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Trawl-related mortality and injuries to the southern king crab *Lithodes santolla* of Patagonia

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Highlights

- SKC mortality is affected by both operational and biological variables.
- SKC have high survival after its return to the sea.
- Trawl-related mortality have a minnor contribution to current SKC fishing mortality.
- This information should be beneficial for the estimations of fishing quotas and help in the effective management of SKC in trawl fisheries.

Abstract

The catch and discard of non-target species could have detrimental effects on bycatch, species due, among others, to the increase in mortality and prevalence of injuries. In Argentina, the southern king crab (SKC), Lithodes santolla, supports a profitable trap fishery but is also caught as bycatch in trawl fisheries. The aims of this work were: i) to quantify the mortality and injuries in SKC caught as bycatch in the hake fishery in San Jorge Gulf (southwestern Atlantic Ocean), ii) to assess the factors that affect their mortality and injury occurrence, and iii) to estimate their postdiscard mortality.Immediate mortality (IM) and injuries in SKC were recorded in hauls of the hake fishery, and then related to operational and biological variables. SKC vitality was assessed using the reflex action mortality predictor (RAMP) test. Postdiscard mortality was analyzed in aquaria and wild (sea cages) conditions. The IM of SKC in the common hake fishery was 31%. The IM, as well as increased injuries and decreased vitality, were directly associated with the time and conditions of air exposure. Both the IM and injury occurrence were also affected by biological variables such as the sex,size and molt stage. Postdiscard mortality was lower in wild conditions than in the aquaria (1%). Our results suggest that SKC could have high resistance to handling and high recovery capacity after its return to the sea. In consequence, the quick return of SKC to the sea may have a positive effect on SKC survival.

Introduction

Benthic-trawl fisheries have several negative effects on benthic ecosystems. Some of the most important consequences are related to the mortality of bycatch species, i.e. the non-target species unintentionally caught during fishing operations. Among other negative impacts, the mortality of discarded bycatch causes biodiversity loss and can lead to changes in community structure and food webs (Stobutzki et al., 2003; Kaiser et al., 2006; van de Wolfshaar et al., 2020). Also, target species discarded in other fisheries can lead to negative fishery interactions (Kennelly, 1995). Reducing mortality of unwanted bycatch species is important for ecological, socio-economic, and ethical reasons (Hall, 1996, Stoner, 2012). As the reduction of bycatch is one of the main goals of fishery management, in the last years, main efforts have been directed towards characterizing and quantifying the bycatch and assessing the mortality of bycatch species (Alverson et al., 1994, Zeller et al., 2018).

The initial step towards understanding and eventually reduce the issues related to bycatch entails accurately quantifying the total volumes of bycatch and mortality rates associated with fishing practices. Fishing mortality has two components: i) accounted mortality, ii) unaccounted mortality of individuals. Firstly, the known and quantifiable mortality of landed catches, whereas, unaccounted mortality is associated with capture, discard on-board. This mortality includes the delayed mortality of organisms that are returned to the sea after being caught and other unobserved components (Uhlmann and Broadhurst, 2015). Most of the bycatch studies have focused on immediate mortality of discarded species (Davis, 2002, Broadhurst et al., 2006) because it is easier to estimate, but to quantify total fishing mortality the incorporation of other components of mortality is necessary (Yochum et al., 2015).

In the past, several approaches and methods have been developed to assess the effects of capture, handling and discarding in delayed mortality (Stoner, 2012). Delayed mortality can be indirectly predicted based on injury assessments and physiological or behavioural indicators. Among these predictors, the Reflex Action Mortality Predictor (RAMP) approach, which is a rapid and noninvasive assessment of reflex actions, has been increasingly used to determine the mortality of crustacean bycatch species in several fisheries (Stoner et al., 2008, Hammond et al., 2013, Rose et al., 2013, Yochum et al., 2015, Yochum et al., 2017, Yochum et al., 2018, Lescher et al., 2021).

Understanding the operational, environmental and biological factors that affect bycatch species survival is crucial to develop effective discard mortality mitigation measures (Davis, 2002, Broadhurst et al., 2006, Depestele et al., 2014). Several works around the world have studied the discard mortality of different commercial crabs in trawl fisheries (Stoner et al., 2008, Hammond et al., 2013, Rose et al., 2013). The mortality discarded species vary greatly depending on the taxon, size, trawling time and speed, air exposure time, injuries, and level of damage (Davis, 2002, Depestele et al., 2014). Compared with other taxa, crustaceans may exhibit greater resilience to fishing-related handling because of their exoskeletons, benefits associated with limb autotomy, and air-breathing ability of some species (Broadhurst et al., 2006, Uhlmann and Broadhurst, 2015).

In species subject to fishing exploitation, knowing the fishing mortality is very important to improve biomass estimations as well as the authorized quota for fishing. It is also important to recognize the various negative effects that fishing practices may have on fishery productivity and their implications for proper fisheries management. Some king crab species support many lucrative trap fisheries around the world, but are also caught as bycatch in many trawl fisheries (Stevens, 2014). In South America the southern king crab (SKC), *Lithodes santolla*, supports commercial fisheries along the coasts of both Argentina and Chile.

In Argentine, the SKC trap fishery began in 2004, in waters adjacent to San Jorge Gulf (SJG). This fishery is based on the 3S rule (sex, size and season), total allowable catch and individual fishing quotas (since 2016—2017). After a period of increase in catches, SKC landings have stabilized at around 1500t year^{-1} since 2019 (Firpo, 2020). Currently, however, this fishery shows some negative signs such as reductions in the landings and in the catch per unit of effort (Firpo et al., 2023).

In SJG, SKC shares its habitat and distribution with other species of great economic importance such as the Argentine red shrimp *Pleoticus muelleri* and the common hake *Merluccius hubbsi*. These species support the main trawl fisheries of the southwestern Atlantic Ocean. Main efforts to characterize the SKC bycatch have been directed towards the Argentine red shrimp fishery due to its low selectivity and the size of fleet and overlapping with the SKC fishery in SJG. Until 2011, the SKC bycatch in the shrimp fishery was close to 2000 t year^{-1} (Iorio et al., 2013, Varisco et al., 2017). However, currently, the shrimp fishery is concentrated out of SJG, in the northern area of national waters, where the abundance of SKC is lower, for which its bycatch has decreased significantly (Mauna et al., 2019). The bycatch of SKC in the hake fishery has received less attention. Ruiz et al. (2020) estimated that the bycatch of SKC in this fishery in SJG is 110 t year^{-1}, 23.05 t of which correspond to commercial-sized individuals (males larger than 100 mm Carapace Length, CL). Mortality of commercials- sized individuals in hake fisheries may appear to be a minor fraction of the actual SKC fishing mortality. However, this has been addressed to a limited extent, and the relationship between SKC mortality, and the effects of mechanical stress caused by trawling, handling, exposure to air, and discards during the fishing process has not been adequately described.

It is well known that king crab species are vulnerable to depletion (Orensanz et al., 1998, Otto and Stevens, 2014), due to their longevity, late maturity, spatial aggregation and population changes by large male-only fishing. In fact, in the past, several fisheries of king crabs collapsed (Otto and Stevens, 2014). Considering the above, the main here aims were: i) to quantify the immediate mortality and injury occurrence in the SKC caught as bycatch in the hake fishery of SJG, ii) to assess the factors that affect their immediate mortality and injury occurrence, and iii) to estimate their post-discard mortality. This information should be beneficial prescribing the fishing quotas and help in the effective management of SKC in trawl fisheries.

Section snippets

Common hake fishery

The common hake fishery in SJG involves two fleets: a high-sea trawler fleet and a coastal fleet. Currently, the high-sea trawler fleet that operates in SJG comprises about 10 vessels greater than 21 m in length, whereas the coastal fleet is comprises about 12 vessels less than 21 m in length. The fishing gear used by both fleets is the bottom trawl, with a mesh size in the codend of 120 mm. The main differences between these fleets are the size of the fishing gear and the treatment of the…

Catch structure, immediate mortality, RAMP scores and injuries

In the on-board sampling, 3639 SKC individuals ((2271 males and 1368 females) from 63 fishing hauls (21 hauls from coastal boats and 42 from high-sea trawlers) were examined. The CL of the individuals ranged between 48 and 138 mm (Fig. 2). Out of the total SKC sampled, 16% were of commercial-sized (males larger than 110 mm CL), whereas 4% were juveniles (CL < 70 mm). In addition, 31% of the SKC individuals sampled were dead at the time of examination (IM). Females examined during February-June…

Discussion

Given that one of the direct impacts of trawl fisheries is the incidental capture of non-target species that are subsequently discarded (Hiddink et al., 2011), understanding what happens to discarded species is essential for proper fisheries management (Suuronen and Gilman, 2020). The ability of non-target species to withstand physical stressors associated with their capture mechanisms, and consequently with survival, is highly variable at the species level (Broadhurst et al., 2006). In…

CRediT authorship contribution statement

Ruiz Nair Soledad: Corresponding author. Manuscript writing. Maria Eugenia López: Revision and writing of the manuscript. Enrique Morsan: Revision and writing of the manuscript. Marin Varisco: Revision of the manuscript. Editing tables and figures.…

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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