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A socio-ecological approach to the declining Catalan clam fisheries

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A B S T R A C T

The world demand for marine bivalves continuously increased from 1980 to 2014. Their fisheries landings in the Mediterranean Sea also increased, until they began to drop in the last decade. This trend was particularly intense in the western Mediterranean Sea, where landings dropped from 4046 t (1996) to 425 t (2012). Since then, they have never recovered. We examined the status of the main commercial clam species in Catalonia (NW Mediterranean) one of the main productive areas of the western Mediterranean Sea, and analyzed the social and ecological context of the different small scale clam fisheries as an example of the Mediterranean as a whole to detect the possible causes of this negative trend. Our results reveal the critical status of all clam fisheries along the entire coast, where most clam stocks are currently collapsed or close to collapse. This trend mirrors the evolution of bivalve fisheries in the western Mediterranean. Many management failures and factors inhibiting the sustainability of clam fisheries over time were detected (*i.e.* the nearly absence of resource monitoring or control of rules enforcement; lack of conflict resolution mechanisms among fishermen and other coastal users; the incongruence between appropriation and provision regulations, and deficient nested enterprises), suggesting that inadequate and incongruent management is largely to blame for the precarious present situation. However, our results also suggest that undetermined additional factors (*e.g.* pathologies, pollution, climate change etc.) have also affected what were already highly stressed populations.

1. Introduction

Bivalve species are found at very high densities in many coastal marine systems. These large aggregations provide a wide range of keystone functions and services in the ecosystem (Norkko and Shumway, 2011) *i.e.* their presence, activity and abundance are crucial for the integrity, stability, organization and diversity of the entire ecosystem (Paine, 1969). Species inhabiting coastal areas (intertidal and subtidal) have been historically subjected to major fishing pressure, as they are easily accessible, relatively simple to harvest and a nutritious source of protein (Defeo, 2003; Gray, 2016).

The world demand for marine bivalves continuously increased last decades. Their production (fisheries and aquaculture) increased from 1980 (3.5 million tons), reaching 16.6 million of tons landed in 2014 (FAO, 2017). In the Mediterranean Sea their fisheries landings followed a similar trend, until they began to drop, with some fluctuations, during the last decade (Fig. 1A). This trend was particularly intense on the western Mediterranean Sea, where landings dropped from 4046 t (1996) to 425 t (2012) (Fig. 1B). Since then, they never recovered.

Clams are among the most valued and commercially exploited bivalve species in the Mediterranean Sea; the wedge clam (*Donax trunculus*), striped venus clam (*Chamelea gallina*) and smooth clam (*Callista chione*) being three of the most highly valued species. These clams are shallow-burrowing suspension-feeding organisms that inhabit clean sandy shallow grounds in coastal waters with a similar geographical distribution. Wedge clams inhabit highly energetic environments on sandy beaches (Brown and McLachlan, 2006) and are essentially distributed in well-sorted fine sand biocenosis between 0 and 3 m (Pérès and Picard, 1964). Striped venus clams inhabit a wider variety of sediment types (sand, sandy-mud and mud), being preferentially distributed on the well-sorted fine coastal sand biocenosis between 3 and 12 m in depth; whereas smooth clams occur in coarse sands between 5 and 20 m (Pérès and Picard, 1964; Baeta et al., 2014). However, these three species have very different growth rates, wedge clams reaching the minimum legal size before the first year of life (Ramón et al., 1995), striped venus clam before the second year (Ramón and Richardson, 1992), and smooth clam around 5 years in the Mediterranean coast of Spain (Baeta et al., 2014).

Most of the clam fisheries in the Mediterranean coast of Spain are small scale fisheries (SSF) (Baeta, 2006; Baeta et al., 2014). These type of fisheries have been poorly managed, monitored, and regulated in Europe despite their high social and ecological importance (Guyader, 2007). This is a direct consequence of the relatively low economic impact and volume of catches (Guyader et al., 2013). Small-scale clam

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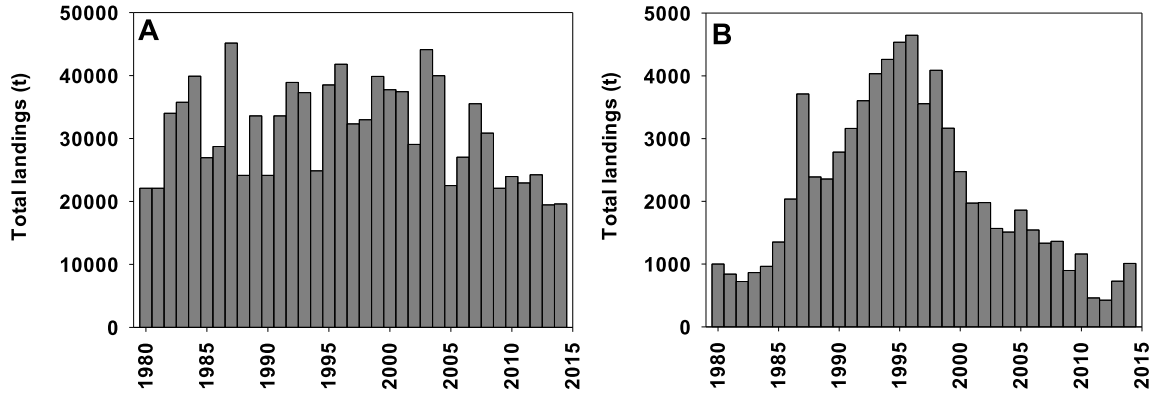

Fig. 1. (A) Total marine bivalve landings (excluding oysters and mussels) on the Mediterranean between 1980 and 2014; (B) Total marine bivalve landings (excluding oysters and mussels) on the western Mediterranean (Division 37.1.1 and 37.1.2) between 1980 and 2014 (FAO-GFCM, 2016).

fisheries have been described as a good example of "*common pool resources*" (CPR) (Steins and Edwards, 1999; Basurto, 2008; Beitl, 2011). CPR refers to systems where a natural resource is subtractable in order to generate a flow of goods and services for shared users, but at the same time is difficult to manage sustainably due to the difficulty of excluding undesired users (Dietz et al., 2002). In this system, the high level of uncertainty of future resource availability tempts users to maximize present benefits before others do likewise, thus reducing the incentives to invest in the sustainability of the resource and leading unequivocally to its inexorable degradation (tragedy of the commons) (Hardin, 1968; Basurto, 2005). Some of the well-known solutions proposed for this 'tragedy' have been applied to certain types of SSF (Cox et al., 2010), but not widely to clams. The most widespread is probably individual transferable quotas (ITQs) (*e.g.* Iceland, New Zealand and the USA), *i.e.* rights to harvest a certain volume of resource (Arnason, 2012). As an alternative to this approach, different levels of co-management have been implemented worldwide as useful tools for clam fishery management with encouraging results. Co-management consists of the sharing of government and local user responsibilities, rights, and duties (Pinkerton, 1989). Defeo et al. (2014) observed after the implementation of a co-management system for the yellow clam *Mesodesma mactroides* SSF at Barra del Chuy, Uruguay, significant improvement in the fishery. Landings were observed to stabilize at similar levels to early phases of exploitation, as well as the enhancement of bioeconomic indicators (i.e. Catch per Unit of Effort (CPUE), individual mean size, abundance, etc.). Similar results have been observed with the geoduck and horse-clam fishery in British Columbia, Canada (James, 2008). Notwithstanding, this approach might also fail, particularly in cases where there is a lack of community organization or governmental support (Castilla and Defeo, 2001). Ostrom (1990) defined the eight design principles that are suitable conditions to facilitate successful management of CPR. These principles are: (1) clearly defined user and resource boundaries; (2) congruence between appropriation and provision rules and local conditions; (3) collective-choice arrangements; (4) monitoring users and resources; (5) graduated sanctions; (6) conflict resolution mechanisms; (7) minimal recognition of rights to organize and (8) nested enterprises. Since then, these principles have been broadly tested, and most literature has proven them to be robust for SSFs worldwide (Cox et al., 2010). Despite the major importance of SSF for the Mediterranean Sea, most of the research done so far has typically focused on the ecological analysis of target species of the fishery, the management analysis being restricted to only one of these principles (*e.g.* "*congruence between appropriation and provision rules*" or "*the study of local conditions*"). Other studies have focused on a socio-economic approach to SSF (Tzanatos et al., 2006; Maynou et al., 2013), but none have evaluated the entire socio-ecological framework around an SSF. Moreover, there have been few empirical studies that have demonstrated the social and institutional conditions conducive to successful co-management outcomes (Cinner et al., 2012).

The objective of this paper is to analyze the social and ecological context of the different small scale clam fisheries on the Catalan coast of Spain (one of the main productive areas) as an example of the western Mediterranean in order to detect the possible causes of the drop in bivalve landings detected since 1996 in the region.

2. Socio-ecological framework

The study was carried out in Catalonia (Regional Autonomous Administration of northeast Spain) located in the northwestern Mediterranean (Fig. 2). The Catalan coast stretches for over 600 km from the French border (northeast) to the Ebro Delta (southwest). In Catalonia, The General Fisheries Directorate (GFD) of the "*Departament d'Agricultura, Ramaderia, Pesca i Alimentació*" (Catalan Government) is in charge of managing clam fisheries. It has legal authority over "territorial" waters (limited by straight lines connecting the tips of the capes) and jurisdiction over activities related to the capture of marine clams. There are four delimited clam fishing areas, which are located in shallow waters (< 30 m), and are geographically isolated. Clam fishing is forbidden outside of these areas, which are: (1) Rosas Bay: the smallest geographical area with a length of 15 km and with only one fishing port with clam fisheries, Rosas (Fig. 2); (2) North Barcelona: has 51 km of coastline, may be distinguished from the other areas by the coarse granulometry of the sand and the area includes three fishing ports with clam fisheries, namely Blanes, Arenys de Mar and Mataró; (3) South Barcelona has 70 km of coast, mainly fine sand beaches and includes three fishing ports in Barcelona, Sitges and Vilanova; and (4) the Ebro Delta: with an extension of 52 km of fine sandy beaches forming a delta, it has four ports with clam fishing activity (Alcanar, La Ràpita, Deltebre and l'Ampolla). Three of the fishing areas are currently open to commercial exploitation (Rosas Bay; South Barcelona and Delta Ebro), but one has been closed since December 2015 (North Barcelona) due to low landings.

Since the Catalan Government assumed the authority to manage clam fisheries from the Central Government of Spain in 1984, together with fishermen it developed certain clam species management plans (Table 1), which mainly described the appropriation rules and regulated standards for the fisheries of a clam species in a specific fishing area with only one fishing gear (*e.g.* clam dredges). They followed a bottom-up management system, developed by associations of clam fishermen and then the GFD created the legal framework. However, most clam fisheries in Catalonia showed a total absence of management. These management plans remained unaltered until 2014–2015, when two new plans replaced the previous ones: (1) a management plan for hand-operated dredges (a fishing gear), exclusively for the Ebro Delta area; and (2) another management plan for clam dredges (a fishing gear), including general rules for the four fishing areas and some