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Socioeconomic and biological causes of management failures in European artisanal fisheries: the case of Galicia (NW Spain)

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Abstract

Coastal ecosystems and artisanal fisheries show a great complexity due to the high number of human factors that influence their functioning and to the number of components involved in the fishing activity. Moreover, a great number of stocks exploited by coastal artisanal fisheries are invertebrates with a strong and persistent spatial structure and a population dynamics that do not fit the finfish models. The present state of the artisanal coastal fisheries in Galicia (NW Spain) is analyzed, presenting different symptoms of a general state of overexploitation derived from the mismatch between management (derived from models designed for industrial finfisheries) and the biological and socioeconomic context. We propose to modify the strategies of research to use inexpensive and rapid methodologies and introduce the fishers' ecological knowledge. A new management policy is outlined based in the establishment of territorial users' rights, the involvement of fishers in the assessment and management process, and the use of protected areas and minimum sizes as key regulation tools.

Keywords: Artisanal fisheries; Assessment; Management; Socioeconomics; Population dynamics; Coastal ecosystems; Invertebrate

1. Overexploitation as a global fishery problem: the role of fisheries sciences

World fisheries are in crisis [1] due to the overexploitation of a large proportion of the stocks. Thus, Alverson et al. [2] report that over 90% of the world's fish stocks have been overexploited, while, according to the FAO [3] 69% of the world's marine stocks are either fully to heavily exploited, overexploited or depleted and therefore are in need of urgent conservation and management measures.

The causes of the collapse of exploited marine populations have been the subject of wide debate, confronting hypothesis that center the problem in an excessive fishing effort which brings about overexploitation, against those that argue that fluctuations in population dynamics are attributable to natural environmental changes. Perhaps the most paradigmatic case of depletion was what occurred in the 1990s with the cod fishery in Newfoundland. Myers et al. [4,5] compared different hypotheses on the reason for this collapse and concluded that the high fishing mortality, due to overfishing was what caused the decline of these stocks. This process has been affected by faulty assessments and by difficulties in enforcing the compliance with the established regulations, particularly regarding discards. The above hypothesis is backed by scientific evidence much stronger than others related to environmental changes, without the intervention of man, that would cause a decrease in recruitment [4]. Similarly, it has been proposed that fishing has been the main cause of the depletion of different species of small pelagic fishes, due to the increase in catchability with the decline in the stock as a result of the shoaling habits of these organisms [6]. Several invertebrate species, largely coastal benthic organisms with a high unit value and subject to exploitation by the artisanal fleets, have been overexploited, and in some instances, depleted [7,8], although these cases are generally much less documented. The overexplotation of marine species has led to extinction or near extinction in some extreme cases, which has not been considered as a possible consequence until very recently [9].

It would appear to be evident that the collapse of many stocks constitutes the final stage of overexploiting generated by an excessive fishing effort. This process may be attributed either to a lack of appropriate scientific in-

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formation or, on occasion, and in spite of suitable assessments, to faulty management systems or failure to enforce the compliance of the fishers. In fact, Roughgarden and Simth [10] propose that theoretically the collapse of several fisheries (such as cod and other demersal species) is due to the failure of the management system, which is often directed at obtaining the maximum sustainable yield and not towards the ecological stability of the system.

Fisheries management has been dominated, up until recently, by a school of thought based on the assumption that in-depth scientific research on the biological foundations of the exploited systems would allow for adequate management. Another line of thought, developed more recently, upholds the fact that the spatial and temporal scales of variability of many systems would make research be of limited value in management, while the design of management and monitoring systems would be highly beneficial [11]. So the ultimate goal of management systems is not to obtain precise estimates of the population parameters by means of stock assessments carried out by scientists, but rather to design monitoring and management systems that will yield long-term catches without endangering the stock [12]. Moreover, another failure in traditional management systems has been the lack of attention paid to the dynamics or behaviour of the fishers as an integral part of the system [11]. Fisheries management science appears to have evolved from the early stages during which understanding the biological foundations of the system was considered the key factor in good management, to a state in which the intrinsic complexity of the exploited stocks and ecosystems, along with the technical and socio-economic factors involved, create the need for reorienting research and management strategies.

In this paper, we analyze the present state of the artisanal coastal fisheries in the context of a European industrial society (Galicia, NW Spain), paying special attention to the state of the art of the scientific knowledge available, the socioeconomical context, and to the management policies in use. The main problems of the present management and research policy will be identified, illustrating the existing mismatch between policy and the biological and socioeconomical context. Different alternatives will be proposed to modify the strategies of management and research to achieve a sustainable exploitation of these resources.

2. A definition of artisanal fishery

Even though the offshore industrial fisheries are the most productive on a world-wide level, the small-scale coastal fisheries have a much greater social significance [1,3,13]. Of the latter type of fisheries, the concept of artisanal fishing is rather ambiguous and variable in terms of the unit of analysis used. We will employ different types of definitions to establish the limits of the scope of our study on Galicia:

(1) From a political and administrative standpoint, the Autonomous Government of Galicia ("Xunta de Galicia") classifies the fishers in (a) bivalve shellfishers ("marisqueo") (intertidal or from boat), (b) inshore ("bajura") boat-based fishers (both bivalve shellfishers and inshore fishers exploit the exclusive economic zone [EEZ]), and (c) offshore fishers (in EEZ and distant waters]. This classification is ambiguous and has been developed mainly as a consequence of the different powers that the central and autonomous governments have on the management of the fisheries. The inshore fishery (vessels less than 150 GRT; "bajura" and "marisqueo") carries out its activity in the waters of the continental shelf and the rías (from the intertidal zone to the start of the slope) (Fig. 1, Table 1). This sector comprises a fleet that fishes on the continental shelf (demersal and pelagic fisheries), and a fleet that operates in the coastal embayments (rías) and shallow oceanic areas. In the latter case, the fishery carried out from a vessel (usually under 12 m in length) can be differentiated from intertidal shellfishers harvesting goose barnacle and some bivalves.

(2) The artisanal and industrial fisheries represent different economic and social strategies, giving rise to important differences, in the technology used and in the ecosystems and stocks exploited. In Galicia, the artisanal fisheries have in most cases a familar structure and a system of profit sharing ("sistema a la parte"). However, the industrial fisheries have a managerial structure in which fishers' profits are constituted by a combination of salaries and a small percentage of the catch value. Artisanal fishers are organized in associations ("Cofradías"), whereas more capitalized fleets constitute organizations with clear corporate interests.

(3) From a technological point of view, the artisanal sector uses low or medium level technological equipment, insofar as the operating chain is simple, consisting of gears handled by one or two people (a minimum of manpower is what makes this technique efficient).

(4) Fishing strategies in artisanal fisheries are based in the flexibility, with a diverse pattern of activity (with respect to the species exploited, location of fishing grounds, and gears used) throughout the yearly fishing cycle. Industrial fisheries present a strategy of intense and continuous exploitation of the same resources in similar habitats using one or a few gears.

(5) From a biological standpoint, the Galician artisanal sector harvests ecosystems located in coastal waters that range from the intertidal zone to waters of 60–80 m depth near the coastline.

If we combine the different definitions, it is possible to describe an artisanal sector in the strict sense of the term — within the existing inshore fishery in Galicia — which would cover the fisheries in oceanic coastal

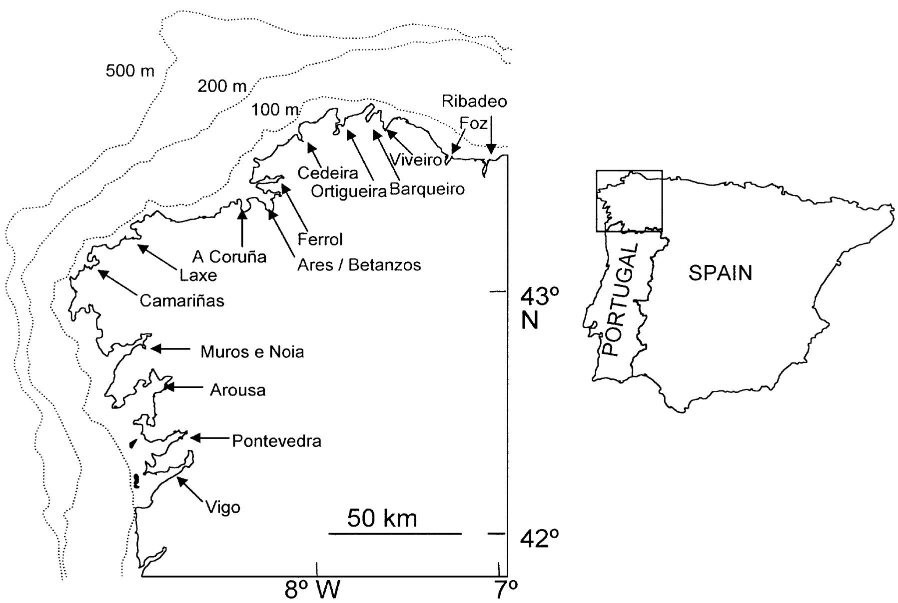

Fig. 1. Iberian Peninsule and Galicia. The isobaths delimit approximately the different fishing grounds (coastal embayments [rías] and oceanic coastal waters, from the shoreline to approx. 60–80 m depth; continental shelf and upper slope, up to 500 m).

Table 1
Characteristics of the fishery fleets (defined by the gears or harvest methods used) operating in inshore waters (continental shelf and rías) of Galicia (NW Spain) corresponding to the political and administrative category of inshore fisheries ("bajura" and "marisqueo") (boats of < 150 GRT). Only the main gears used are included

Gears	Fishing zones	Distance to the coastline	Depth
Fishing lines	Shelf/slope transition	15–40 miles	100–400 m
(pelagic and demersal)	Continental shelf	7–12 miles	
Purse seines	Coastal areas	Shoreline to 12 miles	20–200 m
	Continental shelf		
Trawls (semipelagic and demersal)	Continental shelf	4–12 miles	150–300 m
Gill-nets	Shelf/slope transition	Shoreline to 15 miles	1–400 m
	Continental shelf		
	Coastal areas		
Traps	Coastal areas	Shoreline to 8 miles	1–60 m
Intertidal harvesters/divers	Coastal areas		0–20 m

waters and rías. Although we do, occasionally, include the entire inshore sector in our analyses, we will focus on the artisanal sector in the strict sense, excluding the intertidal harvesting of bivalves, since in many aspects, this type of fishery is more related to an extensive culture than to an actual fishery (because seedling from commercial hatcheries and habitat interventions [cleaning and removing sediments] are habitual practices).

3. Socioeconomics and biology of the Galician artisanal fisheries

3.1. *Social, economical and technical aspects*

Galicia is a region with an autonomous government located in NW Spain (Northeast Atlantic) and with a population of approximately three million inhabitants. It boasts an extensive, irregular coastline (1295 km) with a series of coastal embayments ("rías"), which in many instances take the form of wide, gentle incoming bodies of water, such as the Rías Baixas (in the south) and at other times are smaller in extension and have a more rugged appearance, such as the Rías Altas (in the north) (Fig. 1).

The Galician coast supports a large number of human settlements directly related to the sea due to its great length, its unique morphology, the biological richness of its waters and its strategic situation. At the present time, there are over 80 communities whose economies depend largely on harvesting fish and shellfish resources. They range from large cities (Vigo, A Coruña, etc.), to towns (Riveira, A Guarda, Malpica, Burela, etc.) or small villages that oftentimes have under 200 inhabitants (Barizo, Arou, Oia, etc.).

According to the official census of the Galician fishing fleet in 1994 [14], there were 8811 vessels with 28014 fishers. However, these data only reflect legally registered fishers. In practice, the number of people who carry out fishing activities is substantially higher, since we must also consider, those individuals who are not full-time fishers, but who, during certain times of the annual fishing cycle, do carry out specific fisheries as a supplement to their incomes (e.g. retired persons, taxi drivers, shopkeepers, unemployed, etc.). Although they are difficult to quantify, they must be considered in the artisanal sector as harvesting agents who also have an effect on coastal ecosystems. A large, and not quantified, number of illegal fishers (including a large proportion of divers) operate in these fisheries, especially in shallow waters. Both fishers and scientifical assessments [15] provide evidence of the impact of illegal fishing in the overexploitation of resources.

In Galicia the so-called inshore fishery accounted for almost 2/3 of the human contingent that made up the fishing crews in 1989 [16]. The overall figures taken from the 1994 census [14] present a similar situation: 70% of the fishers work in the inshore sector in vessels less than 9 m in length (72%). Moreover, 49% of this fleet (4329 vessels) pertained to productive units consisting of only one fisher. From an economical point of view and taking only official data into account (data provided by the Xunta de Galicia), the fresh weight of fish landed in 1998 amounted to 171,000 mt with a first sale value of over 57,000 million pesetas (346 million euros). These figures do not include landings channelled through other commercial routes. This is, then, a very heterogeneous fleet using different gears (mainly longlines, purse seines, trawls, gillnets and traps) operating in different areas of the continental shelf and Galician rías (Table 1), and harvesting a total range of over 100 different species.

Within the inshore fishery, the artisanal sector is the most numerous. This usually consists of productive units made up of very few fishers who are usually related to each other. In fact, the generic makeup of these types of vessels tends to constitute ideal models such as father–son(s); father-in-law–son(s)-in-law; cousins, brothers-in-law; etc, completing the crew with people who are not related, when the various family households are unable to supply new members [17].

The following characteristics provide some of the most important arguments in favor of the social importance of the artisanal sector in Galicia, particularly when other, more attractive economic alternatives are not available:

(1) Demography (over 70% of the inshore fishers are artisanal),

(2) social (they usually consist of mostly small owners whose main economic goal is to reach a level of capitalization that will facilitate the social reproduction of the household), and

(3) socio-economic, providing employment and energizing a complex economic sector (fishing–handling–marketing–transport–processing, etc.) There are in fact populations that are almost totally dependent on fishing activity (Malpica, Muxía, Burela, etc.), and significant changes in these fisheries would have a considerable effect on other sectors of production. Moreover, fishing activity is also a source of supplementary income for other groups (unemployees, small shopkeepers, retired persons, etc.)

The artisanal fisheries are characterized by the use of fishing strategies involving diversification (Table 2). The annual fishing cycle can be described basically by the use of different gears and methods depending on the seasonality of the resources and the regulations and legislation of the different administrations (Ministerio de Agricultura, Peca y Alimentación [Ministry of Agriculture, Fishery and Food] of the Spanish Government, and the Xunta de Galicia). However, depending on the ecological characteristics of the areas where vessels from each seafaring village operate, there is usually a primary fishery which is more profitable targeting one or two species (octopus, velvet swimming crab, spider crab, bib, conger eel, queen scallop, etc.) and other fisheries which supplement the primary one (wrasses, sea bream, sea bass, etc.).

3.2. Biological knowledge of exploited stocks

The analysis of the biological information available on the exploited species as well as the assessment methods that have been applied up to the present will clarify the scientific data (or the lack of) in which the management policy is based. We do not intend to carry out a through review of the biological research done on coastal fishing

Table 2
Main artisanal fisheries operating in coastal waters of Galicia. The target species corresponding to each gear are indicated. See Table 3 for scientific names

Gears	Target species
Traps	Octopus Velvet swimming crab Bib (Spider crab)
Tangle- and gill-nets	Spider crab (Cuttlefish) (Fishes)
Fishing lines	Conger Bib
Glass-box/Hook	Octopus Spider crab
Intertidal shellfishers/divers	Bivalves Goose barnacle

resources in Galicia, but rather, we will try to make a diagnosis, in synthesis, of the state of our current knowledge of the exploited resources.

From a biological viewpoint, the artisanal fisheries operating off the Galician coast are multispecific and multi-gear, exploiting a diverse array of species, mainly sedentary benthic or mobile benthic/demersal invertebrates (see classification proposed by Orensanz and Jamieson [13] for fishery resources) with life-cycle phases that occur in shallow waters close to the coastline (Table 3). It is possible to list around 50 species that are harvested for commercial purpose [16]. These include a diverse group, both in terms of taxonomy as well as life styles. Among the most important species from an

Table 3
Main invertebrate species exploited by the artisanal fisheries operating in coastal waters of Galicia (intertidal to 60–80 m). Average yearly total official landings (mt) and value (in millions of pesetas) are presented for 1997 and 1998 (data provided by the Consellería de Pesca, Marisqueo e Acuicultura, Xunta de Galicia). Several species with low official catches are omitted. The official data do not distinguish catches obtained from different fleets; in the case of invertebrates most of the landings for the major part of species correspond to the artisanal fleet. In the case of the fishes (not shown), many species are exploited in Galicia but artisanal catches constitute only a small part of total catch and only some ones are target of the artisanal fisheries (as the bib *Trisopterus luscus* and conger *Conger conger*). Each species is classified according to their spatial structure and mobility (resource types proposed by Orensanz and Jamieson [13]). The main fleets targeting each species are indicated. Species for which semiculture practices (seedling) are carried out are indicated

Common name							
Galician	English	Scientific name	Landings	Value	Resource type[a]	Fleet	Seedling
CRUSTACEANS							
Nécora	Velvet swimming crab	*Necora puber*	93	147	M	B	
Centola	Spider crab	*Maja squinado*	122	192	M*	B	
Boi	Edible crab	*Cancer pagurus*	21	12	M*	B	
Camarón	Prawn	*Palaemon serratus, P. elegans*	63	255	M	B	
Percebe	Goose barnacle	*Pollicipes cornucopia*	342	995	SB	H	
CEPHALOPODS							
Pulpo	Octopus	*Octopus vulgaris*	3728	2371	M	B	
Choco	Cuttlefish	*Sepia officinalis, Sepia elegans*	702	347	HM	B	
Calamar	Squid	*Loligo vulgaris, Loligo forbesi*	1085	642	HM	B	
BIVALVES							
Ameixa babosa	Clam, pulled carpet shell	*Venerupis pullastra*	2334	2435	SB	H, B	Yes
Ameixa fina	Clam, grooved carpet shell	*Venerupis decussatus*	854	1653	SB	H, B	Yes
Ameixa rubia	Clam, banned carpet shell	*Venerupis rhomboides*	316	276	SB	H, B	Yes
Ameixa xaponesa	Short necked clam	*Venerupis japonica, Venerupis semidecussatus*	1369	567	SB	H, B	Yes
Berberecho	Common cockle	*Cerastoderma edule*	2705	893	SB	H, B	Yes
Navalla	Razor clam	*Ensis directus, Solen marginatus, S.vagina*	106	159	SB	H, D	
Longueirón	Sword razor shell	*Ensis siliqua*	59	38	SB	H, D	
Vieira	Scallop	*Pecten maximus*	56	61	SB	B	
Volandeira	Queen scallop	*Aequipecten opercularis*	36	21	SB	B	
Carneiro	Wart venus shell	*Venus verrucosa*	100	70	SB	B	
Relo		*Dosinia exoleta*	1295	138	SB	B	
Cadelucha	Wedge shell	*Donax trunculus, D. variabilis*	38	73	SB	B	
ECHINODERMS							
Ourizo	Sea urchin	*Paracentrotus lividus*	555	53	SB	D	

[a] Resource type:
•SB: sedentary benthic,
•M: mobile benthic/demersal (M*, seasonal or ontogenetic migrations with high mobility),
•HM: highly mobile demersal or pelagic.
Fleet:
•B: boat-based (using traps, gillnets, fishing lines, etc.),
•D: divers,
•Intertidal harvesters.

economic point of view are the crustaceans (the velvet swimming crab, spider crab, prawns and goose barnacle); bivalve molluscs (several species of clams, razor clams, scallops and cockles); cephalopods (octopus, cuttlefish and squid); and fish (a number of species are exploited but catches are generally low; there are no specific fisheries except in cases such as the bib or conger). Harvesting of new groups has begun recently, i.e. the gastropods (abalones) and echinoderms (sea urchins). In some cases, in species presenting migratory processes between coastal and offshore waters (such as the squid, bib, etc.), the artisanal fishery only exploits one stage of the life cycle, while the demersal and pelagic fisheries that carry out their activity on the continental shelf, exploit other stages.

As noted above, of all the species harvested only a few (consisting, on a global level in Galicia, basically of octopus, spider crab, velvet swimming crab and goose barnacle) support fisheries that target one species (excluding bivalve semi-culture in intertidal areas) (Tables 2 and 3). For the remaining species, the strategy of the fishers is directed at catching diverse species using a specific gear, given that the abundance and commercial value of the other species do not allow for the development of unispecific fisheries. The current situation is partially the result of the state of overexploitation or depletion of many of the harvested stocks, as will be discussed later.

In Galicia there is a basic knowledge of the biology and life history of some of the species of interest, e.g. in fishes (bib), crustaceans (goose barnacle, velvet swimming crab, spider crab), cephalopods (squid) or bivalves (clams and cockles) (detailed bibliographical references have been omitted, but are available from the authors). These papers provide basic biological information important for adapting the present management measures based in size limits and/or sex (and other life-history phases) restrictions (e.g., minimum landing size depending on size at sexual maturity; closed seasons depending on reproductive or moult cycles; growth rates and, in a few cases, estimates of natural mortality in order to estimate yield per recruit) [16]. There has not, however, been an attempt to gain an in-depth understanding of the processes that determine the population dynamics of these species such as recruitment, spatial structure, density-dependent processes and spatial variability in growth, reproduction and mortality (although at the present time, some efforts are being made in this direction, as is the case of the spider crab or goose barnacle), that preclude the development of TAC/quota or effort regulations or closed areas systems [18,19].

3.3. Population dynamics of coastal exploited species

The assessment of the artisanal fisheries has been based traditionally on classical models of fish population dynamics developed according to the seminal research of Beverton and Holt [20]. These models include dynamic-pool and surplus production models and virtual population analysis (see [21] or [19] for a review) appropriate for highly mobile demersal or pelagic resources (according to the classification of Orensanz and Jamieson [13] and for the management of industrial fisheries [13,18,22]. However, from a biological standpoint, the species harvested by the artisanal coastal fleet of Galicia, and particularly the great majority of invertebrate species, present a number of characteristics which render the above-mentioned analytical models useless in understanding their population dynamics [18,19]. These species, sedentary benthic or mobile benthic/demersal (Table 3), have a strong and persistent spatial structure (in the sense of Orensanz and Jamieson [13]) and are characterized by the following ([8] present a recent collection of papers analyzing these subjects):

(1) Complex life cycles (planktonic dispersing larval stages and sendentary or low mobile benthic or demersal postlarval stages) [23].

(2) A spatial distribution characterized by the existence of aggregations which are evident on different scales [24,25].

(3) A population structure that could be defined as meroplanktonic metapopulations in which the postlarval stages make up a chain of local populations along the coast with low migration and dispersal levels and interconnected by a planktonic larval stage [26–28]. This aspect determines a decoupling between the local stocks of adults and the subsequent recruitment in the same local population. In some cases there is even evidence of source–sink dynamics in which only some of the local adult populations contribute reproductively to the next generation depending on whether or not the existing local oceanographic conditions favored the larval transport [29].

(4) The aggregated stock-recruitment relationship (due to density-dependent processes, which is the focal point of population regulation in classical models) is not applicable to a segment of a metapopulation [13] (see above). The stock-recruitment relationship is in general not shown although adequate scale will be used [22] or it is detected only when stocks are in very low levels. The processes of physical transport of larvae to appropriate habitats for recruitment has been recently defined as a key (density-independent) process in the recruitment of invertebrates [27,30].

For highly mobile demersal or pelagic fishes exploited by industrial fisheries the spatial scale of exploitation is frequently similar to the spatial scale of the unit stock (a homogeneous fleet exploits most or all of the distribution area) of the population or metapopulation, whereas in artisanal coastal fisheries the fleet is heterogeneous and each sector (defined from a geographic point of view or by gear) exploits specific segments of the metapopulation, so the spatial scale of the metapopulation and of the fleets (usually corresponding to local populations) does not coincide. Therefore, management measures must take the existing spatial heterogeneity into account [13].

Another problem with management systems based on classical models lies in the fact that they have focused on regulating fishing effort, which has been considered as the only relevant human impact on the system. In coastal ecosystems, in contrast, there are a number of activities that give rise to changes or the destruction of key habitats (e.g. [31]), and these may have a greater effect on population abundance than fishing mortality. For example, in the case of the spider crab in Galicia, subtidal (< 10–15 m) habitat for juveniles has been modified along the coast (in some areas $> 25\%$ have disappeared in the last decades). It has been demostrated theoretically that this reduction in carrying capacity has an effect in fishery yield and reproductive effort that is considerably larger than mangement regulations directed to reduce the fishing effort [15].

4. Management of the Galician artisanal fisheries

4.1. Institutions, decision-making and management policies

The artisanal fisheries of Galicia are managed almost entirely from the administration of the Consellería de Pesca, Marisqueo e Acuicultura (Ministry of Fishery, Shellfishery and Aquaculture) of the Xunta de Galicia (Autonomous Government of Galicia) in that it has legal authority from the national government over "territorial" waters (the straight line connecting the tips of the capes) and jurisdiction over activities related to the capture of crustaceans and bivalves.

In essence, the regulatory measures are aimed at species (minimum landing sizes, protection of ovigerous females, maximum catch limits, etc.); gears (number of gears per vessel and fisher, maximum length, minimum mesh size, etc.); spatial and temporal closures (specific zones and depths for concrete gears and species).

The different resolutions, regulations, guidelines, etc. arising from the administration are circulated through newsletters to the fishers' guilds ("Cofradías de Pescadores"; fishers' associations under the auspices of the Xunta de Galicia) in each port and they are under the obligation to provide this information to affected parties.

These rules, regulations, laws, etc. are drawn up by the autonomous administration based "theoretically" on scientific criteria (although, as will be commented on below, there is a considerable lack of data and biological knowledge on the stocks and the coastal ecosystems of Galicia) and mainly political criteria (political forces and lobbies: the central Government, guilds with opposing interests, fishery sectors (longline vs.drift net; bib trap vs. octopus trap; tangle-net and longline, etc.)). The fact that the management of the coastal fisheries in Galicia are, in practice, more politically than scientifically oriented is a direct consequence of the current state of knowledge on these fisheries.

4.2. Stock assessments

In an industrial fishery the relationship between the economic benefits obtained by the fishery and its biological and social complexity is usually high, which would make it possible to develop intensive assessment methods (such as direct surveys, recruitment monitoring, at-sea obervers, etc.). In terms of the artisanal coastal fisheries of Galicia, the economic yield of each one of the species harvested does not appear to be able to support this approach due to the considerable economic and human effort involved (considering the number of species and stocks of each species to be assessed). In this sense, most of the fishery statistical data are highly fragmentary and biased. Many of the Galician artisanal fisheries have long histories, but the first statistical data appear approx. in 1940–50. The level of compliance with the regulations was not assessed (and probably was low) and the quality of the recording systems in different ports was variable. Only recently (from 1994) the Xunta de Galicia has started a comprehensive program to collect fishery statistics for the complete artisanal sector trying to correct the problems stated above.

Some assessments based on the use of statistical data on catches have been carried out in a few cases using specific datasets adequate for this approach. In this way, retrospective stock assessments have been carried out for species such as squid [32], in order to estimate total catch, or the spider crab [33], to estimate the biomass harvested and fishing mortality (using methods based on stock depletion, due to the high exploitation rate). The indirect methods for the reconstruction of stock abundance based on fishery data (such as VPA and similar analyses) and the dynamic models would not be appropriate for use in this situation because the underlying biological model does not fit the exploited resources [18], and, in general, the needed statistical data are not available [19], although some attempts have been made in this direction (e.g. González-Gurriarán [34] did a preliminary yield per recruit analysis of the velvet swimming crab, and Freire et al. [15] modelled egg- and yield-per-recruit in the spider crab taking into consideration the spatial and demographic stage-based structure of the stock).

It is difficult to analyse the level of exploitation to which the Galician coastal resources are subjected to as the assessments carried out to date are either non-existent or highly fragmentary. However, there are a number of indicators that reveal that many of the target stocks of artisanal fisheries in Galicia are being overharvested:

(1) The virtual depletion and collapse of several stocks (for example lobster, spiny lobster, oyster, sea bream)

whose catches are irrelevant today but were historically important in the area,

(2) the time series of catches (despite the problematic interpretation of these statistical data due to a lack of quality control) show that there has been a consistent decline in most cases from the 1940–1960 to the present time, such as in crustaceans (unpublished data),

(3) specific assessments, such as on the spider crab in the Ría de Arousa [33] and the Golfo Artabro (unpublished data), reveal exploitation rates of $\geqslant 90\%$ per fishing season,

(4) fishers' long-term observations are consistent with the above indicators.

5. A proposal for alternative research and management policies for artisanal coastal fisheries

Our conclusion is that a critical state is evident due to the overexploitation of resources leading to economic inefficiency. These problems, in our opinion are linked to the fact that the biological and socioeconomical paradigms in which the management policy is based are not adequate for this artisanal context. But, before proposing alternative management models, the role of artisanal fisheries in western industrial societies should be analyzed: are they useful or simply a socioeconomic anachronism that will disappear in the near future? From our point of view, the artisanal fisheries show a high social and ecological importance in this economic context, and the following facts justify the need of their survival and sustainable management:

(1) They could constitute (and, in fact, they constitute instead of the existing problems) the economic basis of a wide social sector in coastal areas, despite their low profits (the direct or indirect employment associated with a given profit is considerably larger in artisanal than in industrial fisheries) [1,3,13].

(2) they could be an important agent in the conservation of coastal ecosystems (although, in some ocassions, they have negative impacts when the gears modify benthic habitats). The sustainable exploitation of coastal living resources needs management measures directed to the conservation of habitats and ecosystems and could limit other human uses of these habitats with dramatic ecosystem effects.

Therefore, there is an urgent need for the design and application of alternative research and management strategies, and we will outline the main lines of action that in our opinion could allow a sustainable and efficient use of these resources in Galicia.

5.1. Research

In synthesis, the present scientific knowledge presents us with a situation characterized by the availability of only partial information, both in terms of the species analyzed and the study topics. In this sense, it would be fitting to go back to the issue raised in the introduction concerning the possibility of acquiring "complete" scientific knowledge that would be sufficient for appropriate resource management. The idea proposed above concerning the relationship between economic yield and the biological and social complexity of the fisheries as determining factors in the capacity for the development of assessment systems may be applied to stablish the potential limits in the development of intensive scientific research.

In view of this situation, we must seek out alternative ways to acquire information applicable to fisheries management. Perry et al. [19] provide a framework to obtain scientific information for new invertebrate fisheries that, in many cases, could be adequate for the Galician context. Although many of the Galician artisanal fisheries are completely developed and fully or over-exploited, the availablity of scientific information is low and equivalent to many new fisheries around the world. In our view, the main lines of action should be:

(1) For direct assessment purposes, collecting existing scientific information, both from previous work carried out in the region or on the same or similar species in other geographical areas. This information should include basic biological parameters (growth, reproduction and mortality), spatial scale and structure of stocks, habitat use, dispersal and migrations and performance of gears. The Bayesian approach [35] provides an appropriate framework to combine these different information sources to obtain preliminary estimates of the biological and technical parameters of interest, an idea of the potential spatial varaibility and of the uncertainty associated with the estimates.

The spatial structure of most of the exploited resources is a central point both to understand their population dynamics and to design assessment and management methods. One of the parameters of interest for classical fisheries management, the absolute abundance of the stock is difficult to estimate in coastal spatially structured resources, and efforts should be redirected towards the use of indices of abudance and distribution that could be obtained from habitat maps carried out with rapid methodologies [13]. The conectedeness of local populations and the potential larval routes of dispersion determining the source–sink dynamics could be estimated using available or new information about hydrography (i.e., [36]).

(2) In the above scheme, new sources of knowledge that will be able to supplement or broaden our scientific knowledge should be incorporated. The fishers' ecological knowledge or local knowledge [37,38] should have a central role in artisanal fisheries.

(3) Parallel to the above actions, research lines that will carry out an in-depth analysis of the mechanisms that

regulate the population dynamics of the species of interest, in terms of their fishery value as well as their value as biological models, and the behavior of fishers should be developed. This information should help to guide the design of the assesment process suggesting key processes to be included or modified.

5.2. Management

It seems clear that the destiny of open access resources is overfishing and economic inefficiency, especially in cases as Galician artisanal fisheries where a centralized management scheme is unable to develop useful compliance systems. However, there are abundant references to successful management systems that include the users in the management process giving them some kind of rights to use resources (see [39] for a recent review). Following this approach, in the case of Galicia, given the socioeconomical and biological characteristics of the artisanal fisheries, we propose an alternative management model based, in synthesis, in three basic points:

(1) the implementation of territorial users' rights for fishers, based in the spatial structure of the exploited stocks and the geographical areas used for each fishing community. A first problem should be the design of a mechanism to establish the territories combining biological and sociopolitical criteria. Along with these strategies based on territoriality, a restriction or access to the resources inside each community should be established.

(2) integrate fishers in the assessment and management process, collaborating with the government agencies, and develop adaptive management systems to use the experience gained in each territory in a continue process of updating the management system.

(3) the establishment by the co-managers (fishers and government) of regulations in each territory. Marine protected areas and minimum landing sizes should be a key tool in this process, along with other measures devoted to the restriction of fishing effort or to limit the fishing of some species, sexes or life history stages. In the Galician context, the control of the compliance of the fishers with no-take zones is considerably easier than with other regulations of fishing effort. The effect of protected areas in management performance should be equivalent or higher than other regulations and more robust to uncertainties [15]. The other key regulation, minimum landing sizes, is easily implemented and background biological information is available for most of the species. Both regulations are understood and accepted by fishers.

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