

Assessment of three small tuna stocks exploited by the algerian fleet using the CMSY Method

Khadra FERHANI¹, Chalabia CHABET DIS¹, Samia BENSMAIL¹,

Moussa MENNAD¹,

k.ferhani@cnrdpa.dz

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Abstract

Estimating the stock status is one of the most fundamental parts of fisheries management intended to preserve the aquatic resources. In this, study the assessment of three stocks of small tunas (Atlantic bonito *Sarda sarda*, Little tunny *Euthynnus alletteratus* and Bullet tuna *Auxis rochei*) caught in the algerian basin (Geographical Sub-Areas 4) was assessed using CMSY method. This method is suitable for data limited stocks and used to estimate maximum sustainable yield (MSY) and related fisheries reference points (B_{msy} , F_{msy}) from catch and resilience. The results of CMSY model suggest that the stocks of the Atlantic bonito and the Little tunny are overfished ($0.5 \leq B_{2020}/B_{msy} < 0.8$) but not subject to overfishing ($F_{2020}/F_{msy} \leq 1$). The stock of Bullet tuna was assessed as overfished ($B_{2020}/B_{msy} = 0.639$) and subject to overfishing ($F_{2020}/F_{msy} = 1.56$). Results obtained from this first study provide a diagnostic of the stock status of these species, that needs to be refined by applying other models.

Keywords: Small tuna, Atlantic bonito, Bullet tuna, Data-limited, Little tunny, CMSY.

¹ National Center for Research and Development of Fisheries and Aquaculture

Introduction

Anthropogenic pressure along the algerian coast has increased with population growth and the commercial demand for fish species. However, the fisheries management increasingly embodies multiple and conflicting biological, ecological, economic, and social objectives (Kell *et al.*, 2007). To reach sustainable fishing situations, maintaining stocks to the maximum sustainable yield is recommended.

Stock assessment requires both biological interpretation and various statistical-mathematical methods to make quantitative estimations and predictions about the state of a fish stock (Hilborn and Walters 1992). Over the last century, stock assessment methods have progressed from descriptive models, to complex statistical models with many estimated parameters and formal diagnostics.

Several new approaches to assess stock status in data-limited situations have been developed; these models do not assume any population dynamics and are simple for estimating sustainable catch levels. For example, Rosenberg *et al.* (2018) tested a new ensemble of method to estimate the stock status of marine fisheries worldwide. Martell and Froese (2013) have produced a method based on surplus production (Catch MSY). The CMSY method is a useful tool both for regional fisheries managers and organizations. The Food and Agriculture Organization (FAO) is delegated by the United Nations (UN) to monitor global progress in the sustainable use of fisheries resources. The Maximum Sustainable Yield (MSY) (SDG Indicator 14.4.1) is used as a reference point for assessing sustainability,

and the CMSY approach is used to estimate it (FAO, 2022).

In the Mediterranean Sea, Atlantic bonito *Sarda sarda*, Little tunny *Euthynnus alletteratus* and Bullet tuna *Auxis rochei* are commercial products and deserve attention. They are defined as epipelagic, neritic and schooling species (Collette and Nauen, 1983; Vinas *et al.*, 2004). A few studies on identification and stock assessment of these species were carried out; however, more studies have been devoted to their main preys, such as sardine, anchovy and round sardinella (Turan *et al.*, 2004; Jemaa *et al.*, 2015; Ferhani *et al.*, 2021a, b).

The status of small tuna stocks in Algeria (Geographical Sub-Areas; GFCM-GSA 4) is currently unknown. These species have high socio-economic relevance in several local communities of the Mediterranean Sea. Small tuna species have a varied diet composed of small pelagic (clupeids, mullets, etc.), crustaceans, molluscs and cephalopods. Many of these species are also preyed by tunas, marlins and sharks (Fromentin and Bonhommeau, 2012; Ferhani *et al.*, 2017).

This study aims to provide reference points to be used as guidelines for the management of Bullet tuna (*Auxis rochei*), Atlantic bonito (*Sarda sarda*) and Little tunny (*Euthynnus alletteratus*).

Material and methods

Data sources

In this study, the data used was the catch time-series of the three species caught in algerian waters (GSA 4, Fig. 1) from 1991 to 2020, that have been provided by the FAO global catch production database (FAO, 2023).

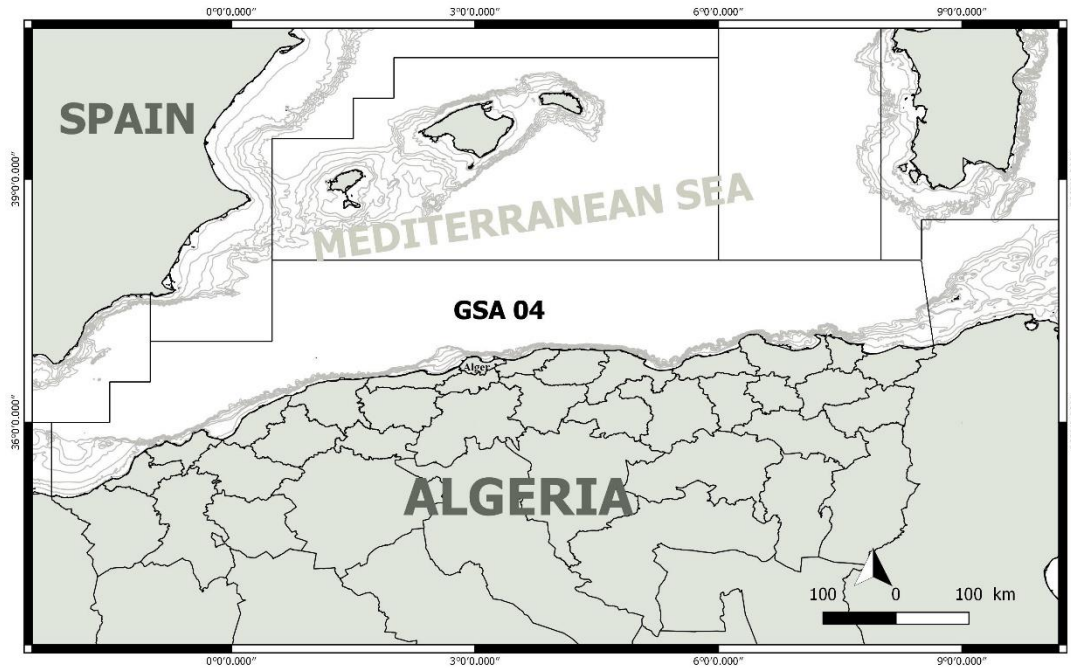


Figure 1. Map of the study area (Algeria GSA04).

CMSY model

This study presents a Monte Carlo method (CMSY) for estimating fisheries reference points from catch data and resilience for data-limited stock assessment as described in Froese *et al.* (2017). The stock status of the considered species was obtained using the Stock Monitoring Tool v0.5an R-Shiny application developed by FAO, and available to the global community. This tool was designed and developed for data-limited situations to evaluate and monitor the sustainability of fish stocks.

Additionally to biomass and sustainable yield, the model estimates other control parameters of fisheries (F_{msy} , B_{msy}), as well as the relative stock size (B/B_{msy}) and stock exploitation level (F/F_{msy}) (Froese *et al.*, 2019).

The CMSY model is based on Schaefer's surplus production model (Schaefer, 1954), which is very simple and therefore very popular:

$$B_{t+1} = B_t + r * (1 - B_t/k) B_t - C_t$$

Where B_t is the total biomass at year t of the time series, r is the intrinsic growth rate, k is the environmental carrying capacity, and C_t is the catch at year t .

The most important output parameters of this model are, fishing mortality corresponding to MSY (F_{msy}) and the biomass corresponding to MSY (B_{msy}) (Ricker, 1975, Carruthers *et al.*, 2014).

Input parameters

This study uses the following parameters as input data: catch time series, resilience of species and prior relative biomass (B/k) ranges corresponding to depletion levels at the start, intermediate, and end of the time series. Resilience is a preliminary (or prior) estimate corresponding to the intrinsic growth rates. The suggested values (Froese *et al.*, 2019) are: high (0.6-1.5), medium (0.2-0.8), low (0.05-0.5), and very low (0.015-0.1). Table 1 presents the ranges assigned to each species. Resilience values were obtained from [FishBase](#). Otherwise, it is possible to take suggestions for

parameters settings according to Froese *et al.* (2019).

Ranges of prior relative biomass (B/k) developed by Froese *et al.* (2019): very strong depletion: 0.01-0.2; strong depletion: 0.01-0.4; medium depletion: 0.2-0.6; low

depletion: 0.4-0.8; nearly unexploited: 0.75-1.0. Input parameters for the CMSY model are shown in Table 1. The interpretation of the results was based on Froese *et al.* (2019) and Zhai *et al.* (2020).

Table 1. CMSY model input parameters (Froese *et al.*, 2017).

Species	Resilience		Depletion B/K ranges		
	Prior ranges r	Status	B _{start} /K	B _{ini} /K	B _{end} /K
<i>Sarda sarda</i>	0.37 - 0.85	Medium	0.2-0.6	0.5-0.9	0.01-0.4
<i>Euthynnus alletteratus</i>	0.37 - 0.85	Medium	0.2-0.6	0.01-0.4	0.01-0.4
<i>Auxis rochei</i>	0.2 - 0.8	Medium	0.2-0.6	0.5-0.9	0.01-0.4

Results

The catch time series of the three small tunas caught by fleets operating in the algerian coast revealed an increase in the catches of *Sarda sarda* about 1042 tons in 2008. After this maximum, catches decreased in 2011. Catches of *Euthynnus alletteratus* were high between 1991 and 2002, a significant decline in catches has been estimated during 2000-2012. The reported landings of *Auxis rochei* steadily increased and reached a record in 2015 at about 1984 tons.

The FAO database shows that the averages of catches over the period 1991–2020 are registered to Bullet tuna (*Auxis rochei*) with

about 628.35 tons (range 173-1984 tons), then to Atlantic bonito (*Sarda sarda*) with 555.18 tons (range 261-1042 tons), and finally to the Litle tunny (*Euthynnus alletteratus*) with 295.2 tons (range 6-585 tons).

From CMSY analysis based on r-k pairs, we can get an overall picture of the environmental capacity and compare the calculated MSY with the catches of the selected year. Results of CMSY analysis are summarized in Table 2. The comparison of MSY with catches in 2020 shows that catches of *A. rochei*, *E. alletteratus* and *S. sarda* were lower than MSY (Table 2).

Table 2. Results for management based on CMSY analysis.

Stock	<i>Sarda sarda</i>	<i>Euthynnus alletteratus</i>	<i>Auxis rochei</i>
r (Year ⁻¹)	0.625	0.485	0.47
K (10 ³ t)	4.27	3.61	7.72
MSY (10 ³ t)	0.672	0.432	0.89
$Catches_{2020}$ (10 ³ t)	0.3694	0.2329	0.7317
B_{msy}	2.13	1.8	3.86
B_{2020}	1.26	1.02	2.47
F_{2020}	0.239	0.239	0.367
F_{msy}	0.313	0.242	0.235
B_{2020}/B_{msy}	0.593	0.563	0.639
F_{2020}/F_{msy}	0.763	0.984	1.56

The small tuna stocks status in the algerian coast, as determined by the CMSY method, are summarized below:

- Catches of *S. sarda* exceeded MSY in 2003, 2006 to 2010 and in 2019. However, the exploitation rate has been above the MSY level recently.
- Landings of *E. alletteratus* exceeded MSY from 1991 to 1999; after this year, catches were below MSY, and the exploitation rate was greater than 1 (except for 03 years 2004, 2012 and 2020).
- Catches of *A. rochei* exceeded MSY for recent years (except in 2013).
- The CMSY model has predicted biomass below the MSY after 2007 for *S. sarda*, after 1991 for *E. alletteratus* and after 2015 for *A. rochei*.
- The relative biomass of *S. sarda* decreased from 2010 onwards and

increased for *E. alletteratus* and *A. rochei* in recent years.

- A wide margin of uncertainty around the last year (2020).
- The last line of graphs (Fig. 2) shows the trend of relative stock size (B/B_{msy}) over relative exploitation (F/F_{msy}). The danger zone is in the lower right quadrant of the graph, the recovery zone is in the upper half of the lower left quadrant.
- The CMSY model indicated that the stock of *S. sarda* is overfished ($B_{2020}/B_{msy}=0.593$) and not subject to overfishing ($F_{2020}/F_{msy}=0.763$), *E. alletteratus* also is overfished ($B_{2020}/B_{msy}=0.563$) and not subject to overfishing ($F_{2020}/F_{msy}=0.984$). However, *A. rochei* is currently both overfished ($B_{2020}/B_{msy}=0.639$) and subject to overfishing

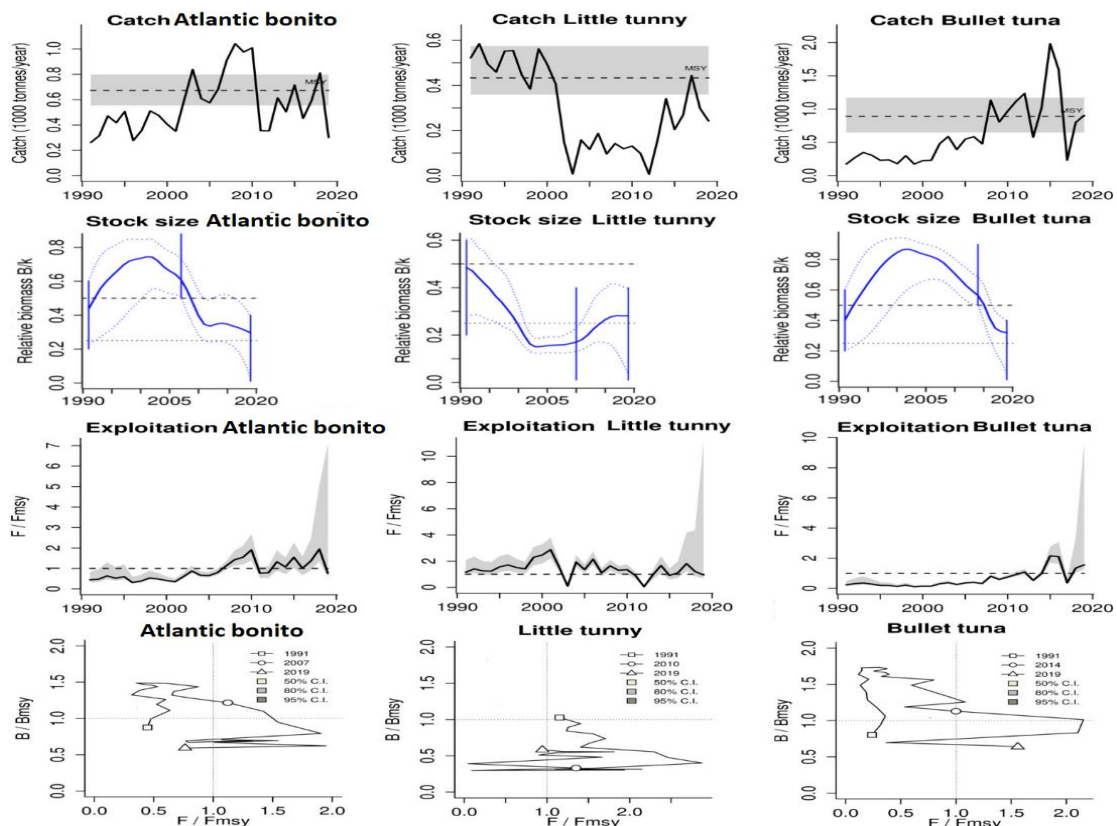


Figure 2. Results of Atlantic bonito (*S. sarda*), Little tunny (*E. alletteratus*), and Bullet tuna (*A. rochei*) stocks from CMSY analysis.

Discussion

The CMSY model can easily be applied to many fisheries because it only requires catch data and some prior ranges. It has been tested in several data-limited stocks for a range of specific stocks (Froese *et al.*, 2017; Winker *et al.*, 2017; Zhai *et al.*, 2020; Liang *et al.*, 2020; Andrašūnas *et al.*, 2022) with results being comparable to other data-poor methods.

This study applied this method to assess the status and exploitation levels of small tuna species fished by algerian fleets in the southwest of the Mediterranean Sea. The Atlantic bonito and the Little tunny were evaluated as overfished and not subject to overfishing. However, Bullet tuna is currently both overfished ($B_{2020}/B_{msy}=0.639$) and in overfishing ($F_{2020}/F_{msy}=1.56$).

Limited studies on stock assessment of small tunas in Algeria were conducted. Ferhani (2016) found that the *A. rochei* was at an optimal level of exploitation. According to the results obtained in this study, and in order to allow stock recovery with better future yields, the management advice is straightforward: maintain the effort at the current level.

In the Mediterranean, the common problem of declared landings is the misidentification between these species, especially young *Auxis rochei* and *Euthynnus alletteratus*. *A. rochei* is not appreciated in spite of being the most abundant in the Mediterranean in terms of larval occurrence (Orsi Relini *et al.*, 2010).

Scombridae are some of the most difficult fish to study, their search is long, and their encounters are irregular, even when the most favourable conditions are met. The presence of these three species is closely linked to the availability of small pelagic which are the preferential prey for small tunas. These three

species are considered priority species of small tunas in the annual ICCAT program SMTYP (ICCAT, 2022). Nevertheless, biological data for these species are insufficient and requires more effort.

In conclusion, results obtained from this first study gives an overview of the stock status of these species. In order to have a rational and sustainable exploitation of these stocks the first management measure suggested is to maintain fishing effort at current level, this may help in recovering the overfished stocks. Furthermore, fisheries statistics and biological data, which can provide a basis of stock assessment and giving appropriate scientific advice, are generally incomplete and not updated. Therefore, more investigations deserve to be undertaken.

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