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Profitability and economic drivers of small pelagic fisheries in West Africa: A twenty year perspective

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ABSTRACT

Small pelagics are the main fish resource in North West Africa. In Senegal, these are mainly sardinellas (*Sardinella aurita* and *S. maderensis*) and bonga shad (*Ethmalosa fimbriata*). The fisheries, mainly encircling gillnets and purse seines, are predominantly performed by artisanal fishers and are of great importance for the Senegalese economy and for food security in the region. However, in recent years, the main conditions for these fisheries have changed and recent observations have shown strong declines in profit. An analysis over the last twenty years (1993–2013) show that the fisheries lost profit between 65% and 100% while operating costs increased by 25% and 90%, for encircling gillnet and purse seine, respectively. While the fuel price dominates as determining factor during the survey period, important other drivers during the last five years were a decrease in fish biomass and an increase in fishing effort.

1. Introduction

Small pelagic fish are abundant in the Canary and Guinea current system off West Africa [1,2]. Along the Mauritanian and Senegalese continental shelf, the dominant species of pelagic fish are sardinella (*Sardinella aurita* and *Sardinella maderensis*) [3] and bonga shad (*Ethmalosa fimbriata*). These small pelagic fish, mainly *S. aurita,* perform a seasonal migration between southern Morocco and southern Senegal [2–4]. They are predominant in landings (volume and value) within the small pelagic fishery in Senegal. The fishery in Senegal has expanded significantly in the 1970s with the adoption of purse seines in the artisanal fishery [5]. Since then, small pelagic fish are the main component of the Senegalese artisanal fishery with on average 230,000 t per year and between 70% and 77% of the total landing over the period 1990–2012 and the total value of small pelagic landing was estimated to be 74,000 k€ in 2014 (Fig. 1). Overall, the exploitation of small pelagic fish is strongly marked by the predominance of round sardinella (*S. aurita*) and flat sardinella (*S. maderensis*), with on average 52% and 37% in landings of small pelagics [6]. These species contribute especially to the supply of the local market [7] and play a dual role in the Senegalese economy, through their contribution to food security, and through employment in the fishery and the processing sector. The revenues generated by sardinella landings are shown in Fig. 1, and are representing 30,000 k€ on average per year between 1995 and 2009. However, the value has doubled since 2009.

The fishery is subsidized by the state since the 1960s in different ways ranging from facilitating credit contracts to direct subsidies on fuel and fixed costs and also zero-rating of inputs. These subsidies are motivated among others by the development of the sector but also to guarantee food security. However this kind of policy is highly criticised to have detrimental effects in a *de facto* open access fishery situation by several authors [8,9].

However, due to the high spatiotemporal variability of sardinella abundance [1,3,10], the increase in fishing effort and in fishing capacity, a decrease in individual income of fishers targeting these species has been observed between 1993 and 2011 [11]. In addition, since 2001, the FAO working group on the assessment of small pelagic fish off Northwest Africa (CECAF) indicated that these stocks are becoming overexploited. They recommended a reduction in fishing effort (see also FAO [12]).

Purse seine and encircling gillnet are the main fishing gears used to catch small pelagic fish. The economic and financial profitability of

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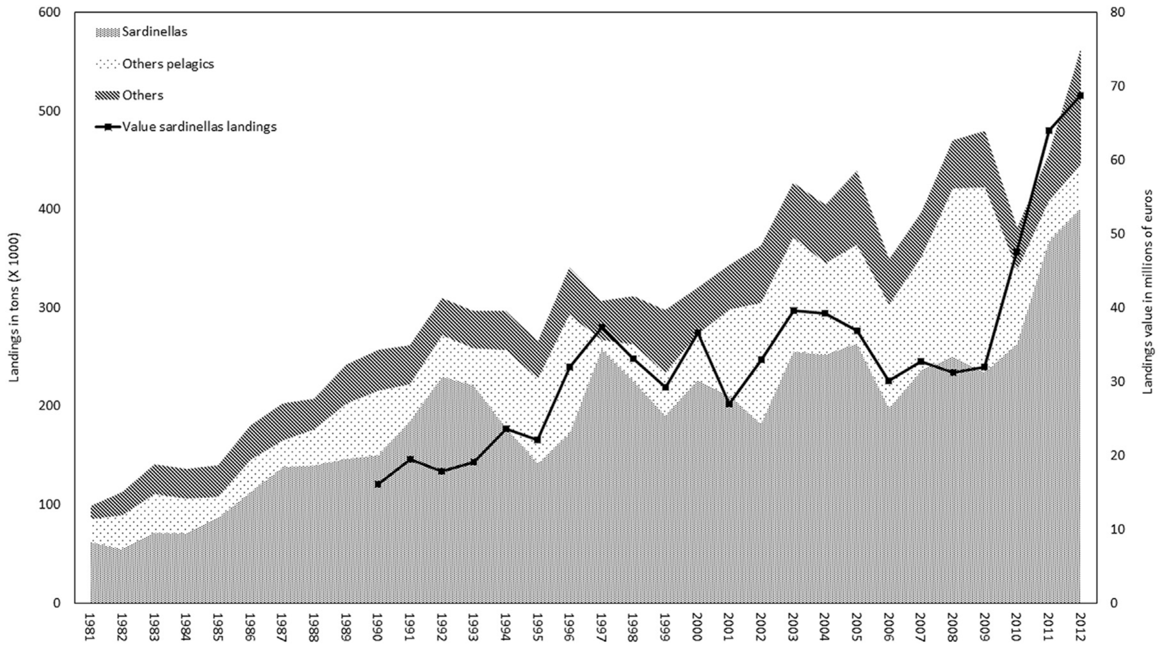

Fig. 1. Senegalese landing and value of landings of sardinella. The proportion of sardinellas, other pelagics and all other landing in the artisanal Senegalese fishery from 1981 to 2012 and the value of sardinella landings (blackline) (source: CRODT, the Senegalese fisheries research center).

artisanal fishing has been monitored fairly regularly between 1993 and 2007 (Senegalese research center (CRODT) and FAO). The last study carried out in 2010 [11] has shown a financial hardship for the small pelagic fishing sector.

Since this last study [11], several important changes have been observed. The first is a contract (2010–2012) between Senegal and a Russian fleet (29 boats) targeting small pelagic fish that had been in place [3,13,14], but which was terminated in 2012 because of political pressure from artisanal fishermen and local NGOs [15].

In addition to subsidies mentioned above, the government decided in 2015 to reserve more than 7600 k€ to subsidize the investment in engines with 1.5 k€ per engine (in addition to preexisting tax exemptions).

Lastly the government implemented a vessel registration program for artisanal boats in 2006 to control the fishing capacity. This included a yearly fishing license of 38€ per purse seine and encircling gillnet. The fishing license is also an obligation in the new fishing code (2015). The objective is to have a better control over the fishing capacity and in addition to cover the externalities of the artisanal fishing sector. However, only a few purse seine and encircling gillnet fishing units have bought this license yet.

The two fleets subject for the analysis are the traditional, coastal and family-oriented encircling gillnet (EG) fishing units, which are compared with the more progressive, flexible and capital-intensive purse seines (PS). The choice of these fishing units is motivated by the fact that 65% of *E. fimbriata* is caught by the EG and 30% by the PS, 40% *S. maderensis* is caught by EG and 55% PS and 98% of *S. aurita* is caught by the PS. The focus of this paper is on the analysis of the development of the economic viability of these two fleets and the drivers behind this development. The results of the short term analysis based on 2014 data are compared with results from previous studies between 1993 and 2007. This enabled us to follow the development over a time horizon of twenty years, but also having a closer look at the more recent years.

2. Material and methods

For this study, several data sources were used:

(i) The dataset of the Oceanographic Research Centre of Dakar Thiaroye (CRODT) already described by several authors [16–21] for catch per unit of effort (CPUE) by species and catch data landed by PS and EG and ex vessel prices of fish.
(ii) The reports of the Senegalese Directorate of Marine Affairs and fisheries (DPM) [13] and the FAO[1] reports of the CECAF[2] for historical data.
(iii) Investment data of fishing units are complemented by interviews with the main engine, boat and net retailers.

The study area and the major landing sites are presented in Fig. 2. From these various sources of data the investment value fixed costs, variable costs, the net income and the subsidies of the fishing fleet are estimated. The economic and financial analysis of fishing vessels is calculated using their operating accounts, the internal rate of return, the delay to recovery of invested capital and the net added value. To compare this study with previous studies, the same method was used to calculate the income. The methodology (Fig. 3) is adapted from Kébé and Horemans [22], a study done for the West African artisanal fisheries.

We did a review of studies conducted since 1993 for Senegal (the first study took place before the devaluation of the national currency i.e. CFA[3] franc "XOF" in 1994) specifically for the years 1996, 1999, 2004 and 2007, to derive a time series of profitability. Deflation was calculated using the consumer price index with 2014 as base year.

The turnover per year per fishing unit is simply derived by multiplication of catch per unit of effort with the number of fishing trips and the price of the species. The catch is composed of the target species (*S. aurita*, *S. maderensis* and *E. fimbriata*) and all other species caught by the fishing vessels.

Operating costs are assumed to be proportional to the fishing units' activity (effort). They include the sum of fuel costs, food and small maintenance costs. The deduction of these total operating costs (TCO) from the turnover gives the gross operating income. This result is divided between capital and labor according to the share system of the

[1] Food and Agriculture Organization of the United Nations (FAO).
[2] Fishery Committee for the Eastern Central Atlantic (CECAF).
[3] Local currency (FCFA= Franc Coopération Financière en Afrique).

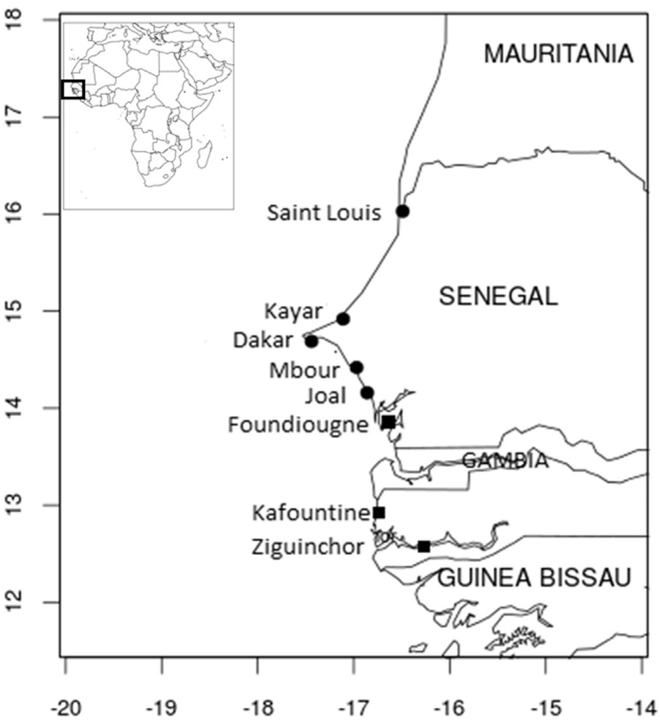

Fig. 2. Map of the study area. Map of the Senegalese marine costal area, the black circles are the main landing sites and the black squares are the secondary landing sites investigated by the national Senegalese's research center (CRODT).

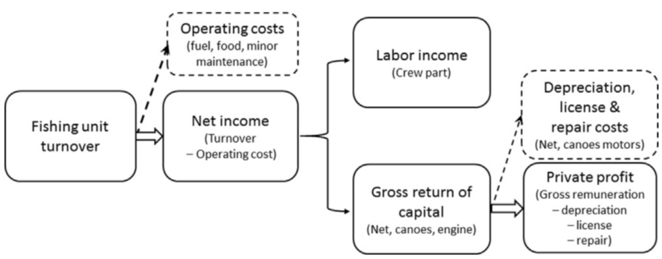

Fig. 3. Income calculation. Income calculation methodology. From the turnover the operating costs is removed and the net income is obtained. The net income is split between labor and capital. From the capital part, the depreciation, the license and the repair costs are removed. From this the private profit is obtained. The dotted arrows mean subtracting and the dashed arrows mean divided.

fishing unit. The share system used to calculate private profit and crew income differs between fisheries. Generally, the boat owner and the crew members share the economic risk of fishing trips. So after deduction of the total operating cost (fuel, food, etc.) from the turnover, the rest (net income) is shared between capital and labor as follows:

- For PS, capital receives 45% of gross operating income and labor 55%.
- For EG, capital and labor receive 27% and 73% of gross operating income [23], respectively.

These percentages can be calculated from the share system rules in place. For a PS, a fairly common practice is to allocate one third of the net income to the fishing gear and the remaining two-thirds are divided between the crew, canoes and engines by one share per crew member and one share for each piece of equipment.

For EG, one share goes to the engine, one share to the fishing gear, one to the boat and one to each crew member. The sum of the shares allocated to fishing gear, motors and canoes represent the gross return on capital.

Finally, the private profit is obtained by deduction of depreciation, permit cost, and repairs from the gross return on capital.

3. Results

3.1 Purse seine (PS)

Investment and operating costs have increased by 30% and 90% respectively during the period 1993–2014 (Fig. 4a, c). Over the same period, owners and fisher income dropped by 66% and 52% respectively. Over the whole period the owner's income is 10 times higher on average than the income of an ordinary fisher. The Payback period has doubled (Table 1). The internal rate of return decreased from 83% to 22%. Operating costs are rather dominated by the cost of fuel. The share of fuel in operating costs has increased, it changed from 60% to 80% during the period.

3.2 Encircling gillnet (EG)

Investment has only slightly changed for the EG net over the whole period. However, as for the ST, operating costs have risen sharply (25%) over the last 20 years. Profit is relatively low compared to ST. It is on average even lower than that of each crew member (Fig. 4b, d).

The Payback period is multiplied by 26 during these 20 years (Table 2). EG's internal rate of return dropped from 15% to 1%. Operating costs again are highly controlled by the cost of fuel, representing 70% of the total costs. However, over the period, the share of fuel in operating costs is relatively constant.

4. Discussion

4.1. On the investment

To complete our profitability analysis and to estimate the completeness and quality of it, the return on capital should be subject to comparison with alternative returns. As the artisanal Senegalese fishery represents an example of an almost open access case, it is expected that profits go towards zero for both gear types. Put differently, it is expected that the internal rate of return (IRR) is equal to an alternative, comparable investment's return that an artisanal fisherman could get. An alternative approach is that the owner's IRR should roughly equal the cost of outside capital. Data on interest rates in the market are difficult to obtain. One reference cites three development projects undertaken to spur the development of the artisanal market. Capital cost for all three projects is at 11% interest rate per year, with a compulsory cash deposit as collateral [24]. It is likely that the cost of capital is higher on the private market not driven by development targets. In comparison, for fisheries with informal credit markets and interlinked credits, the interest rates have been calculated to be between 18% and 47%, depending largely on the lender, amount and collateral [25]. Mallick [26] found an average informal interest rates in agricultural villages in Bangladesh of 103%, with a minimum of 10%. Variability is high, but it is likely safe to assume that private cost of capital is not below 15–20%.

Considering this, an IRR of 22% in 2014 (15% in 2007) points towards a situation of possibly positive, but very small excess profits in the PS fishery and definitely negative profits for EG fishers. While the market is clearly an open access situation (no government intervention concerning capacity), it is possible that market imperfections, especially concerning access to capital as was shown by Ndiaye [27], hinder investment.

4.2. On the methodology

The method to calculate the profitability in this paper has been adapted from FAO [22]. The method is based on traditional economic and financial calculations and is supposed to reproduce the share

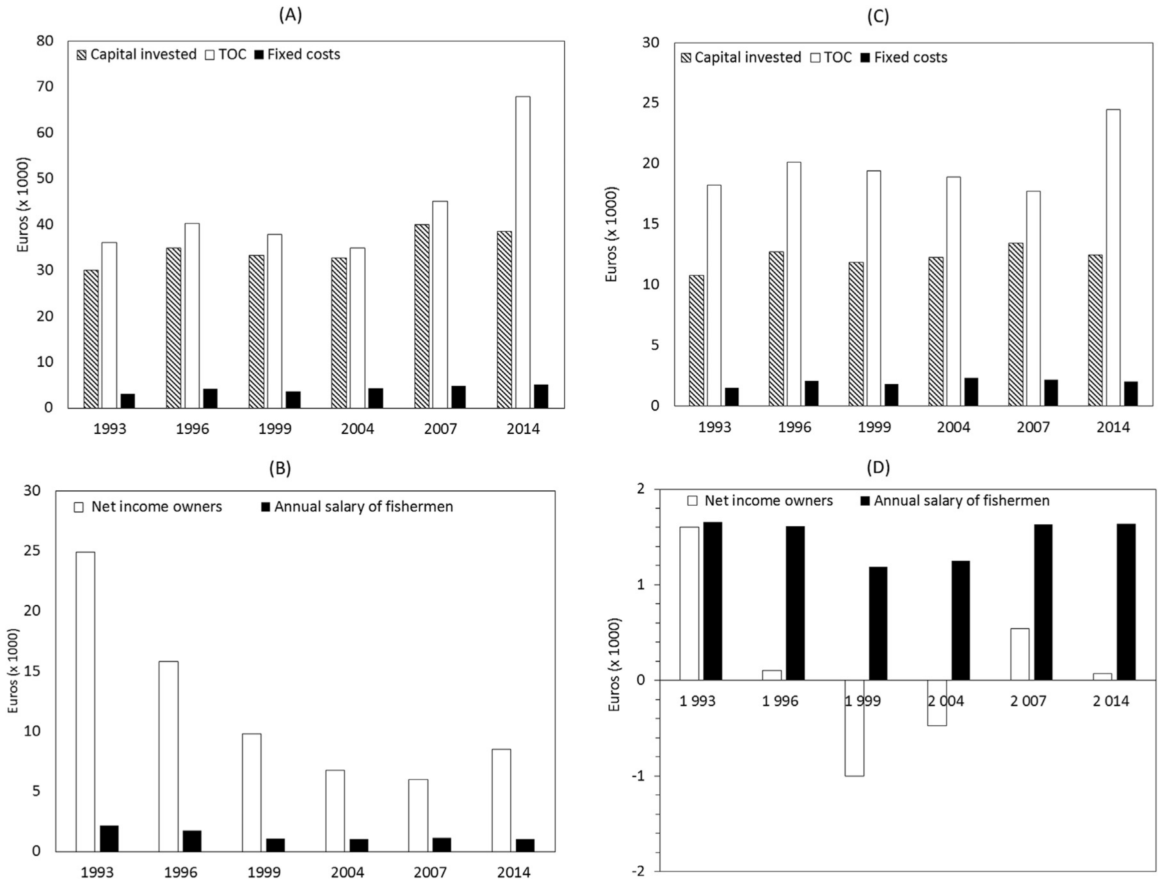

Fig. 4. Change of economic indicators. Change of various economic indicators deflated (2014, base 100) between 1993 and 2014 investment, variation of total operating costs and total fixed costs (a) for purse seine (PS), and (b) for encircling gillnet (EG). In grey the private profit and in black the income per crew member for(c) PS and (d) for EG.

Table 1
Indicators of the profitability ((crew member income, private profit, expressed in Euro the internal rate of return (%) and the Payback period (years)) of purse seine (PS) over the 20 years studied.

Profitability fishing unit PS	1993	1996	1999	2004	2007	2014
Income of crew member per year	2154	1763	1101	1030	1134	1033
Income of the crew per year	43072	35267	22026	20608	22686	20651
Private profit per year	24911	15818	9822	6778	6019	8522
Internal rate of return (%)	82.90	45.42	29.55	20.75	15.05	22.12
Payback period (years)	1.21	2.20	3.38	4.82	6.65	4.52

Table 2
Indicators of the profitability (crew member income, private profit, expressed in Euro the internal rate of return (%) and the Payback period (years) of encircling gillnet (EG) over the 20 years studied.

Profitability fishing unit EG	1993	1996	1999	2004	2007	2014
Income of crew member per year	1659	1612	1189	1248	1630	1638
Income of the crew per year	13274	12894	9510	9984	13043	13108
Private profit per year	1603	104	−1004	−472	543	72
Internal rate of return (%)	14.8	0.8	–	–	4.0	0.6
Payback period (years)	6.7	122.6	–	–	24.8	174.6

systems used in artisanal fisheries. However, it seems that the method is not totally well adapted to the artisanal fisheries because of the variability in the share system. In fact, there are several specific characteristics of small fishing vessels with respect to fishing techniques, fishing season, but also in relation to the nature of the contract between the onboard fishers and the boat owners. Conventionally, pelagic artisanal fishing is done by performing one or several trips a day and the owner of the canoe shares the risks of each fishing trip with the crew. However, especially in some cases where migrants are the crew, the level of risk is often higher because the sharing is done at the end of the campaign after having deducted all costs associated with operation, repair and accommodation. The risk is the disbanding of the crew if there is a series of several bad fishing trips. However, in the classical case of the share system, the sharing is done between all fishers. Only afterwards will the boat owner pay all costs associated with repair.

Especially for EG, the method of calculating income might not be well suited to capture the share system in place. On the one hand, the share system is more in favor of the crew compared to the share system applied on PS canoes. On the other hand, new data from a survey[4] of captains and boat owners in seven landing sites across Senegal shows that the extent to which the fishing unit is a family business varies across gear types. EG have a higher family share. This leads to a capital-labour-remuneration-relationship that is not only characterized by the share systems, but turns out to be more complicated. It is likely that the family members share capital cost and remuneration. In most of the cases the crew lives in the same house and all income from fishing is used for domestic expenses. In addition, the head of family also receives money or part of the share from unmarried fishers. The traditional accounting does not take into account all these aspects and therefore perhaps underestimates the income of the owner of the canoe

[4] It is a database which is under construction. This part of the work is jointly financed by the IRD, the University of Kiel (Germany) and CRODT. It is in the framework of AWA (Ecosystem Approach to the management of fisheries and the marine environment in West African waters) and Preface (Enhancing prediction of Tropical Atlantic climate and its impacts) projects.

acting as family head. All those aspects might explain the low income of EG owners found after calculating profits with this standard method.

For PS fisheries, the operation cost has doubled in twenty years, while that in EG fisheries increased by 25% only. During the same time, the profit of the PS has been divided by three, but is still positive, while that of the EG is almost zero. The dynamics of costs and benefit shows perfectly that both fisheries are on a path towards zero profit, thus an open access equilibrium, as shown already by several authors [28–32] in other fisheries. Given the importance of this fishery for food security and job creation in Senegal, corrective measures should be envisaged before it is too late.

4.3. Drivers of profitability variation

Several factors can explain observed variations of the profitability during the last twenty years. Some factors that may influence the profitability of artisanal fishing units over time are analyzed. The focus is on factors that have an influence on the level of gross operating income: The prices for fish and fuel, effort, CPUE and biomass are discussed. Most variables discussed vary for the different species (*S. aurita*, *S. maderensis* and *E. fimbriata*) and thus gears. While the former is predominantly fished by PS, the latter is the main target species of EG.

For the fuel price, time series data for the period 1992–1996 from [7] is used. For the period 2000–2014, fuel use and value data provided in the yearly DPM reports are used. The latter are aggregated on national and yearly level. All prices are deflated using the consumer price index from World Bank data and already take into account fuel subsidies. The result shows a hump shaped development in the early 1990s (Fig. 5a). In the early 2000s the price remained at the 1995 level, but from 2005 until the World economic crisis in 2008, a sharp rise in fuel prices was observed. Since 2010, there is only a small yearly increase. From this, it is possible that fuel prices may have played a dominant role in the increase of operating costs between 2004 and 2007. However, the sharp rise in yearly operating costs during the last five years cannot be explained by fuel price development only.

During the last five years, a sharp rise in effort for PS is observed (Fig. 5b). The same could not be observed for fuel use, but it is possible that it can be attributed to the fact that fuel data is only available on aggregate level, and not on gear type level. Assuming that fuel use and effort are linearly dependent, fuel use by PS may have risen a lot recently. Therefore, the sharp rise in operating costs between 2007 and 2014 can be attributed mostly to the used quantity, less to the price, of fuel. While the time series data of other components, such as food and small repairs are not obtained, there is no indication as to a dominating role of one of these in the development of operating costs. Fishing effort has remained largely constant for EG over the whole period discussed.

For the ex-vessel prices, the time series data from CRODT were used. The graph shows that output prices are subject to substantial interannual variation, where *E. fimbriata*, which is the most local species, exhibits the highest price variation. For both sardinella species, a general upward trend of prices is present, and the two move closely together (Fig. 6). A recent peak in 2013 and 2014 is visible. For bonga shad, the price generally exhibits a slight upward trend. During the last five years, there is a price hump, although not as pronounced as for sardinella.

CPUE of PS exhibits a general upward trend for both sardinella species. *S. aurita* is the main target species. *S. maderensis* is a more coastal species and its CPUE is lower (Fig. 7a). The variation for *S. aurita* until 2008 is difficult to explain, due to the lack of data especially for the first years. The complex migration patterns and biological traits, described for example in [4] may explain some variation. In addition, because the resources are shared between several countries, the variation of the fishing efforts in the other EEZ can impact the availability of the resources in the Senegalese EEZ.

CPUE for *S. aurita* reached its maximum in 2009, and then fell

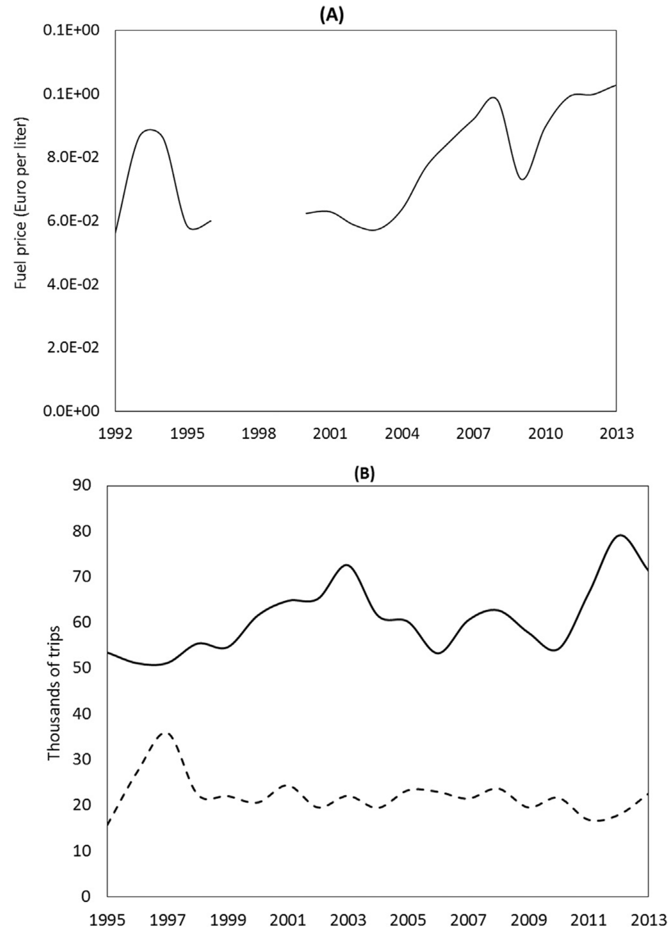

Fig. 5. Fuel price and fishing effort. (a) Change during the study period of the fuel price between 1992 and 2013 and (b) the purse seine (PS) (solid line) and encircling gillnet (dashed line) fishing effort between 1995 and 2013.

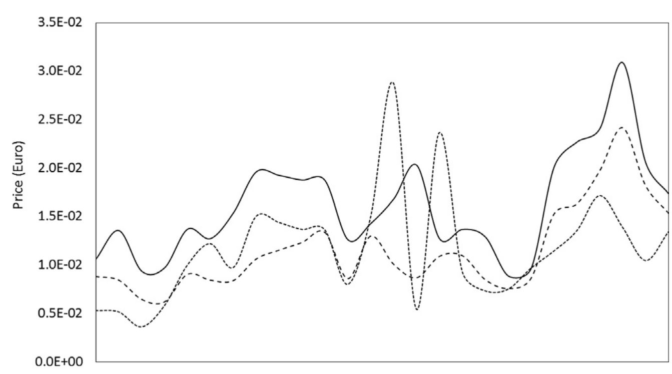

Fig. 6. Ex-vessel prices Ex-vessel prices between 1995 and 2013 of *Sardinella aurita* (solid line), *Sardinella maderensis* (dotted line) and *Ethmalosa fimbriata* (dashed line).

again. The peak in 2009 is in line with the time when prices started to rise. It is strongly assumed that the drop in CPUE over the last five years concerning *S. aurita* may be attributed to a decreasing biomass. First signs of overexploitation may have been explained by the price increase. At the same time, officially starting 2010, a significant amount of sardinella was caught by the Russian fleet according to the contract between the Senegalese state and the Russian fleet [3,13–15]. Since this industrial fleet operates farther from the shore, it is assumed that it mainly targeted *S. aurita*. This contract was heavily opposed by the artisanal fishers and NGOs and finally ended in 2012 [15]. It likely increased fishing pressure heavily. Therefore, it is not surprising that

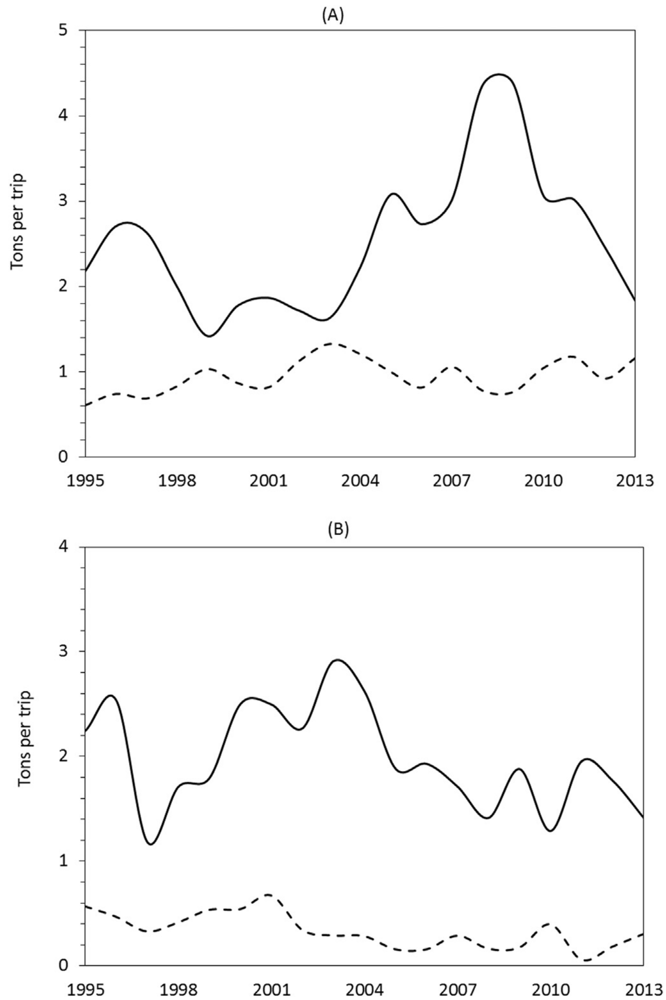

Fig. 7. Catch per unit of effort (CPUE). (a) Catch per unit of effort (CPUE) between 1995 and 2013 for *Sardinella aurita* (solid line) and *Sardinella maderensis* CPUE (dashed line) using purse seine; (b) *S. maderensis* CPUE (solid line) and *Ethmalosa fimbriata* one (dashed line) using encircling gillnet.

after 2012, CPUE dropped significantly. In addition, it is possible that decreasing marginal returns to effort prevail, and part of the drop is attributable to the rise in effort. As visible from the graph, CPUE for *S. maderensis* is far more constant. CPUE of EG concerning both target species exhibits a downward trend (Fig. 7b).

The fishing capacity for both fishing methods has not increased since 2000. While the number of canoes in the purse seine sector has multiplied by more than four between 1970 and 2000 i.e., from 120 to 540, there is only a slight increase afterwards i.e. from 540 to 593 between 2000 and 2012. The encircling gillnet sector showed even a decrease since 1990 (from 137 to 117 between 1990 and 2012). Given that the artisanal fishery is open access, the development in both sectors (PS and EG) can be interpreted as overcapacity. Such context leads to overfishing and could explain the decline in CPUE and the loss of economic performance mentioned above.

In addition to the fishing effort (expressed in days at sea) and the evolution of the fishing capacity, it can be seen that the canoes, the fishing gears and the engine became larger and more powerful. As an example, between 1993 and 2012, most EG canoes have changed from out board engine of 8–15 HP to 25–40 HP (horsepower) and most of the PS canoes changed they engine from 25 to 40 HP to 40–60 HP [7,23,33]. This change led to an increase of effort per fishing day between 1993 and 2014 and increased the fishing capacity. In this work such increase in fishing power over the period considered cannot be integrated directly as not yet estimated.

Summarizing the overview of factors influencing gross operating income, it is concluded that:

During the last five years, a peak in prices has been observed, paired with a peak in effort and a sharp drop in CPUE for PS and *S. aurita*. CPUE for *S. maderensis* is mostly constant. While bonga shad prices also increased slightly for EG fishers, their effort is largely constant and CPUE is falling slightly. It can be concluded that reduced profitability for PS is likely caused by a decrease in biomass, to some extent compensated by the increase in output prices. It is assumed that the inception of the Russian fleet contract may have substantially contributed to the reduced biomass. The substantial drop in EG profitability remains unclear after this analysis. While there is diminishing CPUE for both species (Fig. 7) and the fuel price has risen slightly, both phenomena seem too weak to serve as an explanation.

In the long term, thus over the last 20 years, the most important factor for PS has been the rise in fuel prices over the period since 2003. This suggests that fuel subsidies likely have a large impact on the sector as a whole.

In general, it can be seen, as expected, that the three species and both fleets are closely linked through prices. The next years may show that in more detail: If our hypothesis of a dramatic decrease in *S. aurita* biomass proves correct, PS canoes might redirect their effort towards *S. maderensis*, thus increasing the pressure on EG.

5. Conclusion

During the last twenty years the economic state of the Senegalese artisanal pelagic fishery got worse, with profit decreasing while costs increased. This is linked to several economic (e.g. remuneration of capital, share system) and biological (fish biomass level) factors. The fuel price is identified as a key driver during the last 20 years. Over the last five years, our results showed that a decrease in biomass coupled with an increase in fishing effort is likely responsible for the decrease in profitability. The rise in output prices compensates insufficiently those two adverse impacts. Although the decrease in profitability affects both fisheries, the effect on the PS fishery is less severe than the effect on the EG fishery. The reason might be the difference in the share system, which produces high labor costs for the EG fishery and which led to a slight decrease in numbers of EG boats from 1990 onwards and only more recently (since 2000) in the PS fishing fleets.

Finally, the migration of the resource, making it a shared fish stock, increases the necessity for collaboration in resource management between the countries who share it. So, it is necessary to have a better coordination in mall pelagic fisheries management between these countries. No coordination in the management of resources shared between different countries can lead to a “race for fish” and finally the tragedy of the commons as demonstrated by several authors like e.g. Gordon, Hardin, McWhinnie, Clark and Munro [28,34–36].

Obviously, in a poor data fishery, this study has some limitations. Thus in a next step, a deeper understanding of the interactions and dynamics of the fishery could likely only be investigated with the help of an ad hoc bio-economic model, which integrates all system components such as the dynamics of the resource, the fishing effort in the other countries as well as national change, the change in the fishing power (integrating increase of technology efficiency), the market dynamics and the human dimension (social and cultural considerations). This will allow for a more accurate analysis of the fishery, both in the short and the long terms.

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