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Molting, growth, and energetics of newly-settled blue king crab: Effects of temperature and comparisons with red king crab

Allan W. Stoner [a], Louise A. Copeman [b], Michele L. Ottmar [a]

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Abstract

Populations of blue king crab (BKC) (*Paralithodes platypus* Brandt, 1850) have declined in Alaskan waters over recent decades, and substantial effort is being made to rehabilitate the once important fishery with releases of hatchery-reared juveniles. However, little is known about the species' first year of post-settlement life. This study was conducted to evaluate how temperature mediates growth and energy allocation beginning with the first benthic instar (stage C1). Juvenile BKC were reared in four temperatures (1.5 to 12 °C) for a period of 60 days in low-density populations (150 crabs m^{-2}) and 120 days in individual cultures. Growth rate increased rapidly up to 8 °C, and then leveled off. At 60 days, most of the crabs in 1.5 °C remained at stage C1, most in 4.5 °C were C2, and most in 8 °C were C3, while those in 12 °C were highly variable and ranged from C2 to C5. Growth records for individuals revealed an inverse exponential relationship between water temperature and intermolt period (up to 8 °C). A small decrease in molt increment at 12 °C resulted in crabs 6% smaller than those at 8 °C. Total lipid content increased with temperature in C2 BKC, but the response was variable and not significant in later stages. The proportion of storage class lipids (triacylglycerols) increased with an increase in temperature and polar lipids decreased. Concentrations of essential fatty acids were relatively constant over all temperature treatments, indicating that temperature and growth rate did not affect the biochemical condition of juvenile BKC. Survival rates of BKC (>95%) were similar across temperatures and were much higher than rates observed for red king crab (RKC) (*Paralithodes camchaticus* Tilesius 1815) (65–72%) in identical experiments. Growth rates of the two species were nearly identical up to 8 °C, but RKC grew faster than BKC at temperatures greater than 8 °C, with more molts resulting in larger individuals. Fatty acid (FA) signatures supported the lipid class data and showed that BKC had higher proportions of FA associated with energy storage while RKC had higher proportions of polyunsaturated FAs associated with membranes. These results indicate that BKC are the hardier species, and it shows little sign of cannibalism in culture (unlike RKC), but RKC grow faster at high temperature and are less vulnerable to warming climate. These data help to model temperature-dependent recruitment processes in the field and assist in the design of diets and hatchery conditions for production of seed stocks intended for field release.

Highlights

► Growth of blue king crabs increased with water temperature up to 8 degrees. ► Blue king crabs had higher survival than red king crabs due to low cannibalism. ► Lipid storage in blue king crabs increased with water temperature. ► Blue king crabs had higher lipid storage than red king crabs. ► Blue king crabs were more vulnerable to warming climate than red king crabs.

Introduction

Multi-decadal shifts in oceanographic conditions are well studied in the Gulf of Alaska and the Bering Sea (Hollowed et al., 2001, Hunt et al., 2002, Peterson and Schwing, 2003), and these shifts can cause important changes in the distribution and abundance of both marine fishes and invertebrates (Anderson and Piatt, 1999, Hollowed et al., 2012, Perry et al., 2005). Longer-term trends in sea surface warming and loss of sea ice have also been documented in Alaska (Grebmeier et al., 2006, Sigler et al., 2011, Stabeno et al., 2007), and the potential impacts on economically important species are large (Logerwell et al., 2011, Orensanz et al., 2004). Both positive and negative impacts on fisheries are possible under the scenario of changing climate because of the complexity of changes in temperature, water chemistry, primary productivity, and shifts in species ranges and food web structure (Ainsworth et al., 2011). Temperature has a fundamental and dominant role in the behavior, physiology, growth, and survival of ectothermic animals living in high latitudes and these direct effects are the focus of this study.

King crabs represent some of the most valuable fishery resources harvested from the cold waters of Alaska (Orensanz et al., 1998, Otto, 1989), and two species comprise most of the catch, red king crab (RKC) (*Paralithodes camtschaticus* Tilesius, 1815) and blue king crab (BKC) (*Paralithodes platypus* Brandt, 1850). BKC has been secondary to RKC in value; the largest populations of BKC are more northerly and may be more sensitive to warming conditions in the Bering Sea than RKC. Details on the distribution and fishing histories for BKC are provided by others (Herter et al., 2011, Stevens et al., 2008a). Briefly, BKC live in isolated populations in the Bering Sea, Gulf of Alaska, southeast Alaska, and in the western Pacific Ocean near Japan and Russia. In the United States, the vast majority of BKC have been landed from fishing grounds near St. Matthew Island and the Pribilof Islands with a peak catch (value=$12 million) occurring in 1997. However, catch rates in these areas showed signs of decline in the 1980s, and the populations decreased precipitously in the 1990s (Stevens, 2006). The collapse of king crab fisheries in Alaska has been attributed to both over-harvest and unfavorable environmental conditions for recruitment (Dew, 2010, Dew and McConnaughey, 2005, Orensanz et al., 1998). After long closures of the BKC fishery, some stocks are rebuilding, and short-term openings and annual catch limits (400–800 $MT y^{-1}$) have been re-established at St. Matthew Island since 2009. The fishery for BKC remains closed in all other areas of Alaska.

We have relatively good understanding of fecundity, embryonic development, and hatching in BKC (Herter et al., 2011, Stevens et al., 2008a, Stevens et al., 2008b), and the larvae have been cultured in Alaskan laboratories since 2004 (Persselin, 2006). Despite the fact that BKC are being cultured with the primary intent of restoring wild populations through releases of hatchery-reared juveniles, relatively little is known about their first few years of post-settlement life (see Armstrong et al., 1985, Tapella et al., 2009), particularly with respect to how temperature affects survival, growth, and energy allocation. Consequently, this study was designed in the context of two broad themes — understanding how growth and survival of early juvenile BKC may be affected by warming trends in Alaska, and determining how temperature might be used in developing the best possible methods for culturing crabs in a hatchery setting.

Temperature is generally believed to be the most important extrinsic factor affecting growth in crustaceans (Hartnoll, 1982, Hartnoll, 2001). The largest impact of temperature is on intermolt period, (i.e., the duration between two successive molts), and there are many examples of decreasing intermolt period with increasing temperature. Temperature can also influence the molt increment (i.e., the change in size that occurs between one instar and the next). Effects of temperature on molt increment are variable, with many crustaceans showing no variation over a wide range of temperature (reviewed by Hartnoll, 1982), although RKC demonstrated a small increase in molt increment with increasing temperature (Stoner et al., 2010a).

Lipids and fatty acids (FAs) are vital to developing marine organisms as they provide a dense source of energy ($kcal \cdot g^{-1}$) and are important structural components of membranes (Copeman and Parrish, 2003, Sargent, 1989). Prior work with RKC juveniles has shown that triacylglycerols (TAGs) are the major lipid storage class (Stoner et al., 2010a), in agreement with other studies on crustacean larvae and juveniles (Nates and McKenney, 2000). Further, Copeman et al. (2012) found that TAG levels in RKC cycled within an inter-molt period, with rapid accumulation shown seven days following a molt. Other major lipid classes in crabs include sterols (STs) and phospholipids (PLs), which form important building blocks of cellular membranes. Relative improvements in both larval and juvenile condition in marine crustaceans, such as American lobster (*Homarus americanum* H. Milne Edwards, 1837) and RKC (Copeman et al., 2012) have been attributed to elevated total lipid, TAG per dry weight, and TAG/ST ratios (Fraser, 1989).

The importance of dietary polyunsaturated fatty acids (PUFAs) to the culture of juvenile crustaceans has been investigated for crabs (Zmora et al., 2005), lobster (Limbourn and Nichols, 2009) and shrimp (Lavens and Sorgeloos, 2000). Crustaceans generally require PUFAs such as docosahexaenoic acid (DHA, 22:6n−3), eicosapentaenoic acid (EPA, 20:5n−3), and arachidonic acid (AA, 20:4n−6) at minimum dietary levels because they cannot be formed de novo from shorter chain dietary precursors (Merican and Shim, 1996). Cultured RKC fed on enriched *Artemia* have lower proportions of essential PUFAs (DHA, EPA, AA) than those collected from the wild (Copeman et al., 2012) and it is thought that nutritional deficiencies play a role in elevated mortality during the early life history stages of crabs reared in hatcheries (Daly et al., 2009). The effects of temperature and dietary FAs on juvenile crab vitality are likely interactive. Previous studies show that high levels of essential PUFAs are retained in marine organisms at low temperatures (Dunstan et al., 1999, Hall et al., 2000, Hall et al., 2002) with elevated PUFAs in cellular membranes being important for thermal adaptation.

This study was designed to evaluate the role of water temperature on survival, molting frequency, growth, and lipid storage in the earliest benthic stages of BKC. Four temperatures were tested (1.5° to 12 °C), spanning the normal range of distribution encountered by newly-settled BKC in the field. Lipid and FA analyses were made at each crab molt stage to explore the effects of temperature and ontogeny on crab condition and energy allocation. The results of these experiments are relevant to both aquaculture and changing climate conditions in Alaska, and are compared with somewhat different growth dynamics observed in RKC.

Section snippets

Experimental animals

Blue king crabs for this study were supplied by the Alutiiq Pride Shellfish Hatchery in Seward, Alaska. Nineteen ovigerous female BKC were collected with baited pots set near St. Matthew Island, Alaska, in November and December 2011, air transported to Seward, and maintained at the hatchery on chopped herring and squid until their larvae were released in March 2012. Larvae released from at least three females were mixed randomly and reared in three 190l tanks until the glaucothoe stage was…

Overall crab survival and growth

Blue king crab survivals were very high, over 90%, in all of the treatments over the 60-day monitoring period. The effect of temperature on survival in population cultures was relatively small (Table 1), and differences were not significant at either 30 (ANOVA, $F_{3,8}=1.600$, $p=0.264$) or 60 days ($F_{3,8}=2.730$, $p=0.114$). Overall survival at the end of the experiment was 3.0% higher in individually cultured crabs than in populations, but there were no consistent differences in survival among the…

Effects of temperature on survival and growth

The upper and lower temperature tolerance limits have been studied for a variety of crab species and for different stages of development, particularly in light of warming environment (Kelley et al., 2011, Storch et al., 2011, Walther et al., 2009, Weiss et al., 2009). However, we observed no significant variation in the survival of BKC juveniles over the range of temperatures tested (1.5 to 12°C). In fact, despite some evidence for stress at the high temperature treatment (see below), newly…

Acknowledgments

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References (73)

K. Anger *et al.*

Larval and early juvenile development of *Lithodes santolla* (Molina, 1782) (Decapoda: Anomura: Lithodidae) reared at different temperatures in the laboratory

J. Exp. Mar. Biol. Ecol. (2004)

J.A. Calcagno *et al.*

First year growth in the lithodids *Lithodes santolla* and *Paralomis granulosa* reared at different temperatures

J. Sea Res. (2005)

L.A. Copeman *et al.*

Effects of docosahexaenoic, eicosapentaenoic, and arachidonic acids on the early growth, survival, lipid composition and pigmentation of yellowtail flounder (*Limanda ferruginea*): a live food enrichment experiment

Aquaculture (2002)

B. Daly *et al.*

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Aquaculture (2009)

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J. Biol. Chem. (1957)

V. Freitas *et al.*

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J. Therm. Biol. (2007)

A.B. Hollowed *et al.*

Pacific Basin climate variability and patterns of Northeast Pacific marine fish production

Prog. Oceanogr. (2001)

A.B. Hollowed *et al.*

Effects of climate variations on pelagic ocean habitats and their role in structuring forage fish distributions in the Bering Sea

Deep-Sea Res. II Top. Stud. Oceanogr. (2012)

D. Johnston *et al.*

Decline of a blue swimmer crab (*Portunus pelagicus*) in Western Australia: history, contributing factors and future management strategy

Fish. Res. (2011)

A.L. Kelley *et al.*

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> …However, the evidence yielded by previous studies on the blue king crab, Paralithodes platypus, and the red king crab, Paralithodes camtschaticus, indicates that the majority of instars reared at 1.5 °C remained at C1 to C2. However, crabs reared at a higher temperature of 12 °C reached C5 to C6 after 60 days of culture (Stoner et al., 2010; Stoner et al., 2013). Our results were similar to those pertaining to lithodid crabs, reported by Stoner et al. (2013), who noted that, after 30 days of culture (60 days after hatching) at 24 °C, hatchlings reached C2 to C3 developmental stage, whereas crabs reared at 32 °C were at stage C6 to C7.…

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