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# Predation of the non-native Asian shore crab *Hemigrapsus sanguineus* by a native fish species, the cunner (*Tautogolabrus adspersus*)

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ABSTRACT

Predation of non-native species by native predators can impact the success of an invasion. Recently, the Asian shore crab, *Hemigrapsus sanguineus*, successfully invaded the northeastern coastline of the United States, reaching densities greater than 100 crabs$\cdot$m$^{-2}$ in rocky intertidal areas. The goal of this study was to determine if a specialist fish predator of invertebrates, the cunner, *Tautogolabrus adspersus*, consumes the juvenile stage of *H. sanguineus*. In laboratory prey choice experiments, *T. adspersus* (10.2–22.1 cm total length) consumed greater numbers of native mud crabs (family Panopeidae, 3.0–9.0 mm carapace width) than *H. sanguineus* of similar sizes. *T. adspersus* also consumed more of the native blue mussel, *Mytilus edulis*, when paired with similar-sized *H. sanguineus*. Gut content analysis of 60 *T. adspersus* captured from intertidal zones with high populations of *H. sanguineus* in southeastern Massachusetts revealed low consumption of the invasive species; only 5 of 60 guts contained Asian shore crabs. Frequent prey items found in cunner guts included panopeid crabs, small snails, barnacles, and branching and encrusting bryozoans. Our results suggest that, as long as native prey species are present for consumption, *T. adspersus* will not exert high predation pressure on *H. sanguineus*.



## 1. Introduction

The Asian shore crab *Hemigrapsus sanguineus* (family Varunidae) was introduced to the east coast of North America in the 1980s (Williams and McDermott, 1990) and spread along the coast of the United States from North Carolina to Maine (Epifanio, 2013; McDermott, 1998). It is now among the most common species of crab in rocky intertidal areas (Ahl and Moss, 1999; Kraemer et al., 2007; O'Connor, in press), reaching densities greater than those in its native range (Lohrer et al., 2000a). *H. sanguineus* is particularly abundant in the middle and lower areas of the intertidal zone in habitats with high structural complexity (Brousseau et al., 2002; Ledesma and O'Connor, 2001; Lohrer et al., 2000b), and appears to move to shallow subtidal areas in the winter (Gilman and Grace, 2009). Individuals may grow to > 30 mm in carapace width, although crabs of this size are uncommon (Fukui, 1988; O'Connor, in press).

Native species of mud crabs (*Dyspanopeus sayi*, *Eurypanopeus depressus*, *Panopeus herbstii*) in the family Panopeidae (formerly Xanthidae) live in lower intertidal and subtidal areas along shorelines of the eastern United States, overlapping in range with *H. sanguineus* (Meyer, 1994; Ryan, 1956). Panopeid crab populations in some intertidal zones of Narragansett Bay and Long Island Sound have declined as *H. sanguineus* populations became established (Kraemer et al., 2007; O'Connor, in press).

A lack of predation on *H. sanguineus* by native species could have facilitated the large population sizes of the invader. Predators of *H. sanguineus* are not well known (Epifanio, 2013) but may include fishes and birds. Likely potential fish predators are those that move into rocky intertidal areas to forage at high tide and also possess morphological adaptations to crush prey with hard outer coverings. In its native range, *H. sanguineus* is consumed by the sculpins *Myoxocephalus stelleri* and *Myoxocephalus brandti* (Pushchina and Panchenko, 2002).

The cunner (*Tautogolabrus adspersus*, family Labridae) is one of the most familiar and abundant fish species along the western North Atlantic shoreline, ranging from North Carolina, USA, to Newfoundland, Canada (Munroe, 2002). Species in the family Labridae have a specialized pharyngeal jaw apparatus that is used to crush shells and exoskeletons of their prey (Bowman et al., 2000; Liem and Sanderson, 1986; Olla et al., 1974). Cunner consume a wide variety of invertebrates, with their diet often reflecting the most common food items in the area (Bowman et al., 2000; Edwards et al., 1982; Olla et al., 1975; Whoriskey, 1983). Cunner up to 10 cm feed on smaller motile crustaceans such as amphipods, while cunner larger than 10 cm include more sedentary invertebrates such as barnacles, crabs, and mussels in their diet (Bowman et al., 2000; Chao, 1973; Shumway and Stickney, 1975).

Cunner have a high affinity for benthic substrates and complex structure, forming loose aggregations around rocks, reefs, or docks, as they are a non-schooling fish (Munroe, 2002; Olla et al., 1975). Cunner are often found in the subtidal zone and swim up into the intertidal zone to feed during flood tides (Munroe, 2002; Whoriskey, 1983). They actively feed throughout the day, spending the night in crevices along the substrate (Olla et al., 1975). Cunner have a set home range,

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from which they move only a few meters to forage and breed (Olla et al., 1975).

Few experiments have looked at predation by fish on *H. sanguineus* and the results have been mixed (Epifanio, 2013). In laboratory tests fish prey on *H. sanguineus* in its megalopal (terminal larval) stage, but exert little predation pressure on juveniles (Kim and O'Connor, 2007; Rasch and O'Connor, 2012). One laboratory study found selective predation of *H. sanguineus* over native crabs by cunner, tautog (*Tautoga onitis*), and black sea bass (*Centropristis striata*) (Heinonen and Auster, 2012), but relatively few remains of *H. sanguineus* were found in the guts of the fish species *Fundulus majalis*, *Fundulus heteroclitus*, or *T. onitis* from Narragansett Bay and Long Island Sound (Brousseau et al., 2008; Clark et al., 2006; Kim and O'Connor, 2007).

The purpose of this study was to determine if cunner have the ability to consume *H. sanguineus* in laboratory trials with natural substratum, and to assess consumption of *H. sanguineus* by cunner in the wild. A series of feeding experiments with prey (*H. sanguineus*, panopeid crabs, or blue mussels) presented alone and prey offered in paired trials was conducted. In addition, gut contents of cunner collected from coastal habitats with populations of *H. sanguineus* were analyzed to assess the frequency of consumption of crabs in natural rocky areas.

## 2. Materials and methods

### 2.1. Fish collection and housing

*T. adspersus* (cunner) for use in laboratory feeding experiments were collected in 2011 and 2012 from local estuarine habitats where crab populations were present. Fish with a total length of 10.0–22.1 cm were captured using conventional angling and baited minnow traps. Fish were held in a 500 L flow-through sea water tank at ambient sea temperature (18.3–25.3 °C) and salinity (~30), and fed a diet of frozen shrimp. Rocks and pieces of PVC pipe were added to the tank to provide shelter for the fish.

### 2.2. Invertebrate collection and housing

Asian shore crabs (*H. sanguineus*) were collected from local rocky intertidal areas. Species of mud crabs in the family Panopeidae (*P. herbstii*, *D. sayi*, and *E. depressus*, in that order of abundance) were obtained from traps placed in an estuary. Panopeids and *H. sanguineus* were held in separate aerated 14 L tanks and fed daily. Only crabs with a carapace width of 3.0–9.0 mm with all of their legs intact were selected to provide prey of an appropriate size for the fish to manipulate and crush in their pharyngeal jaws. Blue mussels (*Mytilus edulis*) were collected from intertidal rocks and held in mesh bags hanging from a dock until the day of the experiments. Mussels with a shell length of 3.0–9.0 mm were used in experiments.

### 2.3. Feeding trials

Prey types (mud crabs in the family Panopeidae, Asian shore crabs *H. sanguineus*, and blue mussels *M. edulis*) were offered to individual cunner singly and in paired prey trials. Single prey types consisted of 10 mud crabs, 10 *H. sanguineus*, or 10 mussels. In paired prey trials, prey pairs of 5 mud crabs with 5 *H. sanguineus*, 5 mud crabs with 5 mussels, 5 *H. sanguineus* with 5 mussels, or 10 mud crabs with 10 *H. sanguineus* were offered to individual cunner.

Trials were conducted in six 70.8 L plastic containers (length = 61.9 cm, width = 38.4 cm, height = 29.8 cm, total water volume = 30.5 L) with rounded corners, each receiving flow-through ambient seawater with an inflow rate of 14.5 L per minute. The bottom of each tank was covered with 6 mm of sand (1 L) sifted through a 1 mm sieve, and 10 rocks (longest dimension ≤ 3 cm) were dispersed haphazardly on the bottom of each tank. Prey densities in experiments with 10 animals were 42 prey$\cdot$m$^{-2}$. Each tank was surrounded by a tarp to reduce disturbance and control light settings (14 h light:10 h dark).

Fish used for experiments were acclimated for a minimum of 7 days in the 500 L tank and were active in feeding. Five fish (total length [TL] = 12.0–22.1 cm for single prey trials, 10.2–20.7 cm for paired prey trials) were randomly selected and placed individually in the experimental tanks to acclimate and fast for 24 h, after which prey were added. Fish size did not vary among prey types in single species trials (ANOVA F = 0.80634, df = 42, p = 0.45328).

In addition to the 5 tanks with fish, a sixth tank containing only prey items acted as a control for prey mortality, escape, and experimenter counting accuracy. All prey were successfully recovered from control tanks except for one *H. sanguineus* in one trial.

Each experimental trial was initiated between 0915 and 1130, and ran for 24 h. At the end of the trial, the fish were removed and sediment was probed to locate remaining prey. Missing prey and limbs were considered to have been consumed by the fish. Each of the 5 trials with each prey type and the control was repeated three times, for a total of 15 fish and three controls per prey type. Each fish was used for one individual trial and then returned to the wild. Trials took place from August–October 2011 and June–September 2012.

### 2.4. Gut content analysis

Cunner were collected May through September 2012 from Mattapoisett Harbor (41°39′26.79″N, 70°48′51.67″W) and Gooseberry Island (41°29′20.00″N, 71° 2′11.77″W) in southeastern Massachusetts. Locations selected were rocky intertidal areas with populations of *H. sanguineus*. Capture methods included conventional angling and baited minnow traps set within 2 h of high tide. A total of 60 fish, 40 from Mattapoisett and 20 from Gooseberry, were captured to provide numbers similar to previous studies of cunner diets (Chao, 1973; Green et al., 1984). Only fish with a total length of 10.0–21.3 cm were captured to be consistent with the feeding trials. Fish captured were immediately euthanized with MS-222 and transported on ice to be frozen until dissection.

Each fish was thawed and the entire alimentary canal was removed as cunner lack a true stomach (Chao, 1973). Food contents were rinsed with distilled water and items were identified to the lowest taxon possible using a stereomicroscope. Species identifications of crab carapaces and appendages in fish guts were made using reference specimens.

### 2.5. Statistical analysis

Differences in consumption of single prey types by *T. adspersus* were tested using a generalized linear model (GLM), specifying a Poisson distribution, with a post-hoc general linear hypothesis test (GLHT) (Bretz et al., 2010). To determine if fish size had an effect on the number of prey consumed, data for the 3 prey types were analyzed using a linear regression. For trials with paired prey types, Wilcoxon signed-rank tests were used to test for differences between the median consumption of prey in each prey pair. Prey remains in cunner guts were analyzed using frequency of occurrence to measure the number of times a prey item was identified in a gut as a percentage of all the guts with food in them (Brousseau et al., 2008; Chao, 1973). All statistical analyses were done using t he R project for statistical computing software.

## 3. Results

### 3.1. Single prey species trials

In trials with single species of prey, *T. adspersus* ate more *M. edulis* than either species of crab (Fig. 1). Significant differences were found among all single prey species in the GLM and GLHT analysis: panopeid vs. *H. sanguineus* ($z = 3.77$, $p < 0.001$), *M. edulis* vs. panopeid crabs ($z = 5.69$, $p < 0.0001$) and *M. edulis* vs. *H. sanguineus* ($z = 7.69$,