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How to assign a catch value to fishing grounds when fisheries statistics are not spatially explicit

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SUMMARY: Fishery statistics do not usually include small-scale spatial references to assess the effects of natural or human disturbances. We present a methodology which assigns a geographical origin to the catches and assesses the total revenue of the fishing grounds. Market statistics are combined with the results of an ethnographic survey to provide a spatial allocation of the fishing effort. In the present case study, which corresponds to the Galician coast (NW Spain), 253 vessels from 14 base ports that fish in 80 fishing grounds were identified. The annual total revenue of the catches was 8.28 M€ and ranged from a minimum of 4928 € to a maximum of 0.60 M€ with a mean value per fishing ground of 0.104 M€.

Keywords: coastal waters, economic valuation, fisheries statistics, fishery management, spatial allocation.

RESUMEN: COMO ASIGNAR VALOR ECONÓMICO A BANCOS DE PESCA CUANDO LAS ESTADÍSTICAS DE PESCA NO SON ESPACIALMENTE EXPLÍCITAS. – Las estadísticas pesqueras no suelen incluir referencia espacial a pequeña escala que permita evaluar los daños causados por perturbaciones naturales o humanas. Se presenta una metodología que asigna un origen geográfico a las capturas y permite estimar un valor de explotación de los caladeros. Se combinan estadísticas de comercialización con los resultados de un análisis etnográfico para proporcionar una localización geográfica al esfuerzo de pesca. En particular, se ha estudiado una situación en la que se identificaron 253 embarcaciones de 14 puertos diferentes, que pescaban en 80 caladeros de la costa de Galicia (NW de España). Los ingresos brutos anuales resultantes de las capturas realizadas fueron de 8.28 M€, con un importe promedio por banco de 0.104 M€, oscilando entre un máximo de 0.60 M€ y un mínimo de 4928 €.

Palabras clave: aguas costeras, valoración económica, estadísticas pesqueras, gestión de pesquerías, asignación espacial.

INTRODUCTION

The assessment of damages to marine fisheries caused by the construction of infrastructures, pollution processes or other disturbances is limited, in most cases, owing to the lack of spatial references in catch statistics (Watson *et al.*, 2004). As a rule, the official databases include information on geographic zones that are much broader than the areas affected by most disturbances (Watson *et al.,* 2004). In view of this problem, recent developments in terms of technological solutions have been implemented. An example is the satellite-based monitoring system for fishery activity adopted by the European Union, with which it is possible to relate the catches directly to their origin (EC regulation 2244/2003).

In addition to the damage due to direct fishing mortality, human disturbances cause changes in ecosystem services, which, indirectly and over a longer time frame, are eventually reflected in catches (Vitousek *et al.,* 1997; Costanza *et al.,* 1997; Jackson, 2001).

Transactions at first sale fish markets serve as a basic indicator for assessing the overall value of a

given fishery. However, the information is not sufficient to assign a valuation to a specific geographic area. Hence, the spatial allocation of the total revenue obtained from a fishing ground requires the fishing effort exerted by all the productive units and their incomes to be assessed.

Many coastal populations of Galicia (NW, Spain) are heavily dependent on the exploitation of marine resources due to their strategic location and the morphology of Galicia's broad and biologically rich coastal area (Freire and García-Allut, 2000). In March 2005 construction of a large harbour began at Punta Langosteira in the northwest of Galicia (NW, Spain), that will affect an important area for the local fishing fleet. The new harbour will have several direct repercussions on the fisheries as some fishing grounds will now be occupied by the new port facilities and fishing activities will also be restricted in areas that give preference to navigation. A diversified fleet in terms of gross registered tonnage (GRT), fishing gears and techniques, operates out of a large number of base ports and carries out intense fishing activity in the area. Catches are sold through a daily Dutch (descending price) auction in 17 first sale markets (associated with fishermen's organizations and harbours) located around the new harbour. These markets are managed for the most part by artisanal fishermen's associations (Fig. 1). The construction of this infrastructure has created the need for the fishery sector to assess the economic value derived from the catches of each fishing ground in the affected area.

In the present paper the construction of the Port of Punta Langosteira and the fishing area of the fleet operating from the 17 ports cited above, are used as a case study to develop a methodology for general application that allows a specific geographic origin to be assigned to catches. Next, the economic valuation is broken down into a suitable spatial scale to assess the direct damages caused by local disturbances (Fig. 2). Our method combines the available statistical information (characteristics of the fleet, catch, and total revenue obtained from its sale) with the results of an ethnographic survey (based on interviews with fishermen to identify fishing grounds and to assign them a specific fishing effort). An assessment of the total revenue of each fishing ground that integrates the different results obtained for the study area is carried out by means of a Geographic Information System (GIS).

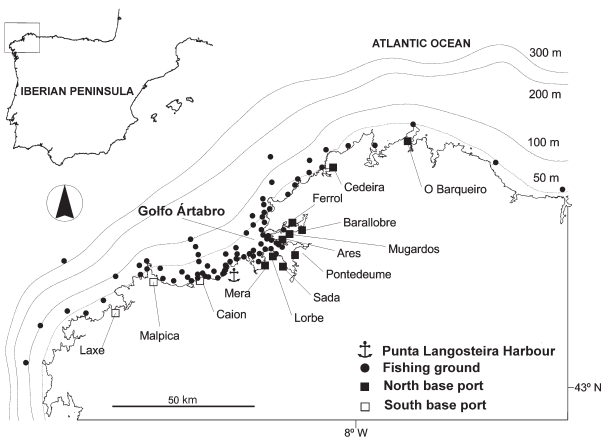

FIG. 1. – Study area in Galicia (NW Spain). The future port of Punta Langosteira, the identified fishing grounds and the base ports of the studied fleet are shown.

METHODS

Catch statistics databases

In order to assess the direct impact of the new port facilities, the unallocated statistical information available on fishery activity was collected, standardized, corrected and updated.

The information related to the fishing fleet operating in the study area was provided by the fishermen's associations. These organizations contributed updated information (year 2005) on the number of vessels, GRT, number of crew members and gears used per vessel (a vessel may deploy several different gears as long as they are not used simultaneously). Data from a total of 389 vessels were initially obtained, but only 253 vessels distributed among 14 fishermen's associations were finally selected (only fishermen's associations with vessels that used to fish in the affected area for some time of the year were considered in the present study). Data were analyzed separately for the fishermen's associations located to the north and south of the Outer Port of Punta Langosteira, due to differences in the relative position with respect to the port and oceanic exposure (the south area is more exposed) (Fig. 1).

The great majority of this fleet (83.0%) uses multiple fishing gear types (traps, long-lines and trammel-nets) according to an administrative and environmentally well-characterized annual fishing cycle. 16.6% operates with purse seines throughout the entire year, and only one vessel uses gillnets seasonally following the reproductive cycle of certain species. The average displacement of the vessels using

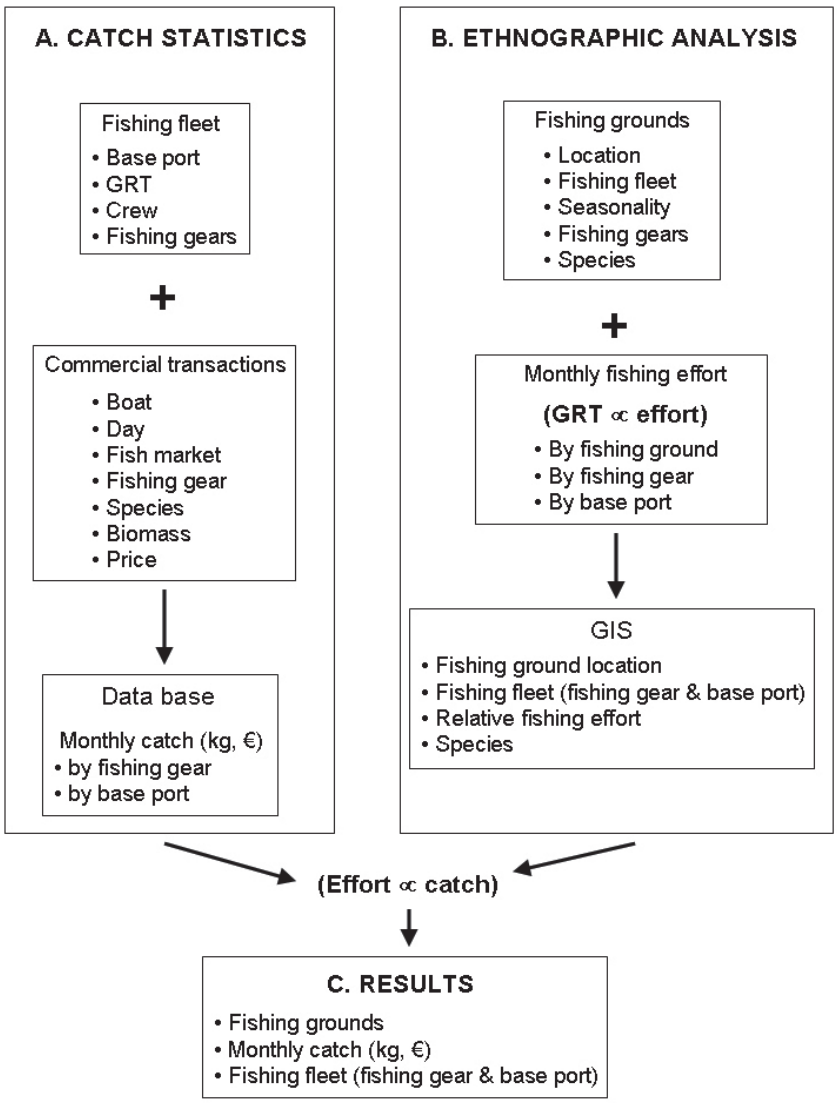

FIG. 2. – Outline of the methodology developed to obtain a spatial allocation of the catch of a fishing fleet from fishing statistics without a geographic location for the catch.

multiple fishing gears is 6.85 GRT, ranging between 37.44 and 0.33 GRT. The average displacement of the purse seiners is 23.02 GRT, ranging between 49.89 and 3.91 GRT.

Information on the commercial catches (kg) and their first sale prices (€) over the course of the 1995-2004 time series came from records kept by the markets and authorized private sellers. A total of 163748 commercial transactions were initially recorded, which also indicated the fishermen's association to which the vessel belonged, the gear used and the commercial and scientific denominations of the catches. The information on the transactions carried out by each vessel is available daily (94.5% of the total), monthly (3.5%) or yearly (1.9%).

The fleet using multiple fishing gear types takes in a large number of species. Of the landings that provide data on the species captured, some of the most noteworthy species are: octopus *Octopus vulgaris* (accounting for 30.6% of the catch by the multiple fishing gear fleet), conger eel *Conger conger* (12.8%), hake *Merluccius merluccius* (6.7%), skate *Raja* spp. (5.0%), cuttlefish *Sepia officinalis* (2.2%) and spider crab *Maja brachydactyla* (1.1%). The purse seiners mainly target sardine *Sardina pilchardus* (49.7%), horse-mackerel *Trachurus trachurus* (41.6%), and mackerel *Scomber* spp. (6.0%). Gillnets catch chiefly hake (40.8%) and pollack *Pollachius pollachius* (31.1%).

As the fisheries in the study area are highly seasonal in terms of the fishing grounds exploited, gears

TABLE 1. – Catch (t) and total revenue (thousands of €) of the fishing fleet for the interval 1995-2004. The relative importance of the catch and the total revenue (percentages of the total) corresponding to each fishing area (north and south) for each fleet are shown.

Year	Purse seine				Multiple fishing gear				Purse seine percentages of total			
	Catch		Total revenue		Catch		Total revenue		Catch		Total revenue	
	North	South	North	South	North	South	North	South	North	South	North	South
1995	6501	728	3080	293	11	0	21	0	-	-	-	-
1996	4019	499	2509	248	6	0	48	0	-	-	-	-
1997	4295	469	2704	289	58	0	206	0	-	-	-	-
1998	2872	4286	2409	2920	365	2043	373	2802	-	-	-	-
1999	3139	3770	2075	2688	443	1713	387	2506	87.6	68.8	84.3	51.8
2000	2621	4085	1768	2424	660	529	821	2402	79.9	88.5	68.3	50.3
2001	3503	4055	2309	2873	177	547	794	2486	95.2	88.1	74.4	53.6
2002	2943	3845	2205	2747	196	598	613	2384	93.8	86.5	78.3	53.5
2003	3043	2040	1799	1029	303	309	1043	1281	91.0	86.8	63.3	44.6
2004	3487	2428	1955	1629	479	575	2070	2601	87.9	80.9	48.6	38.5
Total	36423	26206	22812	17140	2696	6315	6377	16463				

used and species caught, the database was standardized to monthly data. Yearly data were broken down into monthly data, estimated in terms of the monthly percentage of catches taken by vessels with monthly or daily data. In addition, the daily values were aggregated as monthly data.

Using the standardized database (captures per vessel, gear and month), monthly estimations of the captures and their total revenue for the fleets of all the fishermen's associations were obtained for each gear and species captured.

Lastly, estimates of the catches and total revenue of the total number of species caught with each gear were generated. The data not assigned to a specific gear were distributed among the purse seine and multiple fishing gear types based on the relative importance of these gears with regard to the total annual respective catch and total revenue. Only data after 1998 were used since the information provided by the fishermen's associations was more complete after this date (all the fishermen's associations were able to provide data after 1998) (Table 1). The gillnet was omitted from the estimation due to its low relative importance in terms of the total catch (0.1%) and market value (0.4%).

Ethnographic survey for the spatial allocation of fishing effort

A questionnaire was designed to be answered by groups of ship owners affected by the construction of the new infrastructure. The purpose was to reconstruct the annual fishing cycle, to identify the exploited fishing grounds and to obtain information about the fishing effort of each vessel. 26% of the fleet was surveyed (27% of the multiple fishing gear fleet and 24% of the purse seine fleet). The overall response (interviews carried out *vs*. number of existing vessels in the fleet) was 31%, ranging from 33% for the multiple fishing gear fleet to 22% for the purse seiners (Table 2).

TABLE 2. – Number of interviews with ship-owners and skippers for each fishing gear used. Interview dates are indicated.

Base Port	Multiple fishing gear		Purse seine		Date
	Scheduled	Performed	Scheduled	Performed	
Ares	9	5	7	2	18/07/2005
Ferrol	80	5	0	0	08/07/2005
Laxe	13	9	0	0	15/07/2005
Lorbé	15	9	0	0	07/07/2005
Malpica	23	12	14	0	06/07/2005
Mera	10	9	4	0	07/07/2005
Pontedeume	3	1	7	0	18/07/2005
Sada	11	1	12	7	24/06/2005
Caión	10	6	1	1	06/07/2005
Total	174	57	45	10	

The researcher explained the interview procedures to the groups of fishermen who were asked to take part in the survey by the presidents of the different fishermen's associations. In the first stage of the survey that dealt with the detailed mapping of the study area, each fisherman was asked to locate the central point of each fishing ground exploited by his vessel. The locations of the fishing grounds pointed out by the different skippers coincided very precisely according to the scale used (1:55000), even for purse seiners, although they capture highly mobile pelagic fishes.

In the next stage a questionnaire was used. The fishermen had to detail the target species, the fishing gears employed and the seasonal activity of their vessels for each fishing ground. It was found that the seasonal activity according to fishing ground and

fishing gear, and also species caught, were very homogeneous for each fleet (even for different fishermen's associations).

The data obtained from the questionnaires were digitized in a GIS. This system integrates the geographic location of the fishing grounds to define a single seasonal database that identifies the geographic position of each fishing ground, the type of fleet, defined according to gear and GRT, and the fleet's target species.

Catch statistics and allocation of fishing effort databases were analyzed with the following procedure:

1. A relative fishing effort was assigned to each vessel (corresponding to its GRT) and subsequently distributed among the exploited fishing grounds for each season. In cases where one vessel exploited several fishing grounds at the same time, the total effort was divided equally among all the exploited fishing grounds.

2. The monthly use of each fishing ground by each vessel was obtained by dividing the quarterly effort data into equal parts.

3. The monthly use of each ground by each vessel (in GRT) was aggregated to obtain percentages of use in relation to the fishermen's association and gear.

4. Catches and total revenues for each ground, month and gear were allocated using the monthly percentage of use (from aggregated GRT). It is assumed that the proportion of catches obtained by a given fishing fleet operating on a fishing ground is proportional to the fishing effort exerted on this fishing ground.

5. Monthly data according to ground and gear were aggregated yearly.

RESULTS

A total of 80 fishing grounds in the study area, all located at a short distance from the coastline (less than 20 km) were identified. Most of these fishing grounds (94%) are located shallower than 100 m depth, 5% between 100 m and 200 m, while only 1% is located at depths >200 m (Fig. 1).

The annual total revenue resulting from the commercial exploitation of each identified fishing ground was estimated for the time series (1995-2004), but the present paper only includes the estimates obtained for the year 2004. The total revenue of the fisheries is concentrated around the Golfo Ártabro, most probably due to the larger number of base ports in this area (Fig. 3).

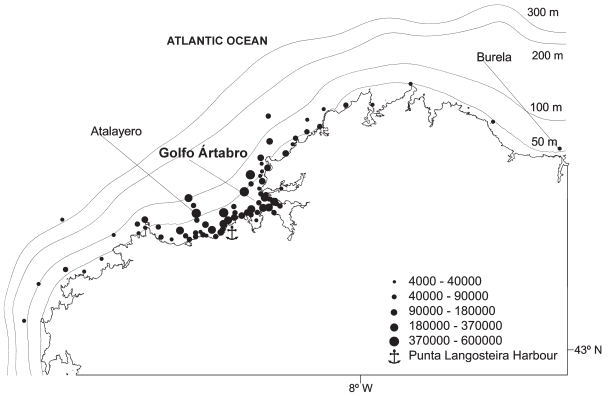

FIG. 3. – Fishing grounds exploited by the studied fleets and total revenue (in €) derived from their commercial exploitation in 2004.

The annual total revenue of the catches of all the fishing grounds studied amounts to a total of 8.28 M€. The most important fishing ground in terms of total revenue for the fleet analyzed is Atalayero, which generates 0.60 M€ annually (7.2% of the total sales). The least important fishing ground in terms of total revenue (0.1%) is that of Burela, with an annual total revenue of only 4928 €. The mean total revenue per fishing ground is 0.104 M€.

The different fleets examined here tend to concentrate their catches in the fishing grounds closest

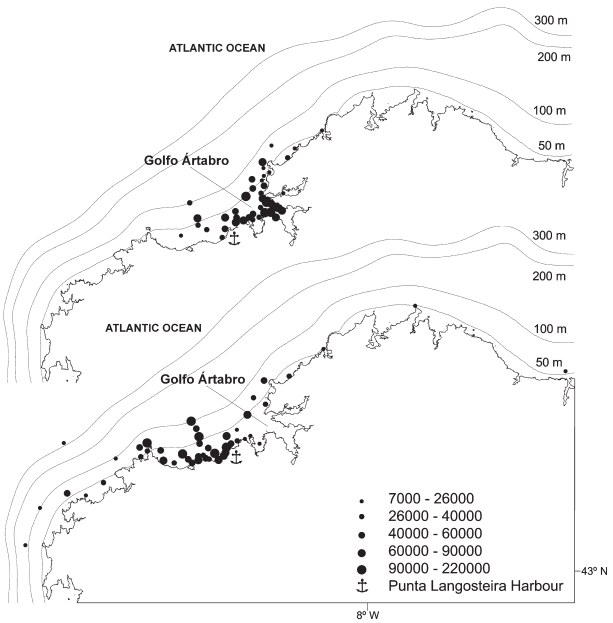

FIG. 4. – Fishing grounds and total revenue (in €) derived from their commercial exploitation in 2004 by the multiple fishing gear fleet with base ports in the north (top) and south (bottom).

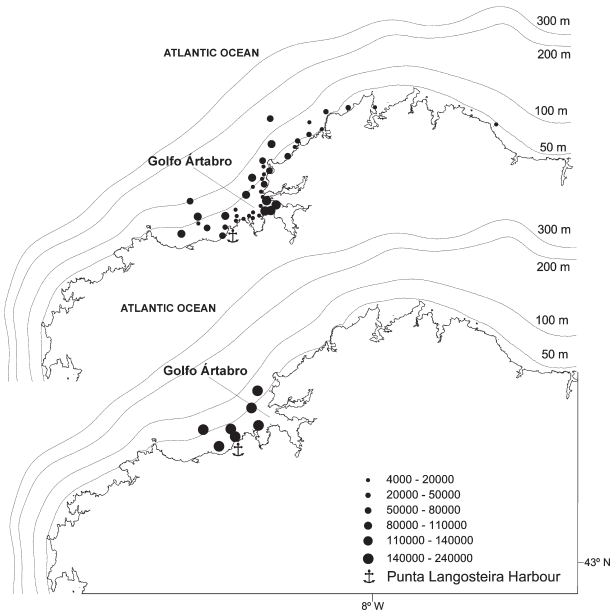

FIG. 5. – Fishing grounds and total revenue (in €) derived from their commercial exploitation in 2004 by the purse seine fleet with base ports in the north (top) and south (bottom).

to their respective base ports. Hence, the north fleet that uses multiple fishing gear types operates in the fishing grounds located in the vicinity of the Golfo Ártabro, while the multiple fishing gear type fleet of the south, although it carries out less concentrated fishing, targets catches to the south of the Golfo Ártabro (Fig. 4).

The way the purse seine fleet uses its fishing grounds is less dependent on the distance from their base ports than the operating strategy of the multiple fishing gear type fleet. However, this does in fact show that the fleet fishes more intensely in the fishing grounds closest to their major ports (Fig. 5).

DISCUSSION

The methodology developed here is based on two main premises. First, it is assumed that the catches taken by a fishing fleet are proportional to the fishing effort exerted by all of the vessels involved in the fishery. Secondly, it is assumed that a fleet's GRT is a good indicator of the fishing effort exerted.

Although using the GRT to measure fishing effort has been widely accepted in papers on marine resource management (Ward *et al*., 2004), some degree of controversy has arisen as to the proportionality between the catches taken by a fleet and the fishing effort exerted. While Harley *et.al*. (2001), Walters (2003); Ahrens and Walters (2005) and Hampton *et al*., (2005) question the validity of this hypothesis, the proportionality - with greater or lesser strictness - between the two variables has enjoyed widespread, implicit use in fisheries management (Richards and Schnute, 1986).

In addition, it was assumed that the catchability of the vessels from each fleet and fishermen's association was homogeneous. Certainly, both the behaviour (seasonal activity at the fishing grounds according to species caught and gears used) and the technology used by the fleets were found to be similar, according to the high similarity of the answers obtained in the survey.

The survey (27% of the vessels using multiple fishing gears and 24% of the purse seiners) is considered adequate to represent the whole fleet and to be used to allocate fishing effort. In spite of this, the estimation of the catch distribution of the southern purse seine fleet must be considered preliminary, owing to the small number of interviews carried out (Table 2).

The results for the time series 1995 to 2004 are based on an ethnographic survey carried out in 2005. Hence, it is assumed that the location of the fishing grounds and their exploitation patterns have remained constant over a 10-year period. This assumption is based on the fact that both location and exploitation methods are traditionally transmitted knowledge and the social and demographic characteristics of the fleet remained relatively stable during this period.

The method proposed here allows us to obtain spatially explicit estimations of the fishery production which are applicable to cases, which are generally quite common, where the existing monitoring and information systems are not able to tackle this objective. Moreover, the combination of statistical data, the ethnographic analyses and spatial analyses by means of GIS, enables this methodology to be applied rapidly and efficiently. This protocol could be easily adapted to other specific situations and is clearly useful in both fisheries management and the assessment of damage caused by disturbances due to natural and human activities. Furthermore, the introduction of GIS tools in this spatial perspective could offer new perspectives and different approaches for managers, scientists and users of marine resources for exploiting the available information.

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