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High-density production of Southern King Crab (*Lithodes santolla*) juveniles in the field for stock enhancement

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Highlights

- Field culture of Southern King Crab juveniles can be successfully addressed at high densities.
- Southern King Crab survival after 5 months of massive field culture reached the 62%.
- Southern King Crab survival and growth in suspended mesh-bags in the field is feasible without external food provisioning.
- The longer the culture period, the grater the size disparity among crabs.

Abstract

The Southern King Crab -SKC- (*Lithodes santolla*) is a highly demanded gastronomic resource in South America, specially from tourism. As many others crab fisheries, the current state of L. *santolla*'s population in the Beagle Channel is compromised, since the production of new recruits is below its potential. In this sense and in order to overcome this limitation, late efforts have been directed towards the development of efficient larvae and juvenile culture, either in hatcheries or in the field for future stock enhancement. With some progress in culturing larvae in hatcheries and some novel results on the feasibility of culturing juveniles in the field, the present study takes a step forward and addressed field culture at high density and for a mid-term period of 5 months. Field culture was performed in prefouled meshed-bags enclosures suspended in the water column. Thus, 2500 stage 1 SKC juveniles were massively cultured for 5 months and no external food provided. Over 62% of the juveniles survived and less than 10% were injured (i.e. lost appendages). The smallest and biggest crabs recovered were 2.20 and 7.05 mm of carapace length respectively. A total of 6 modal groups explained the size frequency distributions of the recovered crabs and over 70% of the survivors ranged between 3.75 and 4.75 mm of carapace length. In comparison with a previous work, our results also show that the longer the culture period, the grater the size disparity among crabs. The effectiveness of SKC juvenile massive culture in the field in terms of survival and growth is encouraging specially since the meshed-bags enclosure system stands as a low cost and low maintenance system to produce large numbers of bigger crabs. This knowledge is crucial in the context of the implementation of a stock enhancement program, which may help to L. *santolla*'s population recovery in the Beagle Channel.

Introduction

The southern king crab (SKC) *Lithodes santolla,* is a highly prized and gastronomically appreciated marine invertebrate in southern South America that has been regularly fished since the 1920s and 30s in Chilean and Argentine waters, respectively (Lovrich and Tapella, 2014; Vinuesa et al., 1996). In Argentina, intensive fishing mainly occurred during the 1970s and 80s and, although captured in an artisanal scale and despite several management rules implemented through time, the stock of SKC in the Beagle Channel is currently threatened. This stock has low relative abundances (as captures per unit effort, CPUE), low percentages of ovigerous females, a juvenilized size structure for both sexes, and an increased size at functional reproduction of females, all leading to a low recruitment probability (Di Salvatore, 2019; Di Salvatore et al., 2021; Lovrich and Tapella, 2017). The current state of the SKC population in the Beagle Channel is not an isolated case. Only four out of 20 crab fisheries around the world were recently ranked as in “good condition,” using sustainability

indexes based on landings, biological information, assessment data and following the traffic light approach of Caddy et al. (2005) (see also Stevens and Miller, 2020).

Thus, the signs of population deterioration led to considering stock enhancement as a tool to overcome the limited production of new SKC recruits in the Beagle Channel. Stock enhancement entails the massive production and release of competitive juveniles or early stages into wild populations. Typically, stock enhancement programs either target the release of large numbers of small postlarvae or pursue the production of fewer, but relatively bigger juveniles (Beal et al., 2002). Both strategies, generally based on hatchery-produced animals, seek a certain balance between time of development and mortality rates, as well as space availability and feeding limitations for rearing animals in land-based facilities. To minimize predation risk on recently released animals, several studies have recently focused on growing animals to bigger sizes before release (Beal, 2012; Beal and Protopopescu, 2012; Daniels et al., 2015; Halswell et al., 2016; Sotelano et al., 2018). Hence, transitioning from hatchery to field culture becomes essential to cope with these crabs' slow-growth, i.e., long culture periods (e.g., Calcagno et al., 2005; Sotelano et al., 2012; Sotelano, 2013) and cannibalistic behavior of many of the target cultured species (Sotelano et al., 2012, Sotelano et al., 2016), and not less important, to reduce the high fixed costs of a long-term operating hatchery.

Massive SKC larval rearing in a hatchery can be relatively easily performed by taking advantage of both larval lecithotrophy (Lovrich et al., 2003) and low cannibalism during the larval period. It is during juvenile SKC rearing that cannibalism represents a bottleneck, since both intra and inter-stage cannibalism is frequent even during intermolt period. Additionally, molt events and high densities strongly enhance this agonistic behavior (Sotelano et al., 2012, Sotelano et al., 2016). A first attempt of a two-month rearing period of juvenile in meshed-bag enclosures in the sea produced 40% overall survival, when feeding was based on the consumption of the fouling community that naturally attaches to the system's constructive materials (Sotelano et al., 2018). Besides some advances in sea-based culture for Homarid lobsters with different degrees of success (Jeffs et al., 2020), this type of culture has not been tested or reported in any other species of king crabs. Although we already proved the feasibility of short-term sea culture of first SKC juvenile stage, the number of crabs manipulated in our first attempt was limited (Sotelano et al., 2018). In this sense, management of high-density cultures along with mid- and long-term culture periods would allow a large-scale production of bigger juveniles to foster the survival of at least some of these animals after release.

Thus, the present study aims to establish the feasibility of high-density juvenile SKC culture, whithout external food provitioning during a mid-term culture period of 5 months.

Section snippets

Larval rearing in hatchery

During July 2017, ovigerous SKC females were captured through baited-traps in the Argentine sector of the Beagle Channel, located at the southern tip of South America. Once in the laboratory (*Centro Austral de Investigaciones Científicas* – CADIC), they were massively acclimated in large bins connected to a Recirculating Aquaculture System (RAS). Three days afterwards, 40 egg-bearing females in good condition (i.e. no missing limbs, active) were transferred into individual aquaria in a second…

Results

Field culture of SKC was performed during almost the entire southern hemisphere summer and the beginning of autumn. Water temperature at deployment site in Ushuaia Bay during sea culture ranged between 6.27 and 10.65 °C with an overall mean of 8.37 °C. Monthly mean temperature peaked in February while the lowest average record during the experimental period was registered during May (Fig. 2).

The meshed-bag line was recovered in good shape, with no remains of sediment inside the bags nor breaks. …

Discussion

Developing cost-effective methodologies to produce large numbers of fitted animals is crucial in the context of the implementation of a stock enhancement program, which may help the L. *santolla* population recovery in the Beagle Channel. Building on earlier work (Sotelano et al., 2018), this study constitutes the first novel results on the feasibility of

growing juvenile king crabs in the sea as a complement to larval hatchery culture. Our findings not only reinforce the viability of SKC sea…

Author statement

Details of each author with their contribution in this paper:

Name of the author and e-mail ID	Types of contribution
Sotelano, *M. Paula*; paulasotelano@conicet.gov.ar ↗ (corresponding author)	Conceptualization, methodology, investigation, formal analysis, laboratory and field works, writing original draft, project management, Funding acquisition
Reartes, Belén Reartes.belen@conicet.gov.ar ↗	Investigation, labotaroy and field works.
Lovrich, Gustavo A. gustavolovrich@conicet.gov.ar ↗	

…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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