Journal of Experimental Marine Biology and Ecology 372 (2009) 31–35

Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Substrate preferences and redistribution of blue king crab *Paralithodes platypus* glaucothoe and first crab on natural substrates in the laboratory

Federico Tapella [a,*,1], M. Carolina Romero [a,1], Bradley G. Stevens [a,2], C. Loren Buck [b,3]

[a] National Marine Fisheries Service, Alaska Fisheries Science Center, Kodiak Fisheries Research Center, 301 Research Ct., Kodiak, AK 99615, United States
[b] Fishery Industrial Technology Center, School of Fisheries and Ocean Science, University of Alaska Fairbanks, 118 Trident Way, Kodiak, AK 99615, United States

ARTICLE INFO

Article history:
Received 27 October 2008
Received in revised form 2 February 2009
Accepted 3 February 2009

Keywords:
Habitat selection
Lithodids
Stock enhancement

ABSTRACT

Despite the importance of blue king crab (BKC) to the Bering Sea fishery, there has been no detailed study of juvenile habitat preferences. Such information is critical for understanding life history and for development of stock enhancement programs. The aims of this study were to determine the natural substrata that glaucothoe prefer to settle on, and whether they or subsequent crab 1 stage (C1) redistribute to different habitats over time. A laboratory experiment was performed in 24 round containers divided in four equal quadrants each filled with one of the following natural substrata: beach sand, gravel, shells and cobble. Containers were assigned to 8 groups of 3 replicates each and were kept at ~6–8 °C. Twenty five glaucothoe were released in each container on day 0, and one group of three replicates was removed for examination at each of the following intervals: 24 h, 7, 14, 21, 28, 35, 42 and 49 days. Numbers of swimming and settled specimens on each substrate and period were recorded. Glaucothoe began to settle immediately after being released since no swimming larvae were found during any sampling periods. Substrata complexity was important for the habitat selection and distribution of blue king crab glaucothoe and crab 1 stage. During the glaucothoe stage, beach sand was rejected and cobble, shell and gravel were chosen equally. After glaucothoe molted to crab 1 stage and became bigger, animals preferred cobble and shell instead of gravel and beach sand. Understanding habitat selection is useful not only for management of crab populations, but also for assessing the potential of various habitats for stock enhancement of blue king crabs.

1. Introduction

Recruitment of many marine decapod crustaceans is a complex process that involves the transition from a planktonic larval to a benthic juvenile phase. During this transition many factors (*e.g.*, current, tides, salinity, temperature, settling behavior, cannibalism, predation, competition, etc.) (Sulkin and Epifanio, 1984; Forward Jr., 1990; Phillips et al., 1991; Fernández et al., 1993; Hasek and Rabalais, 2001; Heck Jr. et al., 2001; Moksnes et al., 2003; Stevens, 2003; Van Montfrans et al., 2003) may affect recruitment success and significantly reduce the number of individuals that survive to adulthood (Wahle and Steneck, 1991; Rabalais et al., 1995). This demographic bottleneck effect is of special relevance for fisheries management and aquaculture (Wahle and Steneck, 1991; Rabalais et al., 1995). For example, the fishery quota for rock lobsters *Panulirus cygnus* in western Australia is based on the abundance of settled puerulus larvae measured 3 and 4 years earlier (Caputi et al., 2003).

Among factors that affect decapod recruitment, postlarval settlement behavior is important for the selection of an adequate substratum that provides shelter and food during critical early juvenile stages. Postlarval stages actively select substrata on which to settle before they undergo metamorphosis to the first juvenile instar (Wahle and Steneck, 1992; Stevens, 2003; Van Montfrans et al., 2003). Moreover, some species are able to delay metamorphosis in absence of suitable substratum (O'Connor, 1991; Harvey, 1993). In some species, such as *Petrolisthes cinctipes* (Jensen, 1991) and *Uca pugilator* (O'Connor, 1993), postlarvae select a settlement substrate occupied by adult conspecifics. Postlarvae may also orient toward nursery areas in response to chemical cues, as demonstrated for *Callinectes sapidus* (Forward Jr. et al., 2003). Decapod postlarvae often select structurally complex habitats for settlement, including those of American lobster *Homarus americanus* (Botero and Atema, 1982), Dungeness crab *Cancer magister* (Fernández et al., 1993), and red king crab *Paralithodes camtschaticus* (Stevens and Kittaka, 1998; Stevens, 2003; Stevens and Swiney, 2005).

* Corresponding author. Current Address: Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Centro Austral de Investigaciones Científicas (CADIC), Houssay 200, V9410CAB, Ushuaia, Tierra del Fuego, Argentina. Tel.: +54 2901 422310; fax: +54 2901 430644.
E-mail address: ftapella@gmail.com (F. Tapella).
[1] Current Address: Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Centro Austral de Investigaciones Científicas (CADIC), Houssay 200, V9410CAB, Ushuaia, Tierra del Fuego, Argentina.
[2] Current Address: University of Massachusetts Dartmouth, School of Marine Science and Technology, 706 S. Rodney French Blvd., New Bedford, MA, 02740.
[3] Current Address: Biological Sciences Department, University of Alaska Anchorage, 3211 Providence Drive, Anchorage, Alaska, 99508.

0022-0981/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.jembe.2009.02.003

Blue king crab *Paralithodes platypus* Brandt, 1850 (BKC) is an important commercially harvested crustacean that occurs in isolated populations around Alaska, as well as the western Pacific Ocean near Japan and Russia. Commercial fisheries for BKC were developed around the Pribilof Islands and St. Matthew Island during the 1960's and reached their peak harvest during the 1980's with annual landings of ~4500 t valued at US$ 9.6–25.6 million. Afterwards, the BKC fishery declined until it was closed for two periods (1988–1994 and 1995–2002), and was finally declared overfished in 2002 (NPFMC, 2002).

Blue king crab have a biennial spawning cycle (Jensen and Armstrong, 1989; Stevens et al., 2008b). During spring, females molt, mate, and extrude eggs which develop for approximately one year before hatching. Larvae hatch in late winter or early spring and develop through four pelagic zoeal stages, followed by a benthic postlarval (glaucothoe) stage which settles on the bottom before metamorphosis to the first juvenile crab (C1) stage (Sato, 1958; Hoffman, 1968).

Blue king crab distribution and habitat preference is related to their life history phase. Adult female BKC live primarily in rocky nearshore areas, whereas males tend to be farther offshore (Blau, 2000). Juveniles (<1 year old) occur in depths from 40 to 60 m in a habitat consisting of a mixture of dead but intact bivalve and snail shells, which usually occurred in pockets among rock, cobble, or gravel habitats (Armstrong et al., 1985). Despite the importance of the BKC fishery, little is known about the settlement habitat and distribution of glaucothoe and young-of-the-year-juveniles. This study was conducted to determine whether blue king crab glaucothoe exhibit a preference for one of four natural substrata commonly found at the Pribilof Islands and if the first crab stage redistributes among those substrata.

2. Methods

2.1. Animals

Adult female and male BKC were collected near St. Paul Island, at approximately 57° N, 169° 30' W in the eastern Bering Sea by trawls during July 2003, and by pots in October 2003 and July 2004. Crabs were wrapped in wet burlap and shipped in insulated containers to the Kodiak Fisheries Research Center (KFRC) in Kodiak, Alaska. Crabs were maintained in an 8000-L tank containing filtered running seawater at 6 °C and fed twice weekly ad libitum with a combination of squid (*Loligo* spp.), herring (*Clupea harengus*), Pacific cod (*Gadus macrocephalus*) or coho salmon (*Oncorhynchus kisutch*) cut into 2 cm chunks. During spring 2005, we facilitated mating to produce female crabs with embryos which developed during 2005 and hatched between February and March 2006. Just prior to releasing larvae, individual females were placed in 50-L plastic totes with filtered running seawater that were immersed in the chilled crab tanks.

2.2. Larval cultivation

In order to obtain a sufficient sample size of BKC glaucothoe for habitat selection experiments, 2000 stage I zoeae from two females were collected by dipping a glass beaker into the hatching totes during the peak hatching period (~10–30 ml larvae·day^{-1}). Larvae were distributed into 8 20-L culture containers (250 in each) filled with 14-L of filtered (5 µm) and UV-sterilized seawater and maintained at 6 °C in a cold room. Containers were aerated continuously to maintain oxygen saturation and keep larvae suspended in the water column. Water was changed and larvae were fed a combination of *Artemia* nauplii (3–5 nauplii·ml^{-1}) and *Thallasiosira nordenskioeldii* diatoms (1000–2000 cells·ml^{-1}) three times per week. Previous cultivation experiments (Stevens et al., 2008a) indicated that this diet was the best combination for larval survival. Dead larvae were removed during water changes. Daily observations were made to determine the occurrence of glaucothoe, when zoea IV stages were close to molting. Glaucothoe were removed from containers and used in the habitat selection experiment within 96 h of molting.

2.3. Habitat selection experiment

A seven week long experiment was conducted to determine the preferred natural substrata for settlement of glaucothoe and whether first instar crabs (stage C1) redistribute among different substrata. The experiment utilized twenty-four 12-L cylindrical containers (28 cm diameter and 19 cm height). The bottoms of the containers were divided in four equal sections by a white PVC strip 6 cm in height. Each section of the container was filled with one of the following natural substrata: 150 cm^3 of beach sand (<1 mm) (S), 150 cm^3 of gravel (2.8–4.8 mm) (G), 200 cm^3 of broken clam (*Saxidomus gigantea*) and cockle (*Clinocardium nuttallii*) shells (4.8–13 mm) (Sh) and 200 cm^3 of cobble (13–20 mm) (C). Before using substrata in experiments, they were rinsed three times with fresh water to remove naturally occurring organisms and dried at 70 °C for 36 h, except for beach sand which required 72 h to dry. In order to avoid location effects, substrata were arranged differently in each replicate as follows (in clock wise order): 1) C, S, G and Sh; 2) C, Sh, S and G; and 3) C, G, Sh and S. The surface of each substrate was ~3–4 cm below the upper lip of the PVC divider. This design allowed glaucothoe to settle in any substratum, but prevented changing substrata by random crawling; glaucothoe could only move between substrata by actively swimming over the divider.

Round containers were filled with 10-L filtered sea water and immersed in one of two water baths (12 in each) with ambient temperature seawater flowing around them; containers were randomly assigned to positions within either bath to eliminate location effects. Water bath tanks were covered with a layer of black plastic that partially blocked the fluorescent lab lighting. Temperature of each tank was recorded at 2 h intervals by an Onset Water-Temp Pro© electronic temperature logger (Onset Corporation, PO Box 3450, Pocasset, Massachusetts 02559).

On 5 May 2006, 25 glaucothoe were released in the center of each round container by pipette. During the course of the experiment, three replicate containers were analyzed and removed from the experiment after periods of 24 h, 7, 14, 21, 28, 35, 42 and 49 days (treatments), respectively. On each treatment date, swimming glaucothoe were counted in each container immediately after removing the black plastic cover. Then, water was siphoned down to the divider edge and live and dead specimens were recorded in each substrate. Individuals that occurred on dividers were recorded as being on "other" substrata. On day 22, dividers were removed because ~25% of glaucothoe had molted to crab stage 1 (C1) and a maximum of 27 days was required to molt to C1 (Stevens et al., 2008a). Thus, we expected that all animals would be stage C1 by day 28 and would no longer be able to swim. Water in the experimental containers was changed every three days by siphoning down to the divider edge and refilling to 10-L again. Glaucothoe were not fed since they do not eat (see review in Stevens and Kittaka, 1998) and C1 were fed ad libitum with "Cyclopeze" frozen copepods three times per week after the water was changed. Proportions of glaucothoe and C1 on each substrate were calculated on the basis of total live animals in each round container.

2.4. Data analysis

Proportions of glaucothoe and C1 on each substrate are presented as means ± 1 SD. In order to determine the preference of glaucothoe and crab I for a natural substrata, analysis of variance (one-way ANOVAs) were performed separately for each of the eight experimental periods. Data were arcsine transformed and assessed for normality and homogeneity of variances by Kolmogorov–Smirnov and Levene tests, respectively (Sokal and Rohlf, 1995). Significant