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Habitat, predation, growth, and coexistence: Could interactions between juvenile red and blue king crabs limit blue king crab productivity?

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Highlights

- We examine intra-guild interactions between juvenile red and blue king crabs.
- Red king crabs preferred complex habitats and responded to predator presence.
- Blue king crabs only preferred complex habitats when a predator was present.
- Predation of red on blue king crabs was a function of habitat and temperature.

- Predation dominated intra-guild interactions and red king crab were dominant.

Abstract

Since the 1970s, dominance of the shallow water Pribilof Islands king crab populations has shifted from blue king crab (Paralithodes *platypus*) to red king crab (*Paralithodes camtschaticus*), potentially influenced by interactions at the juvenile stage. In laboratory experiments, we determined whether habitat and temperature could mediate competitive and predatory interactions between juveniles of both species. We examined how density and predator presence affect habitat choice by red and blue king crabs. Further experiments determined how temperature and habitat affect predation by year-1 red king crab on year-0 blue king crab. Finally, long-term interaction experiments examined how habitat and density affected growth, survival, and intra-guild interactions between red and blue king crab. Red king crabs had a greater affinity for complex habitat than blue king crabs and the presence of predators increased preference for complex habitat for both species. Predation on year-0 blue king crabs by year-1 red king crabs was lower in complex habitats and at colder temperatures. When reared alone, red king crab survival was higher at low densities and in complex habitats. When reared with blue king crab, survival of red king crab was higher in complex habitats and in the presence of blue king crab. Blue king crab survival was substantially lower in the presence of red king crabs regardless of habitat. In both rearing experiments, differences in changes in crab size appeared to be driven by mortality rates and size-selective predation. This demonstrates that interactions between juvenile red and blue king crabs are primarily driven by intra-guild predation and not competition for resources. These results, suggest that juvenile red king crabs have an advantage over blue king crabs which could lower productivity of the Pribilof Islands blue king crab stock since the former became dominant in that system.

Introduction

Somerton (1985) commented on the disjunct distribution of red king crab, *Paralithodes camtschaticus*, and blue king crab, *Paralithodes platypus*, in Alaskan waters. At the time, overlap between the two species occurred only in a few widely spaced bays and fjords, with the major populations occupying distinctly different areas. He proposed three potential mechanisms to explain this observation: 1) differences in thermal tolerance leading to reproductive isolation, 2) competitive displacement of blue king crab by red king crab in areas of potential overlap mediated by differences in thermal tolerance, and 3) differential predation in favor of red king crab, and noted the relative strengths of each hypothesis without reaching a conclusion (Somerton, 1985). In the late 1980s, the red king crab population in the Pribilof Islands area of the Bering Sea increased dramatically (Fig. 1); this area, up till that point, had been populated almost exclusively by blue king crabs (Foy and Armistead, 2012). A period of brief overlap followed the red king crab escalation, after which the blue king crab populations crashed. Blue king crabs are currently at a historically low level of abundance (Foy and Armistead, 2012). As there is no evidence of sweeping changes in regional temperatures or community structure, the fact that red king crabs were able to become dominant in the Pribilof Islands is evidence against the first and third mechanisms proposed by Somerton, at least as they apply to the Pribilof Islands. Although temperature cannot be the mediating factor, the remaining hypothesis of competitive displacement remains as a potential explanation for both the generally disjunct distributions as well as the substantial decrease in the productivity of the Pribilof Islands blue king crab stock. Competition for resources among late juvenile and adult red and blue king crabs has been considered (NPFMC, 2011); however, observations on the foraging habitats of adults of the two species do not support this mechanism (Somerton, 1985).

Difficult to capture and assess in the field, interactions at the early juvenile stage have not been considered as a potential mechanism contributing to the disjunct distribution, but there are several reasons it could be important. Similarities between red and blue king crabs in terms of size and chela morphology make it likely that they feed on similar items (Somerton, 1985) and field data show that adults do have similar diets (Chuchukalo et al., 2011). If juveniles also have similar diets, this could drive competitive displacement (Brenchley and Carlton, 1983), however, post-settlement, juvenile crabs are likely not limited by bottom-up processes as their dietary requirements are low and food is generally abundant (Long et al., 2011, Seitz et al., 2008). More likely, however, is the effect of intra-guild predation between the species. In the laboratory, red king crabs are cannibalistic both within a cohort (Borisov et al., 2007, Daly et al., 2009, Daly et al., 2012a) and among cohorts (Long et al., 2012a, Stoner et al., 2010), to the extent that rearing crab individually is a viable option to reduce cannibalism (Swiney et al., 2013). Blue king crabs are also cannibalistic but intra-cohort cannibalism may be less intense for them than it is for the red king crab (Daly and Long, 2014a, Daly and Swingle, 2013). Although untested, given their morphometric similarities, it is likely that both species would prey on each other if present in the same habitat. In the laboratory, red king crab will prey on blue king crab (Daly and Long, 2014b) and field data, though limited, show that blue king crab will prey on red king crab in the wild (Chuchukalo et al., 2011). As such, more effective predation by one species could lead to displacement (e.g., Dick et al., 1990, Dick et al., 1999, Race, 1982).

Both competition for resources and intra-guild predation as mechanisms for displacement are predicated on the assumption that the juveniles occupy similar habitats in the absence of the other species; habitat partitioning can lead to coexistence for similar species (e.g., Hines, 1982, Meyer, 1994). There is indirect evidence both for and against habitat partitioning between red and blue king crabs in the Pribilof Islands. Both species release their larvae in the spring (Armstrong et al., 1981, Shirley and Shirley, 1989). After four pelagic, zoeal stages, the larvae molt to the settling post-larval or glaucothoe stage and continue to swim until they find a complex habitat, even delaying their molt to the first juvenile instar stage (C1) in order to increase their chances of finding a complex habitat (Stevens and Kittaka, 1998). While both species demonstrate a strong preference for complex habitats, neither demonstrates a high degree of preference among different types of complex habitats such as hydroids, cobble, shell hash, or macro-algae (Palacios and Armstrong, 1985, Stevens, 2003). Habitat choice at the glaucothoe stage is likely important in determining the distribution of C1 crabs in the field (Loher and Armstrong, 2000, Sundberg and Clausen, 1977), but post-settlement movement among habitats may also play a role (Palacios and Armstrong, 1985). The non-discriminatory settling behavior (among complex habitats) of both species supports the idea that they may occupy similar habitats as juveniles; however, field surveys that included both shell and cobble, suggest that red king crab juveniles prefer cobble habitat (Loher and Armstrong, 2000) and blue king crab juveniles prefer shell hash, which is common around the Pribilof Islands (Armstrong et al., 1987), supporting the habitat partitioning hypothesis.

In this study, we examined whether post-settlement interactions between red and blue king crabs could cause decreased production of blue king crabs around the Pribilof Islands, or whether habitat type could mediate interactions between species through habitat partitioning. In particular, we determined how density and predator presence alter habitat choice of year-0 red and blue king crabs, how habitat type and temperature affect predation of blue king crabs by red king crabs, how habitat type affects intra- and inter-specific interactions, and which types of interactions dominate in both species.

Section snippets

Crab rearing and holding conditions

Red and blue king crabs for these experiments were all laboratory- or hatchery-reared. Red king crab broodstock were captured using baited commercial pots in Bristol Bay in the winters of 2008, 2009, and 2010, and transported to the Kodiak Laboratory. In 2008 and 2009, crabs were flown to the Alutiiq Pride Shellfish Hatchery, Seward, Alaska, in coolers with wet burlap and ice blocks. Blue king crab broodstock were also captured near St. Matthew Island in the winter of 2010 and flown to the…

Effects of density and predator presence on habitat choice

Red king crab habitat choice varied with habitat type, predator presence, and year-0 density. In general, red king crabs showed a preference for more complex habitat and their preference was increased in the presence of predators (Fig. 3). In the Cobble–Sand choice experiment, habitat preference varied with predator presence (Table 1). In the absence of predators, crabs did not have a preference for either habitat type, but preference for cobble increased when a predator was present (Fig. 3A).…

Discussion

This study examined the interactive effects of habitat, predation, density, and intra-guild interactions on survival and growth of newly settled red and blue king crabs. We found that hatchery-reared red king crabs have a higher preference for complex habitats than do hatchery-reared blue king crabs, and that both responded to predator presence by increasing affinity for complex habitat. Predation by year-1 red king crabs on year-0 blue king crabs was a function of temperature and habitat type, …

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