Journal of Experimental Marine Biology and Ecology 409 (2011) 215–222

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Marine Biology and Ecology

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

Effects of anthropogenic shoreline hardening and invasion by *Phragmites australis* on habitat quality for juvenile blue crabs (*Callinectes sapidus*)

W. Christopher Long *, Jacob N. Grow [1], John E. Majoris [2], Anson H. Hines

Smithsonian Environmental Research Center, P.O. Box 28, Edgewater, MD 21037, USA

ARTICLE INFO

Article history:
Received 21 June 2011
Received in revised form 24 August 2011
Accepted 29 August 2011
Available online 23 September 2011

Keywords:
Blue crab
Callinectes sapidus
Phragmites australis
Predation
Shoreline development
Spartina

ABSTRACT

Unvegetated, shallow water habitats adjacent to marshes are an important nursery for juvenile blue crabs, *Callinectes sapidus*, in Chesapeake Bay. Alteration of the shoreline, either through the replacement of marshes with anthropogenic structures, such as riprap and bulkheads, or through the replacement of the native marsh grass *Spartina* sp. (*Spartina*) with the invasive *Phragmites australis* (*Phragmites*), may affect the value of this habitat as a nursery. In this study, we compared the effects of four common shoreline types, bulkheads, riprap, *Phragmites* marshes, and *Spartina* marshes, on food availability, feeding, growth, and survival of juvenile blue crabs in adjacent subtidal areas, as well as on the abundance and size of predators in the South River, Maryland. Sites with each shoreline type were randomly selected. We used benthic cores to sample macrobenthic prey and performed gut content analysis on caged crabs to examine food availability and feeding. Growth was estimated using caged crabs. Survival was assayed with a tethering experiment and predators were sampled with a seine net. Riprap had a lower abundance of macrofaunal prey, and the macrofaunal community differed from both marsh types in that it had it had smaller an more opportunistic species such as nematodes and small polychaetes compared to more bivalves and larger polychaetes at the marsh sites; however, gut contents and growth did not vary among shoreline types. Predation pressure on juvenile blue crabs was highest at bulkhead sites and lowest at riprap. Predator abundance did not vary among the shoreline types, though piscine predators were smaller in size near *Spartina* marshes compared to the other shorelines. We conclude that shoreline hardening substantially reduced the value of shoreline habitats for juvenile blue crabs, but that *Spartina* and *Phragmites* are functionally equivalent.

Published by Elsevier B.V.

1. Introduction

In Chesapeake Bay and elsewhere, shallow, unvegetated habitats, especially those adjacent to salt marshes, are important secondary nursery habitats for many macrofaunal species (e.g. Minello et al., 2003) including the ecologically (Baird and Ulanowicz, 1989) and economically (Lipcius and Stockhausen, 2002) important blue crab, *Callinectes sapidus* (Lipcius et al. 2005). These areas provide a refuge from predation (Clark et al., 2003; Dittel et al., 1995; Hines and Ruiz, 1995; Minello et al., 2003; Ruiz et al., 1993), especially for vulnerable molting crabs (Hines et al., 1987; Ryer et al., 1997), and offer a high abundance of macrofaunal prey, which contributes to high growth rates (Seitz et al., 2005, 2006). However, these habitats are changing, both through human development of coastal areas, which includes the alteration of the shoreline (Peterson and Lipcius, 2003), and through replacement of native salt marsh grasses, especially *Spartina* sp. (hereafter *Spartina*) by the invasive common reed *Phragmites australis* (hereafter *Phragmites*) along the US Atlantic coast (Fell et al., 1998).

Although coastal development, land-use patterns, and eutrophication influence large-scale abundance and distribution of blue crabs and their prey resources (e.g. Kemp et al., 2005; King et al., 2005), relatively little is known about small-scale effects of shoreline development. Fragmentation of marshes through costal development may alter shoot density and faunal abundance (Long and Burke, 2007). Hardened shorelines, such as riprap and bulkheads, are associated with a lower abundance of macrofaunal organisms in the adjacent subtidal habitats when compared to marsh shorelines (Seitz et al., 2006; Weis et al., 1998). In the case of bulkheads, this may be due to toxic chemicals leaching from treated lumber (Weis et al., 1998). However, because marshes can supply substantial amounts of allochthonous carbon to subtidal habitats (Quan et al., 2007; Roman and Daiber, 1989; Wainright et al., 2000), replacing them with riprap or bulkheads, which cannot supply such resources, may lower macrofaunal densities (Seitz et al., 2006). Additionally, hardened shorelines are frequently associated with lower densities and smaller sizes of

* Corresponding author at: Kodiak Laboratory, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 301 Research Ct., Kodiak, AK 99615 USA. Tel.: +1 907 481 1715; fax: +1 907 481 1701.
E-mail address: chris.long@noaa.gov (W.C. Long).
[1] Current Address: 915 Northern Goshawk Drive, Columbus, IN 47203, USA.
[2] Current Address: Boston University, Biology Department, 5 Cummington Street, Boston, MA 02215, USA.

0022-0981/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.jembe.2011.08.024

nektonic species (Hendon et al., 2000; Peterson et al., 2000), though not in all cases (Seitz et al., 2006). However, in Southern California, riprap is functionally equivalent to the local natural rocky habitats indicating that effect is not always detrimental (Pister 2009).

Extensive research has been conducted on the ecological effect of *Phragmites* invasions. In general, *Phragmites* differs little from *Spartina* as a habitat for macrofauna (Weis and Weis, 2003). Most nektonic species use both marsh types similarly (Hanson et al., 2002; Jivoff and Able, 2003; Meyer et al., 2001; Osgood et al., 2003; Robertson and Weis, 2007), and macrofaunal densities are equivalent (Osgood et al., 2003; Posey et al., 2003). However, epifaunal abundance is lower in *Phragmites* than in *Spartina* (Robertson and Weis, 2005) and the abundance of some nektonic species, such as juvenile *Fundulus heteroclitus*, may be lower (Able et al., 2003). Also, the hydrology and topology of the marsh differ with *Phragmites* having reduced tidal flooding that may limit use by nekton (Osgood et al., 2003). Taken together, these studies suggest that the replacement of a *Spartina* marsh with *Phragmites* is unlikely to have a significant effect on habitat quality for juvenile blue crabs.

We designed this study to examine the effects of biological and anthropogenic shoreline changes on the value of the habitats as a nursery for juvenile blue crabs. We hypothesized that hardened shorelines would be associated with lower densities of macrofaunal organisms, leading to decreased crab growth rate. Also, we expected that unstructured bulkheads would be associated with higher predation rates than structured habitats such as riprap and salt marshes. Finally, we anticipated that *Phragmites* and *Spartina* marshes would differ little in their functioning as nursery habitats for blue crabs.

2. Materials and methods

2.1. Sampling area

The study was conducted July–September, 2008 in the South River, Maryland, USA, a heavily urbanized tributary of Chesapeake Bay. We investigated four types of shorelines common to the river: Bulkhead, Riprap, *Spartina* marsh, and *Phragmites* marsh. Although this is not a comprehensive set of shoreline types, these were among the most common and represent ~70% of the total shoreline in the system (Table 1). Using data from the Comprehensive Coastal Inventory Program (Berman et al., 2006), we identified all stretches of each shoreline type in the river that had >200 m of continuous shoreline. We verified all sites by visiting them and rejected those that had changed type in such a way as to reduce the length of continuous shoreline to <~100 m by visual estimation. Marsh areas that had a mixture of *Spartina* and *Phragmites* along the shoreline were also rejected although we retained those that had *Spartina* alone along the shore with *Phragmites* upland, well away from the shore. We randomly selected 10 of each of the shoreline types that met our criteria (Fig. 1). At each site, we measured bottom temperature, salinity (using the practical salinity scale), and dissolved oxygen using a DO probe (YSI Model 85, Yellow Springs Instruments, Dayton, Ohio, USA[3]). One of the *Spartina* marshes was later discovered to be a mixture of the two species and was excluded from all analyses.

Table 1
Length and percent of the total length of bulkhead, riprap, *Spartina* marshes, and *Phragmites* marshes along the shoreline in the South River, MD. Total indicates the length of the entire shoreline and Total Developed includes bulkhead, riprap, and other man-made structures such as groin fields, jetties, and marinas. Data is from the Comprehensive Coastal Inventory Program (Berman et al., 2006).

Shoreline type	Length (km)	Percent
Bulkhead	28.5	21
Riprap	20.5	15
Spartina	30.4	23
Phragmites	12.3	9
Total developed	57.0	43
Total	133.3	

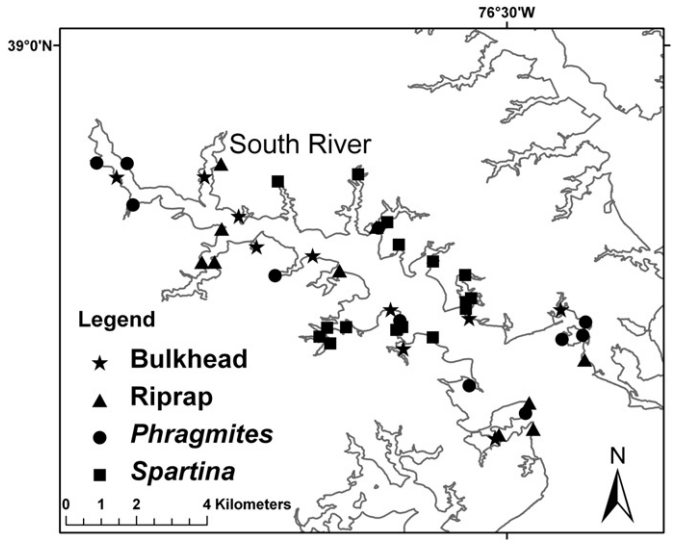

Fig. 1. Map of the South River, Chesapeake Bay, Maryland. Symbols represent sampling sites.

2.2. Crab feeding, growth, and benthic prey availability

Hatchery crabs reared at the Center for Marine Biotechnology were used in all experiments (Zmora et al., 2005). Cages used for both the feeding and growth experiments were constructed with galvanized hardware cloth with a mesh size of 6.5 mm. Cages were 50 cm by 50 cm and 14 cm tall and open at the bottom, with a latchable door cut in the top. At each site, a cage was inserted several cm into the sediment at approximately the central point of the shoreline. One juvenile blue crab, carapace width (cw) 26.3 mm ± 3.0 (SD), was enclosed in each cage and allowed to feed for at least 24 h (Dittel et al., 1995). Crabs were starved for at least 2 days prior to the experiment. Crabs were resampled by enclosing the cage with a stainless steel frame inserted into the sediment. The top of the frame was encircled with vexar plastic mesh to keep the crabs from escaping. The cage was removed and a 10.16 cm diameter benthic core was taken from the center of the caged area. We sampled from within the caged area because we wanted to ensure that a direct comparison between the benthic assemblage in the core and the gut contents of the crab would be possible. The core was sieved on a 0.5 mm mesh screen, frozen, and stored at −20 °C. The caged area was then swept with nets until the crab was found. Digestion was stopped immediately by placing the crab on dry ice until frozen. The crab was then placed on ice before being stored at −20 °C.

Benthic cores were stained with rose Bengal, a vital stain, all animals were removed and identified to the lowest taxonomic level possible (usually species), and the density of each taxa (m^{-2}) was calculated. All crabs were dissected to remove the foreguts. Percent gut fullness was estimated, and the wet mass of the foregut was determined. The contents of the foreguts were identified to the lowest level possible under a stereo-microscope, and percent composition (by volume) of each food type was estimated.

Crab growth rate was determined at each of the four shoreline types by caging a juvenile blue crab, cw 12.0 mm ± 1.5 (SD), as above, and remeasuring them after 4 and 12 weeks. The growth experiment was run immediately after the feeding study using the

[3] Use of trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.