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A comparison of the distribution and abundance of European green crabs and American lobsters in the Great Bay Estuary, New Hampshire, USA

Jason S. Goldstein[a,b,*], Elizabeth M. Morrissey[b], Erika D. Moretti[b], Winsor H. Watson III[b]

[a] The Maine Coastal Ecology Center, Wells National Estuarine Research Reserve, 342 Laudholm Farm Road, Wells, ME 04090, USA
[b] Department of Biological Sciences and School of Marine Sciences and Ocean Engineering, University of New Hampshire, 46 College Road, Durham, NH 03824, USA

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ABSTRACT

Green crabs (*Carcinus maenas)* are an invasive species documented as having negative impacts on the biota of marine and estuarine communities. However, their impact on the American lobster (*Homarus americanus*) is not well understood. During a two-year trap study (2013–2014) in The Great Bay Estuary, NH, we captured 1229 green crabs and 144 lobsters in 248 individual trap hauls (average catch per unit effort = 10.98 ± 1.51 for green crabs and 0.49 ± 0.08 for lobsters), or ~8.5 times more green crabs than lobsters. In general, green crabs were more abundant in areas furthest from the coast (up-estuary), which also tended to be warmer, while lobsters were more abundant in areas closer to the coast (down-estuary). Nevertheless, there was still considerable overlap between the two species. We evaluated the competitive interactions between green crabs and lobsters in the laboratory using a behavioral assay and found that in 31% of the trials, large lobsters (>80 mm in carapace length) killed (and consumed) green crabs of varying sizes that failed to escape or move to safe areas of the enclosure. These results suggest that adult lobsters are not likely vulnerable to green crabs. While there may be reasons why lobsters did not select specific sizes of green crabs to prey on, some crabs may have an impact on juvenile lobsters. These data provide some insight into the distribution and abundance of green crabs and their impact on the lobster population in a large New England estuary that supports a commercial lobster fishery.

1. Introduction

Species range expansions and contractions are in constant flux and are under the influence of both biological and physical factors (Brown et al., 1996). The ability to provide better spatial resolution to distribution patterns of native and non-indigenous (i.e. exotic, invasive) species can provide insight into the relative contributions of ecological and physical factors in shaping these patterns (Ruiz et al., 1997, 1999). Historically, biological responses to non-indigenous species were due to natural processes and often occurred over long (geological) time scales (reviewed in Lonhart, 2009). However, anthropogenic- and climate-mediated processes have played increasingly disproportionate roles in driving shifts in the distribution of invasive species (Ruiz et al., 1997; Cohen and Carlton, 1998; Kennish, 2002).

Traditionally, marine invasions have concentrated on estuarine habitats (see Ruiz et al., 2000; Preisler et al., 2009 for review). Estuarine systems are especially vulnerable to high rates of invasions for three primary reasons: (1) they are often sites of intensive human activity (e.g. shipping, aquaculture, pollution, diking) to which natives are not well-adapted (Cohen and Carlton, 1998; Kennish, 2002); (2) low species richness in estuaries usually translates into high invasion rates due to weak competitive interactions with native species (Wolff, 1999) and; (3) the hydrodynamics of many estuaries (e.g. semi-enclosed circulation) facilitates the retention of many meroplanktonic larvae, both native and invasive (i.e. founder populations, Wasson et al., 2005; Roman, 2006).

Invasions by brachyuran crabs have negatively influenced marine and estuarine communities world-wide and pose legitimate economic and ecological threats (Carlton and Geller, 1993). One such example is the predatory invasive portunid green crab

* Corresponding author at: The Maine Coastal Ecology Center, Wells National Estuarine Research Reserve, 342 Laudholm Farm Road, Wells, ME 04090, USA.
E-mail address: jgoldstein@wellsnerr.org (J.S. Goldstein).

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(*Carcinus maenas*), which has established breeding populations outside its native European range and has since become a common (naturalized) species in New England and the Canadian Maritimes (reviewed in Edgell and Hollander, 2011). Green crabs alter architecturally-complex estuarine habitats (e.g. eelgrass, *Zostera marina*) through bioturbation (Garbary et al., 2014) and have a negative impact on both mussel (*Mytilus edulis*) and oyster (*Crassostrea virginica*) beds (DeGraaf and Tyrell, 2004; Miron et al., 2005).

As predators, green crabs are formidable consumers of a wide variety of benthic marine macrofauna (Mascaró and Seed, 2001) and, in New England waters, have been implicated in declines of soft-shelled clam (*Mya arenaria*) populations (e.g. Bryan et al., 2015). *C. maenas* has also been known to prey upon juvenile fishes (e.g. winter flounder, *Pseudopleuronectes americanus*; Fairchild et al., 2008) and compete with American lobsters (*Homarus americanus*) for space (Rossong et al., 2006; Williams et al., 2006; Haarr and Rochette, 2012). More recently, it was shown that green crabs have the ability to curtail the overall foraging activity and shelter use of small (<35 mm carapace length) juvenile lobsters (Rossong et al., 2011), and prey upon newly settled lobsters (Sigurdsson and Rochette, 2013). Although they are euryhaline organisms and are most commonly distributed throughout coastal and offshore waters (Lawton and Lavalli, 1995), American lobsters are also known to reside in estuarine habitats from Canada to New England. The Great Bay Estuary (herein, GBE) in New Hampshire is home to a year-round lobster population which is a target commercial fishery in the bay (NHFG, 2008; Morrissey, 2016).

The GBE is facing environmental threats (e.g. pollution, coastal development, invasive species, climate change) similar to many other estuarine systems (Kennish, 2002; Oviatt, 2004; PREP, 2014). In recent years, GBE has undergone dramatic ecological changes due, in part, to a cascade of factors that include increases in water temperatures, nitrogen loading, and the degradation of important habitats such as oyster reefs and eelgrass beds (PREP, 2014). It is thought that estuaries may provide resident lobsters with benefits that include accelerated growth and molting cycles (due to warmer temperatures), protection from predation, and reproduction and nursery habitats (Munro and Therriault, 1983; Becker, 1994; Moriyasu et al., 2000; Short et al., 2001; Morrissey, 2016). Both lab and field studies indicate that lobsters can detect small changes in both temperature and salinity and these may guide their seasonal movements in GBE (Jury et al., 1994a; Crossin et al., 1998; Watson et al., 1999; Jury and Watson, 2000). Recent studies further suggest that, because of its highly recessed basin system and hydrodynamic profile, GBE may serve as a sink for postlarval settlement and as a nursery ground for small, juvenile lobsters (Goldstein, 2012; Morrissey, 2016).

Green crabs have firmly established themselves in GBE and other New England estuarine systems for decades (Hayden and Conkling, 2014). Interestingly, the only systematic survey of green crabs in GBE was completed by Fulton et al. (2013) in 2009–2010. During this one-year study, ~0.09 metric tons of green crabs were captured, yielding higher capture rates in the spring and fall and concentrated in the middle section of GBE (i.e. Little Bay). This survey concluded that these spatial and temporal differences in catch were likely due to fluctuations in temperature and salinity (Fulton et al., 2013). While this study provided notable information about the green crab population in GBE, it was not designed to compare the distribution of green crabs with lobsters (only 29 lobsters were collected in total).

Given the importance of the lobster fishery in GBE, along with the continued trend in climate-mediated changes to estuarine communities, a more thorough understanding of this crab-lobster relationship is warranted. Thus, in this study we (1) determined the distribution and size structure of lobsters and green crabs in GBE and; (2) began to examine the behavioral interactions of these two species when placed together in the laboratory.

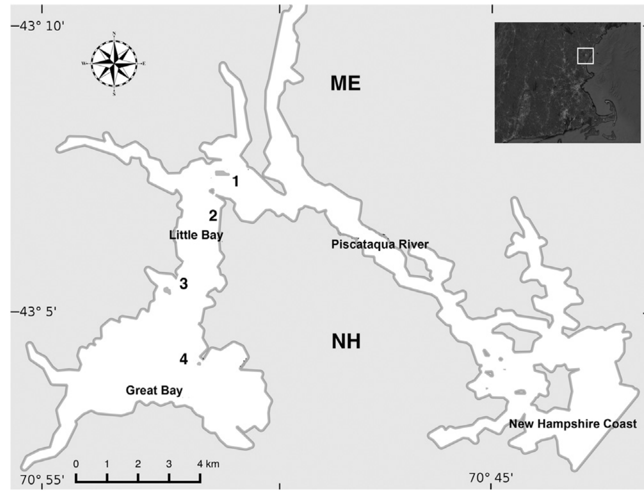

Fig. 1. The Great Bay Estuary (GBE) in southeast New Hampshire and Maine. GBE encompasses three distinct areas: the Piscataqua River, Little Bay, and Great Bay. The location of our study sites are labeled 1–4, and correspond to a coastal-to-estuarine gradient: (1) Goat Island; (2) Fox Point; (3) Adams Point; (4) Nannie Island.

2. Materials and methods

2.1. Study site

The Great Bay Estuary (GBE) is a large, tidally mixed basin that is comprised of ~23 km^2 of surface water and over 160 km of coastline. Great Bay is 15–25 km from the coast and is coupled to the ocean through Little Bay and the Piscataqua River in New Hampshire and Maine (Jackson, 1922; Short, 1992; Fig. 1). Both Great Bay (GB) and Little Bay (LB) possess habitats that are generally characterized by eelgrass beds, extensive mud flats, and oyster reefs (Grizzle et al., 2008) with freshwater input from seven rivers that intermingle with tidal waters, influencing salinity levels, especially after severe episodic events. Both temperature (−1 to >20 °C,) and salinity (0–35 psu) may drastically fluctuate at varying spatio-temporal scales (Jury et al., 1994b). These fluctuations, in turn, set up a dynamic gradient in environmental conditions with which to compare the distribution and abundance of green crabs and lobsters. Our field survey locations (Fig. 1) were selected based on empirical data from past studies (see Jury and Watson, 2013), so as to evaluate the distribution of these two species in a zone of overlapping distribution.

2.2. Field surveys

A trap study was conducted during June-August of 2013 and 2014 (three months in total over each of two seasons) throughout selected sites in Great Bay and Little Bay. Trap trawls (i.e. trap transects) were fished at four fixed sites along a spatial gradient (coastal to estuarine in GBE; Fig. 1). Trawls comprised two trap types: 1) standard ventless lobster traps (see Clark et al., 2015 for design details) and; 2) juvenile collectors, which were made from ventless traps that were modified with a 47 cm square tunnel entrance device (Protoco Enterprises, Inc., North Plains, OR) used to select for small crabs and lobsters.

All trap trawls (four sets in total) were fished along similar depth contours (range = 5–8 m) and were pulled every 2–5 days (i.e. soak time) for each of two years (2013–2014) from June through August. It is important to note that there is evidence to suggest that soak time does, in fact, influence both lobster and crab catch