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Developing and field testing sustainable synthetic baits for the blue crab (*Callinectes sapidus*) fishery

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Highlights

- Aim: Develop a synthetic, sustainable, cost-effective bait for the blue crab fishery.
- Approach: Use simple chemical mixtures embedded in a matrix as mimics of natural baits and test in lab and field trials.
- Results: Synthetic baits are highly effective in lab assays but did not catch crabs in the field.
- Conclusion: Synthetic baits lack key molecules necessary to evoke full sequence of behaviors under field conditions.
- Future: A guide for developing more effective synthetic baits for blue crab and other crustacean fisheries is proposed.

Abstract

Our aim was to develop for the blue crab fishery a synthetic bait that is effective, economically viable, and made from sustainable products. Our approach was to formulate mixtures of commercially available chemicals that are proven to be feeding stimulants for crustaceans. We tested several artificial mixtures: a 32-component mixture that mimics menhaden (= Menhaden Artificial Mixture), the bait used by crab fishers; and three other artificial mixtures based on shrimp muscle that are demonstrated chemostimulants for other crustacean species. We added these artificial mixtures to a matrix to create synthetic baits that release chemicals at the same rate and duration as does menhaden bait. Laboratory behavioral studies showed that these artificial mixtures, especially Menhaden Artificial Mixture, and extracts of synthetic baits containing the artificial mixtures stimulate alerting and grabbing behaviors by crabs, though less than extracts from menhaden itself. Synthetic baits were also ingested by crabs thus demonstrating that they are palatable. However, when synthetic baits containing these artificial mixtures were tested in trapping studies in the Ogeechee and Altamaha Rivers of Georgia, they caught fewer crabs than menhaden-baited traps and no more than no-bait traps. We offer several hypotheses as to why our synthetic traps with artificial mixtures that stimulate feeding behavior in the laboratory are less effective in the field than in the laboratory.

Introduction

In Georgia, the commercial fishery for blue crabs, *Callinectes sapidus*, has historically ranked first in state landings and second in ex-vessel value behind shrimp (Georgia Dept. of Natural Resources, 2018). Georgia also has a sizable recreational fishery for crabs (Duda et al., 2017, Georgia Department of Natural Resources, 2018, Fluech et al., 2019). Beyond Georgia, blue crabs also constitute a major fishery in other U.S. states (Kennedy and Cronin, 2007, National Marine Fisheries Service, 2017, Perry et al., 2022).

Commercial crabbers typically bait their traps with fish to stimulate the chemical senses of crabs to attract and retain blue crabs in the traps (Kennedy and Cronin, 2007). The traps have a bait well that when full will attract crabs to traps and entrance funnels designed to make it easier for crabs to enter than to exit. The traps also have two internal chambers designed so that crabs will move from the first to the second with the second more secure from escape. Traps have two cull rings that are large enough to allow sub-legal but not legal-size crabs to exit traps. The bait in these traps can be consumed by crabs and this is thought to keep crabs in the traps. Thus, baits are thought to be attractants to lure crabs into traps and also a source of food to keep crabs in the traps once they have entered.

Because of their commercial importance, blue crabs have been one of the crustacean species whose chemical senses and feeding behavior have been explored in considerable detail (see these books for reviews: Kennedy and Cronin, 2007, Breithaupt and Thiel, 2010; Derby and Thiel, 2014). Blue crabs use their chemical senses in most aspects of their lives including finding food (Keller and Weissburg, 2004, Weissburg, 2010, Kamio and Derby, 2017). Their chemosensory organs have been described including morphology, physiology, and molecular identity of chemoreceptor proteins (Gleeson, 1982, Gleeson et al., 1996, Aggio et al., 2012, Kozma et al., 2020a). Food-related chemicals stimulate their olfactory pathway beginning with olfactory sensory neurons in aesthetasc sensilla on the antennules, as well as gustatory pathways mediated by non-olfactory chemosensory neurons on the antennules, legs, and other sensory organs (Gleeson, 1982, Keller and Weissburg, 2004, Derby and Caprio, 2024). The olfactory and gustatory pathways mediate different behaviors in crabs and other crustaceans: orientation toward sources of chemical cues in the case of olfaction and local detection of food in the case of gustation, though blue crabs may also use their leg gustatory sense in orientation (Keller and Weissburg, 2004, Weissburg, 2010).

Commercial crabbers in Georgia typically use menhaden (*Brevoortia tyrannus*) as bait, though they occasionally use stripped mullet (*Mugil cephalus*). Bait represents 30–40% of crabbers' expenses. Crabbers who deploy 200 traps currently spend over $800 per week for menhaden, or $2 per trap per week, a significant cost to the crabbers and a significant impact on sustainability of menhaden populations. In some fisheries such as the New England lobster fishery, a decline in availability of the preferred bait, herring, has become a major problem, leading to enacting regulations to limit catch of herring and making this bait increasingly expensive and sometimes even unavailable to lobstermen (National Oceanic and Atmospheric Administration, 2018, National Oceanic and Atmospheric Administration, 2019). Such changes in bait availability are likely to affect more fisheries as bait fish stocks are increasingly harvested at unsustainable rates (Food and Agricultural Organization of the United Nations, 2010, Norse et al., 2010). Assessments of populations of Atlantic menhaden suggest that menhaden populations were fairly stable in 2015 (Atlantic States Marine Fisheries Commission, 2020), though there are more recent reports of concerns that their populations may be decreasing (Hurdle, 2023). Thus, the blue crab fishing industry in Georgia is among those at risk for changing bait fish stocks.

The development of effective, inexpensive, and sustainable synthetic baits would provide alternative baits to crabbers. Such synthetic baits need to release chemicals at rates similar to natural baits. Attempts have been made in the past to develop such synthetic baits for crustacean fisheries. Many of these efforts are difficult to evaluate since they are not published due to proprietary concerns. None has proven to be commercially successful due

to factors such as efficacy, cost, availability, or reliance on animal products (e.g., Allen et al., 1975; Carr et al., 1985; USPTO Report, 2007; La Valley, 2008; Dellinger et al., 2016).

The starting point in our development of an inexpensive, non-animal based synthetic bait was based on years of research on the molecules that serve as feeding stimulants for crustaceans. Some of these molecules have been identified using chemical analysis of natural foods, bioassay-guided fractionation, and behavioral testing, and they are known to include free amino acids, amines, nucleosides, nucleotides, peptides, sugars, and other metabolites (Carr and Derby, 1986, Carr, 1988, Derby and Weissburg, 2014). One bait that we developed and tested in this study is a synthetic bait containing an artificial mixture that mimics the exudate of menhaden (= Menhaden Artificial Mixture). We also developed and tested synthetic baits with other artificial mixtures that have been shown in prior studies to stimulate the chemical senses and feeding behaviors in other crustacean species. These include a Feed Attractant Mixture (=FAM) which when added to soy-based pellets stimulates feeding behavior of the Pacific white shrimp *Litopenaeus vannamei* (Derby et al., 2016, Derby et al., 2018), and a Shrimp Artificial Mixture (=SAM) that stimulates chemosensory responses and feeding behavior of Caribbean spiny lobsters *Panulirus argus* and grass shrimp *Palaemonetes pugio* (Carr et al., 1984, Derby and Ache, 1984, Carr and Derby, 1986, Carr, 1988, Derby, 2000). We made synthetic baits containing these artificial mixtures and tested these baits and mixtures in laboratory behavioral assays to evaluate their efficacy in evoking alerting and grabbing feeding responses and ingestion. Finally, we tested these synthetic baits in field studies with commercial crabbers in coastal Georgia to determine their efficacy in catching crabs.

Section snippets

Animals and animal care

Blue crabs (*Callinectes sapidus*) used in laboratory studies were adults of both sexes. Most of these crabs were collected from traps in the Ogeechee River, and some crabs were purchased from a commercial vendor (Gulf Specimens Marine Laboratories, Inc.:

https://gulfspecimen.org ↗, or Your DeKalb Farmers Market: http://www.dekalbfarmersmarket.com/ ↗). Crabs were transported to the Georgia State University aquatic animal facility. There they were held in aquaria with recirculated, filtered, and…

Release rates of chemicals from natural and synthetic baits

The release rates of chemicals over 48 hr from menhaden natural bait and FAM+HYE synthetic bait are represented in Fig. 1. This figure shows the cumulative concentrations of Total Free Amino Acids (TFAAs) expressed in absolute (Fig. 1A) and normalized (Fig. 1B) concentration values for six time points from 0 to 48 hr of soak time. The concentrations of TFAAs released from synthetic bait were approximately ten times higher than those for natural bait (Fig. 1A). This is because the synthetic bait …

Discussion

The aim of this project is to develop a synthetic bait for the blue crab fishery in Georgia and beyond. This synthetic bait is to be a sustainable product by having no animal matter, to be comparably priced to natural baits, and to equal or at least approach the efficacy of natural baits. The synthetic baits that we tested included one of several artificial mixtures (see Table 1) that contain compounds that stimulate feeding behaviors of decapod crustaceans (see reviews Carr and Derby, 1986; …

Policy and ethics statement

Our work was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for animal experiments.…

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Declaration of Competing Interest

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