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Warrior swimming crab fishing zones along the southwest Baja California peninsula, Mexico

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ABSTRACT

To improve the management of the warrior swimming crab (*Callinectes bellicosus*, Stimpson 1859) fishery along the west coast of Baja California Sur, Mexico, catch, economic value and trip ticket frequency data, from 1998 to 2010, were analyzed by month and locality. Based on the geographic locations of fishing localities and their use frequencies, five fishing zones were identified. The relative contributions to the regional catch, economic value and frequency of use, as well as catch trends and fishing seasons, revealed differences between zones. The proposed zones can be used to design spatial management units that facilitate the monitoring of fishing efforts and evaluate the impacts of these efforts on the resource, economic performance and interactions with other fisheries. We discuss the advantages of the method used and its potential for identifying benchmarks, mainly related to fleet dynamics, in the absence of information regarding resource dynamics.

1. Introduction

According to the Food and Agriculture Organization (FAO), almost 58% of worldwide marine fish population are fully exploited and 31% are overexploited (FAO, 2016). Mexico follow this trend with 70% of marine resources fully exploited and, 20% overexploited (Arreguín-Sánchez, 2006). This data show the need of fisheries management and the importance to use the available information looking for sustainable fisheries (Salas et al., 2007; Fernández et al., 2011; Ramírez-Rodríguez, 2011).

Fisheries management demands in-depth knowledge of how fishing fleets operate, including efficiency and potential temporal and spatial effects on the resource (Hilborn and Walters, 1992). Thus, identification of management zones must be based on biological, economic and social factors related to resource availability, operating costs, product prices and infrastructure for landing, processing and marketing (Ramírez-Rodríguez, 2011). In general, fisheries regionalization aims to address management requirements or opportunities, for example, the fishing zones defined by the FAO for statistical purposes or those designated as marine protected areas (Sanders et al., 2011).

For the swimming crab (*Callinectes bellicosus*, Stimpson 1859; *C. arcuatus*, Ordway 1863; and *C. toxotes*, Ordway 1863) fishery in the Mexican Pacific, fishing regions are defined by the contributions of each coastal state to the country's total swimming crab catch (Fig. 1). This is a small-scale fishery and, according to the National Fisheries Chart, it is at its peak sustainable level in the Gulf of California states; however, it has potential for further development in other states (SAGARPA, 2012).

In 2013, the Mexican states along the Pacific coast reported a total catch of 17,046 t of swimming crab (SAGARPA, 2013). The state of Baja California Sur (BCS) was the third largest producer, contributing 2.9% to the Pacific's total catch, after Sinaloa (66.6%) and Sonora (27.2%). The other eight Mexican Pacific states contributed a combined 3.3%. Although BCS has coastline on the Gulf of California, warrior swimming crab *C. bellicosus* fishing primarily occurs in or near three coastal lagoon systems on the west coast of the Baja California peninsula: Guerrero Negro-Ojo de Liebre, San Ignacio and Magdalena-Almejas Bay (Fig. 1) (González-Ramírez et al., 1996; Ramírez-Félix et al., 2003; Cisneros-Mata et al., 2014).

Because of the important production in Sinaloa and Sonora, the Mexican government established a swimming crab management plan for those estates without include any management action for BCS. The plan includes monitoring, evaluation, bioeconomic studies and socioeconomic studies (SAGARPA, 2014). Although the plan

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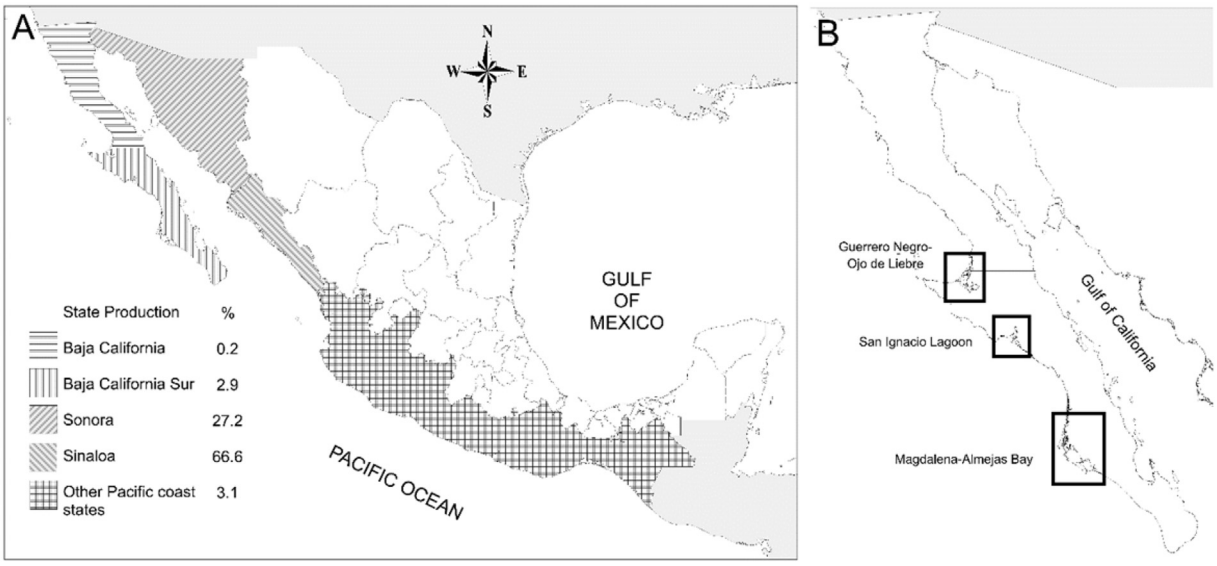

Fig. 1. Relative importance of swimming crab production in coastal states in the Mexican Pacific in 2013 and the main fishing areas in Baja California Sur.

recognizes distinct fishing zones, it does not identify trends or fishing rules for each of them. In BCS, the swimming crab fishery began in 1983 and has exhibited catch variations, with peaks of 568 t in 1990, 896 t in 1997, 889 t in 1998 and 813 t in 2009 (SAGARPA, 2013). The catch decreased to 114 t in 2003 and 271 t in 2011 (Fig. 2). Such annual fluctuations may be related to variations in fishing efforts and resource availability. It has been speculated that El Niño effects influenced the large catches obtained in 1997 and 1998 (Ramírez-Félix et al., 2003).

In the earliest years, swimming crabs were caught using gillnets (González-Ramírez et al., 1996), but in 1996 Chesapeake-like crab traps were introduced and, since 2006 this is the only fishing gear allowed and has to complain with characteristics established in the Official Mexican Norm NOM-039 PESC-2003 (SAGARPA, 2006). Ramírez-Félix et al. (2003) documented 136 vessels licensed to capture swimming crabs in 2001 and estimated over 5000 traps in 1998, 4000 in 2001 and 7000 in 2002. The National Fisheries Chart reported 8000 traps in 2012. There is no data regarding number of traps per fishing zone, but Cisneros-Mata et al. (2014) estimated 45 traps per boat and 102 vessels in Magdalena-Almejas Bay in 2010–2011.

For the swimming crab fishery in BCS, the Official Mexican Norm (SAGARPA, 2006) allows the use of vessels with capacities less than 10 t supplied with up to 80 rigid-structure, Chesapeake-type traps with at least two escape openings for small individuals. The minimum legal size for a catch is a carapace width of 115 mm. Capturing ovigerous females and juveniles is forbidden. Although no fishing zones are recognized, this study analyze catch, economic value and trip ticket frequency data to identify them and contribute to improve the management of the warrior swimming crab in BCS.

2. Methods

The swimming crab production per zone and per fishing season was analyzed using date, place of capture, landing location, catch size in kilograms and beach price data recorded by fishers' in triptickets from 1998 to 2010 at the fisheries offices of the National Commission of Aquaculture and Fisheries (CONAPESCA). The database, which is facilitated by CONAPESCA, was reviewed to standardize all the data to kilograms of swimming crab landed per month per fishing locality.

To identify fishing zones, a hierarchic cluster analysis was applied based on Euclidian distances and complete linkage (R Core Team, 2015) using the distance in kilometers between fishing localities and ports. The latter were defined according to population and infrastructure data from INEGI (2010). Geographic data were based on Ramírez-Rodríguez et al. (2005) and complemented with information from González-Ramírez et al. (1996), Erisman et al.

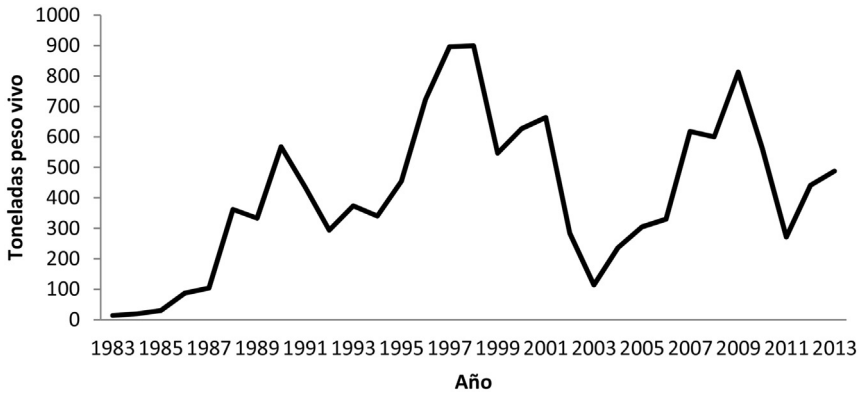

Fig. 2. Total annual catch of swimming crab in Baja California Sur, Mexico (1983–2013).