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Bioeconomic Analysis of Small Pelagic Fishery in Central Algeria

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Abstract

An integrated fisheries management tool based on a bio-economic model was applied to the small pelagics (sardine) fishery in central Algeria (Mediterranean Sea). The basic bio-economic conditions of the fishery were established and relevant biological and economic indicators were analysed under different management scenarios defined by changes on fleet capacity and daily fishing time. The results show that the fishery is subject to high fishing pressure (1,548 units in 1990 and 4,445 units in 2007) (Maouel, 2003, Medrous, 2013) and current government policies aiming to increase fishing capacity (1,493 new units are projected for 2025) (MPRH, 2008) would likely worsen the conservation status of the resource, without contributing to a significant volume of catches or economic profits. Instead, a reduction of daily fishing time would allow decreasing the fishing mortality, without significantly reducing the total production or profits of the fishery to the current fleet. However, the short-term loss faced by the industry is a major constraint towards the acceptability of this type of management measures by the fishing sector.

Keywords: Bio-economic modelling, small pelagics, integrated management, Mediterranean sea, Algerian coasts.

Introduction

Algeria has a long coastline (1,280 km) and large maritime surface (95,000 km^2) whose fisheries resources were recently estimated at 500,000 t of standing stock and potential catches around 220,000 t annually (MPRH, 2010). Fisheries development was encouraged nationwide at the end of the 1990s, as a source of external investment and employment in the national economy, and as a major contribution to food security of the population. For instance, the contribution of fish to human consumption was 3.02 kg^{-1} person^{-1} yr^{-1} in 1999 and it increased to 5.17 kg^{-1} person^{-1} yr^{-1} in 2007. The number of fisheries related jobs was estimated at 50,102 in 2005 (MPRH, 2006).

In spite of this state-sponsored development, which allowed the Algerian fishing fleet to increase from 2,464 to 4,327 units from 1999 to 2011, fish production only increased from 89,818 to 104,008 tonnes over the same period (MPRH 2013). About 78% of this production consists in small pelagic fishes, particularly sardine (*Sardina pilchardus*) (Maouel, 2003; MPRH, 2010) which represented 82% of the later in 1999 (Chakour, 2005) and 85% in 2011 (Medrous, 2013).

The standing stock of small pelagic fishes was assessed at 187,000 tonnes in the course of an Algerian-Spanish cooperation programme (2003-2004). The stock was constituted mainly by 5 species of commercial interest: sardine (*Sardina pilchardus*), round sardinella (*Sardinella aurita*), anchovy (*Engraulis encrasicolus*), horse mackerel (*Trachurus* spp.) and bogue (*Boops boops*).

Given the socio-economic importance of small pelagic fisheries in Algeria and the decreasing productivity of Mediterranean stocks (Garcia, 1989; Rey *et al.*, 1997) it is necessary to apply technical solutions to the problem of fisheries exploitation that would ensure their sustainability. Among the suite of existing tools to help diagnose the state of exploitation of resources and contribute with solutions to their sustainable exploitation (Chaussade and Guillaume, 2006), bio-economic models are useful because they help address simultaneously the biological and economic dimensions of fisheries (Cochet and Gilly, 1990). In particular, bio-economic simulation models are useful in testing the effect of management strategies (Prellezo *et al.*, 2012) and provide a common ground for discussion among the different actors in fisheries systems (i.e. fisheries

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managers, fishermen and scientists) (Gascuel *et al.*, 1993).

Among the bio-economic simulation models available in the European context (Prellezo *et al.*, 2012), the MEFISTO model (Mediterranean Fisheries Simulation Tools: Lleonart *et al.* (2003) was chosen because it is specifically developed for Mediterranean fisheries. This model incorporates an age-structured biological sub model of fish population dynamics coupled with an individual based economic model of the fishing units, linked by means of a fishing mortality vector. MEFISTO has been applied successfully to other fishery case studies in the Mediterranean (Lleonart *et al.*, 2003; Maynou *et al.*, 2006; Merino *et al.*, 2007, Silvestri and Maynou, 2009) and elsewhere in Brazil (Mattos *et al.*, 2006).

The objectives of this work is to perform a bio-economic analysis of the small pelagic fishery in the coasts of Central Algeria (bays of Bou Ismail and El-Djemila) and to evaluate the biological and economic effects of changes to the current conditions in order to devise policy options that will assist fishery managers to enhance the sustainable exploitation of this resource in Algeria.

Materials and Methods

To achieve the bio-economic simulation analysis, we have chosen a study area which extends to ports of Bouharoun and Khemisti, in the bay of Bou-Ismail (350 km^2) belonging to the *wilaya* of Tipaza, and the port of El-Djemila in the same bay (6 km^2) to the east of Bou-Ismail, belonging to the *wilaya* of Algiers. The three ports comprise at present (2007) a fleet of 72 active purse-seiners arranged in 3 categories of engine power: small (115-320 HP), medium (360-500 HP) and large (600-1500 HP). Fishing is permitted daily at night, from $18{:}^{00}$ to $6{:}^{00}$ h in winter and from $19{:}^{00}$ h to $7{:}^{00}$ h the rest of the year, with fishing trips lasting from $8{:}^{00}$ h to the maximum legal limit of $12{:}^{00}$ h. The average number of working days is 240 yr^{-1}. Net sizes vary from 300 m to 500 m long, depending on vessel size. Sardine is the main resource of this fleet, with a small contribution of other small pelagic species (less than 5% in weight), which for the purpose of our model can be considered accessory species (anchovy, round sardinella, horse mackerel).

The bio-economic model MEFISTO (Mediterranean Fisheries Simulation Tool) is a multispecies, multi fleet and multi gear simulation model developed by LIeonart *et al.* (2003). The purpose of this model is to simulate bio-economic impacts under alternative management scenarios on Mediterranean fisheries. It is a dynamic model consisting of three modules or boxes: a stock box, a market box and a fisherman box. These three modules incorporate stock dynamics along with market and fishermen behaviour and are linked through various functions such as harvesting, fishing mortality, price formation, cost of harvesting, investment, fishing effort and catchability (Prellezo *et al.*, 2012). A detailed description of the MEFISTO model is given in LIeonart *et al.* (2003).

The MEFISTO model comprises a stock box simulates multi-species age-structured stock dynamics, and considers two kinds of species: the main species, whose dynamics are completely known (and modelled through an age-structure biological model), and the secondary species, whose dynamics are not known but their catches are proportionate to one of the main target species. In this study only one main specie is included (sardine); other secondary species (such as anchovy or round sardinella) were assimilated to sardine due to their low importance in the catches (<5%) and the similar prices fetched. At each iteration cycle, the stock box receives data on effort and catchability from the fisherman box, whose product is fishing mortality, and generates catches which are then forwarded to the market box. To carry out the simulations, recruitment R at each time t is required. Due to the absence of information on stock/recruitment relationships of the species under study, the simulations were run with constant recruitment ($R= N_0$).

The market box converts the fish catches of each species generated by the stock model into revenues, via constant price functions and then revenues are imported into the fisherman's box. The revenues of a vessel correspond to the income deriving from the sale of the target species.

Our application of MEFISTO to the Bou Ismail – El Djemila area considers 2005 as the reference year ($t=0$) in the simulations, corresponding with the year where biological data were of the best quality to estimate growth, maturity and mortality parameters. The biological parameterization was obtained from routine biological sampling conducted at the Centre National de la Rechercheet Développement en Pêche et Aquaculture (CNRDPA). The sampling comprises annual series of individual fish length (TL, cm) and weight (g), which were used to compute the biological parameters L_{inf}, K, t_0 by means of standard computer routines to estimate these parameters in fisheries (routine ELEFAN in FISAT II, Gayanilo *et al.*, 2002) (Table 1). The assessment of the sardine population and the fishing mortality of the 3 purse seine fleets (small, medium, large) were carried out with the software VIT, a pseudo-cohort Virtual Population Analysis software (Lleonart and Salat, 1997). Given the lack of historical series of stock and recruitment abundance, the analyses were performed under the assumption of constant recruitment (corresponding to the number of effects in the first cohort).

The economic parameters were estimated from field interviews carried among vessel owners in the study area for the period 1998-2007. The questionnaire asked the basic economic information on a vessel-by-vessel basis: volume of catches, ex-vessel sale price, detailed variable costs, detailed fixed costs, amortization, capital, engine power, length and tonnage, labour costs, duration of day trips and annual fishing days. Based on these questionnaires the economic parameters of the three groups of purse seine with different horse power for 2005 required for the application of the MEFISTO bio-economic model were computed (Table 2).

Based on historical data of catches and prices for the period 1998-2007, the price of sardine was modeled following a power model relating the price of sardine to local catches with negative elasticity (negative elasticity arises when the price of catches decreases with increasing production). Other factors influencing price formation were disregarded because they are not important for this species in the study area (e.g. change in price due to fish size or change in price due to fish imports).

Simulation scenarios were built on the basis of the pluri annual orientation plan for Algerian fisheries, which sought to modernize and develop fisheries at the end of the 1990s. The results of these management scenarios are compared to the base conditions of 2005 by a simulation procedure, projecting forward the simulation conditions for 20 years with 1000 iterations. Only the indicators relevant to this comparison were extracted from the simulation runs and shown here in detail: spawning stock biomass, fishing mortality, number of vessels, income, costs and profits. The simulation scenarios were:

Scenario 1: increase in the number of vessels, from 53 units in 2005 to 72 units in 2008 (14 new entrants in 2006 and 5 in 2007).

Scenario 2: building upon the previous scenario, addition of new 6 units of 1500 HP (in the large engine power class) in 2008.

Scenario 3: increasing the daily effort from a maximum of 12 h $d^{-1}$to 15 h d^{-1}.

Scenario 4: decreasing the daily effort from the current maximum 12 h d^{-1} to 8 h d^{-1}.

Results

The biological assessment of the sardine stock showed that the stock is composed of 7 annual cohorts (Table 1), although the majority of catches correspond to age-2 sardine. Fishing mortality (F_{2005} = 0.64 yr^{-1}) was 63% of total mortality.Annual recruitment contributed to 19% of the population biomass, while 81% corresponded to individual growth.

The simulation results for Scenario 1 (increase from 53 to 72 vessels) show that stock biomass would decrease in the area from 20,300 to 16,000 t approximately and remain stable thereafter (Figure 1).

Table 1. Biological growth parameters of sardine (*Sardina pilchardus*) in the Bou- Ismail/El-Djemila area (central Algeria) obtained from fish catch samplings in 2005

Allometricgrowth				a		b
				0.0058 g cm^{-3}		3.1049 cm^3
Von Bertalanffy growth function				L_∞	K	T_0
				21 cm TL	0.51 yr^{-1}	0
Age	Sizes (cm TL)	Maturity	M	Initial number (thousands)	Number of individuals in the catch (thousands)	Weight of catch (tones)
1	<10-13	0.3337715	0.36	89,783	26,835	399.68
2	13.5-16	0.8747217	0.36	529,348	55,148	1,403.97
3	16.5-18	1	0.36	16,115	19,439	805.43
4	18.5-19	1	0.36	4,421	4,015	215.60
5	19.5	1	0.36	1,119	845	51.41
6	20	1	0.36	289	211	13.91

Summary results of the length-cohort analysis (using VIT software) are also shown.

Table 2. Economic parameters of the purse seine fishing fleet in the Bou-Ismail/El-Djemila study area (central Algeria) in 2005 (average by vessel)

Commercialization Costs ("mandataire")	10% of fish sale
Effort costs (fuel, oil)	1.64 million DA yr^{-1}
Value of production (2005, all species)	52 million DA yr^{-1}
Labour costs	25 million DA yr^{-1}
Fixed costs	1.49 million DA yr^{-1}
Net profits	18.87 million DA yr^{-1}
Vessels value	26.14 million DA
price function for small purse seiner	10150 landings $^{-0.010}$
price function for medium purse seiners	8970 landings $^{-0.015}$
price function for large purse seiners	9860 landings $^{-0.02}$

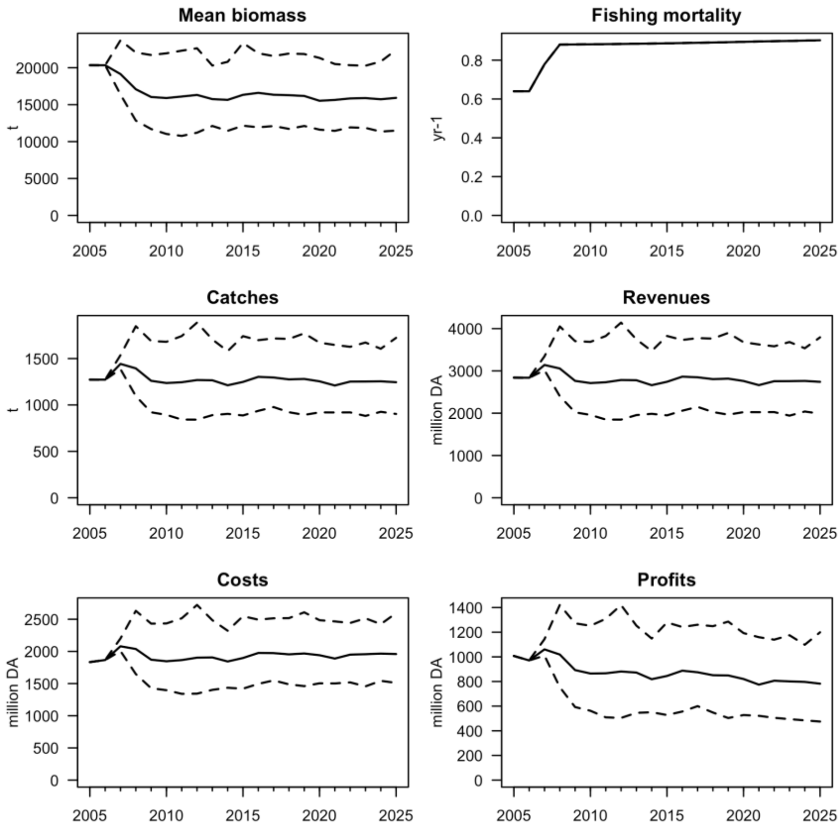

Figure 1. Selected bio-economic indicators of simulation results for Scenario 1.

F/Zwould increase from 0.63 in 2005 to 0.89 in 2008 (26% increase) and up to 0.91% in following years. The increase in capacity simulated under this scenario would permit a net increase of sardine catches from 1280 t in 2005 to 1,450 t in 2007. However, this increase in catches would be transitory. Total costs would also increase in the short term, from 1.81 to 2.10 billion Algerian Dinar (DA) in 2007; and decrease afterwards to 1.85 billion DA approximately between 2009 and 2014, and stabilize after 2016 to 2.0 billion DA (8% higher than the value before the introduction of the 19 new units). Total revenues would also reach a peak in 2007 up to 3.14 billion DA and would decrease between 2007 and 2010 to 2.72 billion DA and stabilize afterwards. Because catches and revenues would be practically constant after 2009 while total costs tend to increase, profits would decrease slowly in the long run, from 1.06 billion DA at the start of the simulation to 0.78 billion DA at the end.

The entry to the fishery of 6 vessels of large engine power (1,500 HP) in 2008 is simulated in Scenario 2 (Figure 2). This event would entail a significant modification of total biomass, decreasing from 20,300 to 14,000 t after the management event, due to the increased fishing mortality (F_{2008}=1.06 yr^{-1}) with F/Z increasing from 0.65 to 0.85. The catches would increase only in the short term by 220 t and would fall back to the previous levels of 1280 t afterwards. The entry of 6 new large boats would entail a reduction of total costs to the fleet, from 2.02 billion DA in 2008 to 1.75 billion DA towards the end of the simulation period, because of reduced catches and, consequently, lower commercialization costs. Total revenues would follow the same dynamics as catches, growing to 2.51 billion DA in 2009 after the introduction of the 6 new boats compared to the initial level, but falling back to 2.44 billion DA in the long run. The balance between revenues and costs would generate decreasing overall profits in the long term, from 0.88 billion DA in 2008 to 0.63 billion in 2025. The profits of individual vessels would actually be 20% lower at the end of the simulation horizon.

The analysis of Scenario 3, consisting in a 25% increase of daily fishing effort from the current 12 $h\cdot d^{-1}$ to 15 $h\cdot d^{-1}$ in 2013 would add to the fishing pressure on pelagic stocks, increasing fishing mortality, without significantly increasing sardine catches (Figure 3). The importance of fishing mortality over total mortality would also increase from 65% in 2013 to 85% in the long run, while stock biomass would decrease, resulting in appreciably constant catches of about 1,300 t annually. Production costs would increase accompanying the effort increase simulated in this scenario, but revenues would decrease slightly, from 2.67 to 2.62 billion. The combination of increasing production costs with a moderate decrease in revenues would result in

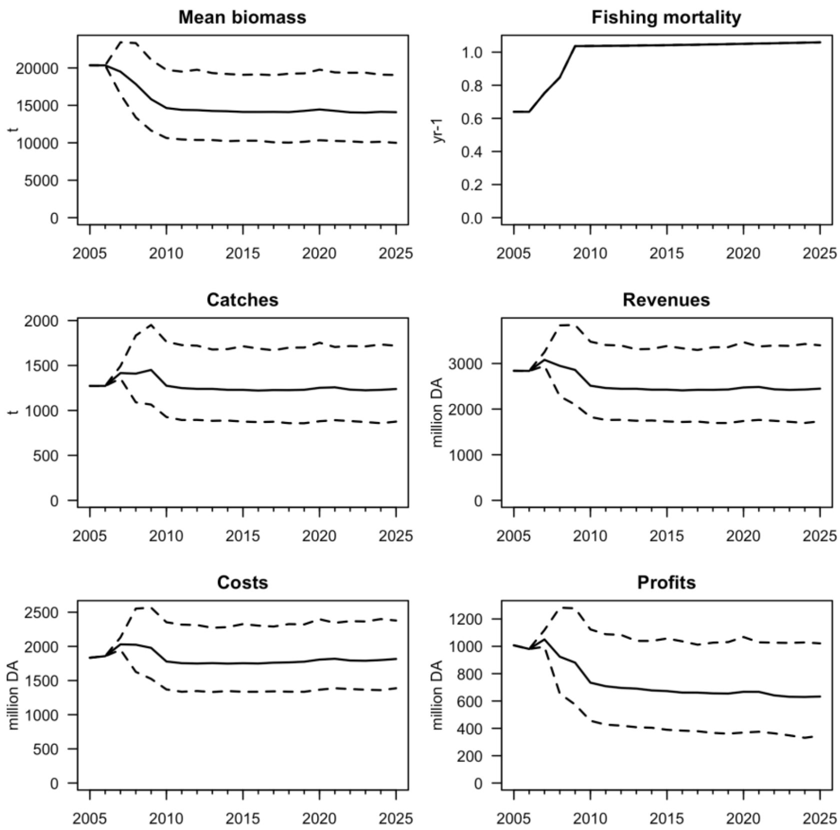

Figure 2. Selected bio-economic indicators of simulation results for Scenario 2.

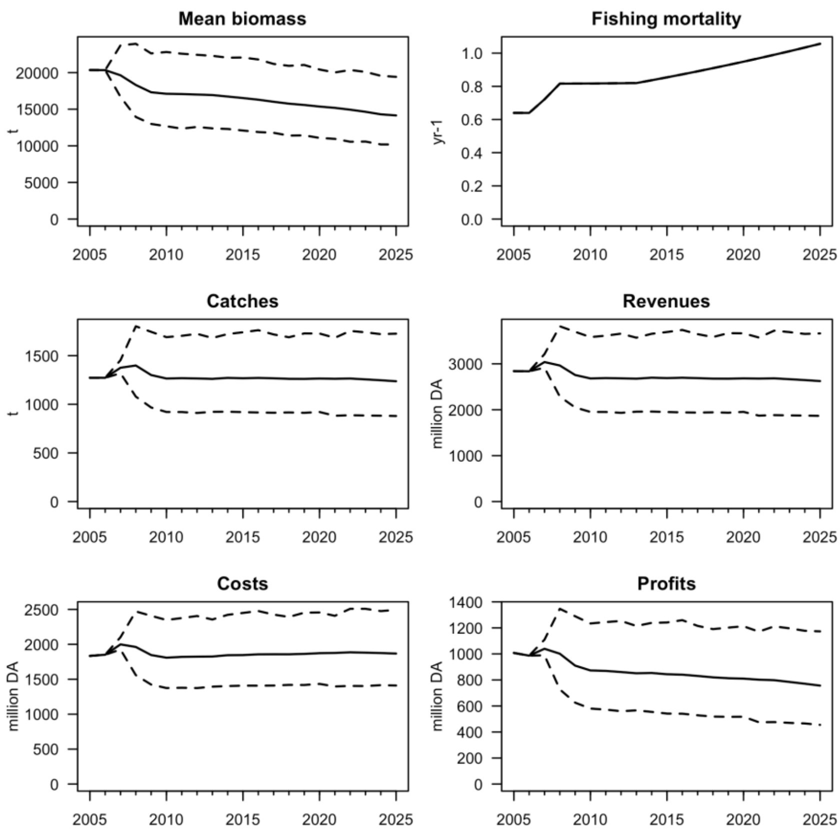

Figure 3. Selected bio-economic indicators of simulation results for Scenario 3.

decreasing profits over time, from 0.85 billion DA to 0.75 billion DA (12% decrease).

The reduction of daily fishing time from 12 to 8 $h \cdot d^{-1}$ in 2013 (Scenario 4) would allow for an important biomass increase, from 16.5 in 2013 to 22.0 thousand t in 2016 and afterwards, when it would become stabilized (Figure 4). Decreasing daily fishing time would be accompanied by a decrease in the importance of fishing mortality, from 65% to 43% of total mortality (over 20% decrease). This reduction in fishing mortality would be naturally accompanied by a temporary decrease in sardine catches in 2014, from 1265 to 962 t, which would recover to 1282 t after 2017. The revenues would follow the same trend, with a reduction of 2.65 to 2.02 billion DA in 2014, stabilizing at 2.69 billion DA after 2017. The reduction of catches is accompanied by a reduction of costs, down to 1.44 billion DA and return to approximately the start values after 2017 (1.89 billion DA). The short term consequences of effort reduction under this scenario would entail an important short-term decrease in profits, from 0.83 to 0.57 billion DA, but the long term stable profits would be around 0.84 billion DA.

Discussion

Stocks of small pelagics in the bays of Bou Ismail and El Djemila (Central Algerian coasts) are mainly composed of sardine (*Sardina pilchardus*), a fisheries resource of traditionally high importance in the Mediterranean (Santojanni *et al.*, 2005). The fraction of the population, making the most important contribution to the fishery is age-2 sardines of 13-16 cm TL (Table 1), which is comparable to other Mediterranean sardine fisheries (Santojanni *et al.*, 2005; Silvestri and Maynou, 2009). From a purely yield-per-recruit perspective (analysis not shown), higher yields of 16 g per recruit would be obtained by increasing the selectivity of the fishery and targeting 3-year old sardines (16-18 cm TL), compared to current yield of 14 g per recruit, but this would result in large short term losses which would jeopardize the continuity of fishing communities in the study area. Instead, different realistic management measures were tested, which would help harmonize the productivity of the stock in the study area with the extractive capacity. It is clear that in 2005, when the biological studies were carried out, the exploitation rate of F/Z = 0.63 was excessively high and policies aiming to reduce the exploitation rate down to 40% (taken as a safe exploitation target for small pelagic stocks: Patterson 1992) are recommended. The situation of excessive capacity was not realized by the fisheries authority, issuing 19 new licenses in the years 2007-8 and planning new 6 large-capacity vessels for 2008 that were finally not commissioned. The entry of 19 new vessels represented a large increase in the

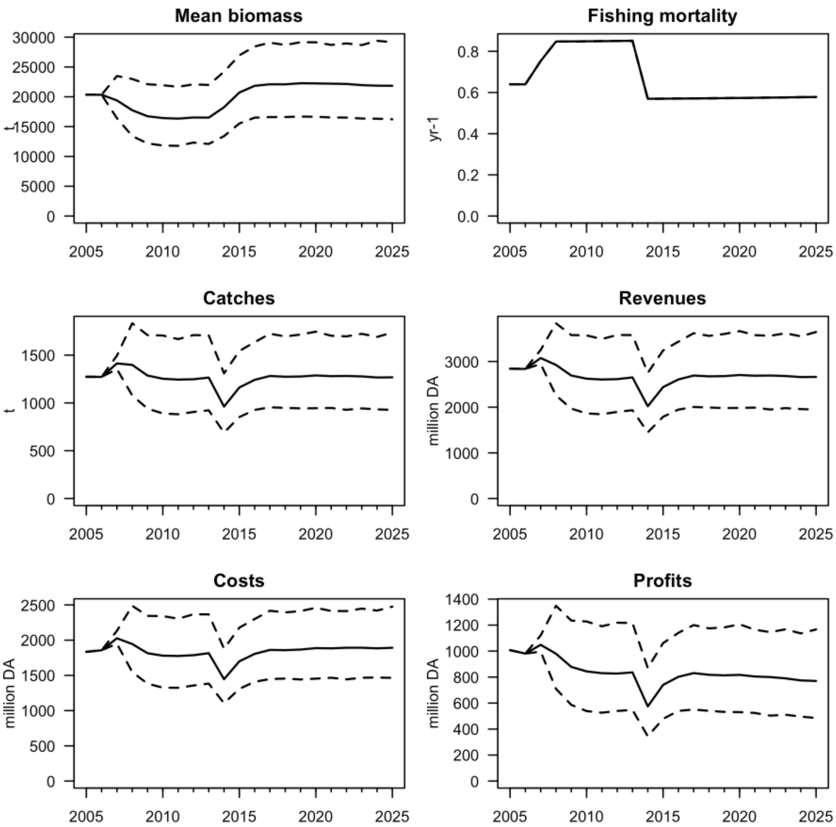

Figure 4. Selected bio-economic indicators of simulation results for Scenario 4.

exploitation rate (up to 91%, Figure 1) with an important reduction in fish biomass and only short term increases in catches and revenues. However, the new 19 units have increased the structural costs of the fishery, for instance fishermen are forced to take bank loans to offset the depreciation of capital (i.e. repair and maintenance of the vessel) and other fixed costs, such as taxes and insurance, which keep growing with time. With increasing costs and a likely stable production level, assuming long term stable recruitment, profits in the fishery would steadily decrease. This policy of increasing fishing capacity in the study area is likely to produce economic losses in the mid and long term while at the same time reducing the biomass of the stock, showing the classical features of rent dissipation in open access fisheries (Clark, 1990). The stock assessment results by Mouhoub (1986) in the bay of Bou Ismail, which show an underutilized sardine fishery capable of sustaining larger exploitation rates and which were the basis for fisheries management in the 1990s, are clearly out dated 20 years after (Zeghdoudi, 2006). The policy of increasing fish production to improve the food security of the population is likewise not valid for the mid and long term because our analyses show that the bulk of catches would be maintained at the same levels as before the entry of these new 19 units. Adding 6 new high capacity units would further aggravate the current overexploitation and overcapacity problems (i.e. increasing fishing mortality, decreasing biomass, and worsening economic performance), because these units have proportionally higher running costs and catches and revenues are shown to decrease in the mid and long term. Overexploitation leads to lower and uncertain yields in the medium and long term, smaller average size of the catches, and consequently lower incomes and lower food security (European Commission, 2011; Guillen *et al.*, 2014).

Importantly, the profits of individual firms would decrease by around 20% in the long term. Reducing fishing effort by shortening the daily fishing trips would not significantly reduce catches in the medium and long term, while ensuring a higher biomass. This measure is also to be recommended on social and economic grounds, because fishermen would have more reasonable working hours, in line with other productive sectors in Algeria.

At the present, fish stock assessments are being carried out by the Algerian ministry of fishing. We are sure that the results of such works will confirm our observations and the best evidence is the increasing importance of small pelagic prices, which was multiplied by three on the market during the period from 2007 to 2012. In fact, they went up from 1800 DA for one 16-kgbox to 6000 DA. This shows that resources are decreasing. This situation is also confirmed by professionals in the study area who are feeling their invoices decreasing by more than the half: from 29000 to 11175 boxes during the same period.

Conclusion

In order to avoid further overexploitation, overcapitalization and mismanagement of economic resources, it would be recommended to forbid new entrants to the sardine fishery in the bays of Bou-Ismail and El-Djemila because any increase in capacity or effort would likely compromise the conservation of the stock and the economic profitability. Limiting the entry of large capacity vessels and, at the same time, reducing daily fishing time would help ensure the sustainability of the sardine fishery studied.

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References

Chakour, S. 2005. Economie des pêches en Algérie. PhD thesis, Algérie: INA.

Chaussade, J. and Guillaume, J. 2006. Pêche et aquaculture. Pour une exploitation durable des ressources vivantes, de la mer et du littoral. Presses universitaires de Rennes, LETG UMR, 6554, CNRS, France.

Clark, C.W. 1990. Mathematical Bioeconomics: The Optimal Management of Renewable Resources, 2nd Edition, Wiley New York, 404 pp.

Cochet, Y., Gilly, B. 1990. Computer programmes for fisheries bioeconomic analysis. BEAM 3: Bioeconomic analytical simulation model, for tropical shrimp fisheries with fixed or random recruitment, FisheriesTechnical Papers, no: 310.2, Rome, FAO.

European Commission. 2011. DG MARE CFP reform package. Available at http://ec.europa.eu/fisheries/reform/docs/msy_en.pdf.

Garcia, S. 1989. La recherche halieutique et l'aménagement: grandeur et servitude d'une symbiose. In: J.P. Troadec (Ed.), L'homme et les systèmes halieutiques et acquacoles marin, Masson et Cie, Paris: 711-744.

Gascuel, D., Duran, J.R. and Fonteneau, A. 1993. Les recherches françaises en évaluations quantitatives et modélisation des ressources et des systèmes halieutiques. Session 3: Modélisation économique des pêcheries. 29 June-1 July 1993. Rennes: Premier forum halieu métrique.

Gayanilo, Jr.F.C., Sparre, P. and Pauly, D. 2002. FISAT II: FAO-ICLARM. Fisheries Assessment Tools, Online User Manual, Rome, FAO.

Guillen, J., Macher, C., Merzéréaud, M., Fifas, S. and Guyader, O. 2012. The effect of discards and survival rate when choosing between landings or catches as yield in the Maximum Sustainable Yield estimation: Application to the nephrops fishery in the Bay of Biscay. Marine Policy, 50: 207-214. doi: 10.1016/j.marpol.2012.12.029

Lleonart, J. and Salat, J. 1997. VIT: Software for fishery analysis. User's manual. FAO Computerized Information Series (Fisheries), No: 11, Rome.

Lleonart, J., Maynou, F., Recasens, L. and Franquesa, R. 2003. Abioeconomic model for Mediterranean Fisheries. the hake off Catalonia (Western Mediterranean) as a case study. Sci. Mar., 67(1): 337-351.

Maouel, D. 2003. Les raisons de la faiblesse quantitative de la production halieutique en Algérie: Cas du port de Bouharoun. MSc thesis, Algérie: INA.

Medrous, K. 2013. Analyse spatio-temporelle de la production halieutique en Algérie. Mémoire d'ingénieur. Algérie: ENSSMAL.

Mattos, S.M.G., Maynou, F. and Franquesa, R. 2006. A bio-economic analysis of the hand-line and gillnet coastal fisheries of Pernambuco State, north-eastern Brazil. Sci. Mar., 70(2): 335-346.

Maynou, F., Sardà, F., Tudela, S. and Demestre, M. 2006. Management strategies for red shrimp (*Aristeus antennatus*) fisheries in the Catalan sea (NW Mediterranean) based on bioeconomic simulation analysis. Aquat. Living Resour, 19(2): 161-171.

Merino, G., Karlou-Riga, C., Anastopoulou, I., Maynou, F. and Lleonart, J. 2000. Bioeconomic simulation analysis of hake and red mullet fisheries in the Gulf of Saronikos (Greece). Sci. Mar, 71(3): 525-535.

Mouhoub, R. 1986. Contribution à l'étude de la biologie et la dynamique de la population exploitée de la sardine (*Sardina pilchardus* Walbum, 1792) des côtes Algéroises (Algérie). Thèse de magistère. Algérie: USTHB.

MPRH 2006. Les statistiques des pêches (2000-2005). Ministère de la Pêche et des Ressources Halieutiques (MPRH), Alger.

MPRH 2008. Schéma directeur de développement des activités de la pêche et de l'aquaculture horizon 2025.Impression: EN NAKHLA, Alger.

MPRH 2010. Les statistiques des pêches. Ministère de la Pêche et des Ressources Halieutiques (MPRH), Alger.

MPRH 2013. Les statistiques des pêches. Ministère de la Pêche et des Ressources Halieutiques (MPRH), Alger.

Patterson, K. 1992. Fisheries for small pelagic species: an empirical approach to management targets. Fish Biol., 2: 321-338.

Prellezo, R., Accadia, P., Andersen, J.L., Andersen, B.S., Buisman, E., Little, A., Nielsen, J.R., Poos, J., Powell, J. and Röckmann, C. 2012. A review of EU bio-economic models for fisheries: The value of a diversity of models. Mar. Pol., 36: 423-431. doi: 10.1016/j.marpol.2011.08.003

Rey, H., Catanzano, J., Mesnil, B. and Biais, G. 1997. Système halieutique: Un regard différent sur les pêches. IFREMER, Paris.

Santojanni, A., Cingolani, N., Arneri, E., Kirkwood, G., Belardinelli, A., Giannetti, G., Colella, S., Donato, F. and Barry, C. 2005. Stock assessment of sardine (*Sardina pilchardus* Walb.) in the Adriatic Sea, with an estimate of discards. Sci. Mar., 69(4): 603-617.

Silvestri, S. and Maynou, F. 2009. Application of a bioeconomic model for supporting the management process of the small pelagic fishery in the Veneto Region, northern Adriatic Sea, Italy. Sci. Mar., 73(3): 563-572.

Zeghdoudi, E. 2006. Modélisation bioéconomique des pêcheries méditerranéennes: Application aux petits pélagiques de la baie de Bou-Ismaïl, Algérie. MSc thesis, Barcelona: University of Barcelona.