资源科学
第32卷 第4期 2010年4月 2010,32(4):620-626
Resources Science
Vol.32,No.4 Apr.,2010

文章编号:1007-7588(2010)04-0620-07

Diagnoses of the State of Exploitation of Small Pelagic Stocks in Senegal by the Use of Size Frequencies: Case of Sardinella

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Abstract: This paper presents a study on assessment of fishery resources based on the sustainable indicators of species adopted in the INCOFISH[1] project. It primarily focuses on the stocks of round sardinella (*Sardinella aurita*) and flat sardinella (*Sardinella maderensis*). Two types of data, constituting data from the Senegalese artisanal fishery landings during the period 1990-2005 and the one collected by the Research Vessel DR FRIDTJOF NANSEN in the Senegalese areas during the period 1995 to 2005 were obtained and utilized. The methodology used in this study was proposed by Froese (2004), which analyzes three simple sustainable indicators in order to obtain meaningful information and diagnoses on the state of exploitation of stocks. The three indicators constitute the percentage of mature fish in catch with 100% as target, the percentage of fish with the optimal size with 100% as target and the percentage of mega-spawners measured as the percentage of old, large fish in the catch. The goal is to catch none (0%) of the size larger than the optimum length plus 10 %. Results showed that the stock of round sardinella seemed to be in a state of overfishing. Juvenile dominated in the catch had not reached the optimal sizes at which the maximal yield could be obtained (growth overfishing). On the other hand, the stock of flat sardinella showed a state of full exploitation. In summary, the sustainable indicators of fishing can be a more powerful tool compared with traditional stock assessment methods. They can also allow all stakeholders of fishing including the public to fight against overfishing and to have a better understanding of fishery management.

Key words: Sustainable indicators; Size at first maturity; Optimum size; Small pelagic; Senegal

1 Introduction

Senegal has a coastline of 718 km, with continental shelf area of 24 000km^2 (Fig.1) from Saint Louis to Cape Roxo. The Senegalese littoral is a zone of strong productivity (seat of an intense upwelling) where fishing has developed in an important way during last decades[1,2]. In Senegal, the fisheries sector occupies a main place in the national economy because of its important contribution to the economic and social indicators. Thus, marine fishing accounts for 15% proportion of active labor and enters 600×10^3 direct or indirect employments. Its share in total exports of the country is of 32%. The fishery products play also an important role in food of the populations, with a contribution of 75% to the nutritional protein animal origin[3]. In particular, the coastal pelagic fish constitutes, in terms of landings the most important marine resources, approximately 1.9×10^6 tonnes per year[4]. In average, nearly 71% of the catches of the pelagic coastal fish was carried out. The exploited coastal pelagic resources are mainly made up of sardi-

Received: Feburary 15, 2010; **Accepted:** March 20, 2010
Fundation item: Sino-Europe Science and Technology Cooperation Program of the Ministry of Science and Technology of the People's Republic of China (0710)
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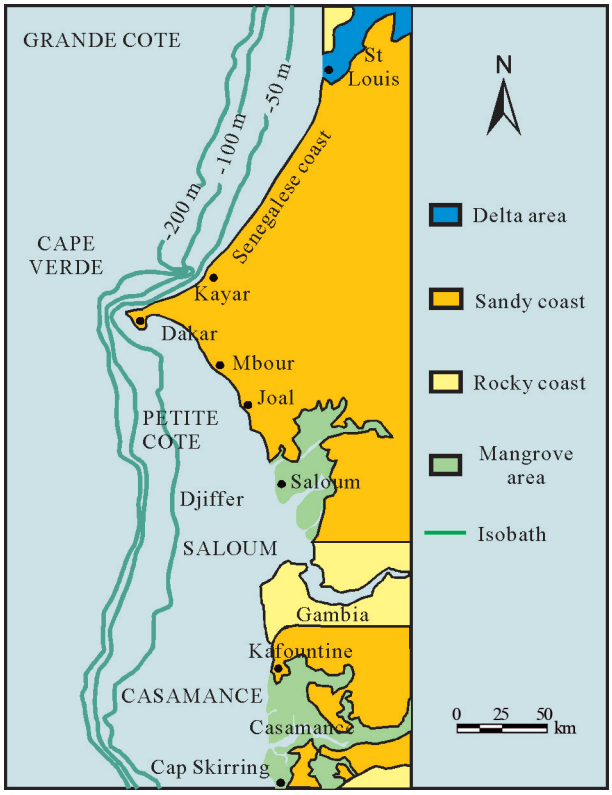

Fig.1 Senegalese coastlines

nella (Sardinella aurita and Sardinella maderensis), chub makerel (Trachurus trecae and Decapterus rhonchus), mackerel (Scomber japonicus), and bonga (Ethmalosa fimbriata).

In Senegal, the exploitation of small pelagic resources is ensured by both diversified artisanal fishing and industrial fishing. The most important coastal pelagic unloading is done by artisanal fishing which is in constant evolution. In the context of intensification of exploitation, we are interested here in sardinella which among small pelagic coastal are exploited in Senegal the most important (nearly 80% of unloading). Both sardinella Sardinella aurita (Valenciennes, 1874) and Sardinella maderensis (Lowe, 1838) are abundantly caught in upwelling area of western North Africa. They carry out migrations of great amplitude between Morocco and the southern zone of Senegal[5-7].

The small pelagic resources which are the sheared stocks on the under regional level, are the subject of direct evaluation by the acoustic method since 1970[8], and indirect evaluation by the Working Group of the Committee of Fishings of Atlantic Center East (COPACE) of Food and Agriculture of the United Nations (FAO). Thus, with an aim of contributing to a better management and sustainable exploitation of these fisheries, we will try to establish the diagnoses of stocks of the two sardinella by using the same methodology which was proposed within the framework of project INCOFISH (Integrating Multiple Demands on Coastal Zones with Emphasis on Fisheries and Aquatic Ecosystems of the European Union). It is about a simple, easily comprehensible and less expensive concept based on the calculation of three sustainable indicators of fishing suggested by Froese[9]. The question which arises in terms of evaluation is to know if these indicators are able to replace or to supplement the traditional methods of evaluation. In this document, the biological material and the method used are initially approached. Then the results resulting from the analysis in terms of specimens per class of size and from the evolution of the annual percentages of the indicators will be presented. Lastly, the results will be discussed from the point of view of management and installation.

2 Materials and Method

2.1 Materials

The data used to test the sustainable indicators on stocks of sardinella comes from the Oceanographical Research Center of Dakar-Thiaroye (CRODT) which is the structure specialized in the fisheries research of the Senegalese Institute of Agricultural Research (ISRA). Two series of data have been used: (a) length frequency and time series of Senegalese artisanal fishing landings from 1990 to 2005; (b) acoustic surveys data of Senegalese area by the R/V Dr. Fridtjof Nansen from 1995 till 2005. For this type, the data have been extrapolated.

2.2 Method

The indicators proposed by Froese[9] have been used. They are three simple sustainable indicators which are:

(1) Percentage of mature fish in catch. The target of management would be to let all the fish (100%) reproduce at least once before they are captured to reconstitute and maintain stocks reproductive healthy. The maturity of the population is regarded as reached

when 90-100 percent of individuals which compose reached sexual maturity. The corresponding size ($L_{m90\text{-}100}$) is generally not available in the literature. It is thus calculated (Table 1) in the following way starting from the intermediate size of sexual maturity L_{m50} (50 percent of the individuals of a species reached sexual maturity), generally available in the conventional databases.

$$L_{m90\text{-}100}=L_{m50}\times 1.14 \quad (1)$$

Table 1 Length of first sexual maturity L_{m50} and $L_{m90\text{-}100}$ of sardinella (cm)

Species	L_{m50}	$L_{m90\text{-}100}$	References
S. aurita	21	24	Fréon (1988)[10], Sénégal
S. maderensis	16	18	Fréon (1988)[10], Sénégal

(2) Percentage of fish having the optimal size (L_{opt}) in catch. The target of management is to let fish grow sufficiently before capturing them. In a distribution of the sizes of the population, L_{opt} is the size to which the number of captured individuals multiplied by their average individual weight is the maximum. It is thus with this size that the output can be obtained. As it is impossible to capture all the individuals with the same size, the objective of management would be to capture all fish with $L_{opt\pm 10}$. L_{opt} is obtained starting from the parameters of growth and natural mortality in the following way [11] (Tables 2 and Table 3):

$$L_{opt}=L_{\infty}\times(3\times(3+M/K)) \quad (2)$$

Where M is the coefficient of natural mortality, L_{∞} is the theoretical asymptotic length and K is the coefficient of growth. K and L_{∞} are the parameters of the von Bertalanffy growth function. We will thus consider fish captured between ($0.9\times L_{opt}$) and ($1.1\times L_{opt}$)

(3) Percentage of the "mega-spawners". The target of management is to ensure the survival of a significant proportion of the oldest fish whose size is higher than ($1.1\times L_{opt}$). The percentage of these fish in the capture which will be regarded as representation of adequacy depending on the strategy of management: - if the objective is to prevent the capture of "mega-spawners", the value concerned will be zero percent; - if the capture of "mega-spawners" is not prohibited, the structure of sizes of the catch should reflect the structure of stock. In this case, a proportion from 30 to 40 percent of "mega-spawners" in catch would be the indication of a healthy stock; - a percentage less than 20 percent of "mega-spawners" in the catch means that stock is threatened on the level of its reproduction.

Table 2 Growth parameters of von Bertalanffy [11] used for pour calculation of L_{opt}

Species	K	L_{∞} (cm)	M	L_{MAX}(cm)	References
S. aurita	1.20	37.00	0.72	37.00	Camarena[7], Senegal
S. maderensis	0.30	37.50	0.54	37.00	Camarena[7], Senegal

Table 3 Optimum length of sardinella (cm)

Species	L_{opt}	$0.1\times L_{opt}$	$L_{opt}-0.1\times L_{opt}$	$L_{opt}+0.1\times L_{opt}$
S. aurita	31	3.1	28	34
S. maderensis	23	2.3	21	26

3 Results

3.1 Length Frequency of Unloaded Specimens

The application of the indicator to the time series of length-frequency data for the pelagic Sardinella aurita unloaded by artisanal fishing shows that the majority of the specimens were captured before their size of first sexual maturity, in other words it has a prevalence of juvenile in total catch (Fig.2a). It is also noted that the captured fish were of size smaller than the optimum size where the maximum yield can be obtained. For the data obtained from acoustic surveys (Fig. 2b), the series present of the heterogeneous captures dominated at the same time by the small ones and mature fish. However, for artisanal fishing data one notes that the captured individuals did not reach the optimum size.

The examination of the catch composition shows that the majority of the specimens of flat sardinella unloaded by artisanal fishing were between the size of the first sexual maturity and the range of optimum size where the maximum yield by recruit can be obtained. This would suggest a sustainable exploitation of the stock of flat sardinella. Some mega- spawners are also presented in catch (Fig.3a). For acoustic surveys data, the analysis shows the same tendency that artisanal fishing (Fig.3b).

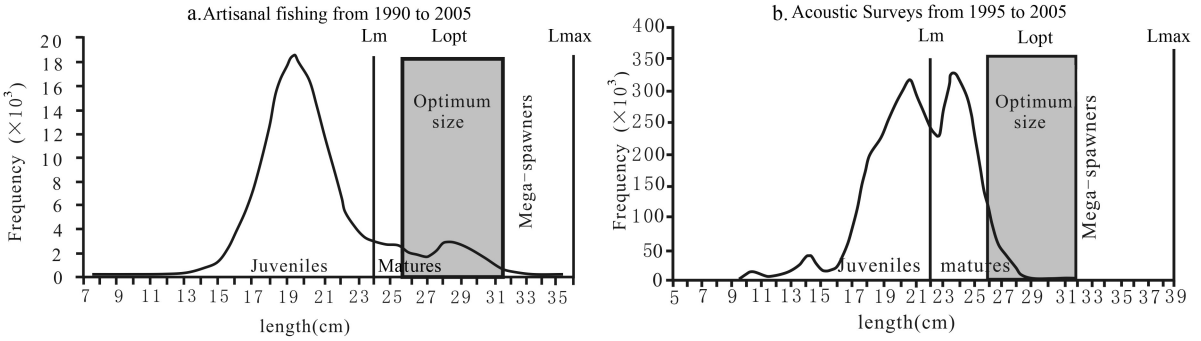

Fig.2 Length frequency of Sardinella aurita landed in Senegal where L_m is the length of first maturity, L_{opt} is length with maximum yield per recruit can be obtained and L_{max} is the maximum size reached during this period

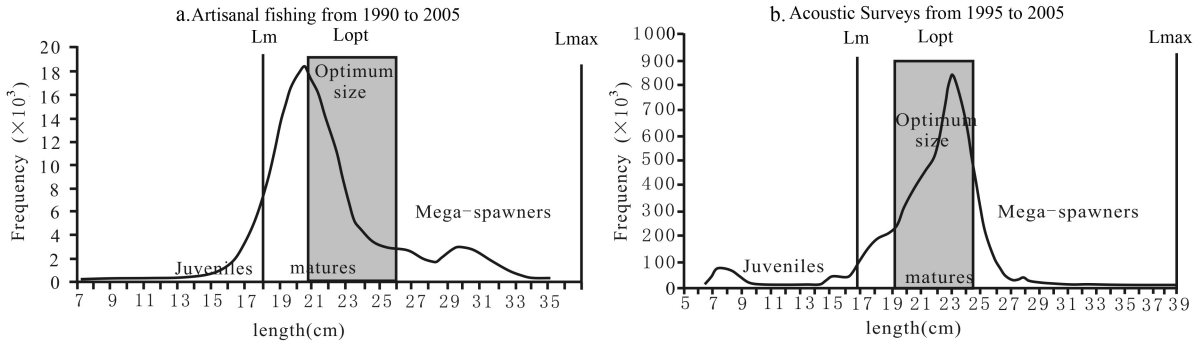

Fig.3 Length frequency of Sardinella maderensis landed in Senegal where L_m is the length of first maturity, L_{opt} is length with maximum yield per recruit can be obtained and L_{max} is the maximum size reached during this period

3.2 Evolution of the Annual Percentages of Indicators

The Fig.4a shows that the percentage of mature fish in the catch of Sardinella aurita has increased by 20% in 1990 with more than 60% in 1997 and since 1998 this percentage fell to reach 20% in 2005. Concerning fish having optimal size, their percentage was above 15% except the peaks which were recorded in 2003 (42%) and 2005 (36%). The percentage is lower compared with the target of 100%. One note also that the mega -spawners are almost absent in the total catches. For acoustic surveys, the analysis reveals that the percentage of mature fish was above 60% since 1995 excluded the value of 80% recorded in 2004 (Fig.4b). The percentages of fish with optimum size and mega-spawners were very weak. These indicators would suggest that stock is overexploited.

The annual evolution of percentages of indicators shows that the percentage of mature specimens of Sardinella maderensis (Fig.5a) was above 50 % except 1999 and 2002. For the specimens with optimum size, their percentage was above 80% from 1990 to 2002, then the En 2004, the percentage has reached 80 % thus approaching the value targets of 100% but in 2005 it has declined again to 30%. However, the percentage of mega-spawners was above 25% between 1990 and 2004 but in 2005, it has strongly increased up to 57%. The percentage of mature specimens was above 30% since 1995 (Fig.5b). Concerning the specimens with the optimum size, their percentage has strongly declined of 89% in 1995 to 43% in 1997 for then increasing up to 93% in 2000 and decreased again in 2001 (53%) and since 2002 it has increased to about 89% in 2005. On the other hand the percentage of the super reproducers was above 15% since 1995.

4 Discussion

Broadly the results obtained highlight trend evolutions which are almost similar for the two types of data. It appeared according to the analysis that the stock of round sardinella Sardinella aurita shows the signs of overfishing. In fact, the strategy of current exploita-

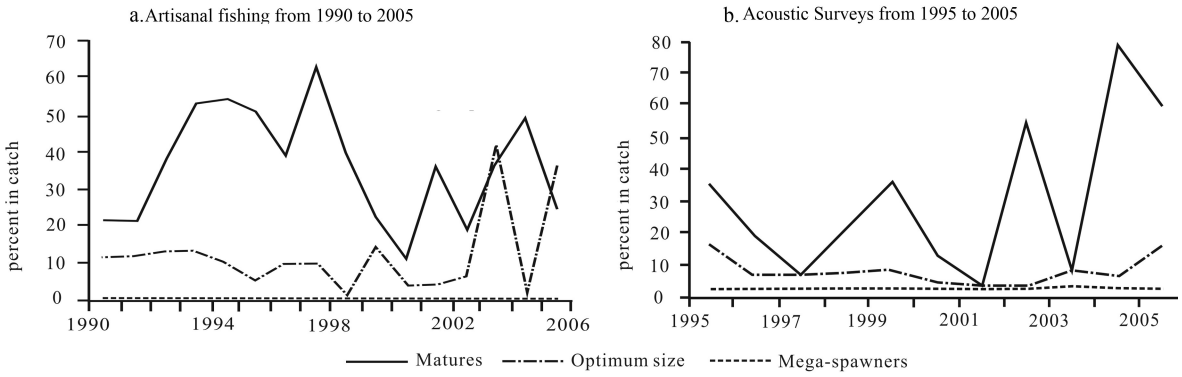

Fig.4 Annual percentages of fish mature, fish at size optimal and mega-spawners in the Senegalese catch of *Sardinella aurita*

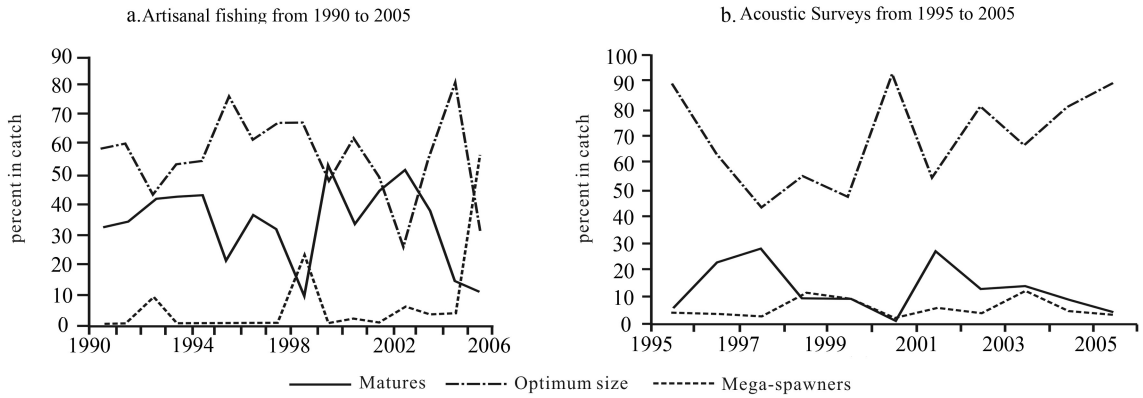

Fig.5 Annual percentages of fish mature, fish at size optimal and mega-spawners in the Senegalese catch of *Sardinella maderensis*

tion tends to reduce the fecundity of this stock because the majority of captured fish were not likely to reach their size compatible with a good reproduction. According to Garcia[12], a stock on fished will consist of juvenile because of fall of life expectancy and consequency of a low fecundity. On the other hand, it appeared in the analysis that the captured specimens of flat sardinella had the chance to reproduce and they reached their optimum size. This would suggest that the stock of flat sardinella is not overexploited, Those results seem to confirm the diagnosis of the work group of FAO[13].This stock knows also an overexploitation of growth, the fish are captured before their optimal size where the maximum yield can be obtained. The increase in the pressure on the juvenile can certainly involve a rise of the catch of number but the average weight of the specimens becomes lower. It would be thus much more interesting to capture fish with a big size to approach the optimal weight like suggested it well[9].

In addition, the diagnoses show that for two stocks, the percentages of super reproducers in lower part of the values of 30 - 40% represent an age of healthy structure. Indeed the mega-spawners play several important roles in the long-term life of a population. According to Solemdal[14] and Trippel[15], the large females are much more fecund because the number of eggs increases exponentially with the size in the majority of species, their eggs also tend to being bigger, thus giving a greater chance to survival of larvae. In fact, they are considered like distributors of good genes and provide a natural insurance against the failures of posterior recruitment[11,16].

The differences observed could be related to the variability of sampling, with spatiotemporal fluctuations of the distribution of resource (in particular migratory). Indeed, the sardinella are able to do migrations between different favourable zone[5] and the distances covered are more important as the specimens are large[6].

5 Conclusion

The analysis of the durable indicators of two stocks the sardinelles, made it possible to highlight a situation of overexploitation of recruitment and growth of the round sardinella contrary to the flat sardinella which does not present apparently a sign of overexploitation. But, taking the fact that these two stocks are shared into account, it would be more logical if not necessary to apply this methodology on the scale under regional.

This study showed the capacity of these indicators to inform correctly about the statute of stocks. The indicators used made it possible to refine the diagnoses of the health condition of stocks. The method used seems to be completely conclusive and could be extended to all the species for which sufficient data are available.

The application of the three indicators should make it possible for the fisheries to increase their unloading and their incomes in spite of the natural mortality of some youthful before their optimal length. In the same way, the mega-spawners, in failing of being saved in the catch, will appear in reasonable proportions in these last. In conclusion, the sustainable indicators could be used like management tools of stocks.

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体长频率分析法在塞内加尔沙丁鱼资源开发中的应用

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摘　要: 本研究利用Incofish项目开发的可持续发展指标开展渔业资源评估应用研究。研究对象为金色小沙丁鱼 (Sardinella aurita) 和短体小沙丁鱼(Sardinella maderensis)。数据来源于1990年—2005年间塞内加尔个体渔业渔获量及由DR FRIDTJOF NANSEN调查船在塞内加尔海域获得的渔获量。采用Froese (2004年)提出的三个可持续捕捞指标, 为渔业资源量的开发状况作出诊断和评估。这些指标包括: 渔获物中成鱼的百分比(以100%为最佳)、达到最适开捕体长鱼的百分比(以100%为最佳)和大型产卵鱼的百分比(以0%为最佳, 体长大于最适开捕体长1.1倍的雌鱼即为大型产卵鱼)。分析结果表明: 金色小沙丁鱼处于过度捕捞状态, 幼鱼在其渔获物中占有优势地位, 捕捞到的金色小沙丁鱼多数小于最适开捕体长, 即生长型过度捕捞; 短体小沙丁鱼处于充分开发利用状态。总体结果揭示, 可持续捕捞指标能够成为替代或完善传统资源评估方法的有用工具。渔业相关的利益主体(包括公众)通过这些指标能够避免过度捕捞, 从而更好地理解渔业管理。

关键词: 可持续捕捞指标; 初次性成熟体长; 最适开捕体长; 小型中上层鱼; 塞内加尔