, immature (juvenile) red king crabs intensely consume and eliminate benthos; therefore, in places where their numbers are large, they may substantially affect benthic communities of the coastal zone, especially those located on soft grounds and characterized by a low productivity (and, hence, biomass). In the areas where juvenile crabs are abundant, the differential elimination of individual groups of benthos may lead to changes in the natural structure if benthic biocenoses, including changes in their trophic structure.

Table 2. Elimination of benthos by juvenile red king crabs at depths shallower than 40 m as estimated from experimental data

Size group, mm	Number of crabs (literature data for 2003)	Annual average elimination of benthos, (g specimen)/day	Annual elimination of benthos (for 340 days), g/specimen	Annual elimination of benthos, t
20	1300000	0.4	136	180
25	5400000	0.9	306	1650
30	6900000	1.5	510	3520
35	4900000	2.5	850	4170
40	5950000	3.7	1260	7500
45	7500000	3.8	1300	9750
50	7500000	4.1	1390	10 430
55	3400000	4.5	1550	5300
60	3700000	5.4	1840	6800
65	3200000	6.4	2180	7000
70	2300000	7.2	2500	5800
75	1170000	8.8	3000	3500
80	400000	13.0	4500	1800
Total of all size groups				67400

ACKNOWLEDGMENTS

We are grateful to A.N. Zuev, O.V. Savinkin, T.I. Antokhina, I.N. Marin, and Yu.A. Zuev for the help in collecting the material and to A.A. Frolov, O.Yu. Ivanov, and L.A. Khananova for assistance in our work.

This study was carried out in the framework of the Federal Program "The Ocean: Study of the Ocean Nature."

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