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Review

Temperature effects on life-history traits cause challenges to the management of brachyuran crab fisheries in the Humboldt Current: A review

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ABSTRACT

Owing to the influence of the Humboldt Current many cold-water adapted brachyuran crabs of commercial interest have vast (>40° latitude) distributional ranges along the Pacific Coasts of Peru and Chile. Development of artisanal diving and trapping fisheries on these crabs (mainly Cancridae and Xanthidae) is either uncontrolled (Peru) or existing management measures, like the minimum landing size of 12 cm carapace width, and the prohibition to catch ovigerous females, are poorly enforced (Chile). Under El Niño conditions, occurring on average every 4 years, the upper temperature limit of these temperate species can be exceeded in Peru, leading to mass mortalities of adult crabs and a breakdown of the artisanal crab fishery. Temperature changes (latitudinal or in the course of El Niño Southern Oscillation) may have pervasive effects on reproduction and early life history stages as represented for *Romaleon setosus,* which ultimately determine the recruitment of crabs to the fishery. The recent development of the fishery, namely the decline of the landings of *Romaleon setosus* and *Homalaspis plana* in Central- to Northern Chile, compensated by the rapidly developing fishery on *Metacarcinus edwardsii* in Southern Chile is presented and discussed in the light of temperature effects on the crabs' (reproductive) biology. We conclude that an enforcement of the legal minimum size is needed to allow for a sustainable fishery of both species throughout their distribution range.

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1. Introduction

Artisanal "shellfish-fisheries" in the near coastal zone of Chile and Peru are inferior in landings compared to the large-scale industrial fisheries operating in the pelagic upwelling waters of the Humboldt Current (e.g. anchovies, jumbo squid and squat lobster). Nevertheless, among the more than 60 species of benthic invertebrates caught (e.g. bivalves, gastropods, sea urchins, tunicates, giant barnacles and crabs) many are of high economic value on the domestic- and export markets (Bustamente and Castilla, 1987; Thatje et al., 2008). Shellfish are gathered by hand at low tide or caught from small boats with traps and by "hooka-diving", which is the most widely employed artisanal fishing technique

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in Chile and Peru. These fisheries are quite selective and do relatively little direct harm to the ecosystem. However, the sheer number of artisanal fishermen, ~70 000 in Chile (SERNAPESCA 2008) and ~38 000 in Peru (IMARPE, 2008) combined with the *de facto* open access to the fishery have caused some of the most valuable resources, like the muricid gastropod *Concholepas concholepas* to collapse (e.g. resulting in a closure of the Chilean fishery from 1989 to 1992) (Castilla and Fernández, 1998). Learning from the collapse of *C. concholepas,* a law for the design of "management and exploitation areas for benthic resources" (MEABR) has been fully enacted in Chile in 1995 (Castilla, 1996; Bernal et al., 1999). "Territorial user rights in fisheries" (TURFs) are granted to local fisheries cooperatives, which are responsible for the monitoring and co-management of benthic invertebrates in MEABR (Castilla, 1996), but with very limited ability to prevent poaching (Castilla and Gelcich, 2006). The number of fishermen and the size of MEABRs vary, but in few cases can reach up to 150 individuals in larger syndicates and 150 ha per area (Thatje et al., 2008). MEABRs (506 in 2007) were primarily created in the areas of the highest productivity of *C. concholepas*, but nowadays also key-hole limpets (*Fissurella* sp.) and sea urchins (*Loxechinus albus*) are managed on the basis of annual stock assessments (Stotz, 2007). While this approach seems promising for these semi-sedentary invertebrates, the benefits for brachyuran crab resources in smaller MEABRs is hampered by their mobility (Fernández and Castilla, 1997, 2000; Castilla and Fernández, 1998). Therefore, the crabs *Romaleon setosus* (formerly *Cancer setosus* Molina, 1782) and *Homalaspis plana,* considered valuable "secondary resources", are presently only caught outside the MEABR due to the lack of management plans for these species (Stotz, 2007).

Brachyuran crab landings have greatly increased in the last two decades in Chile and Peru. The Chilean landings of 6500 t in 2008 were mainly based on *Metacarcinus edwardsii* (formerly *Cancer edwardsii* Miers, 1881), *R. setosus* (Cancridae) and *Homalaspis plana* (Xanthidae) (SERNAPESCA, 2008), while in Peru landings of ~1600 t in 2007 were based on *R. setosus, C. porteri* and *Platyxanthus orbignyi* (Xanthidae) (IMARPE, 2008). Despite the long fishing tradition, the scientific knowledge as a basis for management guidelines, has not kept pace with their rates of exploitation (Fernández and Castilla, 2005). In Peru, there are no management guidelines for brachyuran fisheries at all, while in Chile a uniform minimum carapace width of 12 cm and the prohibition to land ovigerous females represent the only legal management measures. So far, basic life-history parameters for the majority of exploited brachyuran crabs in the Humboldt Current are poorly known (e.g. reproductive periods and size of maturity).

This paper aims to give an overview of brachyuran crab ecology and highlight the challenges for fisheries management in Chile and Peru. We advocate that the adaptive management of shellfish species with wide latitudinal distribution needs to consider the local responses of stocks to macroecological driving factors in order to be effective.

2. Distribution of cold water adapted crabs in the Humboldt Current

Cancrid crabs and many other species of evolutionary cold-faunal origin owe their wide distributional ranges along Pacific South America to the influence of the cold Humboldt Current (MacKay, 1943; Nations, 1975; Nations, 1979). The brachyuran crab species studied follow the Humboldt Current in distribution range (Fig. 1) and have vast (>40°latitude) distributional ranges along the Pacific Coast of Peru and Chile. The reported northern distributional limits of *R. setosus*, *M. edwardsii*, *H. plana*, and *P. orbignyi* (~2°S) coincide with the limit of the Humboldt Current (Fig. 1) (Rathbun, 1930;

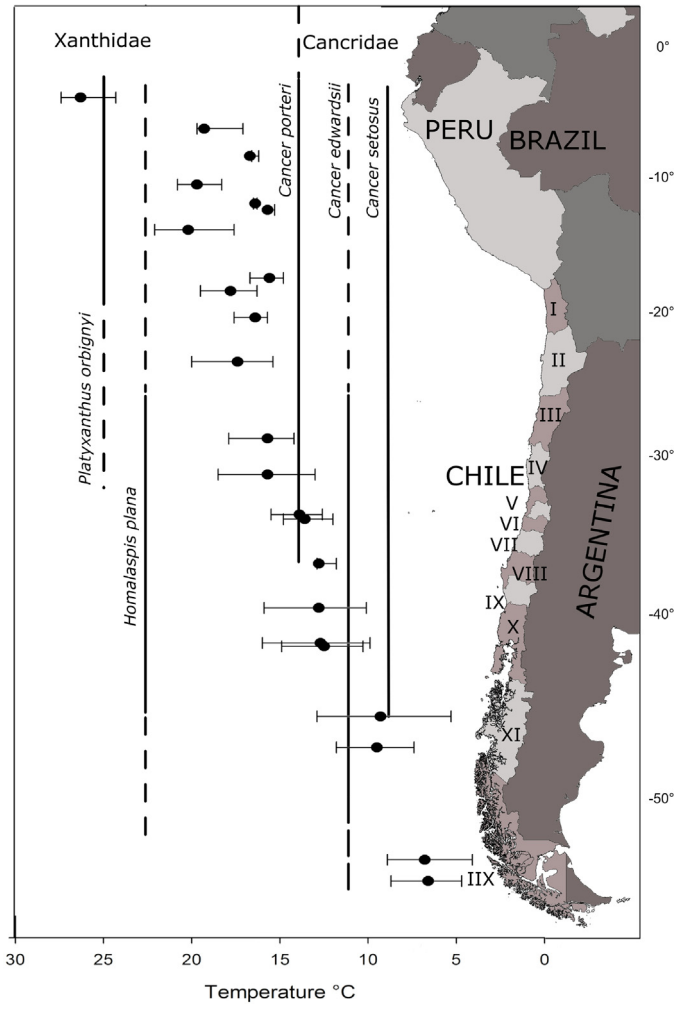

Fig. 1. Distributional ranges of *Metacarcinus edwardsii*, *Romaleon setosus, C. porteri* (Cancridae) and of the Xanthidae *Homalaspis plana*, and *Platyxanthus orbinyi* along the coast of Peru and Chile (continuous lines: range of regular fisheries captures; hatched lines: reported maxium range) (Rathbun, 1930). The long-term mean SST (1996–2006) is shown for various coastal locations. The seasonal temperature oscillation is indicated by the "error bars": the left hand side being the mean SST in January (austral-summer) and the right hand side the mean SST in July (austral-winter) (IMARPE, 2008)(CENDHOC, 2008). The administrative regions of Chile are indicated (I–XII) as in 2007.

Garth, 1957; Retamal, 1981) and support MacKay (1943) suggesting that *cancrid* crabs are principally restricted to waters colder than 24 °C. What may seem like an exception is the more tropical distribution of *C. porteri*, which appeared to avoid the higher temperatures through a deeper distribution below the thermocline (Garth, 1957). More recently, it was revealed that the morphological differences of the deep-water form of Central America actually represent a distinct species, *C. johngarthi* (Carvacho, 1989; Carvacho and Bonfil, 1989).

Under El Niño conditions, occurring on average every 4 years, temperatures may surpass the limits of the cold-temperate adapted fauna and flora. In the 1982/83, El Niño sea surfaces temperatures rose above 30 °C (+10 °C compared to the long-term mean) in Northern Peru, causing mass-mortalities of the commercially important crabs *R. setosus* and *P. orbignyi* and a migration to deeper waters of *C. porteri* (Arntz et al., 1988). These effects of El Niño were reflected by collapsing brachyuran crab catches along the Peruvian coast (Fig. 2). The "tropicalization" of the Humboldt Current under the 1982/83 El Niño allowed for a southward range extension by 13° latitude of penaeid shrimps (e.g. *Xiphopenaeus riveti*; *Penaeus*