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Artisanal fisheries management using a DPSIR approach: The analysis of dredge fisheries in the south coast of Portugal

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Artisanal fisheries management using a DPSIR approach: The analysis of dredge fisheries in the south coast of Portugal

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1. Introduction

To guarantee the sustainable development of artisanal fisheries, management actions are required as a way of control the state of the ecosystem and ensure the socio-economic stability of fishermen communities. The specification of effective regulatory policies to overcome existing problems requires updated information on the whole system status, and knowledge of the interrelations between factors.

The identification of appropriate indicators, both quantitative and qualitatively, is essential to characterize the status and trends of an ecosystem. Study reported in this paper applies the Driving force – Pressure – State – Impact – Response (DPSIR) framework (EEA, 1999) for the construction of indicators that can be used to design managerial actions to promote the sustainability of artisanal fisheries. The DPSIR framework adopts a multidisciplinary perspective, which enables the integration of indicators reflecting different dimensions of a system. The application of the DPSIR framework enables understanding of causal relationships between human actions and ecosystem changes.

This paper specifies a DPSIR model for monitoring artisanal fisheries in the Atlantic Arc. This will be followed by the application of the DPSIR framework to analyze the sustainability of the artisanal dredge fleet that operates in the south coast of Portugal.

2. DPSIR framework overview

Indicators are increasingly being developed and used as management tools. The establishment of a set of indicators must supply clear information to simplify, quantify or qualitatively describe a system. The information collected must give a base for decision making by managers, stakeholders or regulatory authorities.

The Pressure – State – Response (PSR) framework was developed by the Organization for Economic Co-operation and Development (OECD) in 1993. This model structures environmental information and actions in indicators, defining cause and effect relationships between human activities (P), changes in the state of the environment (S) and society reaction (R) (OCDE, 1993). The PSR framework was enhanced by the European Environmental Agency (EEA) in 1999, becoming the Driving force – Pressure – State – Impact – Response (DPSIR) framework (EEA, 1999), with addition of two new categories: pressure (P) and impact (I). According to this framework, social and economic development corresponds to driving forces (D) that exert pressure (P) on the environment and, as a consequence, the state (S) of the environment changes. These changes may involve health conditions, resources availability and biodiversity. Finally, this leads to impacts (I) on the ecosystems, including human health and materials that may elicit a societal response (R). This response feeds back on the driving forces and pressures or on the state or impact directly, through preventive, adaptive or curative actions. This perspective of the interaction between environmental and human systems is illustrated in Figure 1.

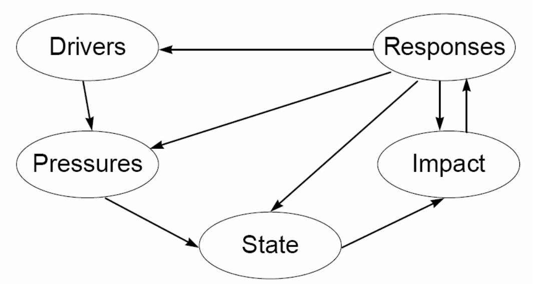

Figure 1. The DPSIR Framework (EEA, 1999).

In many studies where the DPSIR methodology was applied to fisheries, marine areas and other related thematic, the fishing industry appears frequently as a driving force indicator (e.g. Crossland et al., 2001; Caeiro et al., 2004; Pacheco et al., 2007; Henriques et al., 2008; Ojeda-Martínez et al., 2009). In spite of the fishing industry being easily identified as a driving force indicator, to turn this indicator into numbers that could describe the reality of an entirely sector in an effective way is a complex task.

Ojeda-Martínez et al. (2009) considered the fishing activity as a main driving force, which was then divided into sub-driving forces that could describe the fishing industry, such as the number of fishing boats, number of fishers, fishing sector profit, GDP produced by the sector, number of investments done in the sector or vessels' power. To the authors best knowledge, the only research that applied the DPSIR approach to artisanal fisheries was carried out by Mangi et al. (2007). This study focused in a region of Kenya, where population dynamics, unemployment, tradition/culture, tourism and poverty were the driving forces chosen. A detailed bibliographic survey with focus on DPSIR applications to coastal zones, fisheries and marine areas is available in Camanho et al. (2009).

3. Methodology: the DPSIR framework adapted to artisanal fisheries

The purpose of this section is the selection of an appropriate set of DPSIR indicators for artisanal fisheries. This requires the identification of the main factors associated to this activity. Based on the review of several studies and also through an analysis of the information available in Portugal, a set of DPSIR indicators was defined, which are summarized on Table 1 to 5. The indicators selected for each DPSIR category are organized into main topics whenever this detail is considered relevant.

The main driving forces selected for artisanal fisheries are presented on Table 1. Those driving forces were chosen since they characterize the socio-economic context that affects artisanal fisheries activity. The fishermen characterization is considered particularly important: the educational level and the social context can be associated to fishermen behavior. The vessels characterization is directly related to the quantity of fish caught, particularly vessels' power and Gross Register Tonnage (GRT).

Table 1. DPSIR indicators for artisanal fisheries - Driving Forces.

Indicator	Definition
Fishermen characterization	
Number	Number of fishermen
Age	Age of fishermen
Educational level	Educational level of fishermen (low, medium, high)
Social context	Description of the social context of fishermen
Vessels characterization	
Number of vessels	Number and type of vessels
Average Power	Average power of vessels (kW)
Average GRT	Average Gross Register Tonnage (GRT) of vessels
Average Length	Average length of vessels (m)
Average age	Average age of vessels (years)
Average number of licenses	Average of number of fishing gears licensed per vessel
Fishing Revenue	
Revenue per vessel	Average monthly revenue per vessel
Revenue per species	Average monthly revenue per species
Revenue in wholesale market	Difference between price in wholesale market and in second sale (low, mean, high)
Fishing industry share	Fishing industry share in the public budget
Demand of target species	
Internal market	Demand of internal market (low, medium, high)
External market	Demand of external market (low, medium, high)
Levels of dependency from external markets	Demand of external market in relation to national demand (low, medium, high)
Competing entities	
Aquaculture production	Target species production in aquaculture (tonnes)
Commercial fleet	Target species catches by commercial fleet (tonnes)
Imports	Quantities of target species that enter the national market

The revenue achieved with artisanal fisheries is important information to quantify the relevance of the fisheries analyzed in the national context, as well as the profitability potential and economic relevance of this activity. The demand of target species describes customers' propensity to buy the catch, and the relative importance of internal vs. external demand, reflecting the dependency levels from external markets to sell the fish. Competing entities that can also provide the target species to the market are also considered, specifically aquaculture production, the commercial fleet activity and imports. Pressure indicators are seen as the way driving forces contribute to change the ecosystem state.

Table 2 shows the five pressure indicators selected: fishing area, fishing trips, discards, fuel consumption and the quantity of fish caught. The authorized fishing area is regulated by Portuguese and European legislation.

Table 2. DPSIR indicators for artisanal fisheries – Pressure.

Indicator	Definition
Fishing area	Area where fisheries are performed
Fishing trips	Total number of trips and average number of trips per vessel
Discards	Organic matter thrown to the sea (tonnes)
Fuel consumption	Fuel consumed on fishing activity (m^3)
Quantity of fish caught	Weight of fish caught by specie (kg/species)

Table 3 summarizes the state indicators selected. They describe the actual situation of the natural resources and relevant changes verified in the ecosystem analyzed. Changes to target species abundance, describes the situation of the biological stock and its evolution over time. The characterization of ecosystem encompasses all species and dependencies between species, habitat and other relevant variables. This indicator intends to describe relationships within the ecosystem and also provide biological and environmental information.

Impact indicators represent how changes in the system state affect human and ecosystem wellbeing. Therefore biotoxins levels in the target species, whose consumption can cause human diseases, and the main changes in the ecosystem constitute impact indicators, which are summarized in Table 4.

Table 3. DPSIR indicators for artisanal fisheries – State.

Indicator	Definition
Changes to target species abundance	Temporal variations in the biological stock of target species (g/5 min tow dredging)
Characterization of ecosystem	
Overview	Description of relevant aspects of the ecosystem
Species diversity	Enumeration of species that integrates the ecosystem
Species recruitment	New species that entered the ecosystem
Spawning stock biomass per species	Spawning stock biomass per species
Mean size of species	Mean size of target species

Table 4. DPSIR indicators for artisanal fisheries – Impact.

Indicator	Definition
Biotoxins	Number of biotoxins episodes per year
Main Changes in the ecosystem	Description of relevant changes verified in the ecosystem

The response indicators selected are presented in Table 5, which represent human initiatives with the aim to improve the state of ecosystem. Accordingly, the following main topics were defined: National legislation, enforcement and compliance, funds invested on the activity, and educational programs.

Table 5. DPSIR indicators for artisanal fisheries – Response.

Indicator	Definition
National legislation	
Limit of catch	Daily limits of catch by vessel and by species
Fishing closure periods	Periods when fisheries are interdicted
Gears restrictions	Restrictions on types and characteristics of gears
Other restrictions	All the significant and applicable legislation
Enforcement and compliance	
Level of fines	Number of applied fines to illegal actions
Fleet surveillance	Description of the monitoring activities
Funds invested on the activity	
European	European funds for artisanal fisheries
National	National funds for artisanal fisheries
Local	Local funds for artisanal fisheries
Educational programs	Number and type of educational programs over time

4. Application of the DPSIR framework to dredge fisheries in the south coast of Portugal

The main purpose of this section is to use the DPSIR indicators previously selected to characterize a specific artisanal fishery and suggest management actions for promoting its sustainability. The fishery selected as case study is the artisanal dredge fleet operating in the south coast of Portugal.

Artisanal dredge fisheries can be performed with two types of dredges, pushed by hand or towed by boat, and they are essentially used for harvesting bivalve mollusks, such as clams and razor clams, from the seabed.

The present study focuses only on the towed by boat dredge fisheries, which target four bivalve species in the south coast of Portugal: surf clam (*Spisula solida*), donax clam (*Donax trunculus*), razor Clam (*Ensis siliqua*) and the striped venus (*Chamelea gallina*). Target species are also illustrated in Figure 2 to 5.

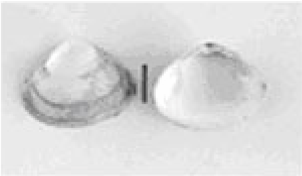

Figure 2. Surf clam. Scale bar = 1 cm.

Figure 3. Donax clam. Scale bar = 1 cm.

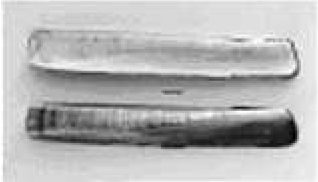

Figure 4. Razor clam. Scale bar = 1 cm.

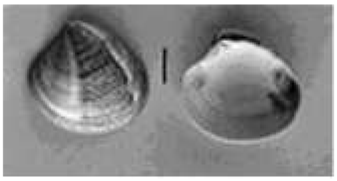

Figure 5. Striped venus. Scale bar = 1 cm.

Two types of dredges can be used in the fishery: the grid dredge (GD), where the catch is retained in a metallic grid, and the traditional dredge (TD), where the catch is retained in a net bag attached to the dredge mouth, as illustrated in Figure 6.

Due to data unavailability, some of the indicators could not be characterized properly. In these cases, this analysis will reveal some aspects that should be given more attention, and hopefully contribute to launch new data collection procedures.

Figure 6. Traditional dredge (TD) and grid dredge (GD).

4.1. Driving forces

Fishermen characterization

To date, it was not possible to obtain information on number of fishermen that practice dredge fishing of bivalve species, but we believe this data was collected for the period 2004 to 2008 and will be available soon.

Regarding age and education level, data will only be available for the skipper of the vessel, for the year of 2008. There is no available information in what it concerns the social context of fishermen.

Vessels characterization

Artisanal vessels dedicated to dredge fisheries can be classified into two fleet segments: local and coastal. Local fleet vessels have an overall length lower than 9 meters and the coastal fleet vessels have an overall length between 9 and 14 meters. This analysis explored all vessels that operated with dredge gears in the south coast of Algarve. There were a total of 67 vessels that were licensed at least in one year between 2001 and 2008 (35 local and 32 coastal vessels). As some vessels may only have a dredge fishery license for some of the years analyzed, this resulted in an unbalanced panel data sample. The main characteristics of licensed vessels, in each of the years considered, are summarized in Table 6.

The number of vessels has remained fairly stable between 2001 and 2008, both for local and coastal vessels. The average power of local vessels had a small increase, but in the case of coastal vessels happened the reverse – a small decrease. It is stated by legislation (DR Portaria no. 254/2008) that the vessels used for dredge fishing are limited to a maximum power of 73.5 kW. Both local and coastal fleets presented a small increase in GRT. Concerning vessels' length, no significant changes occurred in the period considered.

Table 6. Main characteristics of vessels.

		2001	2002	2003	2004	2005	2006	2007	2008
No. of vessels	Local	27	28	29	32	28	28	29	28
	Coastal	23	24	25	27	25	25	25	24
Average power (kW)	Local	42.8	43.1	43.0	43.8	46.3	46.3	46.6	46.7
	Coastal	66.8	67.1	66.6	65.6	65.6	65.9	65.2	64.9
Average GRT	Local	3.6	3.6	3.6	3.8	4.0	4.1	4.2	4.2
	Coastal	9.0	9.0	8.9	8.9	9.1	9.5	9.6	9.6
Average length (m)	Local	7.0	7.0	7.0	7.1	7.3	7.3	7.4	7.3
	Coastal	10.9	10.9	10.8	10.7	10.8	10.8	10.8	10.7
Average age (years)	Local	13.7	14.1	14.6	14.1	13.2	13.4	13.9	14.4
	Coastal	43.8	43.4	42.6	40.3	38.8	33.1	33.0	32.0
Av. no. licences	Local	2.4	2.7	3.2	3.2	3.6	3.5	3.5	4.1
	Coastal	2.7	2.8	2.6	2.7	2.8	2.9	3.0	3.2

Regarding vessels' age, local fleet has an average age of 14 years in the period considered, but the age of coastal fleet decreased significantly, which suggests a renewal of the coastal fleet. The dredge fleet is also characterized by year of construction in Figure 7, where vessels are separated by fleet segment (local and coastal). The majority of considered coastal vessels were constructed before 1960 (15 vessels), and a lack of investment on the coastal fleet renewal can be observed in the following decades, with the exception last one (between 2000 and 2008). Local fleet is significantly newish in comparison with the coastal fleet. The majority of local vessels were constructed between 1980 and 1989. Local fleet also registered a renewal effort in the last decade (between 2000 and 2008).

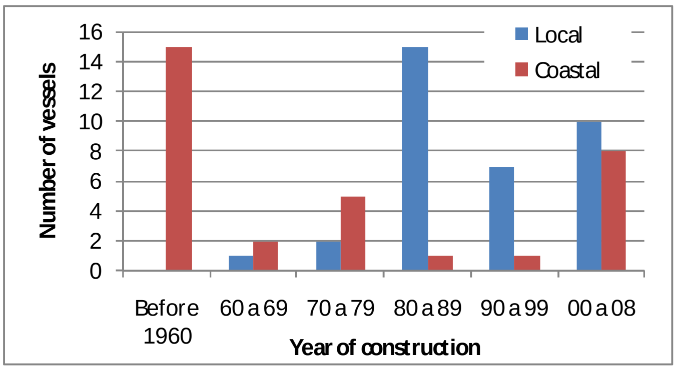

Figure 7. Characterization of the dredge fleet vessels by year of construction.

The noticed increase on vessels' licenses can be associated to the legislation that simplified the fishing licenses process from 2008, giving to fishermen more flexibility in the choice of fishing gears to each fishing trip.

Fishing Revenue

The data available relative to the average annual revenue for each target species are presented in Table 7, with fleet segment differentiation. The annual revenue of surf clam presents high values for 2003 and 2004 in comparison with the other years analyzed, both for the local and coastal fleets. It is also noticed that the coastal fleet achieved more revenue with surf clam than the local fleet for all the years analyzed. Regarding to the donax clam annual revenue, the local fleet obtained highest revenue than the coastal fleet for all the years after 2002. The razor clam annual revenue is slightly expressed, given that this specie wasn´t allowed to be cached in some years due to the low biological stock verified. Nevertheless it is possible to verify that local fleet hasn't significant revenue for this specie. Striped venus has been having some oscillations (in 2004) but the global tendency is the decrease of its revenue, and coastal fleet always presented higher revenue than the local fleet for this specie.

Table 7 – Annual revenue of target species with fleet segmentation (in 10^3 euros).

		2001	2002	2003	2004	2005	2006	2007	2008
Surf	Local	19	34	261	146	29	2	16	27
clam	Coastal	57	120	745	689	269	65	109	127
Donax	Local	246	216	314	412	367	258	288	401
clam	Coastal	284	90	81	201	253	177	205	158
Razor	Local	8	0.2	0	4	0.2	0	0	0
Clam	Coastal	134	29	0	47	23	0.8	0	0
Striped	Local	4	287	126	39	325	225	101	22
venus	Coastal	45	646	613	184	527	402	179	69
Total	Local	277	536	701	601	721	485	406	451
	Coastal	520	885	1439	1122	1074	645	493	355

Figure 8 shows the average revenue of a fishing trip for local vessels, with species differentiation, between 2001 and 2008. The maximum average revenue per trip occurred in 2003, with 189€. With the exception of the year 2007, that shows a decrease in revenue, the values have been stable over the years considered. The average revenue per trip of all the years analyzed is 155€. Donax clam is the most significant specie for the local fleet revenue.

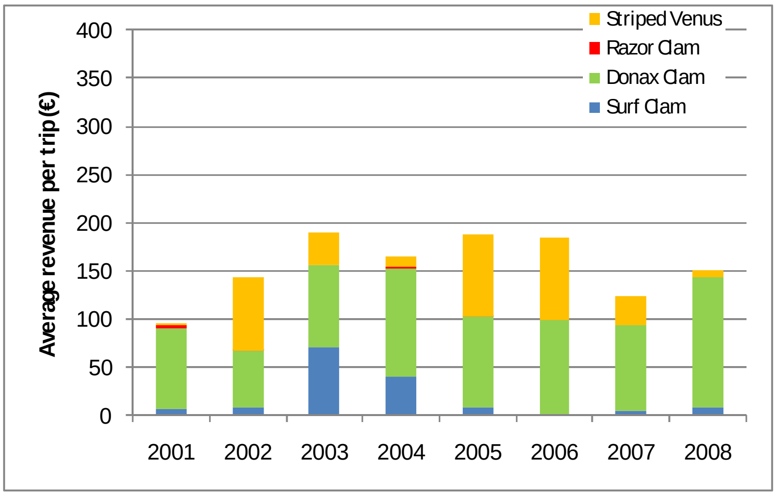

Figure 8. Average revenue per trip with species differentiation for Local fleet (in euros).

Figure 8 characterises the revenue of the coastal fleet. After 2003, there is a clear decreasing tendency in the revenue obtained per fishing trip. The average revenue per trip, considering all the years analyzed, is 225€. Another interesting conclusion is that between 2001 and 2006 the coastal fleet has much higher revenue per trip than the local fleet. However, the revenue per trip became quite similar for the two fleets in 2007 and 2008.

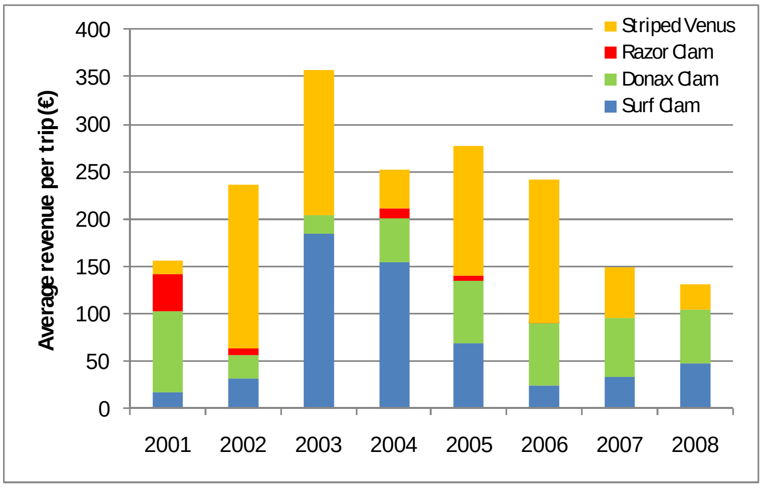

Figure 9. Average revenue per trip with species differentiation for Coastal fleet (in euros).

The importance of dredge fisheries in the context of Portuguese fisheries is not known, but the quantity of fish caught with dredge gears represented 7,9% of the total captures for the Portuguese artisanal fisheries in the year of 2005 (Dias et al, 2007).

It would also be important to know for each target species of dredge fisheries, the difference between the price in wholesale market and in second sale. This would give an idea if the fishermen have organized themselves in order to market their products so as to ensure that a higher part of the catch value returns to them. The most usual case in artisanal fisheries is a highly concentrated distribution sector that earns the largest percentage of revenues. Although no quantitative information on the difference between price in wholesale market and in second sale is available for the target species of dredge fisheries in Algarve, we hope to obtain qualitative estimates for this indicator. The average price of target species sale in wholesale market is presented in Table 8.

Table 8. Average price of target species in wholesale market (€/kg), with fleet segmentation.

		2001	2002	2003	2004	2005	2006	2007	2008
Surf	Local	0.57	0.79	0.60	0.50	0.55	0.52	0.50	0.96
clam	Coastal	0.54	0.75	0.59	0.50	0.50	0.50	0.50	0.88
Donax	Local	1.59	1.58	1.61	1.61	1.61	1.60	1.66	2.35
clam	Coastal	1.49	1.49	1.44	1.49	1.50	1.50	1.50	2.18
Razor	Local	1.74	2.00	-	1.50	2.00	-	-	-
clam	Coastal	1.90	2.00	-	1.50	1.90	2.00	-	-
Striped	Local	1.50	1.50	1.41	1.52	1.50	1.50	1.50	1.50
venus	Coastal	1.49	1.50	1.44	1.50	1.50	1.50	1.50	1.51

It is possible to conclude that the local fleet always achieved a better wholesale price than the coastal fleet for the surf clam and the donax clam. This apparent advantage of local vessels can partially be explained by the auction system (descent-price). The first landed clams are sold at higher price. Operating nearer to the coast, the local vessels can arrive first to the wholesale market with their captures.

The prices of these surf clam and donax clam stayed almost unaffected between 2001 and 2007, and both present an ascent in 2008. The price of the razor clam is volatile, possible due to the small quantities caught. Striped venus prices are similar both in local and coastal fleets, and no relevant price change was observed in the period analyzed. Due to the good organization of the distributers they may be able to determine the prices in wholesale market that best serves their interests. It is possible that the price in second sale may have increased as a response to the smaller amounts available. Another possible explanation is that the quantities actually available in the retail market are quite different from those registered in the wholesale market, either due to the imports or to undeclared catches.

Demand of target species

In relation to the demand of the target species, we can qualitatively characterize it using a likert scale, with three levels (high, medium and low), in what concerns the internal market and sector imports. However, this information is not available yet.

In spite of the lack of quantitative information relative to target species demand, it is possible to characterize the Portuguese demand of fish. National production of fish would allow satisfying a level of consumption per capita of the order of 23 kg/year. This number, in spite of identical to the European Community average, is insufficient to satisfy the national consumption, which is about 57 kg/year. Portugal is in third place of fish consumption at the world level, after Japan and Iceland (DGPA, 2007). Figure 10 represents the world fish consumption per capita between 2003 and 2005 (FAO, 2009).

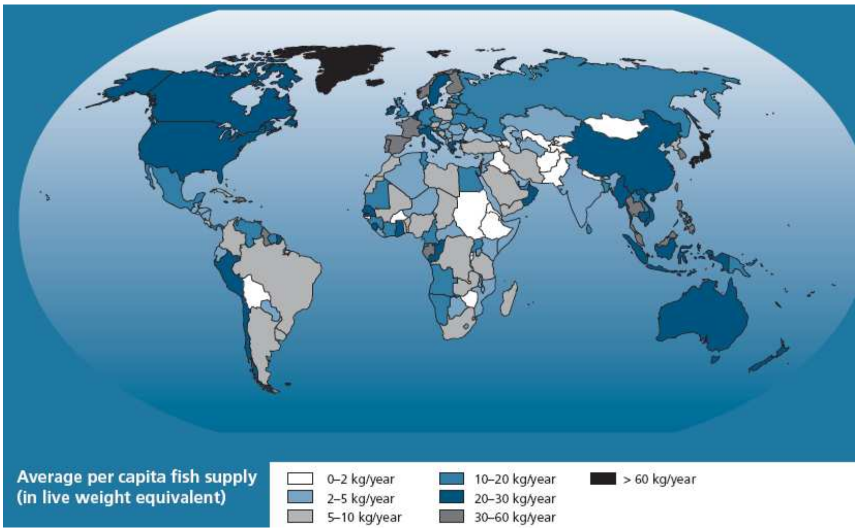

Figure 10. World per capita fish consumption: average 2003-2005, FAO (2009).

Competing entities

The target species of dredge fisheries are not caught by commercial fleets in Portuguese territorial waters, and are not produced in aquaculture. However, we estimate that import flows are significant, but no quantitative measures could be obtained at the time of this study.

4.2. Pressures

Fishing area

Dredge fisheries are allowed at depths exceeding 2.5 meters and must be held further than 300 meters from the coastline during the bathing season, as stated in the legislation (DR

Portaria no. 1102-E/2000). In Portugal, dredge fisheries are mainly operated between 3 and 20 m depth (Constantino et al., 2009).

The Portuguese south coast has five harbours with registered dredge fishing vessels: Faro, Olhão, Fuzeta, Tavira and Vila Real de Santo António (Figure 11). Dredge fishing fleet operates from these five harbours, in order to decrease navigation time between the harbour and the bivalve beds. The Portuguese south coast between Cape São Vicente and Faro is not being exploited due to the rocky nature of the substrata or due to the deplection of bivalves stocks within that area.

Figure 11. Harbours with associated dredge fishing vessels.

Fishing trips

Table 9 provides a characterization of fishing trips. The total number of trips for dredge vessels corresponds to the total annual number of days at sea, as the activity of these vessels is characterized by trips of one day. Only the trips for which the vessels landed the fishing haul in the wholesale market were counted in the statistics reported. It is not possible to know the average length of time of these trips and areas visited. There is no information available in what concerns to the time spent in each trip, however a GPS system is already being tested in PRESPO project context. It is waited that the GPS devices will allow achieving more relevant information such as the distance and time of trips performed.

Table 9. Characterization of the fishing trips

	2001	2002	2003	2004	2005	2006	2007	2008
Total no. of trips per year	6291	7465	7740	8102	7732	5316	6582	5723
Average no. of trips per vessel and per year	126	144	143	137	146	100	122	110

It is clear to identify a decreasing tendency on the total number of trips performed between 2004 and 2008, of about 29%. The number of trips made by each vessel has also decreased around 21% in the same period. This tendency is someway contradictory to the investment done on boats acquisition, but it is also important to consider the flexibility given by the legislation on fishing gear licenses, that can direct the fishermen activity to capture other species.

Discards

There is no information available in what concerns discards.

Fuel consumption

Regarding fuel consumption, data is only available for the vessels with diesel engines since this type of fuel is subsidized (Table 10).

Table 10. Fuel consumption (m^3). Source DGPA.

	Consumption	2001	2002	2003	2004	2005	2006	2007
Local vessels	Total	2859	2511	2778	2377	2476	2726	3089
	Mean per trip	0.97	0.67	0.75	0.65	0.64	1.03	0.94
Coastal vessels	Total	4781	4488	4771	5026	4702	4033	4165
	Mean per trip	1.43	1.20	1.18	1.13	1.21	1.51	1.26

The average fuel consumed in each trip, presented in Table 10 reports a maximum in 2006 for both local and coastal vessels. It is possible to conclude that there are no significant changes in these values on the other years, varying between 0,64 m^3 and 1,03 m^3 for local vessels and between 1,13 m^3 and 1,51 m^3 for coastal vessels.

Quantities of fish caught

Table 11 summarizes the annual amounts landed of each species, in tonnes. After 2004, a significant decrease in the total amount of fish caught is verified (this tendency is mainly supported by the decrease on surf clam catches).

The average quantity of fish caught per local and coastal trip are presented in Figures 12 and 13 respectively.

Table 11. Annual quantities caught (in tonnes).

	2001	2002	2003	2004	2005	2006	2007	2008
Surf Clam	139	204	1699	1670	591	132	250	174
Donax Clam	345	196	251	391	397	280	310	243
Razor Clam	75	15	0	34	12	0.4	0	0
Striped Venus	33	622	514	149	568	417	187	61
Total	592	1038	2464	2244	1569	830	746	478

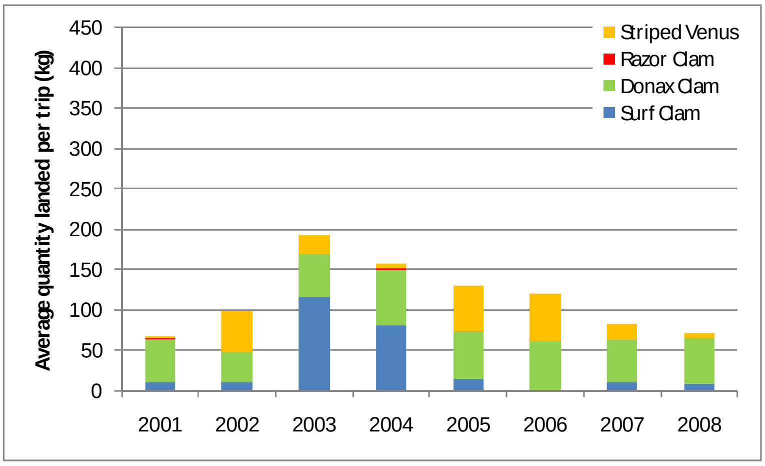

Figure 12. Average quantity of fish landed per local vessel trip, with target species differentiation (kg).

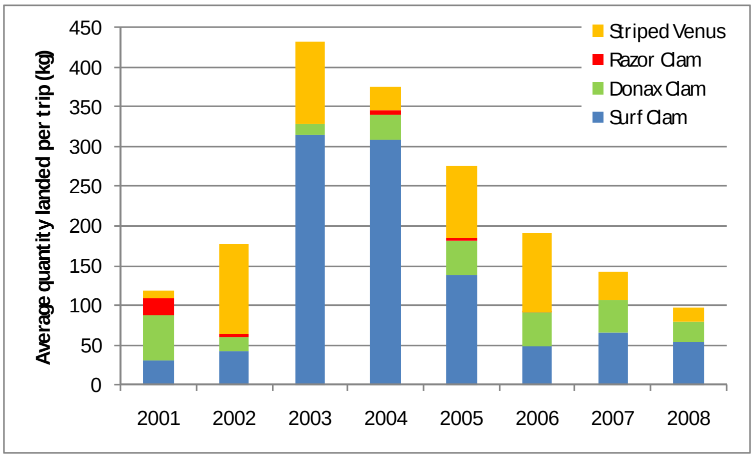

Figure 13. Average quantity of fish landed per coastal vessel trip, with target species differentiation (kg).

Despite the sharp decrease on the quantities landed by the local fleet, the revenue obtained doesn't follow the same tendency (see Figure 8). This mainly due to the reduction of surf clam captures. The quantity landed by coastal vessels also presents a significant declining tendency after 2003, which is similar to the tendency in revenue for this fleet (see Figure 9).

Between 2003 and 2008, and considering both local and coastal fleets, the average quantity of fish landed per trip decreased about 74%. One effect that may explain the fall in the quantities landed is the decline of biological stock levels. Consequently, the effort required to perform a profitable fishing trip with dredges increased. This scenery may encourage fishermen to reduce the number of fishing trips targeted to bivalve clams and redirect efforts to other species.

4.3. State

Changes on target species abundance

The abundance of target species is measured by a biomass indicator (grammes per 5 minutes of tow), and is presented in Table 12. The indicator of percentual change is measured in relation to the year immediately precedent of the year analyzed. The biological stock of surf clam presents a decreasing tendency between 2004 and 2006, showing a small recovering in 2007. Donax clam presents a stable biological stock, however a maximum is noticed in 2003. Relatively to razor clam a sharp decreasing is noticed since 2004, and the biological stock for 2007 is very low (9 g/5 min tow) in comparison with the remaining years of analysis. Striped venus presents a major decline in 2004, which is the year with the lowest biological stock for this specie. Although striped venus recovered in 2005, the tendency verified in 2006 and 2007 is of diminishing.

Table 12. Abundance of target species in g/5 min tow dredging.

	2002	2003	2004	2005	2006	2007
Surf Clam	987	857	666	170	73	113
Percentual change	-	-13%	-22%	-75%	-57%	54%
Donax Clam	34	91	48	51	42	42
Percentual change	-	167%	-47%	5%	-16%	-1%
Razor Clam	51	45	76	42	10	9
Percentual change	-	-12%	70%	-45%	-76%	-7%
Striped Venus	280	209	78	361	291	113
Percentual change	-	-25%	-63%	366%	-20%	-61%
Total (for all species)	1352	1203	869	623	415	276
Percentual change	-	-11%	-28%	-28%	-33%	-33%

The trend in the evolution of biological stock over the years, based on the information reported in Table 12, is shown in Figure 14.

Characterization of the ecosystem

There is no available information on species recruitment or spawning stock biomass. However, we expect to be able to obtain other relevant data, including the medium size of the target species.

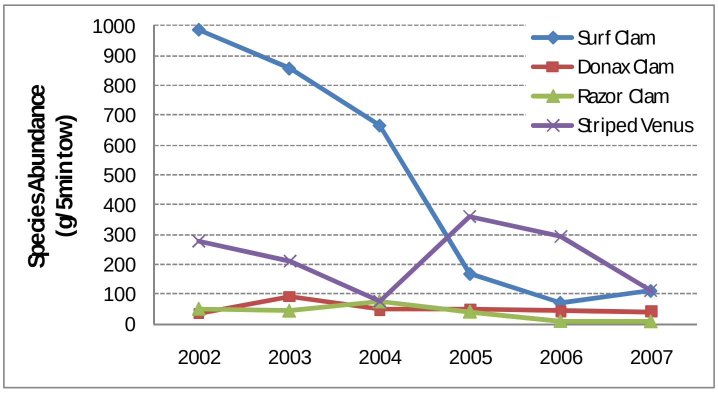

Figure 14. Evolution of biological stock levels (g/5min tow).

4.4. Impact

Biotoxins levels

In the last 10 years, dredge fisheries were interdicted only in few occasions due high levels of biotoxins.

Main changes in the ecosystem

The study by Gaspar et al. (2003) concluded that the impact on the sediment caused by GD and TD is expected to be similar, although the impact on macrofauna may be different. This study states that gear type has effect on the percentage of damaged and dead individuals left on the dredge track. It was concluded that both GD and TD cause no significant damage on the uncaught clams (uncaught clams are the ones that entered the dredge but passed through the net bag or grid during the fisheries operation) and that the damage on uncaught individuals was directly related to gear efficiency (the catching efficiency of the GD is 98% and of the TD is 90%). The severity of accumulated fishing effects also depends on the scale and intensity of the activity.

Rufino et al. (2008) performed a study with main focus on bivalve diversity in the south coast of Portugal, between Quarteira and VRSA. This study was able to conclude that bivalve diversity increased from coarser to finer grain sizes although it was not possible to establish a clear trend. It is known that sediment type can influence metabolic activity and burrowing time of bivalves (Huz et al., 2002). Rufino et al. (2008) also states that richness and diversity of bivalve increases steadily from 3.5 to 16 m depth. Wave action and air exposure are factors that make a harsher environment for bivalve as state in Dexter (1992).

Regarding the influence of seasonality on bivalve diversity, Rufino et al. (2008) observed a large fluctuation. There were springs with greater diversity than autumns, from 2000 and 2005, but the inverse situation was observed in 2001, 2002 and 2006. Rufino et al. (2008) also concluded that the coastal area between Faro and VRSA was richer and with more diversity than the area between Cape São Vicente and Faro. This may be attributed to factors such as longitudinal gradient and greater habitat heterogeneity.

Chícaro et al. (2002) studied the changes in community structure as a response to fishing disturbance. This research compared two areas of the south coast of Portugal: Vilamoura, a continuously fished area at the time of the research, and Lagos, that was a non-fished area. They concluded that macrofauna abundance and diversity were higher in the non-fished area which may reflect the dredge impact on macrofauna. The species that only live on the non-fished area here identified: larger animals, such as bivalves with more than 60mm, and fragile species. Thus, dredge fishing impact is described through the dominance of opportunistic short-lived species and also through the decrease of long-lived sessile species.

Rufino et al. (2008) states that fisheries impact on benthic communities increase with depth. The shallow communities are more resilient to fishing and natural disturbance (shallow communities are normally exposed to wave action and air, thus they are more resistant). This study also states that shallow communities' resilience could explain the impossibility of defining impacts on bivalve diversity for local fisheries. Constantino et al. (2009) developed a study where two areas (close to Faro harbor), with different depth (6 and 18 m), were analysed to understand whether impacts and recovery of benthic environment are related to depth. For both areas they obtained very high recovery rates (shallower areas had a faster recovery). No clear impacts were detectable for the shallower areas, but for the 18 m depth area it was observed a significant decrease on all biological variables after dredging. There are no solid conclusions regarding to recovery time of the exploited environments (Constantino et al. 2009).

4.5. Response

National legislation

The Portuguese legislation began to define limits of daily capture for each target species and per vessels type from 2001 onwards (DR Portaria no. 543-D/2001). These limits are summarized in Table 13.

Table 13. Limits of daily captures per species and per vessels (kg).

		2001	2002	2003	2004	2005
Per vessel	Until 1,8 GT	110	75[1]	75[2]	n.a.	145
	Between 1,8 and 2,8 GT	165	110[1]	110[2]	n.a.	215
	Between 2,8 and 3,8 GT	210	140[1]	140[2]	n.a.	275
	More than 3,8 GT	300	200[1]	200[2]	n.a.	390
Per specie	Surf Clam	200	200	400	n.a.	225
	Donax Clam	220	150	150	n.a.	150
	Razor Clam	100	50	50	n.a.	30
	Striped Venus	100	200	200	n.a.	250

[1] These limits shall be increased by 50% if more than half of the catch is of surf clam (*Spisula Solida*).
[2] These limits shall be increased by 200% if more than half of the catch is of surf clam (*Spisula Solida*).

The incentives given by Portuguese legislation, justifies the sharp increase in surf clam catches compared with other target species in 2003 and 2004 (see Table 11).

It is defined by legislation an interdiction period between May 1 and June 15 (DR Portaria no. 419-B/2001). Extraordinary interdictions are imposed when episode of biotoxins occur. In addition, if the biological stock of species is very low, the fisheries can also be interdicted for that species (e.g., this occurred for two months, in March and April 2006, for all the target species of dredge fisheries in the south coast of Portugal, see DR Portaria no. 208-A,/2006). Fisheries are allowed six days per week (between Sunday and Friday) and each vessel can make a single trip per day.

The GD is the most recent dredge, applied after 1999, and since then the majority of the Portuguese south dredge fleet uses it (Gaspar et al. 2003). At the moment, the TD is only used for targeting razor clams.

Legislation for both GD and TD (DR Portaria no. 1102-E/2000) establishes that the maximum width of the dredge mouth is 1 meter and the interval among teeth should be always larger than 15 mm. The maximum length of the teeth is determined according to the target species (DR Portaria no. 1423-B/2003), as shown in Table 14.

Table 14. Maximum length of the teeth.

Species	Lenght of the teeth
Surf clam	200 mm
Donax clam	200 mm
Razor clam	550 mm
Striped venus	200 mm

Legislation for the GD (DR Portaria no. 1423-B/2003) specifically establishes that grid bars must be metallic and parallel, disposed in the direction of the length. The bars can have a maximum length of 125 cm, a maximum height of 50 cm and a maximum width of 80 cm. The distance among the bars is determined according to the target species, as indicated in Table 15.

Table 15. Distance among bars for GD.

Species	Distance among bars
Surf clam	≥ 12 mm ± 0,5mm
Donax clam	≥ 8 mm ± 0,5mm
Razor clam	≥ 9 mm ± 0,5mm
Striped venus	≥ 12 mm ± 0,5mm

Although TD is essentially used for targeting razor clams, legislation (DR Portaria no. 1423-B/2003) specifies for TD the minimum size of the mesh of the net bag for all the target species (Table 16).

Table 16. Minimum size of mesh for TD sack.

Species	Minimum size of the mesh
Surf clam	≥ 30 mm
Donax clam	≥ 30 mm
Razor clam	≥ 30 mm
Striped venus	≥ 30 mm

Enforcement and compliance

We could not yet obtain information concerning fines for illegal fisheries. We also hope to obtain information on fleet surveillance.

Budget invested / subsidies to the fishing activity

The European funds are transferred for the national authority. These funds are distributed competitively, to which the fishermen can apply their vessels for maintenance purposes. We hope to obtain the values of subsidies attributed to dredge vessels from Algarve.

Educational Programs

There are mandatory courses of professional formation for fishermen. They were accomplished 2679 courses in 2008 and it is foresee that 6376 courses will be performed till the end of 2009, for the entire Portuguese fish sector (DGPA, 2008). However information doesn't exist on how many dredge fishermen already frequented it.

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