PRELIMINARY STOCK ASSESSMENTS OF SMALL PELAGIC FISH POPULATIONS OFF WEST AFRICA

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A report prepared by the *Sea Around Us* for the MAVA Foundation

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EXECUTIVE SUMMARY

An assessment of the status of 376 fish and invertebrate populations (or 'stocks'; of which 69% are straddling and 18% are small pelagics) belonging to 69 species exploited by fisheries in 13 Marine Ecoregions (MEs) off West Africa, overlapping with the Exclusive Economic Zones (EEZs) of 25 countries was performed using the CMSY method applied to annual catches (1950-2014) reconstructed by the *Sea Around Us*.

The main finding was that a large majority of the assessed populations (88%) had biomass below that associated with Maximum Sustainable Yield (B_{MSY}), 6% were collapsed ($B < 0.2\ B_{MSY}$), and 12% were considered healthy and can produce MSY.

As expected, cases with unreliable catch statistics generated questionable results and high uncertainties. In particular, the CMSY method, when applied to catch statistics from countries that 'manufactured' high catches in recent decades, suggested lower declines in biomass than likely occurred. This implies that the results presented herein are conservative, i.e., do not exaggerate declining trends in biomass.

Overall, while available catch data and ancillary information could be better, it was possible to assemble incontrovertible evidence that the great majority of small pelagic species and stocks along the Northwest African coast are overfished, some strongly so.

This could be perceived as 'bad news'. This is not new. Previous analyses suggested this as well. However, we want here to emphasize the positive aspect of our finding. Thus, our results also imply that a reduction of the fishing mortality that these fish stock currently experience would lead to an increase of their biomass, and catch increases of millions of tonnes. The development of the rebuilding policies that would lead to such catch increases is outside of the scope of this report. However, the need for, and potential of such policies will have to be kept in mind when discussing this report.

This study is preliminary in that informative priors could be provided only for a few stocks. A plan is briefly presented on how this shortcoming could be mitigated by holding a regional workshop in a country of Northwest Africa where the assessments could be repeated with improved catch data and/or improved constraints (i.e., priors). In the meantime, this report presents summaries of the status of the stocks of small pelagic fish for the Marine Ecoregions overlapping the Exclusive Economic Zones of the 7 countries where MAVA operates (in form of PDFs); further information may be found at www.seaaroundus.org under the respective MEs or EEZs.

INTRODUCTION

Since the late 1990s, there is a widespread perception that fisheries, almost everywhere, are in crisis, mainly due to a huge build-up in fishing effort and a declining resource base (Watson *et al.* 2013; Costello *et al.* 2016). However, while detailed stock assessments are available in many economically developed countries (e.g., the EU, Norway, the US, Canada and Australia), confirming large-scale resource depletion and providing a baseline for rebuilding effort (particularly in the US, the EU and Norway), similar stock assessments are generally lacking for developing countries in general, and Northwest Africa in particular.

There are many reasons for this deficiency, notably: (1) lack of expertise, only slowly alleviated through various training workshops (Venema *et al.* 1988; Palomares and Froese 2017); (2) the frequently cited "lack of data" and (3) a dearth of methods to generate at least preliminary assessments with the limited data that are available. While (1) remains a real problem, (2) and (3) have been mitigated, in the last 2 decades, through the development of computer-intensive methods relying mainly on fisheries catch time series. Moreover, a comprehensive global set of fisheries catch data has recently emerged, i.e., the reconstructed catches of the *Sea Around Us*, which corrects many of the worst problems associated with the database of landings (not catches!) disseminated by the Food and Agriculture Organization of the United Nations (FAO), which is largely based on unmodified submissions by its member countries (see Pauly and Zeller 2016a and www.seaaroundus.org).

Notably, the reconstructed data of the *Sea Around Us* (freely available at www.seaaroundus.org) include discarded catch and distinguish between different fishery sectors (industrial, artisanal, subsistence, and recreational). Perhaps most importantly, these reconstructed catch data are spatialized, i.e., distributed over 180,000 half degree latitude/longitude cells, with this spatialization accounting for the biological distribution of each taxon in the data as well as the access fishing countries may have to waters of other countries (Zeller *et al.* 2016). This allows marine catches to be assigned to spatial entities much smaller than the 19 giant Statistical Areas that FAO uses to assign marine landings. Thus, *Sea Around Us* data have been readily assigned to Exclusive Economic Zones (see the 273 EEZs in Pauly and Zeller 2016b), 64 Large Marine Ecosystems (LMEs; Pauly *et al.* 2008; NOAA 2018), and 232 Marine Ecoregions identified by Spalding *et al.* (2007).

Marine Ecoregions (MEs) are areas roughly corresponding to ecosystems, i.e., communities of plants, animals and other living organisms, which, jointly with the non-living components of their environment, can be found in particular habitats and which interact with each other. Thus, MEs serve as 'units' for the stock assessments that are presented in this report. We are aware that MEs do not necessarily overlap with all distinct populations of various exploited species, but the ecology-based geography they provide are more realistic (especially when grouped to account for 'straddling' stocks) than using the political boundary-based EEZs for our stock definitions, or even the giant artificial FAO Statistical Areas that were used for some global assessments (Costello *et al.* 2012; Rosenberg *et al.* 2014).

The assessments presented here should give an impression of the status of small pelagics in the EEZs of the Northwest African countries which overlap with the MEs where their stocks are located. However, we also assessed fish other than small pelagics, including highly migratory species, which 'straddle' EEZ or ME boundaries (and which may also occur in the High Seas) grouped by FAO areas or by combined MEs covering the areas where they migrate (see www.seaaround.org).

Reconstructed catches *vs* official catches

The catch time series data used for the present study are based on FAO data, corrected and complemented through a procedure called 'catch reconstruction' documented in Zeller *et al.* (2007), Lam *et al.* (2016), Palomares *et al.* (2016) and Zeller *et al.* (2016). The actual reconstructions were largely performed on a per-country (or overseas territory) basis, with over 200 papers (*Fisheries Centre Working Papers*, chapters in *Fisheries Centre Research Reports*, book chapters and articles in peer-reviewed journals) documenting the time series reconstructions in 273 EEZs or parts thereof (see Pauly and Zeller 2016b). For West Africa, this involved the contributions cited for the 25 countries (27 EEZ "chunks") in Appendix I. Herein, the catch of industrial, artisanal, subsistence and recreational fisheries of each country was presented, based on catch and related data from FAO or the fisheries agency of the country in question, complemented with data from other sectors as required to obtain a complete time series, from 1950-2010 (now updated to 2014) of catches by the above-mentioned sectors including estimates of illegal and previously unreported catches. In Appendix I, we also present the uncertainty scores indicating the quality of the underlying reconstructed catch data (for each two decade period and for each of the four fisheries sectors considered), which infers on the reliability of the stock assessments presented here.

The difference between reconstructed *vs.* official catches can be huge, for example in countries which emphasize industrial tuna catches, but neglect to document catches of nearshore reef fishes, which massively contribute to their food security (Zeller *et al.* 2015). Overall, the reconstructed catches for the seven countries where MAVA operates (Cape Verde, Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal and Sierra Leone) over the last 65 years amount to 238 million tonnes, which is 4% of the global world total. Note that this is about 70% higher than reported catches. In addition, reconstructed catches are taxonomically disaggregated to a finer level than official catches. In some cases, however, this yielded species-specific time series of dubious validity, depending on how the disaggregation was performed.

In this report, we present average annual catches for the last five years of the reconstructed catch time series data (2010-2014). In some analysis, e.g., estimating foregone catch, we present results for the last year (2014) of the time series.

Marine ecoregions *vs* EEZs

The EEZs that countries can claim since the UNCLOS was concluded in 1982 extend a maximum of 200 nautical miles from the coast of maritime countries and their territories. Over 90% of the world's marine fisheries catch originates from EEZs. In some cases, e.g., around isolated islands, the inshore fauna belongs to a distinct ecosystem, and hence their exploited fish populations can be treated as distinct 'stocks.' However, in the majority of cases, the EEZs along countries' coasts encompass a range of different ecosystems. Therefore, in order to better address ecosystem issues in fisheries data and assessments, a more nuanced spatial system of MEs is offered by the *Sea Around Us* in addition to EEZs and LMEs.

The Marine Ecoregions of the World (often referred to as MEOW, but here labelled MEs) are biogeographic entities along the world's shelves and coasts, as defined by Spalding *et al.* (2007).

ME data and GIS shapefiles are available from a joint WWF/Nature Conservancy project. MEs have clearly defined boundaries and definitions and are generally smaller than LMEs.

MEs were derived to represent and spatially group ecological patterns of species and communities in the ocean, and to serve as a tool for conservation planning worldwide. The presently available ME system focuses on coast and shelf areas and does not consider open-ocean pelagic or deep benthic environments. The *Sea Around Us* anticipates that parallel but distinct systems for pelagic and deep benthic biotas can be integrated in the future, possibly leaning on the Pelagic Provinces concept of Spalding *et al.* (2012), and/or the biochemical provinces of Longhurst (2010).

Adopting and presenting MEs as part of our spatial data system ensures that the stock assessments we performed for all maritime countries in the world, and to Northwest African countries in particular, based on the well-established data-poor CMSY method, originally proposed by Martell and Froese (2013) and operationalized by Froese *et al.* (2016a), are applied at appropriate ecosystem scales. Internal consistency in our global spatial data allocations are ensured in two steps: (1) we slightly modified some ME boundaries to correspond to existing EEZ boundaries; and (2) we assigned the 232 MEs of Spalding *et al.* (2007) to our 273 EEZs (and parts thereof) as a function of the MEs' overlap with the EEZs (see Appendix 1). Thus, the ME boundaries as presented and used on the *Sea Around Us* website may differ slightly from the ME shapefiles available from the WWF.

The CMSY method

The Catch Maximum Sustainable Yield (CMSY) method first proposed in Martell and Froese (2013) and updated in Froese *et al.* (2016a) is based, like the Maximum Sustainable Yield (MSY) concept from which it gets its name, on an approach to fish population dynamics formulated by Schaefer (1954, 1957; see Figure 1). This approach, also known as 'surplus-production' modeling, assumes that a given ecosystem has, for any animal population, a specific carrying capacity (k), and that if this population is reduced through an external event (e.g., fishing), the population will tend to grow back toward its carrying capacity. Such growth (r_B) will be determined by the attributes of the individuals of the population in question (individual growth rate, age at first maturity, natural mortality, fecundity, etc.), and by the current

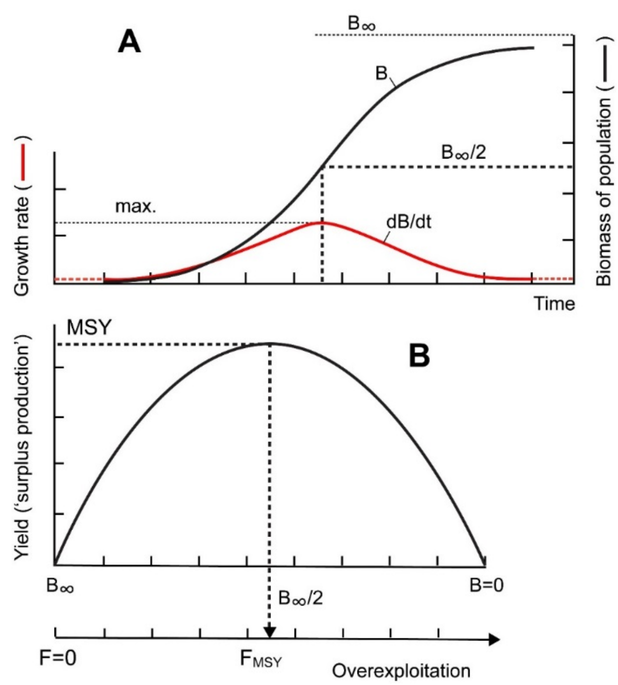


Figure 1. Basic principles behind (Schaefer-type) surplus-production models. A: the population size (i.e., biomass; B) of any living organisms (incl. small pelagic fish) will, if released into a new ecosystem, increase slowly, then rapidly, then again slowly as the carrying capacity of the ecosystem (B_∞) is approached. B: The growth of that population (dB/dt), when plotted against biomass, generates a parabola, with low values of dB/dt (i.e., 'surplus production') near carrying capacity (B_∞) and near B=0. Surplus production has a maximum value at $B_\infty/2$, corresponding to Maximum Sustainable Yield. Surplus-yield predictions, and the CMSY method thus rest on a sound theoretical basis, as density-dependent limitation of carrying capacity is known to occur in all ecosystems (see also text and Figure 2).

abundance (B) of the population. Thus, the abundance of a very small population cannot grow by a large amount, even if its r_B is relatively high, and neither will a population that is near carrying capacity, because in this case, r_B is close to zero. In other words, while the maximum population growth rate $r_B = r_{max}$ occurs at very low population size and r_B declines to zero as the population approaches its maximum size, high population growth occurs at intermediate abundance levels, and the maximum occurs at k/2. Note that the decline in r_B at high levels of abundance is not caused by density dependence of adults, but of recruits (due to a 'hockey stick' stock-recruitment curve), such that at carrying capacity, loss of adult biomass is replaced by recruit biomass, and thus recruit biomass and adult natural mortality (M) determines k. We follow the (slightly confusing) convention in the ecological literature to use r for maximum population growth rate instead of the more telling r_{max}.

Thus, a fishery can maintain a given population at any given biomass level, by removing for every year, a biomass amount equivalent to the natural growth of that population. Also, because production of new biomass is maximized at half carrying capacity (k/2), MSY is obtained when the unfished biomass (B_0) is halved, assuming B_o~k. The CMSY method is built on this conceptual framework, essentially consisting of tracing random trajectories of its likely biomass for a given exploited stock and identifying the trajectories that remain viable while accommodating the catches taken from this population and a few other constraints. Here, 'remaining viable' means not going extinct, and the constraints (or 'priors') are assumed biomass reductions caused by fishing, a range for the carrying capacity (k) of the ME in question for the species under study, and a range of likely values of r, i.e., its maximum intrinsic rate of population growth (see Figure 2). Qualitative measures of r, i.e., resilience (as defined in Musick 1999 and refined in Musick *et al.* 2000), were taken from FishBase (www.fishbase.org). For most exploited species, FishBase also provides priors from biological parameters, especially natural mortality (M), the von Bertalanffy growth parameter K, generation time, maximum age, and fecundity. Note also that FishBase and SeaLifeBase were consulted for all taxonomic and common names (English and French) such that we present our results using the valid scientific names used in FishBase and SeaLifeBase, as well as the official English names considered by FishBase and SeaLifeBase and the French names used in the region.

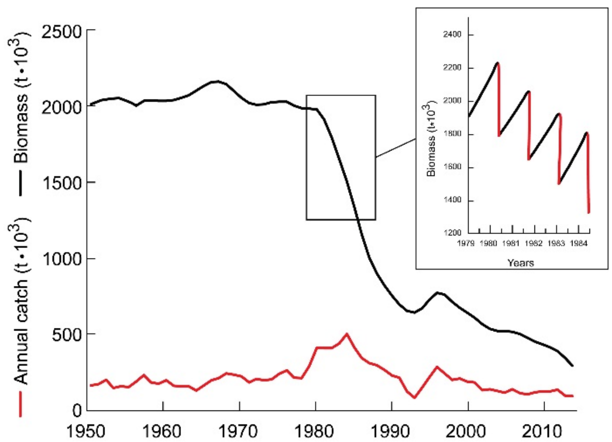


Figure 2. Illustrating the basic principle of the CMSY method: population biomass trajectories are projected from a start year (here 1950) where the biomass is assumed to be a (generally high) fraction of carrying capacity (k, or B_∞) which increase via annual growth increments (as a function of population growth rate, r, and B/B_∞, see Figure 1) and decrease due to catches (in red, see insert). The trajectories that are retained are those that do not crash the population and conform to various constraints (see text).

In practice, given a catch time series and a wide range of growth rate–carrying capacity (r and k) estimates, this produces several biomass trajectories to identify r and k values that produce viable trajectories. Constraints refer specifically to independent prior knowledge about (a) the reduction of biomass by fishing (in %) from carrying capacity at the start of the time series (1950), and (b) the reduction of biomass at the end of the time series (here: 2014). Stock depletion data obtained from general knowledge about the fishery ("good", "not as good as it used to be", "bad", "very bad") is translated into broad ranges of carrying capacity, e.g., 0.4-0.8*k (i.e., 40-80% of the biomass level at the start of the fishery or of a particular point in time where the biomass level is explicitly known) for "good" or 0.01-0.4*k for "bad". Finally, the version of the CMSY model used here also implements a Bayesian version of the full Schaefer model (BSM), which uses relative biomass time-series (e.g., catch per unit of effort or CPUE) from official stock assessments when available, typically resulting in narrower estimates of fisheries reference points and good agreement with the age-based more-data-demanding assessments (see Froese *et al.* 2016a, 2018). In this report, we present the resulting B/B_{MSY} estimates of the CMSY analyses as an average of the last five years (2010-2014).

In 2014, the West African reconstructed catches represented 14% of the 110 million tonnes global catch. Of these 15 million tonnes of West African total catch, only 46% was aggregated to the species level. This part of the *Sea Around Us* reconstructed catches that were disaggregated for 69 West African species listed in Appendix II, represent over 376 stocks from 13 MEs. These stocks represent 90% of the catch disaggregated to species level for the period 1990-2014. A little over 56% of the stocks (representing 26 species) were considered to be 'straddling', while 4% were excluded due to questions about the underlying catch data and 6% were excluded because more than 20% of the catch were from discard estimates (6%).

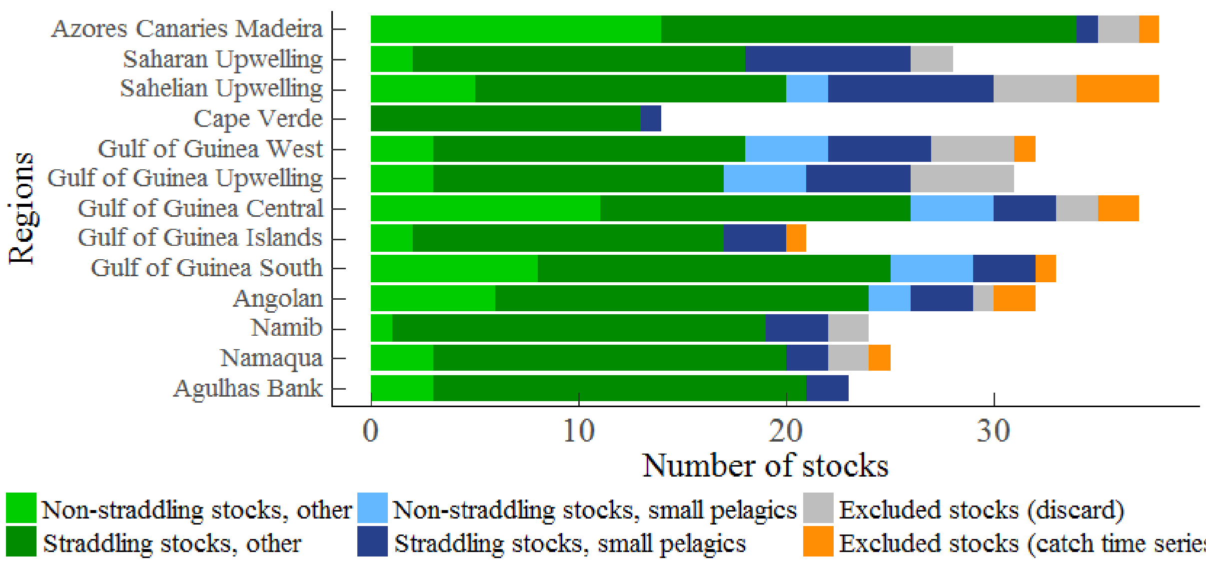


Figure 3. Summary of the number of stocks analyzed (n=376) by marine ecoregion (n=13), including the number of stocks excluded from this analysis due to uncertainties in the underlying catch data or because more than 20% of the catch is from discard estimates (n=37).

Of the 339 stocks kept for analysis, about 60% are from Gulf of Guinea marine ecoregions (West, Upwelling, Central, Islands, South; see Figure 3). For each assessed stock, we provide biomass B/B_{MSY} and exploitation F/F_{MSY} estimates based on either the CMSY or BSM results. The five-year (2010-2014) average of B/B_{MSY} estimated for each of the stocks included here indicate that 6% of these stocks are collapsed ($B < 0.1*k$ or $B < 0.2*B_{MSY}$), 23% are grossly over-fished ($0.2*B_{MSY} \leq B < 0.5* B_{MSY}$), 27% are over-fished ($0.5* B_{MSY} \leq B < 0.8*B_{MSY}$), 32% are slightly over-fished ($0.8*B_{MSY} \leq B < 1.0*B_{MSY}$), and only 12% are of healthy stock size ($B \geq B_{MSY}$) and capable of producing catches close to MSY (Figure 4).

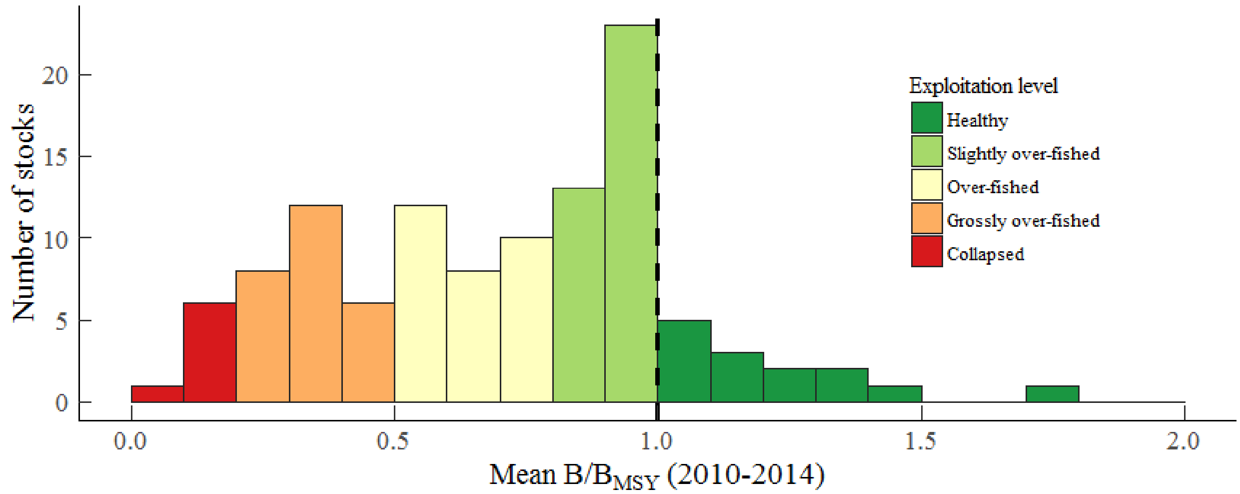


Figure 4. Frequency distribution of mean B/B_{MSY} over the most recent five-year period (2010-2014) for 339 West African stocks (from 26 countries and/or territories) analyzed in this study.

If these populations were allowed to rebuild, they would be expected to generate higher sustainable catches. A preliminary conservative estimate gives the foregone catch for the examined stocks as 6.4 million tonnes per year (30%), when catches in 2014 are compared with 90% of MSY level catches (the 90% value accounts for the fact that predator-prey interactions make it impossible to achieve MSY for all stocks simultaneously). This study examined only stocks identified to the species level, i.e., 46% of the total global catch for the region. If the above percentage is scaled up to the total catch, this would amount to a preliminary estimate of about 8 million tonnes of foregone catch. Note that the global foregone catch was estimated to be at 26 million tonnes (Palomares *et al.* 2018). This implies that the West African stocks can contribute a third of that foregone catch to global fisheries if only they were left to recover by fishing near MSY level.

The stock assessments are currently presented, for each stock, in the form of a 2-page 'Summary report' described below (see also Figure 5). In the near future, the same data (or improved assessments, as the case might be) will be presented as interactive graphs for which underlying data can be downloaded.

Stock summaries reports

First page (Figure 5a)

Title: Common name of the species in the Marine Ecoregion.

Species: Scientific name of the species.

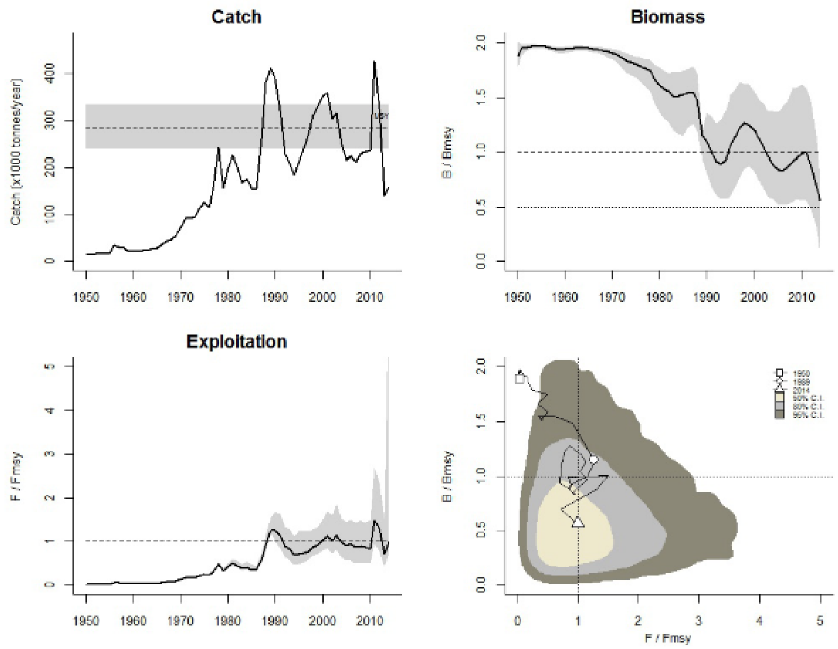
Stock Code: Identification code for species in an ME.

Marine Ecoregion: Name of Marine Ecoregion (or list of MEs, or FAO area or Ocean if straddling).

Region: RFMO area, FAO area, NAFO area, and/or ICES area the ME overlaps with.

European anchovy in Gulf of Guinea West

Species: *Engraulis encrasicolus*, Stock code: Engr_enc_WesternAfrica.
Region: ICCAT.
Marine Ecoregion: Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan, Namib, Namaqua and Angulhas Bank.
Reconstructed catch data used from years 1950 - 2014
For figure captions and method see http://www.seaaroundus.org/cmsy-method



Results for management (based on CMSY analysis)

Fmsy = 0.401, 95% CL = 0.282 - 0.57 (if B > 1/2 Bmsy then Fmsy = 0.5 r)
Fmsy = 0.401, 95% CL = 0.282 - 0.57 (r and Fmsy are linearly reduced if B < 1/2 Bmsy)
MSY = 283, 95% CL = 239 - 334; Bmsy = 704, 95% CL = 455 - 1090 (1000 tonnes)
Biomass in last year = 397, 95% CL = 55.5 - 554 (1000 tonnes)
B/Bmsy in last year = 0.564, 95% CL = 0.0789 - 0.787
Fishing mortality in last year = 0.401, 95% CL =0.287 - 2.87
F/Fmsy = 0.998, 95% CL = 0.716 - 7.14
Comment: Combined catch from Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan, Namib, Namaqua and Angulhas Bank.

1

Figure 5A. Summary report for *Engraulis encrasicholus*, or European anchovy (*anchois*) in the Gulf of Guinea West. This anchovy is among the top three most caught species in the region (with the highest average catch of 257 t year^{-1} for the period 2010-2014), and after *Sardina pilchardus* (1885 t year^{-1}, straddling Sahelian and Saharan Upwellings) and *Scomber colias* (277 t year^{-1}, straddling the Azores Canaries Madeira and Saharan Upwelling MEs). It is also the widest ranging of these three species, straddling the MEs of the Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan, Namib, Namaqua and Angulhas Bank. A: Page 1, presenting results for management use, which indicates the stock assessment model adapted for the stock (CMSY or BSM).

Catch data source: *Sea Around Us* catch data for specified years, in tonnes (1000 kg).

URL for figure captions: This URL link takes the user to the method page where the detailed figure captions are available.

Catch graph: Catch data that were analyzed, with the estimate of MSY; the grey area indicates approximate 95% confidence limits.

Biomass graph: Estimate of relative biomass (B/B_{MSY}) with approximate 95% confidence limits.

Exploitation graph: Estimate of relative exploitation rate (F/F_{MSY}), with F_{MSY} accounting for reduced recruitment when the stock biomass drops below 0.5 B_{MSY}. Grey area indicates approximate 95% confidence limits.

F/F_{MSY} vs B/B_{MSY} graph: Trajectory of relative stock size (B/B_{MSY}) *vs* relative exploitation (F/F_{MSY}), with approximate 50 %, 80 % and 90 % confidence limits for the end year.

Numeric results for management (based on CMSY or BSM analysis):

F_{MSY}: MSY-level rate of fishing mortality with approximate 95% confidence limits when the stock is within safe biological limits ($B > 0.5\ B_{MSY}$).

F_{MSY}: MSY-level rate of fishing mortality with 95% confidence limits when stock is below safe biological limits ($B < 0.5\ B_{MSY}$). F_{MSY} is then linearly reduced.

MSY: Maximum sustainable yield with approximate 95% confidence limits.

B_{MSY}: Biomass required to produce MSY, in 1000 tonnes, with approximate 95% confidence limits.

Biomass in last year: Estimate of biomass (B) in the last year in 1000 tonnes with approximate 95% confidence limits.

B/B_{MSY} in last year: Estimate of relative biomass in the last year with approximate 95% confidence limits.

Fishing mortality in the last year: Estimate of fishing mortality (F) in the last year with approximate 95% confidence limits. Units in $year^{-1}$.

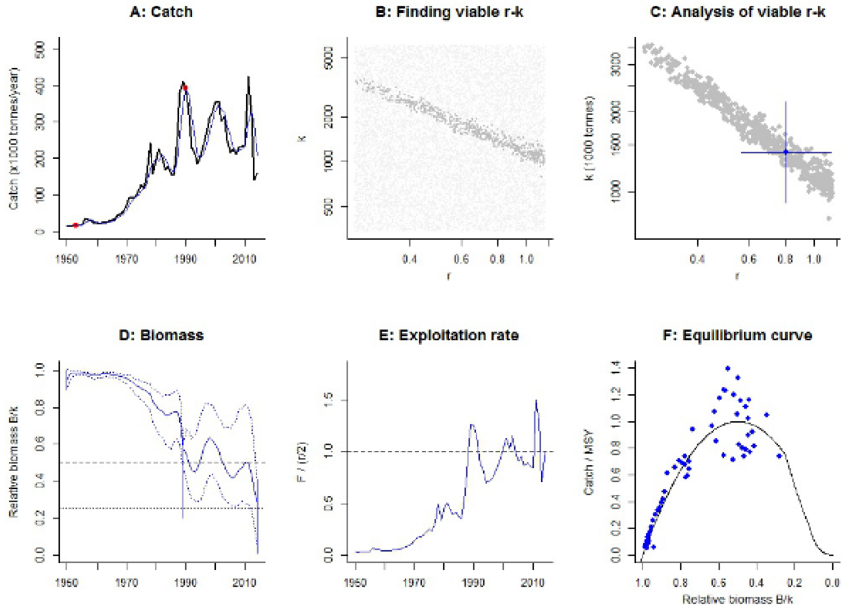
F/F_{MSY}: Estimate of relative exploitation rate in the last year with approximate 95% confidence limits.

Comment: Description on any adjustments to priors or to CMSY method defaults done on the stock.

Second page (Figure 5b)

A: Catch graph: The *Sea Around Us* catch time series indicated by the bold black line. The three-year moving average indicated by the thinner blue line. Red circles indicate the highest and lowest catch used in the derivation of priors.

B: Finding viable r-k: The r-k log space that was explored, with dark grey points being r-k pairs found to be compatible with the catches and the prior information.



Results of CMSY analysis with altogether 609 viable trajectories for 582 r-k pairs

r = 0.803, 95% CL = 0.565 - 1.14; k = 1408, 95% CL = 910 - 2180 (1000 tonnes)
MSY = 283, 95% CL = 239 - 334 (1000 tonnes/year)
Relative biomass last year = 0.282 k, 95% CL = 0.0394 - 0.393
Exploitation F/(r/2) in last year = 0.998
Relative abundance data type = None
Prior initial relative biomass = 0.9 - 1 default
Prior intermediate relative biomass = 0.2 - 0.6 in year 1989 default
Prior final relative biomass = 0.01 - 0.4, default
Prior range for r = 0.26 - 1.2 expert, prior range for k = 339 - 6057 (1000 tonnes) default
Source for relative biomass:

2

Figure 5B. Summary report for *Engraulis encrasicholus*, European anchovy (*anchois*) in the Gulf of Guinea West. B: Page 2, presenting the results of the CMSY analyses and the Bayesian Schaefer model for cases when CPUE from independent sources are available. For this particular stock, no independent CPUE estimates were available.

C: Analysis of viable r-k: The most probable r-k pair among the dark grey r-k points are indicated by a blue cross, which also indicates the approximate 95% confidence limits. If a BSM analysis was performed, the black points show possible r-k pairs, with the red cross indicating the most probable r-k pair with approximate 95% confidence limits.

D: Biomass: Estimate of relative biomass from CMSY shown by the blue solid line with blue dotted lines indicating approximate 95% confidence limits. If relative abundance data were available and used, an additional red solid line is shown, scaled to the BSM estimate of B_{MSY} = 0.5 k, with red dotted lines indicating the approximate 95% confidence intervals. The vertical blue lines indicate the prior biomass ranges.

E: Exploitation rate: CMSY estimates of exploitation rates in blue. BSM estimates of exploitation rates are in red.

F: Equilibrium curve: The Schaefer equilibrium curve of catch/MSY relative to B/k with an indent at B/k < 0.25 to account for reduced recruitment at low stock sizes. The blue dots are CMSY estimates with red dots being BSM estimates, if present.

Results of CMSY analysis with total number of viable trajectories given of r-k pairs:

r: Maximum intrinsic rate of population growth estimated by CMSY r-k pairs with approximate 95% confidence limits. Units in $year^{-1}$.

k: Carrying capacity or unexploited size of stock, in 1000 tonnes, with approximate 95% confidence limits.

MSY: Maximum sustainable yield from CMSY with approximate 95% confidence limits, in 1000 tonnes per year.

Relative biomass last year: Estimate of biomass (B) in the last year in 1000 tonnes with approximate 95% confidence limits.

Exploitation F/(r/2) in last year: Exploitation rate for the last year of time series.

Results from Bayesian Schaefer model (BSM) using catch & CPUE (section will appear only if relative abundance data were available and used).

r: Maximum intrinsic rate of population growth estimated by CMSY r-k pairs with approximate 95% confidence limits. Units in $year^{-1}$.

k: Carrying capacity or unexploited size of stock with approximate 95% confidence limits.

Relative biomass (last year): Estimate of relative biomass (B/k) in the last year in 1000 tonnes with approximate 95% confidence limits.

Exploitation F/(r/2) in last year: Relative exploitation rate for the last year of time series.

q: catchability coefficient. Required to relate relative abundance to biomass.

Prior range of q: Low and high limits of range for q.

Relative abundance data type: There are three possibilities, 'None,' 'CPUE,' 'Biomass.'

Prior initial relative biomass: Can be user input or default values.

Prior intermediate relative biomass: Can be either input by users or default values.

Prior final relative biomass: Can be either input by users or default values.

Prior range for r: Intrinsic rate of population growth. Can be either input by users or default ranges (from resilience).

Prior range for k: Initial range of k used, calculated from prior r and catch.

Source for relative biomass: URL to source of relative biomass, if available.

Stocks in the countries where MAVA operates

In the following, the stock assessments that were performed for the marine ecoregions in West Africa are illustrated via some of the results obtained for the three MEs overlapping with the EEZ of countries where MAVA operates (Figure 6). Therein, emphasis is given to the biomass trends of the stocks that were covered, as these can provide the information required for a traffic light system reflective of the stock status. Note that the chunks of EEZs for each West African country and the list of MEs per EEZ are available in Table 1. Also, since the stock assessment results are now available on the *Sea Around Us* website, we only provide a summary of the stock status results for each of these three MEs.

We investigated 84 stocks from these three marine ecoregions (see Figure 7), of which, 5% were excluded due to doubts about the reliability of the underlying catch data and 10% were excluded because more than 20% of the catch originated from discard estimates. Of these, 51% are straddling along the Northwest African coastline (and possibly further north and/or south) and 10% are considered non-straddling. Small pelagics (14 straddling and 6 non-straddling) consist 24% of these stocks.

Table 1. The EEZs and marine ecoregions of West Africa from Morocco to South Africa. The countries (7) and marine ecoregions (3) in bold font signify the areas where the MAVA operates.

EEZ (and parts thereof)	Marine Ecoregion
Angola	Angolan
Azores Isl. (Portugal)	Azores Canaries Madeira
Benin	Gulf of Guinea Central
Cameroon	Gulf of Guinea Central
Canary Isl. (Spain)	Azores Canaries Madeira
Cape Verde	**Cape Verde**
Congo (ex-Zaire)	Gulf of Guinea South
Congo, R. of	Gulf of Guinea South
Côte d'Ivoire	Gulf of Guinea Upwelling
Equatorial Guinea	Gulf of Guinea Islands
Gabon	Gulf of Guinea South
Gambia	**Sahelian Upwelling**
Ghana	Gulf of Guinea Central
Ghana	Gulf of Guinea Upwelling
Guinea	**Gulf of Guinea West**
Guinea-Bissau	Gulf of Guinea West
Guinea-Bissau	Sahelian Upwelling
Liberia	Gulf of Guinea West
Madeira Isl. (Portugal)	Azores Canaries Madeira
Mauritania	Sahelian Upwelling
Morocco (Central)	Saharan Upwelling
Morocco (South)	Saharan Upwelling
Namibia	Namaqua
Namibia	Namib
Nigeria	Gulf of Guinea Central
Sao Tome & Principe	Gulf of Guinea Islands
Senegal	Sahelian Upwelling
Sierra Leone	Gulf of Guinea West
S. Africa (Atl. & Cape)	Agulhas Bank
S. Africa (Atl. & Cape)	Namaqua
Togo	Gulf of Guinea Central

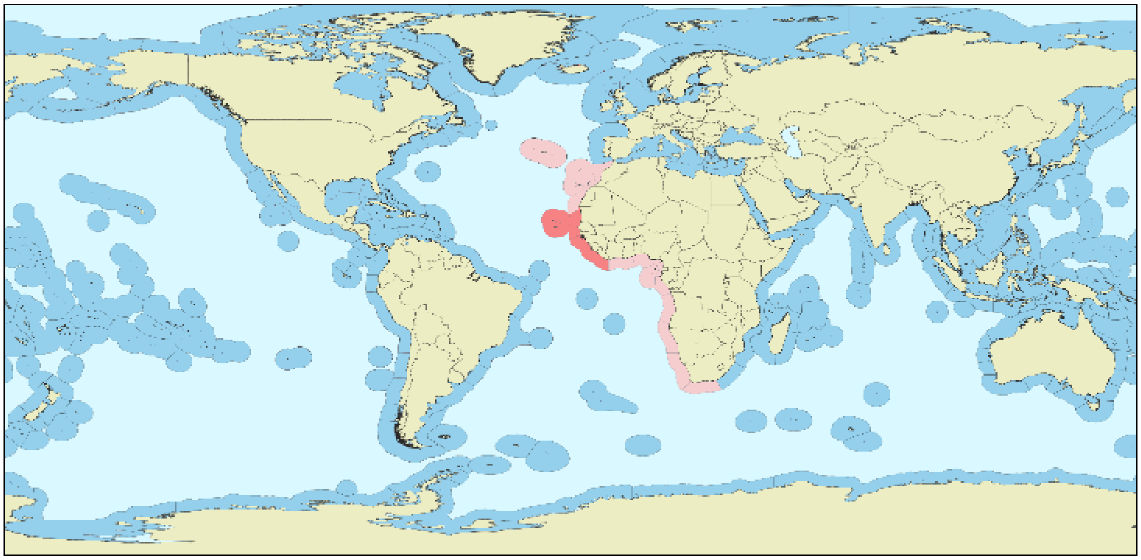


Figure 6. The 232 Marine Ecoregions of the World (modified from Spalding *et al.* 2007). The 13 Marine Ecoregions overlapping with the Exclusive Economic Zones of West African countries are shown in pink and the three where MAVA operates in red.

Of the 71 stocks that we were able to analyze (Figure 7), two are considered collapsed, i.e., 1) the horse mackerel, *Trachurus trachurus* (B/B_{MSY} = 0.10), which straddles the Sahelian Upwelling, Saharan Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling marine ecoregions; and 2) the common octopus, *Octopus vulgaris* (B/B_{MSY} = 0.19), in the Gulf of Guinea West marine ecoregion. A little over 76% of these stocks have B/B_{MSY} values ranging from 0.26 to 0.99 (grossly overfished, overfished, and slightly overfished) and 18% are considered healthy with B/B_{MSY} values >1.

Horse mackerel populations have been declining with little indication of positive recruitment, which prompted the IUCN to include it in the IUCN Red List of threatened species as Vulnerable (see Smith-Vaniz *et al.* 2015). Similar concerns were expressed for populations of the common octopus since the quality of the underlying data on which the most recent assessments are based is questionable (see Meissa *et al.* 2016, which indicates that the 2016 biomass represents 34% of the virgin biomass)[2].

In 2014, the catch from the three MEs where MAVA operates amounted to 4.5 million tonnes, which is about 29% of the catch for all of West Africa. Of these, 38% were disaggregated to species level. The estimated total MSY_{2014} level catch for the stocks analyzed here is 5.8 million tonnes, which suggests a foregone catch of about 4,000 tonnes, and which suggests a total foregone catch of 6,400 tonnes.

[2] See also the FishSource page for the Senegal-Gambia stock of *Octopus vulgaris* at: https://www.fishsource.org/stock_page/2237

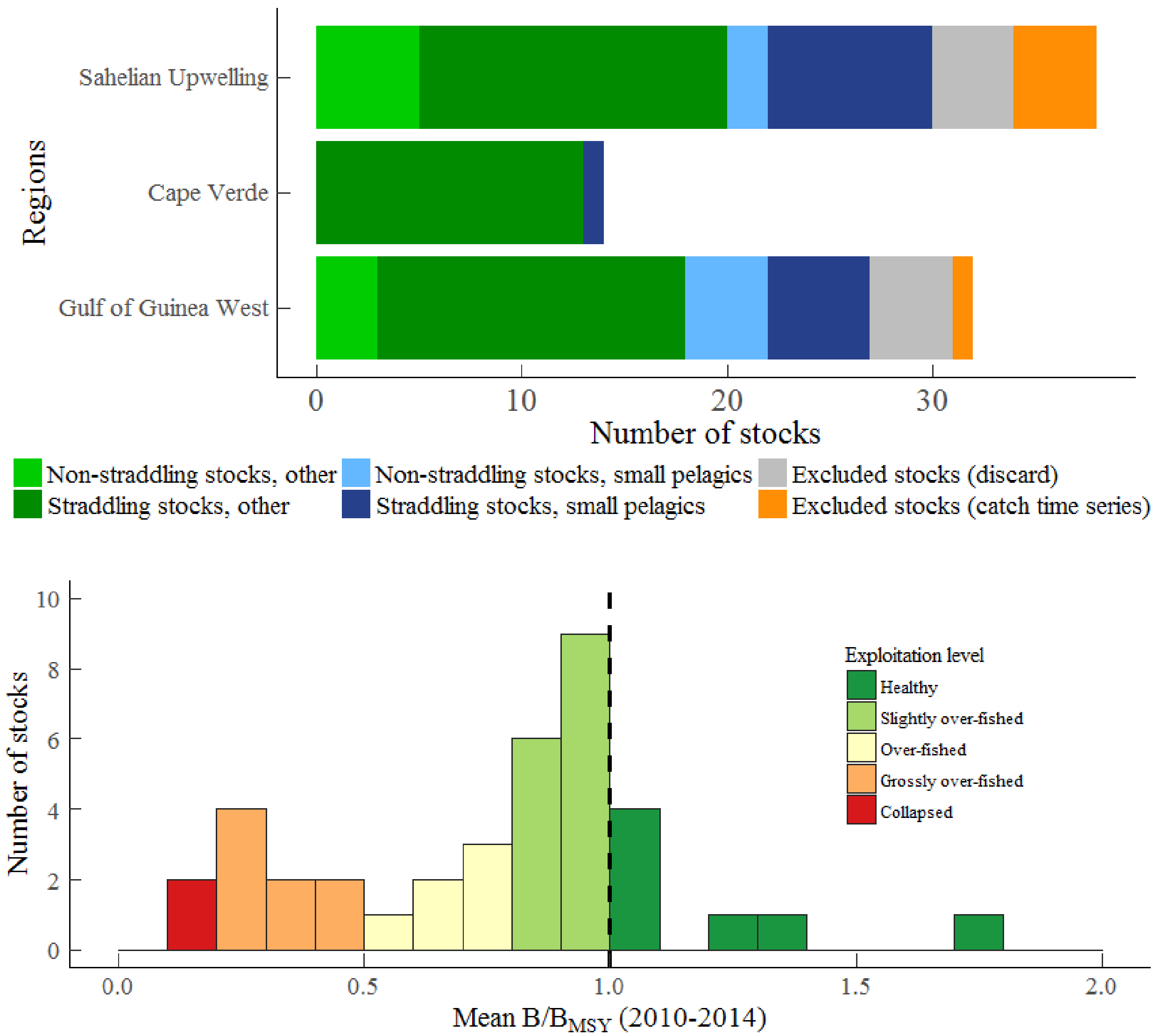


Figure 7. Summary of the stocks analyzed for the three marine ecoregions (Cape Verde, Sahelian Upwelling and Gulf of Guinea West) where MAVA operates. Upper panel: Number of stocks analyzed (n=84) by marine ecoregion (n=3), including the number of stocks excluded from this analysis due to uncertainties in the underlying catch data or because more than 20% of the catch is from discard estimates (n=13). Lower panel: Frequency distribution of mean B/B_{MSY} over the most recent five-year period (2010-2014) for these stocks. Note that the 2 collapsed stocks are the common octopus and the horse mackerel (*Octopus vulgaris*, *Trachurus trachurus*, respectively).

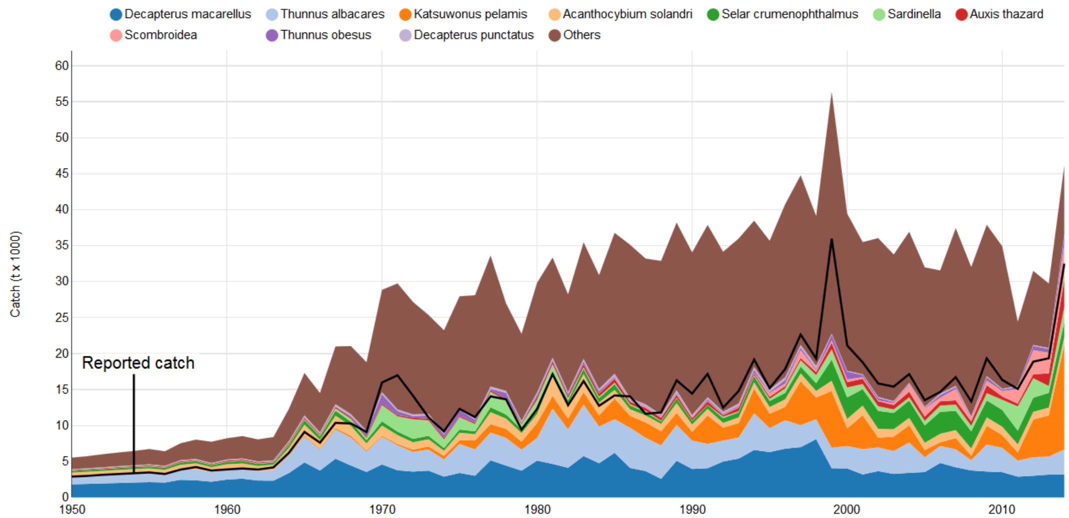


Figure 8. Catch composition of the Cape Verde marine ecoregion adapted from the *Sea Around Us* website and which shows a dominance of mostly straddling stocks, like the mackerel scad (*Decapterus macarellus*) and large pelagics (*Thunnus albacares, Katsuwonus pelamis* and *Acanthocybium solandri*) over the 65-year period analyzed here.

Cape Verde

The Cape Verde EEZ is entirely within the Cape Verde marine ecoregion. The total catch in the ME for 2014 is 46 thousand tonnes, i.e., 0.3% of the West African catch (see Figure 8). Most of the stocks analyzed for this ME belong to medium and large pelagics. The yellowfin tuna and the mackerel scad straddling the Eastern Central Atlantic Ocean are the large pelagic species with the highest catch (2010-2014 annual average catch of 7 million tonnes and 0.3 million tonnes, respectively). We analyzed 15 straddling stocks ranging from the North African coast (Sahelian Upwelling, Saharan Upwelling, Gulf of Guinea West, Cape Verde and Azores Canaries Madeira) to the open Atlantic Ocean. Overall, the CMSY analyses indicate that 80% of these stocks fall in one of the three overfished categories (including the mackerel scad with a B/B_{MSY} value of 0.55, i.e., grossly overfished), and 20% are healthy and capable of producing MSY.

Gambia, Guinea-Bissau, Mauritania, Senegal

The Sahelian Upwelling ME encompasses the EEZs of the Gambia, Guinea-Bissau, Maritania and Senegal. The catch that this ME had in 2014 is 2,235 thousand tonnes, i.e., 15% of the West African catch, which is dominated by the round sardinella (*Sardina aurita* 2014 catch of 300 thousand tonnes) and followed by the Madeiran sardinella (*Sardinella maderensis* at 136 thousand tonnes), cobia (*Rachycentron canadum* at 131 thousand tonnes), horse mackerels (*Trachurus* spp at 123 thousand tonnes) and European pilchard (*Sardina pilchardus* at 107 thousand tonnes; see Figure 9). We investigated 38 stocks, of which 8 were temporarily excluded due to problematic catch time series (n=4) and because >=20% were coming from discard estimates (n=4). Of the 30 stocks retained for analyses, 7 are non-straddling and 23 are straddling. Overall, the CMSY analyses indicate that in this ME, one of these stocks is collapsed (horse mackerel, *T. trachurus* with $B/B_{MSY} = 0.1$), 77% fall in one of the three overfished categories and only 19% are healthy and capable of producing MSY. Note that the round sardinella, which dominates the 2014 catch has a B/B_{MSY} value of 1.2, which falls in the healthy category, albeit a decreasing trend since 2010 (see Figure 11).

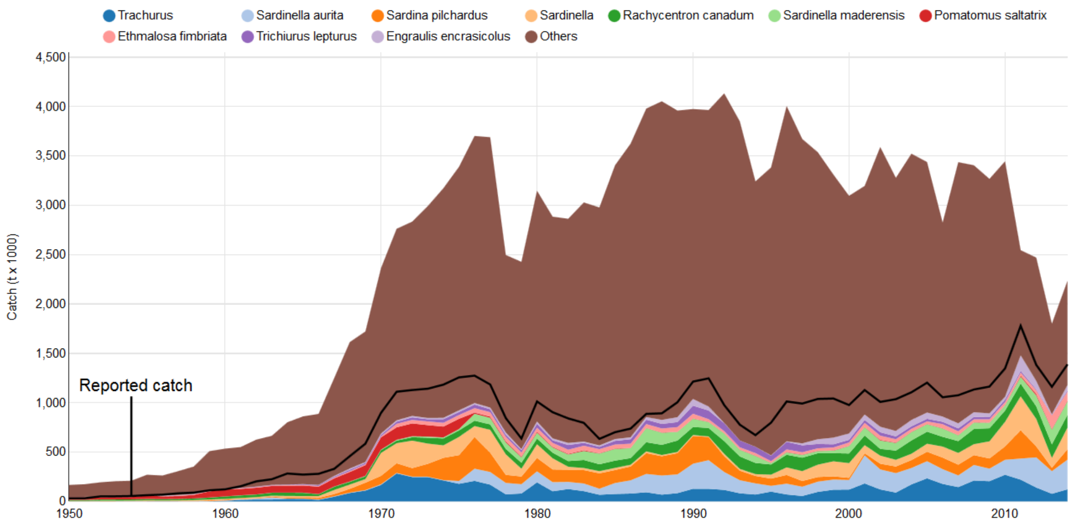


Figure 9. Catch composition of the Sahelian Upwelling marine ecoregion adapted from the *Sea Around Us* website and which shows a dominance of *Trachurus* spp., *Sardinella aurita*, *Sardina pilchardus, Sardinella* spp., and *Rachycentron canadum* over the 65 year period analyzed here.

Guinea, Guinea-Bissau, Sierra Leone

The Gulf of Guinea West marine ecoregion encompasses the EEZs of Guinea, Guinea-Bissau, and Sierra Leone, and had a 2014 catch of 2226 thousand tonnes, i.e., 15% of the West African catch. This catch was dominated by bonga shad, *Ethmalosa fimbriata*, with a 2014 catch of 233 thousand tonnes, i.e., 10% of the region's catch. This is followed by cephalopods (2014 catch at 148 thousand tonnes), *Sardinella* spp. (55 thousand tonnes), croakers, *Pseudolithus* spp. (39 thousand tonnes) and lesser African threadfin, *Galeoides decadactylus* (39 thousand tonnes; see Figure 10). We investigated 32 stocks (7 non-straddling; 20 straddling), of which 5 were temporarily excluded due to problematic catch time series (n=1) and because >=20% were coming from discard estimates (n=4). Overall, the CMSY analyses indicate that two of these stocks (*T. trachurus* and *Octopus vulgaris*; see above discussion of these two stocks) are collapsed, 75% fall in one of the three overfished categories and only 18% are healthy and capable of producing MSY. Bonga shad, which dominates the 2014 catch has a decreasing B/B_{MSY} trend since 2000 and is categorized as slightly overfished (five year B/B_{MSY} of 0.96; see Figure 11).

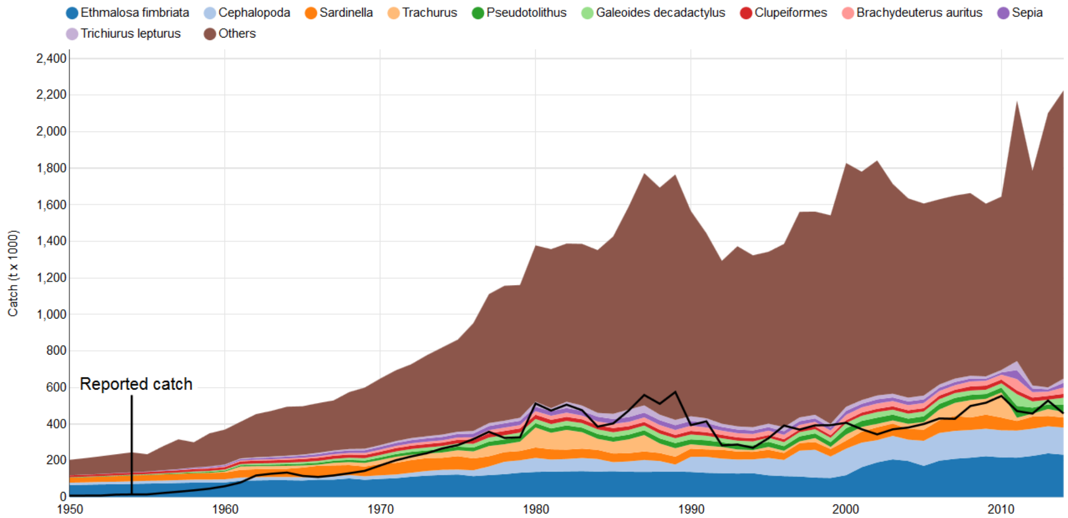


Figure 10. Catch composition of the Gulf of Guinea West marine ecoregion adapted from the *Sea Around Us* website and which shows a dominance of *Ethmalosa fimbriata*, Cephalopoda, *Sardinella* spp., *Trachurus* spp., and *Pseudolithus* spp. over the 65 year period.

Small pelagic stocks in Northwest Africa

Since the 2000s, the small pelagic stocks of interest in Northwest Africa consist of sardine (*Sardina pilchardus*), sardinellas (*Sardinella aurita* and *S. maderensis*), horse mackerels (*Trachurus trachurus* and *T. trecae*) and chub mackerel (*Scomber japonicus*) (see FAO 2001). This list was extended to include shad (*Ethmalosa fimbriata*), anchovy (*Engraulis encrasicolus*), and false scad (*Caranx rhonchus*[3]; see CECAF 2018). Our analyses added to this list some species that make up 90% of the Sea Around Us reconstructed catch disaggregated to the species level, but which are not targets (or have not been) for stock assessment in the region, i.e., the West African ilisha, *Ilisha africana*, flathead grey mullet, *Mugil cephalus*, mackerel shad, *Decapterus macarellus*, and European pilchard, *Sardina pilchardus*. This brings the number of small pelagic species we present in Table 2 to 13, five of which are considered non-straddling and eight are straddling.

Sardine tops the list with a five year average catch (2010-2014) of about 2 million tonnes, followed by round sardine (341 thousand tonnes), European pilchard (257 thousand tonnes), Madeiran sardinella (249 thousand tonnes), bonga shad (229 thousand tonnes), and Cunene horse mackerel (112 thousand tonnes).

Our analyses (presented in Figure 11A) indicate that of the non-straddling stocks, the round sardine of the Gulf of Guinea West marine ecoregion is considered grossly overfished (B/B_{MSY} = 0.29; Figure 11A-E), three are considered slightly overfished (West African ilisha of Gulf of Guinea West, bonga shad of Gulf of Guinea West and flathead grey mullet of Sahelian Upwelling) and

[3] CECAF (2018) used *Decapterus rhonchus*, a senior synonym of the current valid name *Caranx rhonchus* (see https://fishbase.ca/Nomenclature/SynonymSummary.php?ID=152158&GSID=15397&Status=synonym&Synonymy=senior%20synonym&Combination=new%20combination&GenusName=Decapterus&SpeciesName=ronchus&SpecCode=1899&SynonymsRef=3397&Author=(Geoffroy%20Saint-Hilaire,%201817)&Misspelling=-1).

two are considered healthy (Madeiran sardinella of Gulf of Guinea West and bonga shad of Sahelian Upwelling). As for the straddling small pelagic stocks, our analyses (Figure 11B) indicate that Atlantic horse mackerel is now collapsed (B/B_{MSY} = 0.10; Figure 11B-G), while false scad is grossly overfished (B/B_{MSY} = 0.48; Figure 11B-A), and mackerel scad is overfished (B/B_{MSY} = 0.55; Figure 11B-B). The rest of the stocks are slightly overfished (n=4) and two are considered healthy (round sardinella straddling Sahelian Upwelling and Saharian Upwelling, B/B_{MSY} = 1.23, Figure 11B-E; Cunene horse mackerel B/B_{MSY} = 1.74, Figure 11B-H).

Our results indicate that most of the non-straddling stocks started to experience decreasing biomass trends since the 1970s (Figure 11A). The decline in biomass of bonga shad and West African ilisha in Gulf of Guinea West came later in the 2000s. The overall trend, however, suggests strong declines in biomass. Similar results are shown for straddling stocks, which show five stocks (Figure 11B-A, B, C, D, G) with continuously decreasing biomass trends since the 1960s; two stocks with an erratic trend since the 1980s (Figure 11B-E, F) and one stock showing recovery from the 2000s (Cunene horse mackerel in Western Africa; Figure 11-H).

We cannot compare our results with those obtained by CECAF (2018) because the stock definitions used in their assessment do not match the marine ecoregion definition of the stocks that are analyzed here. However, we come to similar conclusions concerning the Atlantic horse mackerel (average 2010-2014 catch of 1.9 thousand tonnes), which should no longer be exploited and it is now listed as 'Vulnerable' by the IUCN Red List of Threatened species (see Smith-Vaniz *et al.* 2015). Similarly, our results for the western stock of round sardinella agree with the CECAF (2018) assessment that it is grossly overfished.

The CECAF (2018) analyses included assessments for groups of species by genus and failed to assess some stocks due to lack of suitable data. Given that the *Sea Around Us* reconstructed catches are disaggregated for most of the important species groups, our CMSY analyses might provide proxies in cases where the underlying catch reconstruction data are somewhat reliable (see Appendix I).

Thus overall, while available catch data and ancillary information could be better, it was possible to assemble incontrovertible evidence that the great majority of small pelagic species and stocks along the Northwest African coast are overfished, some strongly so.

This could be perceived as 'bad news'. This is not new. Previous analyses suggested this as well. However, we want here to emphasize the positive aspect of our finding. Thus, our results also imply that a reduction of the fishing mortality that these fish stock currently experience would lead to an increase of their biomass, and catch increases of millions of tonnes. The development of the rebuilding policies that would lead to such catch increases is outside of the scope of this report. However, the need for, and potential of such policies will have to be kept in mind when discussing this report.

Table 2. List of small pelagic species considered in this study and which are found in the seven countries in which MAVA operates. All scientific names used here are currently valid and checked with FishBase. English and French names are also obtained from FishBase and may pertain to the official FAO name or name used in a country. Average catches (t; 1000^3) and B/BMSY values are annual averages by marine ecoregion for the period 2010-2014.

Scientific name	**English name**	**French name**	**Marine ecoregions**	**EEZs**	**Ave. catch**	**Ave. B/BMSY**	**Stock status**
Considered not straddling							
Ethmalosa fimbriata	Bonga shad	Ethmalose d'Afrique	Sahelian Upwelling	Mauritania, Senegal, and Gambia	65	1.36	Healthy
Ethmalosa fimbriata	Bonga shad	Ethmalose d'Afrique	Gulf of Guinea West	Guinea-Bissau, Guinea, and Sierra Leone	229	0.96	Slightly over-fished
Ilisha africana	West African ilisha	Alose rasoir	Gulf of Guinea West	Guinea-Bissau, Guinea, and Sierra Leone	9.2	0.92	Slightly over-fished
Mugil cephalus	Flathead grey mullet	Mulet jaune	Sahelian Upwelling	Mauritania, Senegal, and Gambia	8.3	0.97	Slightly over-fished
Sardinella aurita	Round sardinella	Allache	Gulf of Guinea West	Guinea-Bissau, Guinea, and Sierra Leone	10.6	0.29	Grossly over-fished
Sardinella maderensis	Madeiran sardinella	Grande allache	Gulf of Guinea West	Guinea-Bissau, Guinea, and Sierra Leone	5.1	1.03	Healthy
Considered straddling							
Caranx rhonchus	False scad	Comète coussut (Chinchard jaune)	Sahelian Upwelling, Saharan Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling	Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea, and Sierra Leone	17.6	0.48	Grossly over-fished
Decapterus macarellus	Mackerel scad	Comète maquereau	Cape Verde, Azores Canaries Madeira, Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands and Gulf of Guinea South	Mauritania, Cape Verde, Senegal, Gambia, Guinea-Bissau, Guinea, and Sierra Leone	3.2	0.55	Over-fished

Scientific Name	English Name	French Name	Marine Ecoregions	EEZs	Ave. Catch	Ave. B/BMSY	Stock Status
Engraulis encrasicolus	European anchovy	Anchois	Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan, Namib, Namaqua and Angulhas Bank	Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea, and Sierra Leone	257	0.83	Slightly over-fished
Sardina pilchardus	European pilchard (Sardine)	Sardine commune	Sahelian Upwelling and Saharian Upwelling	Mauritania, Senegal, and Gambia	1885	0.95	Slightly over-fished
Sardinella aurita	Round sardinella	Allache	Sahelian Upwelling and Saharian Upwelling	Mauritania, Senegal, and Gambia	341	1.23	Healthy
Sardinella maderensis	Madeiran sardinella	Grande allache	Sahelian Upwelling and Saharian Upwelling	Mauritania, Senegal, and Gambia	249	0.98	Slightly over-fished
Trachurus trachurus	Atlantic horse mackerel	Chinchard d'Europe	Sahelian Upwelling, Saharan Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling	Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea, and Sierra Leone	1.9	0.10	Collapsed
Trachurus trecae	Cunene horse mackerel	Chinchard du Cunène	Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan and Namib	Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea, and Sierra Leone	112	1.74	Healthy

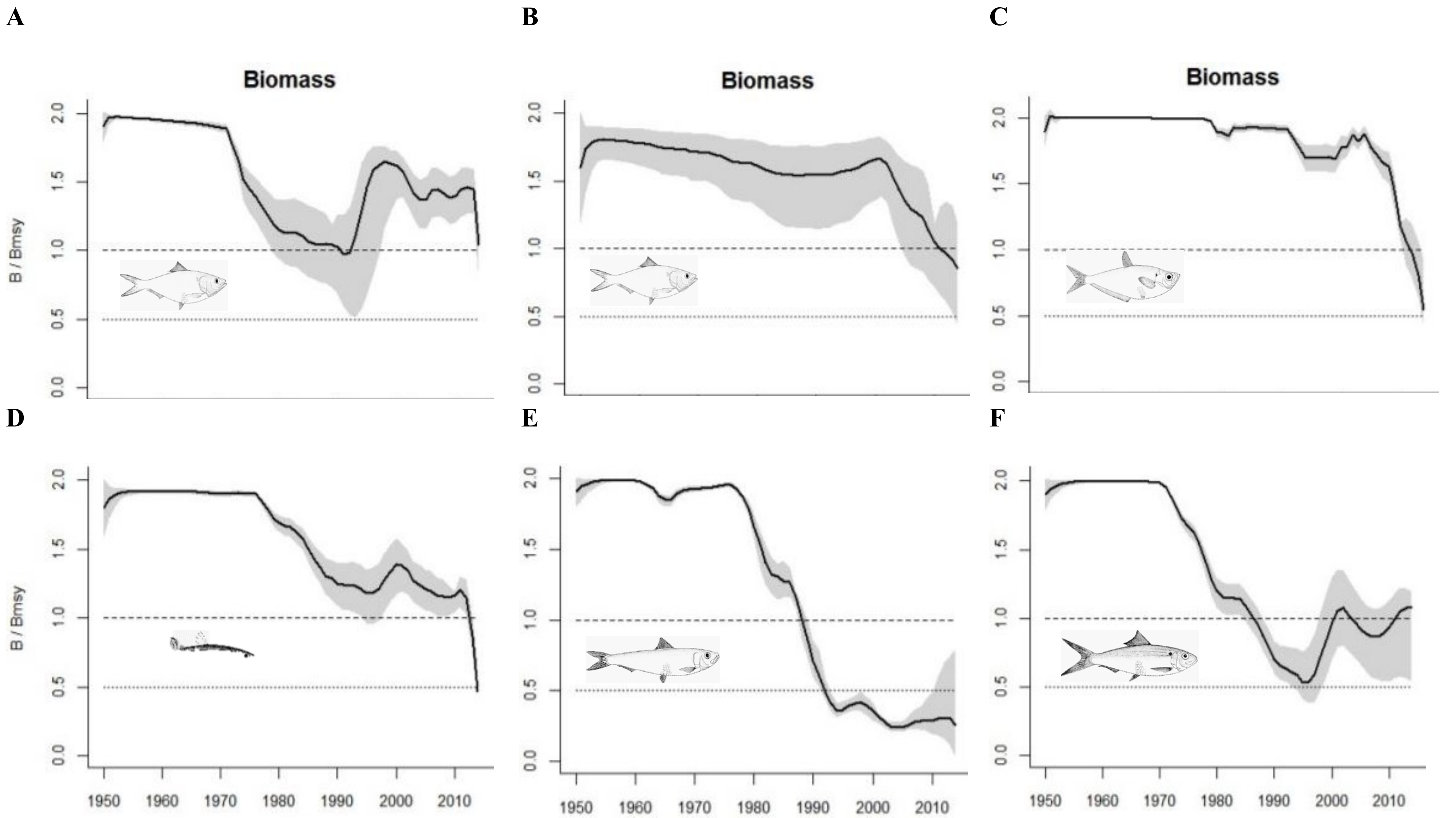


Figure 11A. Results of the CMSY analyses based on Sea Around Us reconstructed catch time series for 1950-2014 for non-straddling stocks in the marine ecoregions where MAVA operates (see Table 2 for numerical results): (A) *Ethmalosa fimbriata* in the Sahelian Upwelling, (B) *Ethmalosa fimbriata* in the Gulf of Guinea West, (C) *Ilisha africana* in the Gulf of Guinea West, (D) *Mugil cephalus* in the Sahelian Upwelling, (E) *Sardinella aurita* in the Gulf of Guinea West, (F) *Sardinella maderensis* in the Gulf of Guinea West.

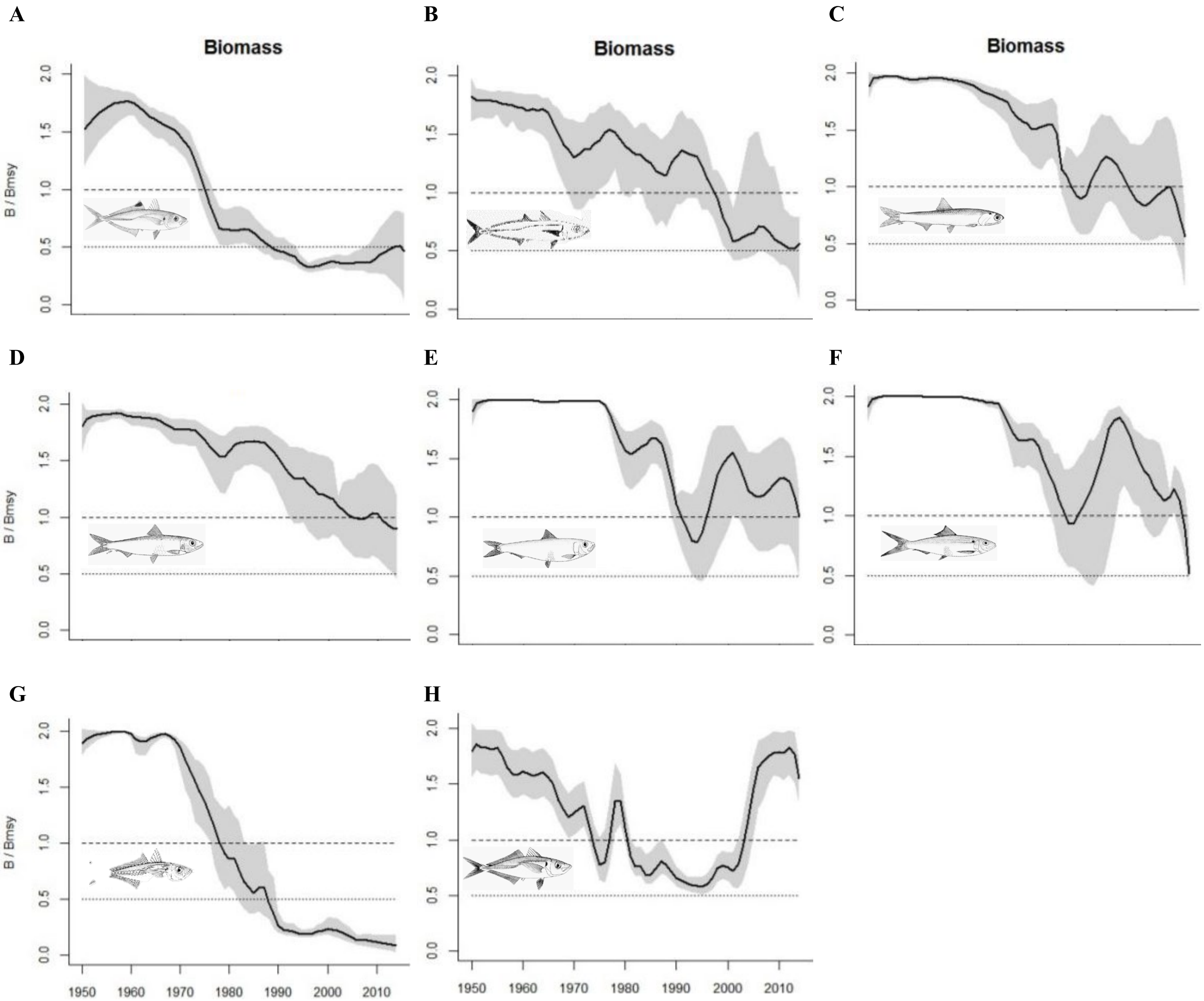


Figure 11B. Results of the CMSY analyses based on Sea Around Us reconstructed catch time series for 1950-2014 for straddling stocks in the marine ecoregions where MAVA operates (see Table 2 for numerical results): (A) *Caranx rhonchus* in North Western Africa, (B) *Decapterus macarellus* in the Eastern Central Atlantic, (C) *Engraulis encrasicolus* in Western Africa, (D) *Sardina pilchardus* in the Saharan Upwelling and the Sahelian Upwelling, (E) *Sardinella aurita* in the Saharan Upwelling and the Sahelian Upwelling, (F) *Sardinella maderensis*, (G) *Trachurus trachurus* in North Western Africa, (H) *Trachurus trecae* in Western Africa.

Stocks assessments on the *Sea Around Us* website

Accessing the currently available summaries

The 2-page summaries of the stock assessments performed for this study, and deemed reliable enough, can be accessed on the *Sea Around Us* website (www.seaaroundus.org) by clicking 'Our interactive graphs' (left panel) on the landing page. Then, there are two options for accessing the stock assessments:

1. Choose an EEZ, and when it appears, scroll down until you get to 'Marine Ecoregion(s)'. There, you will find the name of one, or several MEs overlapping with the EEZ in question; click on the name of the ME of interest, and once it appears, scroll down to find a list of assessed species. Click on the one you want to see, and the 2-page summary PDF will appear, as presented in Figure 5;
2. Use the toolbar to select Marine Ecoregion ('ME'); when a map of MEs appears, use it or use the toolbar to select an ME. Once the ME page appears, scroll down to find a list of assessed species. Click on the one you want to see, and the 2-page summary PDF will appear, as presented in Figure 5.

The next steps

The stock assessment work of the *Sea Around Us* will continue to be provided and updated every time that the catch data is updated. These updates will include the following:

1. We will redo the preliminary stock assessments presented here, following an update of the *Sea Around Us* catch data which will correct for all straightforwardly fixable data problems identified in the course of this study;
2. Many of the stocks that were assessed without being constrained by independent estimates of relative biomass will be reassessed under such constraints. This applies to stocks in Northwest African countries, for which relative biomass data can likely be found with the help of regional and national experts;
3. Some parts of the RAM Legacy Database of stock assessments and similar databases pertaining to stocks predominantly in developed countries may also be used to provide constraints, thus preventing a situation where their contents may be used in an attempt at invalidating the *Sea Around Us* assessment (see also below). However, in cases where the biomass indices from the RAM Legacy Database do not represent our stocks, or when the time series of catches used for the stock assessment had been truncated (as is often the case, see Préfontaine 2009), we will either ignore these indices and search for historical indicators of biomass levels to adjust the 'start', 'mid' or 'end' B/k values;
4. A module will be added to the *Sea Around Us* website that will allow presenting stock assessments as interactive graphs, i.e., all the graphs currently presented in form of PDFs. This web-module will also document, for each stock, all the constraints involved, and download all data behind all graphs, which may be rerun on the user's computer. This module will follow the *Sea Around Us* open data policy;

5. The methodology presented in this report can be used in a training workshop with a goal of providing an alternative to conventional methods that need a suite of parameters that might not be available in data-poor situations like that encountered by CECAF (2018). The *Sea Around Us* could conduct a training workshop applying the method presented here to MAVA partners in West Africa.

Overall, this project, which has succeeded in making hundreds of (sometimes preliminary) stock assessments available to many countries that never saw any, will build on this success, improve these stock assessments and their underlying catch database, and disseminate the result, which should help toward rebuilding the many stocks which, as this study shows, require rebuilding throughout the world.

However, for a few of these stocks, the underlying reconstructed catch data would need to be reviewed by national fisheries experts associated with the MAVA network. Appendix I might help indicate the stocks that need review. We would thus recommend for the MAVA to support the review of these stocks with the final goal of improving the data set that the *Sea Around Us* can use to update the catch reconstructions for the EEZs implicated.

ACKNOWLEDGEMENTS

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APPENDIX I: LIST OF MARINE ECOREGIONS BY EEZ

EEZ	Sector	1950-70	1970-90	1990-2010	2010>	Average	Reference
Angola	Artisanal	1	3	3	2	2.25	Belhabib and Divovich (2014)
	Industrial	3	3	2	1	2.25	
	Recreational	2	3	3	2	2.5	
	Subsistence	1	3	3	2	2.25	
Azores Isl. (Portugal)	Artisanal	3	3	4	3	3.25	Pham *et al*. (2013)
	Industrial	3	3	4	3	3.25	
	Recreational	2	3	3	2	2.5	
	Subsistence	2	2	3	2	2.25	
Benin	Artisanal	2	4	4	3	3.25	Belhabib and Pauly (2015a)
	Industrial	3	3	3	2	2.75	
	Recreational	0	0	0	0	0	
	Subsistence	3	3	3	2	2.75	
Cameroon	Artisanal	1	3	3	2	2.25	Belhabib and Pauly (2015b)
	Industrial	2	2	2	1	1.75	
	Recreational	0	0	0	0	0	
	Subsistence	2	2	1	1	1.5	
Canary Isl. (Spain)	Artisanal	3	3	4	3	3.25	Castro *et al*. (2015)
	Industrial	0	0	0	0	0	
	Recreational	2	2	3	2	2.25	
	Subsistence	2	1	2	1	1.5	
Cape Verde	Artisanal	4	4	4	3	3.75	Santos *et al*. (2012)
	Industrial	1	1	4	3	2.25	
	Recreational	2	2	4	3	2.75	
	Subsistence	2	2	2	1	1.75	
Congo (ex-Zaire)	Artisanal	2	3	1	1	1.75	Belhabib *et al*. (2015)
	Industrial	2	3	0	0	1.25	
	Recreational	0	0	0	0	0	
	Subsistence	1	2	2	1	1.5	
Congo, Republic of	Artisanal	2	4	4	3	3.25	Belhabib and Pauly (2015c)
	Industrial	2	4	3	2	2.75	
	Recreational	0	0	0	0	0	
	Subsistence	2	4	4	3	3.25	
Côte d'Ivoire	Artisanal	2	3	3	2	2.5	Belhabib and Pauly (2015d)
	Industrial	4	4	4	3	3.75	
	Recreational	0	0	0	0	0	
	Subsistence	2	3	2	1	2	

EEZ	Sector	1950-70	1970-90	1990-2010	2010>	Average	Reference
Equatorial Guinea	Artisanal	2	2	4	3	2.75	Belhabib *et al.* (2016a)
	Industrial	0	3	3	2	2	
	Recreational	0	0	3	2	1.25	
	Subsistence	2	2	4	3	2.75	
Gabon	Artisanal	2	4	4	3	3.25	Belhabib (2015a)
	Industrial	3	3	4	3	3.25	
	Recreational	0	0	0	0	0	
	Subsistence	3	2	3	2	2.5	
Gambia	Artisanal	2	3	3	2	2.5	Belhabib *et al.* (2016b)
	Industrial	3	3	3	2	2.75	
	Recreational	2	2	3	2	2.25	
	Subsistence	2	3	3	2	2.5	
Ghana	Artisanal	3	3	3	2	2.75	Nunoo *et al.* (2014)
	Industrial	4	4	4	3	3.75	
	Recreational	0	2	3	2	1.75	
	Subsistence	2	2	3	2	2.25	
Guinea	Artisanal	2	3	4	3	3	Belhabib *et al.* (2012a)
	Industrial	2	4	2	1	2.25	
	Recreational	0	0	0	0	0	
	Subsistence	2	2	2	1	1.75	
Guinea-Bissau	Artisanal	2	3	3	2	2.5	Belhabib *et al.* (2018)
	Industrial	0	0	0	0	0	
	Recreational	0	2	4	3	2.25	
	Subsistence	2	3	3	2	2.5	
Liberia	Artisanal	3	3	3	2	2.75	Belhabib *et al.* (2016b)
	Industrial	0	0	4	0	1	
	Recreational	0	0	0	0	0	
	Subsistence	1	3	3	2	2.25	
Madeira Isl. (Portugal)	Artisanal	2	3	3	2	2.5	Shon *et al.* (2015)
	Industrial	2	3	4	3	3	
	Recreational	2	2	2	1	1.75	
	Subsistence	2	2	2	1	1.75	
Mauritania	Artisanal	2	3	4	3	3	Belhabib *et al.* (2012b)
	Industrial	2	2	4	3	2.75	
	Recreational	0	4	4	3	2.75	
	Subsistence	2	2	2	1	1.75	
Morocco (Central); Morocco (South)	Artisanal	3	4	4	3	3.5	Belhabib *et al.* (2012c)
	Industrial	3	3	3	2	2.75	
	Recreational	2	2	4	3	2.75	
	Subsistence	2	2	2	1	1.75	

ME	Sector	1950-70	1970-90	1990-2010	2010>	Average	Reference
Namibia	Artisanal	0	0	0	0	0	Belhabib et al. (2016b)
	Industrial	4	4	4	3	3.75	
	Recreational	3	3	3	2	2.75	
	Subsistence	2	2	3	2	2.25	
Nigeria	Artisanal	2	3	3	2	2.5	Etim *et al.* (2015)
	Industrial	1	3	3	2	2.25	
	Recreational	0	0	0	0	0	
	Subsistence	1	3	3	2	2.25	
Sao Tome & Principe	Artisanal	2	3	3	2	2.5	Belhabib (2015)
	Industrial	0	0	0	0	0	
	Recreational	0	0	0	0	0	
	Subsistence	2	3	3	2	2.5	
Senegal	Artisanal	2	2	3	2	2.25	Belhabib *et al.* (2013)
	Industrial	3	3	4	3	3.25	
	Recreational	2	2	4	3	2.75	
	Subsistence	3	3	3	2	2.75	
Sierra Leone	Artisanal	2	3	4	3	3	Seto *et al.* (2015)
	Industrial	0	4	4	3	2.75	
	Recreational	0	0	0	0	0	
	Subsistence	1	1	1	1	1	
South Africa (Atlantic and Cape)	Artisanal	2	2	2	1	1.75	Baust *et al.* (2015)
	Industrial	2	2	2	1	1.75	
	Recreational	2	2	3	2	2.25	
	Subsistence	2	2	3	2	2.25	
Togo	Artisanal	3	3	3	2	2.75	Belhabib *et al.* (2015)
	Industrial	3	3	3	2	2.75	
	Recreational	2	2	2	1	1.75	
	Subsistence	3	3	3	2	2.75	

APPENDIX II: LIST SPECIES IN WEST AFRICAN MARINE ECOREGIONS

Scientific name	Engish name	French name	Straddling	ME 1	ME 2	ME 3	ME 4	ME 5	ME 6
Acanthocybium solandri	Wahoo	Thazard-bâtard	Yes	Atlantic Ocean					
Argyrosomus regius	Meagre	Maigre commun	No	Gulf of Guinea West	Sahelian Upwelling				
Atherina presbyter	Sand smelt	Joël, Athérine	No	Azores Canaries Madeira					
Auxis thazard	Pompano	Auxide	Yes	Atlantic Ocean					
Brachydeuterus auritus	Bigeye grunt	Lippu pelon	No	Angolan	Gulf of Guinea Central	Gulf of Guinea South	Gulf of Guinea Upwelling		
Caranx crysos	Blue runner	Carangue coubali	No	Gulf of Guinea Islands					
Caranx hippos	Crevalle jack	Carangue crevalle	No	Gulf of Guinea Central					
Caranx rhonchus	Devil anglerfish	Comète coussut	Yes	Sahelian Upwelling, Saharan Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling					
Chaceon maritae	West African geryon	Géryon ouest-africain	No	Angolan					
Chloroscombrus chrysurus	Atlantic bumper	Sapater	No	Gulf of Guinea Central	Gulf of Guinea Upwelling				
Conger conger	Conger eel	Congre d'Europe	No	Azores Canaries Madeira					
Coryphaena hippurus	Common dolphinfish	Coryphène commune	Yes	Atlantic Ocean					
Decapterus macarellus	African forktail snapper	Comète maquereau	Yes	Cape Verde, Azores Canaries Madeira, Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands and Gulf of Guinea South					
Dentex gibbosus	Pink dentex	Gros denté rose	No	Azores Canaries Madeira	Gulf of Guinea South				
Elops lacerta	West African ladyfish	Guinée d'Afrique occidentale	No	Gulf of Guinea Central					

Scientific name	Engish name	French name	Straddling	ME 1	ME 2	ME 3	ME 4	ME 5	ME 6
Engraulis capensis	Southern African anchovy	Anchois de l'Afrique australe	Yes	Natal & Agulhas Bank					
Engraulis encrasicolus	European anchovy	Anchois	Yes	Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan, Namib, Namaqua and Angulhas Bank					
Ethmalosa fimbriata	Bonga shad	Ethmalose d'Afrique	No	Gulf of Guinea Central	Gulf of Guinea South	Gulf of Guinea Upwelling	Gulf of Guinea West	Sahelian Upwelling	
Etrumeus whiteheadi	Whiteheads round herring	Shadine de Angola	No	Agulhas Bank	Namaqua				
Euthynnus alletteratus	Little tunny	Thonine commune	Yes	Atlantic Ocean	Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South and Angolan	Sahelian Upwelling, Saharan Upwelling, Gulf of Guinea West, Cape Verde and Azores Canaries Madeira			
Farfantepenaeus notialis	Southern pink shrimp	Crevette blanche, Bangbo, Crevette grosse, Crevette rose du Sud	No	Gulf of Guinea Central	Sahelian Upwelling				
Galeoides decadactylus	Lesser African threadfin	Petit capitaine	No	Gulf of Guinea Central	Gulf of Guinea South				
Helicolenus dactylopterus	Devil anglerfish	Sébaste chèvre	No	Azores Canaries Madeira					
Ilisha africana	Blue marlin	Alose rasoir	No	Gulf of Guinea Central	Gulf of Guinea Upwelling	Gulf of Guinea West			
Istiophorus albicans	False scad	Voilier de l'Atlantique	Yes	East Atlantic					

Scientific name	**Engish name**	**French name**	**Straddling**	**ME 1**	**ME 2**	**ME 3**	**ME 4**	**ME 5**	**ME 6**
Katsuwonus pelamis	West African geryon (crab)	Listao	Yes	Eastern Atlantic Ocean					
Lithognathus mormyrus	Sand Steenbas	Marbré	No	Angolan					
Makaira nigricans	Blue marlin	Makaire bleu	Yes	Atlantic Ocean					
Mugil cephalus	Flathead grey mullet	Mulet à grosse tête	No	Sahelian Upwelling					
Mullus surmuletus	Surmullet	Rouget de roche	No	Saharan Upwelling					
Octopus vulgaris	Common octopus	Pieuvre	No	Gulf of Guinea West	Saharan Upwelling	Sahelian Upwelling			
Pagellus bellottii	Red pandora	Pageot à tache rouge	No	Gulf of Guinea Central	Gulf of Guinea Upwelling				
Pagellus bogaraveo	Blackspot seabream	Dorade rose	No	Azores Canaries Madeira					
Pagellus erythrinus	Common pandora	Pageot commun	No	Azores Canaries Madeira					
Pagrus pagrus	Bluespotted seabream	Pagre rouge	No	Azores Canaries Madeira					
Plectorhinchus mediterraneus	Rubberlip grunt	Diagramme gris	No	Azores Canaries Madeira					
Polydactylus quadrifilis	Giant African threadfin	Gros capitaine	No	Gulf of Guinea Central	Gulf of Guinea Islands	Gulf of Guinea South			
Pomadasys jubelini	Sompat grunt	Grondeur sompat	No	Gulf of Guinea South	Sahelian Upwelling				
Prionace glauca	Blue shark	Peau bleue	Yes	Atlantic Ocean					
Pseudotolithus elongatus	Bobo croaker	Otolithe bobo	No	Gulf of Guinea Central	Gulf of Guinea South	Gulf of Guinea West			
Pseudotolithus senegalensis	Cassava croaker	Otolithe sénégalais	No	Gulf of Guinea Central					
Rachycentron canadum	Cobia	Mafou	Yes	Sahelian Upwelling, Saharan Upwelling, Gulf of Guinea West					
Sardina pilchardus	European pilchard	Sardine commune	Yes	Sahelian Upwelling and Saharian Upwelling					
Sardinella aurita	Round sardinella	Allache	No	Angolan	Gulf of Guinea Central	Gulf of Guinea South	Gulf of Guinea Upwelling	Gulf of Guinea West	Sahelian Upwelling and Saharian Upwelling

Scientific name	Engish name	French name	Straddling	ME 1	ME 2	ME 3	ME 4	ME 5	ME 6
Sardinella maderensis	Madeiran sardinella	Grande allache	No	Angolan	Gulf of Guinea Central	Gulf of Guinea South	Gulf of Guinea Upwelling	Gulf of Guinea West	Sahelian Upwelling and Saharian Upwelling
Sardinops sagax	Pacific sardine	Pilchard sudaméricain	Yes	Gulf of Guinea South, Angolan and Namib	Namaqua, Agulhas Bank, Natal and Delagoa				
Sarpa salpa	Salema	Saupe	No	Azores Canaries Madeira					
Scomber colias	Atlantic chub mackerel	Maquereau espagnol atlantique	Yes	Azores Canaries Madeira and Saharan Upwelling					
Scomberomorus tritor	West African Spanish mackerel	Thazard blanc	Yes	Saharan Upwelling, Sahelian Upwelling, Azores Canaries Madeira, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan and Namib					
Selar crumenophthalmus	Bigeye scad	Sélar coulisou	Yes	Cape Verde, Azores Canaries Madeira, Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan, Namib, Namaqua and Angulhas Bank					
Seriola dumerili	Greater amberjack	Sériole couronnée	No	Azores Canaries Madeira					
Sparisoma cretense	Old parrotfish	Perroquet vieillard	No	Azores Canaries Madeira					
Sphyrna zygaena	Smooth hammerhead	Requin-marteau commun	Yes	Atlantic Ocean					
Spondyliosoma cantharus	Black seabream	Dorade grise	No	Azores Canaries Madeira					

Scientific name	Engish name	French name	Straddling	ME 1	ME 2	ME 3	ME 4	ME 5	ME 6
Thunnus alalunga	Albacore	Germon	Yes	Atlantic Ocean, South					
Thunnus albacares	Yellowfin tuna	Albacore	Yes	Atlantic Ocean					
Thunnus maccoyii	Southern bluefin tuna	Thon rouge du Sud	Yes	South Atlantic, Southwest Pacific and Indian Ocean					
Thunnus obesus	False scad	Thon obèse(=Patudo)	Yes	Atlantic Ocean					
Thunnus thynnus	West African geryon (crab)	Thon rouge de l'Atlantique	Yes	East Atlantic and Mediterranean					
Thyrsites atun	Snoek	Escolier	No	Agulhas Bank	Namaqua				
Trachinotus ovatus	Pompano	Palomine	No	Azores Canaries Madeira					
Trachurus capensis	Cape horse mackerel	Chinchard du Cap	No	Agulhas Bank	Angolan	Namaqua	Namib		
Trachurus picturatus	Blue jack mackerel	Chinchard du large	No	Azores Canaries Madeira					
Trachurus trachurus	Atlantic horse mackerel	Chinchard d'Europe	No	Gulf of Guinea South	Sahelian Upwelling, Saharan Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling				
Trachurus trecae	Cunene horse mackerel	Chinchard du Cunène	Yes	Saharan Upwelling, Sahelian Upwelling, Gulf of Guinea West, Gulf of Guinea Upwelling, Gulf of Guinea Central, Gulf of Guinea Islands, Gulf of Guinea South, Angolan and Namib					
Trichiurus lepturus	Largehead hairtail	Poisson-sabre commun	No	Angolan	Gulf of Guinea Central	Gulf of Guinea South			
Umbrina canariensis	Canary drum	Ombrine bronze	No	Angolan	Gulf of Guinea South				
Xiphias gladius	Swordfish	Espadon	Yes	South Atlantic					
Zeus faber	John dory	Saint Pierre	No	Sahelian Upwelling					

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