Evolution of fishing capacity in a Mediterranean fishery in the first two decades of the 21st c.

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ABSTRACT

The viability of Mediterranean marine fisheries is increasingly under threat due to the low biological productivity of overexploited stocks, low economic performance of the fishing units, and offer of unattractive jobs, among other. This has resulted in a decrease of 30% in the number of fishing units active in European Union Mediterranean fisheries over the period 1995–2016. The detailed causes for this decline are investigated here based on an analysis of the entry/exit dynamics of the entire fleet having operated in Catalonia (NW Mediterranean) as a case study. The decision made by owner-operators, in terms of entering, remaining or exiting the fishery, of 1195 fishing units in the period 2000–2018 was analysed. The results show that fishing vessels have a high probability (95%) of remaining in the fishery and very low probability of entering (<1%). The exit rate was estimated at 4.5% annually, resulting in a reduction of 42% of the fleet size over the study period, from 894 active vessels at the beginning of 2000 to 518 at the end of 2018. A statistical analysis of the factors conditioning the entry/exit dynamics by means of a multinomial choice model showed that the age of the vessel, the value of landings, the amount of decommission aid offered by the local fisheries management administration and a proxy variable for fuel costs were significant explanatory variables. The study concludes that the fleet is likely to continue to shrink, without immediate stock or ecosystem conservation benefits, unless bold steps to reformulate fisheries management in the Mediterranean are taken.

1. Introduction

Classical fisheries bioeconomic models show that, under an open access regime, aggregate fishing effort will tend to overshoot the maximum sustainable yield (MSY) that the fishery can produce and reach a bioeconomic equilibrium (Clark, 1990; Walters and Martell, 2004). Although in practice it is difficult to estimate the MSY level and the point of bioeconomic equilibrium, in input-regulated fisheries such as Mediterranean fisheries where heavy overfishing is diagnosed (Colloca et al., 2013), managers have sought to implement effort-reducing policies in order to better align fishing capacity with the resource base, with questionable success (Cardinale et al., 2017). The failure of fisheries management in the Mediterranean has negative consequences on local economies because these fisheries are producing lower rents than what would be possible at levels of exploitation compatible with MSY (Froese et al., 2016) and also on marine ecosystems (among other: negative impacts on marine food webs (Libralato et al., 2008), marine mammals, sharks or seabirds (Ferretti et al., 2008; Maynou et al., 2011), and the seafloor (de Juan et al., 2007)).

During the second half of the 20th c. The size and fishing power of Mediterranean fishing fleets grew progressively and reached maximum values at the end of the 1980s or mid 1990s, depending on the area (Franquesa et al., 2008), often encouraged by public administrations and in the absence of rigorous scientific advice, resulting in the expansion of fisheries exploitation and the depletion of marine living resources (Coll et al., 2014; Colloca et al., 2013). Landings increased continuously from the early 1970s to the early 1990s (Colloca et al., 2017). The largest catches were obtained also around the same period, peaking at ca. 1.1 Mt in 1994, and have been declining ever since, to ca. 0.8 Mt in 2016 (SOMFI, 2018). Bas et al. (1985) examining FAO data for the 1960s and 1970s already noted the role of technological progress and fleet modernization in the decline of Mediterranean fishery resources. Although excessive fishing pressure is often cited as the main cause for the decline of fishery resources, other impacts such as sea warming, pollution or invasive species are contributing to reduce the resilience of already overfished stocks (Colloca et al., 2017). Mediterranean fisheries suffer from low economic performance (Colloca et al., 2013; Sabatella et al., 2017; DG MARE, 2017) due to a wide range of...
factors, including chronically overexploited stocks (Vasilakopoulos et al., 2014), low competitiveness against seafood imports or aquaculture products (Guillen and Maynou, 2015; DG MARE, 2017), high production costs (particularly, fuel costs: Cheillari et al., 2013; Guillen and Maynou, 2016), or low intergenerational turnover, among other. For instance, Sabatella et al. (2017) showed that the economic performance of different fleets in Italian waters had been deteriorating in the period 2004–2015 and the weak recovery in the last three years of their study (due to exceptional low fuel prices and growth in fish biomass) was negatively affected by misdirected fisheries management actions. The negative trends in the economic indicators were naturally accompanied by a strong decrease of capacity of the fishing fleets. Similarly, Guillen and Maynou (2016) showed that the low economic efficiency of fishing fleets in Catalonia, coupled with the low biological productivity of overexploited fish stocks, helped explain the large reduction in the number of vessels at sea (activity) and number of vessels (capacity) in this fishery. The results of recent fish stock assessments for the target species in GSA 61 show that the stock biomass of four of the main 7 stocks is low or declining (European hake, red mullet, Norway lobster and sardine), with the other three (deep-water rose shrimp, blue and red shrimp and European anchovy) stable or increasing (STECF, 2017, 2019). Additionally, all 7 stocks are overexploited, with current ratios of fishing mortality to fishing mortality at MSY between 2 and 5 (STECF, 2017, 2019). The low economic performance reported in these case study fisheries can probably be extrapolated to other areas of the Mediterranean sea (Sabatella et al., 2017; Sánchez-Lizaso et al., 2020). The decrease in the number of fishing units can be estimated at 30% for EU Mediterranean member states, from ca. 51 000 in 1995 to 36 000 in 2016 (combining data from Franquesa et al., 2008 and SOMFI, 2018). The reduction of the fleet size has been facilitated, as elsewhere in European fisheries, by public funds in the form of scrapping or decommission aids channelled through specific instruments of the Common Fisheries Policy (Penas Lado, 2016, Chapter 5).

Although the overall reasons for the attrition of the Mediterranean fishing fleet are clear, the short term dynamics of the fleet, in terms of entry or exit into the fishery, have been little studied. The reduction of ca. 15 000 vessels over a 20-year period mentioned above correspond to the same amount of individual decisions for these owner-operated economic units. Studies of entry/exit dynamics in other areas of the world have shown that vessel age, realized or expected income and the existence of scrapping funds are often factors helping vessel owners decide to abandon the activity and decommission the vessel (Tidd et al., 2011; Cordon Lagares and Garcia Ordez, 2015; Feenstra et al., 2019). However, the existence of social considerations, such as tradition or pride, conditioning the entry/exit dynamics have also been documented (Crosson, 2015; Pascoe et al., 2015).

The objective of this work was to understand the reasons explaining why vessels owners chose to remain, enter or exit marine fisheries in Catalonia over the period 2000–2018 based on the statistical analysis of the dynamics of the entire fleet.

2. Material and methods

2.1. Data

The marine fisheries fleet operating from the fishing ports in the Autonomous Region of Catalonia (Spain, NW Mediterranean) operates under a fisheries management scheme that allows for the detailed daily monitoring of the fleet’s activity. The fishing units can operate for a maximum of 12 h/day during weekdays only. Fishing capacity is limited by restricting access to marine commercial fisheries to licensed operators. Other input control measures include prescriptions on the technical specifications of fishing gear, following the European Union Regulation 1967/2006 (Annex III). Output management measures, such as catch limits, are not implemented (see Bellido et al., 2020 for details on Mediterranean fisheries management). Fishing vessels sell the product through the distribution channel in each fishing port at the daily auction. The resulting sale bids are centralized by the local fisheries management agency2 in a large database for reporting to the national and European fisheries agencies. Access to the database was granted for this study, at the appropriate aggregation scale and with the name of the vessel dully anonymized to guarantee data confidentiality. This type of data permits to examine the evolution of quantities of interest at fine scale, contrary to other large data sets, such as the European Commission Data Call Framework (Dörner et al., 2018) that produces fisheries data aggregated at the level of geographical subareas and fleet segments and preclude the assignment of specific covariates to each fishing unit.

The data set contained information on the daily activity of the 1 195 fishing units having operated in the area from January 1, 2000 to December 31, 2018 (19 complete years). The fishing units are officially classified in five types, according to the license held: otter bottom trawlers (corresponding to fleet segment OTB in classification of the European Data Collection Framework), purse seiners (PS), small scale coastal fishing (coded SSCF here, but corresponding to a large variety of fishing units using set nets and traps), surface longlines (LLD) and bottom longlines (LLS). The technical characteristics of the fleet are summarized in Table 1. Note that due to the low number of fishing units in LLD and LLS these were not included in the statistical analysis.

The raw data was re-organized in a database for this study. This database contained information on technical characteristics for each vessel (license type, year of construction, tonnage (GT), length-overall, engine power (kW)), as well as year of entry to the fishery and year of exit from the fishery. Because the objective of the analysis was to understand the reasons explaining why vessels owners remain, enter or exit the fishery, a set of 10 possible explanatory variables was built from the original data set and ancillary data (Table 2): vessel age (years), gross tonnage (GT), individual vessel annual income (€), annual income of each vessel’s fleet segment (€), individual vessel annual landings (t), annual landings of each vessel’s fleet segment (t), number of vessels in the fleet segment, fuel price * vessel’s engine power (kW), individual vessel possible decommission grant (€). To help justify the reasons for selecting these variables, it is important to recall that Mediterranean fisheries are mostly practiced by owner-operators who often have fishing as the only economic activity. The decision of remaining in the fishery or exiting the fishery is purely a short term decision based on the immediate utility of the decision, not so much the tactical decision of a company or cooperative owning a large fleet of industrial vessels. Entry into the fishery was observed very infrequently in the study period and it is assumed to be related to vessel substitution.

Vessel age as explanatory variable was included to examine the assumption that older vessels may have higher rates of exit, because of increased maintenance costs or decreased technical efficiency with time. Annual landings in volume (t) or value (thousand Euro) are used to model the effect of higher production in making the decision, i.e. more productive units are likely to remain in the fishery. The average annual landings (also in volume and value) for the previous two years was also included in the model to see to what extent the short term history of productivity may influence the choice. The average annual landings (in volume and value) of the other units of the fleet segment of each vessel were included in the analysis to analyse the possible role of the perception of under-performing or over-performing relative to the rest can have in the decision taken, because vessel owners expect their vessel

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1 Geographical SubAreas (GSA) are defined by the General Fisheries Commission for the Mediterranean, for fisheries management purposes (http://www.fao.org/gfcm/data/maps/gsa). The study area covers half of the geographical extension and fishing units of GSA 06 (Northern Spain).

2 Directorate General for Fisheries and Maritime Affairs of the Autonomous Government of Catalonia. http://agricultura.gencat.cat/ca/ambits/pesca/.
(nominal or categorical variable) was used to examine whether certain
to perform at least as well as the rest of the fleet segment. The number of
vessels (fleet size) of each fleet segment was used to evaluate whether
leaving the fishery ("exit") or commissioning a new fishing unit to the fishery ("enter").

that entitles vessel to receive a premium for decommission, corre-
sponding to the EU capacity limitation instruments IFOP and EFF (Official Journal of the Autonomous Community of Catalonia, corre-
sponding to the dates: November 08, 2006, May 29, 2009, June 28, 2010, November 14, 2011, November 06, 2012, October 18, 2013, August 08, 2014, July 29, 2015, November 22, 2017). The amount of
the decommission grant is directly related to the vessel’s size measured in
GT. Note that because GT is highly correlated with length-overall in the
study fleets, vessel length was not included in the models as explanatory
variable.

### Table 2
Candidate explanatory variables for the entry/remain/exit model. Fleet segment
was used as a categorical variable, in addition to the nine quantitative variables
listed in the table. The values given are average and extremes (minimum – maximum).

| Fleet segment (Category) | OTB | PS | SSCF |
|------------------------|-----|----|------|
| Vessel age (YR)        | 35.47 (2-113) | 28.79 (6-77) | 35.08 (22-45) |
| Tonnage (GT)           | 54.64 | 37.43 | 4.10 |
| (4.64-178.49)          | (4.01-80.51) | (0.32-24.68) |
| Vessel annual income (K€) | 210.4 | 280.5 | 41.9 |
| (126.6-273.8)          | (176.4-365.9) | (10.7-59.6) |
| Fleet segment annual income (K€) | 210.2 | 278.5 | 41.9 |
| (189.6-229.5)          | (240.0-298.3) | (38.8-45.1) |
| Vessel annual landings (T) | 39.37 | 177.5 | 7.0 |
| (219.9-50.76)          | (117.3-234.1) | (1.5-91.1) |
| Fleet segment annual landings (T) | 39.37 | 176.6 | 7.0 |
| (35.1-43.4)          | (153.7-206.0) | (6.3-7.9) |
| Fleet segment number of vessels | 269 (245-321) | 83 (77-98) | 324 (288-389) |
| Fuel price * KW/1000   | 126.5 | 126.3 | 24.7 |
| (42.9-191.8)          | (87.5-163.8) | (12.2-33.4) |
| Vessel possible decommission grant (K€) | 303.7 | 240.6 | 49.0 |
| (186.9-414.4)        | (193.7-291.8) | (21.0-67.0) |

The value of commercial fishing to an economic agent (here, a fishing vessel) can be summarized by a utility function, which is a model of the different alternatives face by the agent, such as to continue in the fishery, invest in different fishing gear, change the target species, or stop fishing altogether. These and many other alternatives are ranked by each economic agent based on perceived or realized income, costs or even non-economic considerations, such as family tradition (see Crosson, 2015 or Pascoe et al., 2015 for the role of subjective factors). The relative utility of commercial fishing was analysed for the three main fleets segments in Catalonia (otter bottom trawl, purse seine and small scale coastal fishing), as an example of a data-rich Mediterranean fishery to understand the main objective drivers explaining the evolution of Mediterranean fishing fleets. A random utility model was applied to
to the decision made by each vessel every year in terms of remaining in the
fishery, exiting or entering. This type of models assume that the
decision taken by the vessel owner (remain, exit or enter) maximizes
his/her utility. The model allows to examine statistically which attri-
butes of the decision, or explanatory variables, help explain the decision
taken. Formally, based on the formulation of a multinomial logit model on a set of unordered choices (McFadden, 1981), the utility of each
decision (choice) for each vessel is:

$$ U_i = \beta_j w_i + \epsilon_i, $$

where $U_i$ is the utility to vessel owner $i$ of choice $j$, $w_i$ are the attributes of
vessel $i$ (explanatory variables) and $\beta_j$ are the coefficients determined by
the model. The probability that vessel $i$ decides to remain ($j = 1$), exit ($j = 2$) or enter ($j = 3$) the fishery is given by:

$$ P(j_i = j) = \frac{e^{\beta_j w_i}}{\sum_{j=1}^{3} e^{\beta_j w_i}}. $$

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3 http://ec.europa.eu/energy/en/data-analysis/weekly-oil-bulletin.
where \( y_i \) is the actual decision taken by fishing unit \( i \) from set available (\( J = 3 \)). Model estimation was carried out using the function `multinom` of the `nnet` R library (Ripley and Venables, 2016). The model building process started by fitting a multinomial model with each of the single candidate explanatory variables. The model with the lowest AIC was retained and bivariate multinomial models were then compared against AIC. The forward model selection scheme was carried forward while the decrease in AIC was larger than 10 units (Burnham and Anderson, 2002). To examine the partial effect of each significant explanatory variable, the selected model was used to predict the probability of entering or exiting (relative to remaining) using a range of values for the explanatory variable and keeping the other significant variables at the average value. The standard error of the coefficient of the explanatory variable was used to calculate 95% confidence intervals of the partial effects.

3. Results

Table 1 shows that, on average across the fleets, 94.56% of the decisions taken were to remain in the fishery. Only two fleet segments, bottom trawl (OTB) and purse seine (PS), had percentages of the remain decision higher than average. These two fleet segments are composed of semi-industrial fishing vessels, with relatively large size, landings and income (Table 2). The proportion of exit decisions taken was 4.55% (Table 1), with values lower than average only for the bottom trawl fleet segment. The proportion of exit was highest for set longliners (LLS), whose fleet size has decreased by almost 2/3 over the study period. The enter decision was on average less than 1%, with values higher than average in bottom trawl (OTB) and surface longliners (LLD). These two fleet segments were the segments with lower rates of decrease in the number of vessels from 2000 to 2018 (30 and 36%, respectively).

The multinomial choice model was applied only to the main three fleet segments, bottom trawl (OTB), purse seine (PS) and small-scale coastal fishing (SSCF). The results are shown in Table 3. The model selection process retained a model with four terms (vessel age, vessel income, decommission premium and fuel consumption) as the best model, with AIC = 5089.25 and deviance explained 44.01%. The negative sign of the coefficients of the selected model, relative to the choice remain, show that older units are more likely to exit than to remain, while the units actually entering the fishery are of lower age than the units remaining, as could be expected (Table 4). The coefficient of the second explanatory variable, annual income of the vessel, is negative both for vessels exiting and entering the fishery. In the case of the former, the result is easily interpreted as vessels with lower income are more likely to exit than to remain. In the case of the negative coefficient for vessels entering, it can be interpreted considering that the income corresponds to the year when the decision to enter is taken and the vessel will have worked less than the total number of days available or that, being its first year in activity, was less performing than the vessels choosing to remain. In the case of the decommission premium, both coefficients were positive, although the coefficient for vessels entering the fishery had a value almost double than those exiting. The possibility of high decommission premium is a statistically significant incentive to quit the fishery, but it has an even higher effect to enter the fishery, possibly because of a perceived link by new operators between the decommission price and the decrease of competing vessels. The last significant explanatory variable, a proxy for fuel consumption, shows that vessels entering the fishery have lower fuel * kW, while those exiting the fishery would have higher values.

Note that variables related to the value or volume of landings of the previous 2 years or the variable related to landings of the entire fleet segment were not statistically significant. This suggests that the decisions are taken without regard to the “memory” of performance of the vessel or other vessels in the fleet segment. Apparently, the prospective entrants do not take into account, or perhaps they don’t know accurately, the average income of their future peers. Note also that the differences in remain/entry/exit by fleet segment shown in Table 1 are not captured by the multinomial model, likely because the differences are small.

The results of the multinomial model are also shown in Fig. 1 as plots of the partial effect of each explanatory variable, controlling for the other variables in the model. The probability of exiting the fishery increased linearly for vessels 10–50 years old, but decreased abruptly for vessels less than 10 years of age (Fig. 1A). Likewise, the probability of entering the fishery was higher for new vessels, as it is to be expected. Fig. 1B shows that the probability of exiting or entering the fishery increased non-linearly with decreasing income in the year when the decision was taken. The probability of entering or exiting was positively and non-linearly related with the possible decommission price offered (Fig. 1C). Finally, the proxy for fuel costs in Fig. 1D shows that vessels with high costs tend to exit the fishery, but are less likely to enter the fishery.

4. Discussion

Mediterranean marine fisheries have been undergoing a prolonged crisis of productivity in the last 2–3 decades (Colloca et al., 2017; Vasilakopoulos et al., 2014) due to a variety of internal and external reasons. Among the internal reasons, the chronic state of overexploitation of the target resources is well known (SOMFI, 2018). Other internal reasons such as lack of investment or low intergenerational renewal rates are often adduced, albeit research results are not abundant (Gonzalvo et al., 2015). The competition of the product of Mediterranean marine fisheries with imports of seafood from other areas or origins (wild caught/aquaculture), or increasing costs of production are additional, external factors that could help explain the low economic performance of the fisheries (Guillén and Maynou, 2016; Sabatella et al., 2017).

Table 4

| enter  | exit |
|--------|------|
| Intercept | 1.335 | -2.871 |
| age | -0.290 | 6.94 x 10^-4 |
| income.own | -1.70 x 10^-5 | -2.14 x 10^-5 |
| premium | 9.58 x 10^-6 | 5.34 x 10^-6 |
| fuel*kW | -2.66 x 10^-4 | 9.18 x 10^-4 |

Table 3

| candidate model | term 1 | term 2 | term 3 | term 4 | AIC | residual deviance | explained deviance |
|----------------|--------|--------|--------|--------|-----|------------------|-------------------|
| 1               | age    | income.own | premium | –      | 5149.373 | 6676.46 | 42.04% |
| 2               | age    | income.own | premium | GT     | 5138.214 | 6622.73 | 42.50% |
| 3               | age    | income.own | premium | catch.own | 5134.976 | 6611.25 | 42.60% |
| 4               | age    | income.own | premium | fuel*kW | 5089.250 | 6449.17 | 44.01% |
| 5               | age    | income.own | premium | catch.fleet | 5100.288 | 6488.30 | 43.67% |
| 6               | age    | income.own | premium | income.fleet | 5092.209 | 6459.66 | 43.92% |
| 7               | age    | income.own | premium | NV.fleet | 5126.707 | 6581.94 | 42.86% |
| 8               | age    | income.own | premium | fleet segment | 5109.646 | 6507.29 | 43.51% |
combination of these factors resulted in decreasing number of vessels in all fleet segments, from 30 to 64% in this study, depending on the fleet. The analysis of the decisions taken by 1195 vessels having operated in Catalonia marine fisheries over the period 2000–2018 showed that overall the units have a high probability of remaining in the fishery (decision remain was taken ca. 95% of the times). The high probability of remaining in the fishery can be simply explained because this is the main economic activity and, often only source of income, of these mostly owner operated fishing vessels. Entering rates were very low, typically lower than 1% on average for all segments. This low rate of entry is due to legal restrictions (management based on limited effort, whereby a new vessel in the fishery is only allowed in exchange of an older vessel) and also low economic expectative of the activity. Exit rate was estimated at 4.5% annually on average across fleets and has resulted in a decrease of 42% in the number of vessels operating in the area, from 894 active vessels in 2000 to 518 in 2018. The results showed that age of the vessel, annual value of landings, decommission funds and high energy costs are the factors that explain the entry/exit dynamics in this fishery. Cordón Lagares and García Ordaz (2015) also found that funds for vessel scrapping and low revenues were important factors explaining the entry/exit dynamics of a purse seine fleet in the Gulf of Cadiz (SW Spain). Income from fishing, but also changes in past income, were reported to be significant in deciding to exit the fishery in a study by Pascoe et al. (2015), in addition to other social considerations, such as continuing a family tradition, which was not tested here. Family tradition, pride or sense of belonging to a specific group with local roots are likely to be important in Mediterranean fisheries entry/exit dynamics and deserve further study. Crosson (2015) showed that these considerations may be as important or more than the value of landings in a range of European fisheries.

Although the factor fleet segment was not significant in the multinomial choice model, the data showed that the bottom trawl segment is the segment with lower exit rates and high enter rates (Table 1), suggesting that this is the fishery segment for which economic expectative is highest. Although the reasons for the relative stability of bottom trawlers warrant a detailed investigation, a likely reason is the specialization of the large units (vessels 18 m LOA or more) of this fleet segment on the lucrative deep-water crustacean fishery. Crustaceans (Norway lobster and Blue and Red shrimp) make 40% of the landings of trawlers larger than 18 m LOA, on average, in recent years, according to official DCF data (https://stecf.jrc.ec.europa.eu/dd/fdi), and their economic incidence is even higher due to their high unit price. Pinello et al. (2018) showed that the fishing units involved in deep-water crustacean trawling in the Straits of Sicily have higher technical and scale efficiencies than coastal trawlers operating on the continental shelf in the same area.

It should be noted that the decrease in vessel numbers is not necessarily accompanied by a decrease in fishing power. Our results show that the units that are more likely to exit are older vessels, with relatively low income and high fuel consumption. Fig. 2A shows how the average capacity (in GT) of individual vessels have increased over the study period for the three fleets, especially during the first decade of the century: The vessels remaining in the fishery are larger and presumably have higher fishing power. Similarly, Fremstra et al. (2019) documented that vessels exiting the Australian rock lobster fishery had substantially lower catchability and that the overall catchability of the remaining units increased over the study period. The rate of entry of new vessels is very

![Fig. 1. Partial effect of each significant explanatory variable, relative to the choice remain, conditioned on the average values of the other variables in the model (Table 2). A: age of the vessel (years), B: income of the vessel (€), C: decommission premium (€), D: fuel price * engine power as indicator of costs (€/l * kW, in thousands). The 95% confidence interval (grey shading) was calculated from the standard error of the coefficients.](image-url)
low in the Mediterranean (<1% in our case) but it is likely that the units that enter the fishery have higher fishing power, overall contributing to increase fishing power, as has been shown in specific case studies (Damasas et al., 2014) and for world fleets (“technological creep”, Palomares and Pauly, 2019). The results also show that decommission premium has a higher effect on entering the fishery than on exiting, suggesting that, assuming that new units have higher fishing power than decommissioned units, the subsidy may not work properly as intended, i.e. to promote a decrease in fishing mortality. Assuming that fishing mortality (F) is linearly related to fishing effort (E) through a constant of catchability, F = q · E, and applying a “technological creep” value of 2% annually to equation (2) in Palomares and Pauly (2019) would yield a 46% increase in F over the 19-year study period. That is, the strong observed decrease in fleet size (42%, Table 1), would have practically no effect on the reduction of fishing mortality, which is one of the management objectives of the Common Fisheries Policy (Penas Lado, 2016). Recent stock assessments for GSA 06, to which the study area belongs, show that fishing mortality has fluctuated around a mean value or even increased in the last 10–15 years that cover the assessment period of the different species, pointing to the weak link between fishing effort and fishing mortality (STECF, 2017, 2019).

Fig. 2B shows that the proxy for fuel costs used here (fuel price · kW) has increased over the study period by ca. 50%, with fluctuations due to changes of fuel price in the world markets. Larger fuel costs have been shown in this study to influence the decision to exit the fishery, but in addition vessels interested in remaining in the fishery can take steps to counter increasing production costs, by changing fishing practices or reducing fishing time, as observed by Abernethy et al. (2010) or Cheilari et al. (2013). Guillon and Maynou (2016) found that a part of the active vessels in the Catalonia fishery had undergone technical improvements or energy-saving modifications. Fig. 2C show that average landings per vessel are not increasing for bottom trawlers of small scale coastal fleets, despite the reduction in fleet numbers or the increasing capacity of individual vessels.

Concentration of fishing capacity in a reduced number of fishing units is probably a natural evolution of fishing fleets when the resource base is highly overexploited as in the Mediterranean sea. However, social and demographic factors, which have been little studied, could also be important in explaining the strong decrease in the number of vessels, especially the low attractiveness of employment at sea and lack of renewal of human capital (pers. obs.), resulting in what Johnson and Mazur (2018) call “graying of the fleet” in a study of the otherwise profitable New England lobster fishery.

The results of this analysis and those of other authors (Cardinale et al., 2017; Vasilakopoulos et al., 2014) suggest that reducing the size of the fleet (capacity reduction) or attempts at limiting fishing effort have been and will continue to be inefficient in managing Mediterranean fisheries. The results of stock assessment, using different data sets and different methodologies, repeatedly point to excessive fishing mortality applied to the majority (80–90% of assessed stocks) of Mediterranean fish stocks (Colloca et al., 2013; Froese et al., 2016; STECF, 2017, 2019).

The Mediterranean fisheries management model should move to i) limit the fishing mortality of juvenile fish (improve selectivity and/or protect nursery areas), ii) control the quantity of removals by setting TACs limits, and iii) set up an efficient monitoring, control and enforcement programme. The socio-economic effects of stronger management are anticipated to be negative in the short term (Froese et al., 2016), but proper attention to commercialization of local, high-quality fisheries products might help offset the costs and put Mediterranean fisheries in a more rational economic context (Bellido et al., 2020; Sánchez-Lizaso et al., 2020).

Declaration of competing interest

I declare no conflicts of interest.

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