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Review

Physical oceanographic processes affecting catchability of spanner crab (*Ranina ranina*)—A review

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ABSTRACT

This review examines the influence of physical ocanographic processes on catchability of spanner crab (*Ranina ranina*) in northeast Australia. Physical oceanographic processes may affect crab catchability by influencing their activity levels and ability to detect bait. Bottom temperature, current velocity, and swell intensity appear to influence catches of spanner crab. At this stage, it appears warmer temperatures enhance catchability of spanner crab. Spanner crabs were more catchable in stronger currents, and crabs were observed to arrive from down-current of baited traps. However, a decline in catch was observed following periods of intense swell. Data derived from Waverider buoys suggest that occasionally these periods create strong wave-induced seabed current velocities, lead to at depths of 70 m. The oscillatory motion of wave-induced seabed velocities may cause higher suspended sediment concentrations. These observations corroborate the views of local fishermen that spanner crabs avoid 'murky' water. The effect of turbidity on catchability requires further research. Overall, we advocate that studies employ robust methodologies to measure physical oceanographic processes to accurately predict catchability. Moreover, large-scale physical oceanographic processes may also play an important role in catchability of spanner crab; including upwelling, eddies, and the East Australian Current. Integrating physical oceanography and fisheries interactions will considerably benefit commercial fishermen as well as provide valuable information for evidence-based management of these valuable resources.

Contents

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1. Introduction

Fisheries are highly valuable resources worldwide, but are under continuous pressure to meet increasing demand. As these industries expand, they should be closely monitored to ensure harvests do not exceed sustainable levels (Hill and Wassenberg, 1999). Many fishery management regimes require well developed performance indicators, analytical methodologies, and decision rules for resource sustainability (O'Neill et al., 2010). Changes to current and historical approaches have typically focussed on tightening management controls on effort and total allowable catch (TAC) (Dichmont and Brown, 2010). Although tight management controls may help ensure the sustainability of fisheries, it is important to understand the optimum ecological conditions in which fishery species thrive.

Physical oceanographic processes may affect fisheries by modifying the species' abundance and/or catchability (Green et al., 2014)—a particularly important, but poorly understood, factor frustrating ecologically-based stock assessments. A better understanding of catchability is important, as it is a useful indicator of changes in stock size while accounting for fishing effort and allowing for improved management of the fishery (Arreguín-Sánchez, 1996). Abundance and catchability are factors that ultimately determine how large or small each harvest will be. Species abundance is affected by abiotic factors during their larval stages, as the transport of larvae can be explained by the physical forcing of wind and associated currents (Goodrich et al., 1989; Olaguer-Feliú et al., 2010; Wing et al., 1995), whereas their adult stage has mainly been governed by biotic factors (Green et al., 2014). Catchability depends on the fishing strategy for the target species (Arreguín-Sánchez, 1996), using a passive fishing method (relying on attraction to bait) or an active method such as trawling or haul netting. Catchability is also associated with varying equipment, crew, and environmental conditions (Pennington and Godø, 1995). Poor weather frequently prevents the operation of smaller vessels and consequently accounts for annual catches being consistently less than the potential Total Allowable Commercial Catch (TACC) (Dichmont and Brown, 2010). A range of environmental conditions may also explain crab abundance via their effect on the species' growth and survival (Zheng and Kruse, 2006). Such effects would ultimately impact catchability in the long-term. However, physical oceanographic fluctuations may also impact short-term catchability.

Coastal and shelf water fishery habitats experience very complex physical oceanographic fluctuations. These waters interact with tides, shelf-break fronts, upwelling, estuarine fronts, and the coastal topography (Acha et al., 2004). Shelf-break fronts are often associated with large-scale processes, including major boundary currents and eddies (Jilan, 2004). With such complex physical oceanographic processes, biophysical interactions in shelf water habitats are even more complex. This paper explores literature and methodologies used to determine whether physical oceanographic processes are influencing the catchability of spanner crabs. Due to high variability of shelf waters in the coastal ocean, the Australian fishery is of particular interest in this study.

2. The Australian fishery

Commercial fisheries for the spanner crab have been established across the Indo-Pacific, and Australia accounts for the greatest annual landings (Kennelly and Scandol, 2002; Thomas et al., 2013). The Australian fishery is centred on shelf waters along the coast of southern Queensland and northern New South Wales (NSW) (Brown et al., 1999; Skinner and Hill, 1986) mostly in depths between 30 and 80 m (Dichmont and Brown, 2010). The crab fishery developed in the 1970s as a result of substantial catches being taken in waters adjacent to Moreton Island (Brown et al., 1999; R. Freeman, pers. comm.). After the development of a profitable live export market in the early 1990s, the fishery grew and annual catches increased to over 3000 t, at which point stringent output-based management arrangements were developed (Brown et al., 1999). This fishery is divided into six management regions subject to individual TACCs (Fig. 1).

The TACC has fluctuated since the live-export market was established, currently set at 1631 t (McGilvray and Johnson, 2014). In recent years, the annual catch in Queensland has averaged about 900–1000 t with approximately 100 t from NSW (McGilvray and Johnson, 2014). The reduction in catch since the early 2000s is largely due to the introduction of the TACC-based management plan and an associated reduction in fleet size (Brown et al., 2013). TACC operates with individual transferable quota and was first introduced in the mid 1990's as a sustainability measure after a substantial increase in fishing effort, where the total number of boat days increased from 2733 in 1990 to 17,765 in 1994 (up 550% in 4 years) (Brown et al., 1999). A particularly informative illustration of the reduction of fishing effort and improved catch rate since the mid 1990's can been found in Dichmont and Brown (2010), Fig. 2. Since reduced effort accounts for the substantial reduction in catch, the influence of physical oceanographic processes affecting total annual catch are considered to be minimal over the long-term. Other important considerations include the lifecycle of the spanner crab, known behaviour, and preferred habitats. Only by understanding both fishery management controls and ecological factors that may affect catchability of spanner crab is it possible to determine additional physical oceanographic effects.

3. Habitats, lifecycle and catchability

Spanner crab (*Ranina* ranina) populations occur from the east coast of Africa across the Indian Ocean to as far as the Hawaiian Islands (Baylon and Tito, 2013; Kasinathan et al., 2007). They are known locally under various names, including kona crab (Hawaii), red frog crab (Japan), curacha (Philippines), krab ziraf (Seychelles), and spanner crab is the local name in Australia (Baylon and Tito, 2012; Dichmont and Brown, 2010). Their habitats occur mainly in shelf waters, sometimes adjacent to coral reefs (Thomas et al., 2013). The crabs' distribution patterns typically occur on sandy substrates with little vertical structure (i.e. rocky or coral reef) (Boulle, 1995; Brown et al., 2008; Moussac et al., 1987). The crabs are hypothesised to spend most of the time buried in the seafloor with only their eyes protruding to avoid predators (Faulkes, 2006; Kirkwood et al., 2005). They spend longer periods buried during spawning summer months, only emerging to feed and mate (Brown et al., 2001, 1999; Kennelly and Watkins, 1994; Krajangdara and Watanabe, 2005; Skinner and Hill, 1986; Thomas et al., 2013). Minagawa (1990b) observed complete larval development, from first instar zoea to megalopa, occurs over 36–62 days and, once fully developed, megalopae and juvenile crabs buried into the sand. From juveniles to adults, Kirkwood et al. (2005) found they grow slowly and the age of recruitment to the fishery was predicted to be 4.5 years and 6.5 years for males and females, respectively. Males and females are known to reach 150 mm and 120 mm carapace length, respectively (Dichmont and Brown, 2010), which, based on model results from Kirkwood et al. (2005), may take up to 15 years.

Catchability of spanner crab is affected by moulting and their reproductive cycle, and thus catchability may ultimately depend of the time of year. Skinner and Hill (1987) conducted a laboratory experiment on spanner crabs and observed that males and females did not feed for 52 and 22 days, respectively during moulting. In the Australian fishery, newly moulted spanner crabs frequently appear