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Deliverable D2.5

Review of current stock assessment models used in Case Studies

22/08/2020

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Executive Summary

More than 20% of the European fishing fleets catches are taken from non-European waters. Access to these waters is often based on agreements with coastal states that allow the EU fleet to fish from surplus stocks in return for financial support. These agreements have been subjected to criticism, as these fisheries are sometimes poorly regulated and management decisions are often based on limited knowledge, compliance, and enforcement capabilities. It is also too often the case that trust between stakeholders is lacking. The aim of the FarFish project is to overcome these hurdles. The FarFish project is designed around six case study areas in which the European fleet is actively engaged in fishing activities, including Cape Verde, Mauritania, Senegal and Seychelles, as well as the international high-seas areas in the southeast and southwest Atlantic.

Specific Objective 1 of FarFish is: "*To advance knowledge and collate data related to biological characteristics of the main fish stocks in selected fisheries outside EU waters that are important for the EU fleet, and to evaluate the relevance and applicability of appropriate stock assessment methods for these fisheries.*" In this context, the review and evaluation of stock assessment models used in the different Case Studies and the status of the stocks is one of the primary objectives of the project. **This report contains a review the stock assessment carried out for the target species in each of the case study areas.**

For the tuna fisheries, managed through the Regional Fisheries Management Organizations (ICCAT and IOTC, available data allows for a wide range stock assessment, ranging from catch and effort based Surplus Production models to the state of the art Stock Synthesis approach that can accommodate both age and size structure in the population and multiple stock sub-areas.
In the case of demersal and small pelagic species assessed at the regional level through CECAF and FAO, a more limited range of stock assessment methods and models are used, namely variations of Surplus Production models, and in some cases length-based cohort analysis and yield per recruit. There are few examples of the use of data-limited methods; the exception being the Catch at MSY (CMSY) approach developed by Martell and Froese (2013) and used by ICCAT and CECAF for some species.

The status of tuna and tuna-like species in the Atlantic shows a mixed picture. For some species, mainly by-catch species but also a target species (skipjack tuna), no formal assessment is possible due largely to lack of suitable data and/or to the characteristics of the species (skipjack tuna). Only two species (swordfish and blue shark) are considered not overfished or subject to overfishing, while half the other assessed species are considered subject to overfishing.

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In the Indian Ocean, based on the same reference points used by ICCAT, bigeye tuna, skipjack, swordfish and blue shark are considered subject to overfishing. Yellowfin tuna and striped marlin are considered overfished/subject to overfishing, while blue marlin and indo-pacific sailfish are assessed as not overfished but subject to overfishing.

For the 26 demersal species/stocks assessed by CECAF/FAO, half of the 19 that could be assessed were judged to be over-exploited, while seven were considered fully exploited and only three not fully exploited. Due to insufficient data, inconclusive results were obtained for seven stocks, although additional information from fisheries and scientific surveys suggests that many are overexploited.

For the Southwest Atlantic, limited assessment is possible due to lack of RFMO and the fact that the European Union (EU) fleet accounts for a fraction of the non-EU long-distance fleets for which no data is available. For the Southeast Atlantic, lack of data has hampered stock assessment for some species. However, the South East Atlantic Fisheries Organisation (SEAFO) has put in place a number of management measures and harvest control rules for some of the target species such as Patagonian toothfish, alfonsino, and deep-sea red crab

This review has shown that lack of suitable data for classical stock assessment methods is an underlying theme in all the case studies and that to date, there has been limited use of data-limited models or approaches applied. For example, in the case of Mauritania and Senegal the number of demersal species/stocks (19) for which there is some kind of stock assessment is a fraction of the total number of commercial demersal species and stocks (more than 100 species/stocks). For these other data-limited or data-poor species FarFish can provide the tools to carry out stock assessment based on the DLM tools package which has minimal requirements (catch time series and life history parameters). FarFish deliverable 2.6 and the final WP2 report will identify sources of data, especially time series of fisheries independent catch per unit effort data from research surveys, that the CS partners can use to assess these species. In the case of by-catch species of pelagic fisheries (Seychelles and Cabo Verde) FarFish has actually compiled data for selected species that are not currently assessed by ICCAT or IOTC and these are used to illustrate the DLM package that has been developed. Thus, based on data that is mainly available from time series of research institute national surveys, along with life history parameters, FarFish can play an important role in showing how DLM can be used to carry out stock assessment of the many species for which there is currently no assessment, thereby contributing to improved management and sustainable exploitation.

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Abbreviations

ASAP	Age Structured Assessment Program
ASPIC	A Stock Production Model Incorporating Covariates
ASPM	Age Structured Production Model
BDM	Biomass Dynamic Model
BSP	Bayesian Surplus Production Model
BSP-SS	Bayesian state-space production model
CECAF	Fishery Committee for the Eastern Central Atlantic
CMSY	Catch at MSY (a data-limited stock assessment method)
CS	Case Study
COREWAM	Conservation and Research of West African Aquatic Mammals
CRODT	Centre de Recherches Océanographiques de Dakar-Thiaroye
DCF	Data Collection Framework
DG MARE	Directorate-General for Maritime Affairs and Fisheries
EAFM	Ecosystem Approach to Fisheries Management
EEZ	Exclusive Economic Zone
ERA	Ecological Risk Assessment
EU	European Union
FAD	Fish Aggregating Device (or Fish Aggregation Device)
FAO	The Food and Agriculture Organization of the United Nations
FBOA	Fishing Boat Owners Association (Seychelles)
FICZ	Falkland Islands Conservation Zone
FOCZ	Falkland Islands Outer Conservation Zone
FPA	Fisheries Partnership Agreement
HCR	Harvest Control Rule
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
IEO	Spanish Institute of Oceanography
IMROP	Institut Mauritanien de Recherches Océanographiques et des Pêches
INDP	Instituto Nacional de Desenvolvimento das Pescas (Cape Verde)
IOTC	Indian Ocean Tuna Commission
ISRA	Institut Sénégalais de Recherches Agricoles
JABBA	Just Another Bayesian Biomass Assessment
MS	Member State
MSC	Marine Stewardship Council
NPOA	National Plan of Action for the Conservation and management of Sharks
OCOM	Optimised Catch Only Method
OPAGAC	Organization of Producers of Frozen Tuna
PSA	Productivity-Susceptibility Analysis
RFMO	Regional Fisheries Management Organisation
SCAA	Statistical catch-at-age model
SEAFO	South East Atlantic Fisheries Organisation
SFA	Seychelles Fishing Authority
SFPA	Sustainable Fisheries Partnership Agreement
SPRFMO	South Pacific Regional Fisheries Management Organisation
SRA	Stock Reduction Analysis
SS3	Stock Synthesis
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total Allowable Catch

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TL	Total Length
UNGA	United Nations General Assembly
VME	Vulnerable Marine Ecosystems
WP	Work Package
XSA	eXtended Survivors Analysis

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1 Introduction and context

Work Package 2 (WP2) in the FarFish project is titled "Advancing biological knowledge and evaluation of current stock assessment models" and focuses on the biological and ecological status of resources within the selected Case Studies (CS). The review and evaluation of stock assessment models used in the different CS and the status of the stocks is the primary objective of Task 2.4 (Evaluation of current stock assessment models), but this report is an outcome of that task.

The scope of this review are the main target species of EU small pelagics, tuna and demersal fisheries, considering the focus of the FarFish project which is the Sustainable Fisheries Partnership Agreements (SFPA) in Cape Verde, Mauritania, Senegal, Seychelles, and International waters of the southwest and Southeast Atlantic. In the case of EU purse seine and longline tuna fisheries, in addition to the main tuna target species, so-called tuna-like by-catch species such as billfish, sharks and other pelagic species are also included. Demersal, largely bottom trawl fisheries target specific species such as black hake but also catch a wide variety of demersal fish and cephalopod species.

In the Southeast Atlantic, these concern deep-sea fisheries which are carried out by relatively few vessels from distant-water fishing nations and coastal states. Fishing activity has decreased considerably in this area. In the Southwest Atlantic the fishery is dominated by non-EU long distance fleets, with no Regional Fisheries Management Organization (RFMO).

For the other CS, the scientific process of stock assessment takes place in context of RFMOs, although data collection is the responsibility of the flag states and it is an obligation to report these data to the respective RFMOs. These concerns both members/parties and cooperating parties to the RFMO.

In this respect, national fisheries research and assessment that concerns coastal resources are not directly relevant to the present study as the target and bycatch species are almost all under the management mandate of RFMOs. However, it is important to note that national authorities have the responsibility of collecting data, ideally as complete and robust as possible, and report this to the respective RFMO, including basic biological studies (e.g. length/weight relationships, growth studies, etc.). Coastal fisheries can account for substantial quantities of the relevant species, tunas in particular, but these data feed into the science process at the RFMO level.

This report contains a review of the main stock assessment procedures, models, methods, reference points and harvest control rules (HCR) currently in use in each of the FarFish CS.

2 Cape Verde

The current Protocol (2014-2018) of the SFPA with Cape Verde provides for fishing opportunities for up to 71 EU vessels to fish for tuna and other highly migratory species in 3 fishing categories: 28 tuna seiners, 30 surface long liners and 13 pole-and-line vessels. Overall uptake across categories during the first three years of the Protocol has ranged from 58% to 68% (Amador *et al.* 2018).

According to Amador *et al.* (2018), an average of 21 EU tuna purse seiners and 14 surface longliners were authorised to fish in Cape Verde waters during the period of the Protocol. Most of tuna purse seiners currently active in the Atlantic Ocean obtained a fishing authorization for Cape Verde, which shows the interest in this fishing ground. For pole and line vessels, operation in the Cape Verde fishing zone was restricted due to prohibitions of catching live bait within the 12 nautical miles, which is allowed in Senegal.

The SFPA with Cape Verde is also important because Spanish and Portuguese longliners and Spanish purse seiners use the port of Mindelo to land and transship catches to the EU. French purse seiners prefer using Dakar in Senegal as their operational base, but landings depend on circumstances at the time (current location, prices, transshipment opportunities and costs).

Cape Verde also offers fishing opportunities to fishing vessels from other states. A list of non-EU vessels licensed to fish in the Cabo Verde EEZ in 2017 provided by Maritime and Port Agency included the following nationalities and numbers of named vessels (Amador *et al.* 2018):

- Japan 8 (longliners)
- Senegal 6 (4 purse seine, 2 pole & line)
- El Salvador 4 (purse seine)
- Curaçao 3 (purse seine)
- Panama 2 (purse seine)
- Belize 1 (purse seine)

High seas reporting, monitoring and surveillance of fishing activity in Cabo Verdean waters is currently ineffective (Amador *et al.* 2018). Cape Verde authorities rely on logbooks from EU vessels, but there are concerns about the completeness of the reporting of foreign fleets in general.

Tuna fishing is also important in national fisheries, which consists of an artisanal sector and a semi-industrial sector. The main targets of the national are target tuna, small pelagics and demersal resources, where the semi-industrial fleet accounted for about 70% in 2018 (INDP, pers. comm.). Foreign owned purse seiners have also been registered under the Cape Verde flag (four in 2016), but this is no longer the case at present.

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2.1 Defining the main species of interest

During the period 2011-2017 annual catches by EU tuna vessels have averaged about 6,500 tonnes, but these were as high as 10,000 tonnes in 2014 and 2017 (Table 1), almost double the reference tonnage set by the Protocol (Amador *et al.* 2018). Most of the catches are taken by Spanish vessels (98%), and tuna represented 70% and blue shark 20% of the total catch in 2017 (Amador *et al.* 2018). When the purse seiners are less active in the region, blue shark targeted by the longliners represents the majority of the catch.

It is evident from Table 1 that tropical tunas such as yellowfin, skipjack and bigeye tuna are the main targets of the purse seine and pole and line fleets. In the past, swordfish was considered the primary target of EU longline fisheries with substantial catches of Blue shark. However, Table 1 shows that this can be considered shark fisheries, including both Blue and Mako shark, while swordfish are caught in small quantities.

Table 1: Catches of EU vessels in Cape Verde waters. (Unit: tonnes)

Gear	Group	Species	2011	2012	2013	2014	2015	2016	2017	Avg.
Longline			**2,919**	**3,374**	**2,878**	**1,445**	**2,947**	**2,119**	**2,178**	**2,551**
	LL tuna total		61	29	37	9	23	17	17	28
	LL shark total		2,254	3,030	2,647	1,382	2,797	1,979	2,058	2,307
	LL others total		604	315	194	54	127	124	103	217
		Blue shark	2,104	2,893	2,527	1,332	2,695	1,888	1,952	2,199
		Finfishes nei	277	277						
		Swordfish	280	282	174	47	111	109	92	156
		Shortfin mako shark	99	132	120	51	102	89	100	99
		Bigeye tuna	28	26	36	9	20	16	14	21
		Mako sharks	19	19						
		Marlins,sailfishes,etc. nei	19	20	4	-	11			
		Silky shark	30	0	-	10				
		others	64	21	17	7	19	18	20	24
Pole & Line			**429**	**72**	**240**	**1,284**	**1,361**	**1,414**	**1,328**	**875**
	P&L tuna total		429	72	240	1,284	1,361	1,413	1,328	875
	P&L shark total		-	-	-	-	-	-	-	-
	P&L others total		-	-	-	-	-	1	0	0
		Skipjack tuna	346	60	218	1,265	1,208	1,009	969	725
		Bigeye tuna	18	12	16	3	67	221	270	87
		Yellowfin tuna	65	-	5	16	86	183	89	63
		others	-	-	-	-	-	1	0	0
Purse seine			**328**	**2,254**	**4,140**	**6,969**	**659**	**962**	**6,477**	**3,113**
	PS tuna total		328	1,999	4,140	6,960	659	962	6,476	3,075
	PS shark total		-	-	-	10	-	-	-	1
	PS others total		**-**	**255**	**-**	**-**	**-**	**-**	**2**	**37**
		Skipjack tuna	185	1,288	3,577	6,263	583	513	5,145	2,508
		Yellowfin tuna	51	502	121	163	33	271	737	268
		Bigeye tuna	86	155	371	475	42	171	503	258
		others	7	309	71	69	-	7	92	79
Tuna total			818	2,100	4,146	8,253	2,042	2,392	7,821	3,977
Shark total			2,254	3,030	2,647	1,392	2,797	1,979	2,058	2,308
Others total			604	569	194	54	127	124	104	254
Grand total			**3,677**	**5,699**	**7,257**	**9,699**	**4,966**	**4,494**	**9,983**	**6,539**

Source: Amador et al. 2018 and DGMARE

Bycatches of the EU longline vessels to be dominated by tuna species such as bigeye and yellowfin tuna, as well as other shark species such as longfin mako (Table 2). Various other billfish are also caught but apparently in small numbers.

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Bycatches of pole & line are low and consist of tuna species. The same applies to the purse seine fishery, but it is interesting to see that neritic tunas are present in the catches, frigate tuna in particular.

Table 2: Bycatch species; further detail on catches of species groups and others taken by EU vessels in Cape Verde waters. (Unit: tonnes)

Code	Scientific name	Name	2014	2015	2016	2017	2018
Longline							
ALB	*Thunnus alalunga*	Albacore			0		
BAZ	*Sphyraenidae*	Barracudas, etc. nei	0			0	
BET	*Thunnus obesus*	Bigeye tuna	9	19	16	15	4
BLM	*Makaira indica*	Black marlin	0	1	4	2	0
BUM	*Makaira nigricans*	Blue marlin	1	0			
DOL	*C. hippurus*	Common dolphinfish	0	1	1	0	0
LEC	*L. flavobrunneum*	Escolar	0	0	0	0	1
LMA	*Isurus paucus*	Longfin mako		0	2	7	16
MLS	*Tetrapturus audax*	Striped marlin			2	4	0
SAI	*Istiophorus albicans*	Atlantic sailfish	1	3	2	1	0
SFA	*I. platypterus*	Indo-Pacific sailfish				0	
SPF	*T. pfluegeri*	Longbill spearfish		2	1	0	
SSP	*T. angustirostris*	Shortbill spearfish	5	6	5	4	2
WAH	*A. solandri*	Wahoo	0	0		0	
WHM	*Tetrapturus albidus*	Atlantic white marlin		1			
YFT	*Thunnus albacares*	Yellowfin tuna		3	1	3	
Pole & Line							
ALB	*Thunnus alalunga*	Albacore					1
FRI	*Auxis thazard*	Frigate tuna		1	1	0	
Purse seine							
ALB	*Thunnus alalunga*	Albacore	2				
BIL	*Istiophoridae*	Marlins,sailfishes,etc. nei				2	
FRI	*Auxis thazard*	Frigate tuna	96	3	7	89	59
FRZ	*A. thazard, A. rochei*	Frigate and bullet tunas				5	
LTA	*Euthynnus alletteratus*	Little tunny (=Atl.black skipj)				2	
MZZ	*Osteichthyes*	Marine fishes nei					1

Source: DGMARE

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Catches by other foreign fleets that are taken in the waters of Cape Verde are not available. However, it appears that Japanese longliners have the same target as EU longliners (sharks) (Amador *et al.* 2018) and it is reasonable to assume that purse seiners go after the same species as EU vessels.

National fleets account for about 70% of total catches in the Cabo Verde zone, the EU 22% and Japan 8% (Amador *et al.* 2018).

Catches of tuna and tuna-like species by national fleets has varied considerably, ranging from 14,000 to 32,000 tonnes (Table 3). For major tuna species, this appears related to the activity of 4 industrial purse seiners that registered under the Cape Verde flag. These have since reflagged. For small or neritic tunas, this variability appears to be inherent to the fishery.

Table 3: Catches of tuna and tuna-like species by national fleets. (Unit: tonnes)

Code	Species	2010	2011	2012	2013	2014	2015	2016	2017
ALB	*Thunnus alalunga*		5				5		
BET	*Thunnus obesus*	656	1,077	735	1,378	2,368	2,764	1,680	1,107
SKJ	*Katsuwonus pelamis*	5,881	8,294	5,764	16,444	16615	17,600	10,925	7,823
YFT	*Thunnus albacares*	6,008	6,060	4,638	7,596	4763	7,866	6,990	2,837
	Sub-total	**12,545**	**15,436**	**11,137**	**25,417**	**23746**	**28,236**	**19,594**	**11,766**
FRI	*Auxis thazard*	1,139	983	2,082	2,717	5686	3,556	2,324	1,795
LTA	*Euthynnus alletteratus*	447	368	311	570	310	131	218	113
WAH	*Acanthocybium solandri*	499	496	450	445	445	445	490	228
	Sub-total	**2,085**	**1,847**	**2,842**	**3,732**	**6441**	**4,133**	**3,031**	**2,136**
Total		**14,630**	**17,283**	**13,979**	**29,149**	**30188**	**32,369**	**22,625**	**13,902**

Source: ICCAT

2.2 Responsibility for data collection and stock assessment

Management of the above mentioned highly migratory species is co-ordinated through ICCAT. The tuna species and swordfish are directly covered by the ICCAT Convention, while the two shark species (Blue shark and shortfin mako) are also identified under the ICCAT Convention as 'bycatch species of special importance'. The text of the ICCAT Convention covers tuna and tuna-like fishes (the Scombriformes with the exception of the families Trichiuridae and Gempylidae and the genus Scomber) and such other species of fishes exploited in tuna fishing in the Convention area as are not under investigation by another international fishery organization.

In general, data is collated on target and non-target, associated and dependent species affected by tuna fishing operations, i.e. marine turtles, marine mammals, seabirds, sharks and fish species caught incidentally (bycatch). Responsibility for the collection of fisheries data lies with the flag state national

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authorities or institutions and it is an obligation for members and cooperating non-members to report these data to the ICCAT Secretariat.

The main types of data collected are catches, discards, bycatches, and effort by species/fleet/gear by 1º squares (purse seine) or by 5º squares (longline). This is supplemented by data from tagging (e.g. growth, mortality, movement), and any other data available for scientific research in the various countries or at regional level. In practical terms, many coastal countries struggle with being able to provide complete data for their tuna fisheries and there is often the issue of data quality.

Stock assessment is carried out by specific panels using the best available data, including data compiled by the Secretariat, ancillary data from other sources, and possible estimates of data to fill known gaps.

2.3 Stock status and reference points used

The main species of interest are yellowfin, skipjack and bigeye tuna which are the main targets of the EU purse seine fleet. Blue shark appears to be the main target of EU longline fleet with various other bycatch species such as swordfish, billfish, and other shark species.

The state of these stocks is a mixed picture (Table 4). Bigeye tuna is overexploited, and yellowfin tuna is overfished. The North Atlantic stock of Blue shark is being fished sustainably and this is also the case for the N. Atlantic stock of swordfish (i.e. Cape Verde lies in the N. Atlantic stock zone). There is concern for the state of stocks of other billfish and the shortfin mako shark.

Note that the reference points relate to fishing mortality and biomass in relation to maximum sustainable yield (MSY), defined as the largest average catch that can be taken continuously from a stock under existing environmental conditions. There are two related reference points: F_{MSY} is the fishing mortality rate that eventually results in the largest yield on average (MSY) and B_{MSY} is the corresponding average stock size. The following definitions have been set in relation to these reference points:

- Subject to overfishing ($F_{year}/F_{MSY} > 1$)
- Not subject to overfishing ($F_{year}/F_{MSY} \leq 1$)
- Overfished ($B_{year}/B_{MSY} < 1$)
- Not overfished ($B_{year}/B_{MSY} \geq 1$)

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Table 4: Stock status of selected species under management by ICCAT (relevant to Cape Verde)

Species	Catch in 2017 (unit: 000 tons)	MSY estimate (unit: 000 tons)	Relative Biomass	Relative Fishing Mortality	Overfished	Overfishing	Kobe colour codes	Year of full assessment
Tropical tunas								
Bigeye tuna	78.5	76.2 (72.7-79.7)	0.59 (0.42-0.80)	1.63 (1.14-2.12)	Yes	Yes		2018
Skipjack tuna: East Atlantic	242.3		Likely >1	Likely <1	Not likely	Not likely		2014
Yellowfin tuna	139.3	126.3 (119.1 – 151.3)	0.95 (0.71-1.36)	0.77 (0.53-1.05)	Yes	No		2016
Billfish								
Swordfish: North Atlantic	10.0	13.1 (11.8-15.0)	1.04 (0.82-1.39)	0.78 (0.62-1.01)	No	No		2017
White marlin	0.40	0.87-1.60	0.50 (0.42-0.60)	0.99 (0.75-1.27)	Yes	Not likely		2012
Blue marlin	2.0	3.1 (2.4-3.5)	0.69 (0.52-0.91)	1.03 (0.74-1.50)	Yes	Yes		2018
Sailfish: East Atlantic	1.6		0.22-0.70	0.33-2.85	Yes	Possibly		2016
Sharks								
Blue shark: North Atlantic	39.7		1.35-3.45	0.04-0.75	Not likely	Not likely		2015
Shortfin mako shark: N. Atlantic	3.1		0.57-0.95	1.93-4.38	Yes	Yes		2017

Note: Stock status definitions and colour code

Source: ICCAT

Biomass (B) / Fishing Mortality (F)	Overfished (Byear/BMSY< 1)	Not overfished (Byear/BMSY≥ 1)
Subject to overfishing (Fyear/FMSY> 1)		
Not subject to overfishing (Fyear/FMSY≤ 1)		
Not assessed / Uncertain		

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2.4 Stock assessment

It is important to bear in mind that the models used for stock assessment depend on the available data, and in some cases, it is not considered possible to carry out a full formal assessment such as in the cases of various neritic tuna species and other bycatch species. Various indicators are used instead (e.g. catch, CPUE, size, etc.), or catch-based methods, when the data does not provide for a formal assessment.

The general approach to stock assessment of tunas is to run different modelling approaches in order to have a good basis for a comparison. Discrepancies and/or inconsistencies, when comparing the results of various model types, is used to focus attention on what are the key parameters (sensitivity analysis) that affect outputs and identifying ways of reducing the uncertainty inherent in the data. Age structured models are capable of a more detailed representation of complicated population and fishery dynamics, and these provide for the possibility of integrating several sources of data and biological research, which cannot be considered in simple production (biomass) models. In the end, the choice of model(s) depends on the data available and its quality.

Of the major tunas, skipjack tuna is an important and abundant resource, but it has generally been difficult to carry formal assessments of these stocks in all oceans. Traditional stock assessment models are difficult to apply to skipjack because of their particular biological and fishery characteristics (on the one hand, continuous spawning, spatial variation in growth and on the other, discrimination of effort for free schools and Fish Aggregating Devices (FADs), transition between these two fishing methods which are difficult to quantify).

The following information was extracted from supporting information on the assessments, which are available on the ICCAT website[3]. More details on each assessment model are provided separately in section 4.7.

Bigeye tuna: assessment in 2018 used several modelling approaches, ranging from non-equilibrium production models and Bayesian state-space (JABBA - Just Another Bayesian Biomass Assessment) production models to an Integrated Age Structured Model (Stock Synthesis: SS3).

Yellowfin tuna: in 2016 three age-structured models and a non-equilibrium production model were used (ASPIC - A Stock Production Model Incorporating Covariates; ASPM – Age-Structured Production Model, VPA – Virtual Population Analysis, SS3).

[3] www.iccat.int

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Skipjack tuna (East Atlantic): two surplus biomass production models (one non-equilibrium conventional model and one Bayesian model) were used in 2014. However, it was not possible to provide a reliable estimate of the maximum sustainable yield nor provide advice on the state of the eastern stock.

Swordfish (North Atlantic): assessment was carried out in 2017 using three models; a Surplus Production Model (ASPIC - A Stock Production Model Incorporating Covariates), a Bayesian Surplus Production Model with process error (BSP2 - Bayesian Surplus Production 2) and an Integrated Age Structured Model (SS3).

White marlin: two models were used to estimate the status of the stock in 2012; a production model (ASPIC), and a fully integrated model (SS3).

Blue marlin: both surplus production and age-structured models were used in 2018.

Sailfish (Eastern Atlantic): a Bayesian surplus production model and a Stock Reduction Analysis models (SRA) were used to assess the stock in 2016.

Blue shark (North Atlantic): two models were used in 2015; a Bayesian surplus production model and the integrated model (SS3)

Shortfin mako shark (North Atlantic): as the data has improved considerably, various models were used in the 2017 assessment; BSP2-JAGS (Just Another Gibbs Sampler emulating the Bayesian production model), JABBA, CMSY (Catch at MSY), and SS3.

Small tunas: this group consists of all the other tuna and tuna-like species, as listed below:

- BLF: Blackfin tuna (*Thunnus atlanticus*)
- BLT: Bullet tuna (*Auxis rochei*)
- BOM: Atlantic bonito (*Sarda sarda*)
- BOP: Plain bonito (*Orcynopsis unicolor*)
- BRS: Serra Spanish mackerel (*Scomberomorus brasiliensis*)
- CER: Cero (*Scomberomorus regalis*)
- FRI: Frigate tuna (*Auxis thazard*)
- KGM: King mackerel (*Scomberomorus cavalla*)
- LTA: Little tunny (*Euthynnus alletteratus*)
- MAW: West African Spanish mackerel (*Scomberomorus tritor*)
- SSM: Atlantic Spanish mackerel (*Scomberomorus maculatus*)
- WAH: Wahoo (*Acanthocybium solandri*)
- DOL: Dolphinfish (*Coryphaena hippurus*)

Little is known about the stock structure of many of the small tunas and the available data does not allow for quantitative assessments of stock status of the majority of the species. Nonetheless, few regional assessments have been carried out.

In 2017, Ecological Risk Analysis (ERA) was updated for small tuna caught by longline and purse seine fisheries in the Atlantic. The study found that the top 3 stocks at risk in the Atlantic Ocean that should deserve most of the managers' attention were little tunny (*E. alleteratus*), wahoo (*A. solandri*) and king mackerel (*S. cavalla*).

An alternative approach, using length as an indicator of exploitation, showed in most cases poor yield optimization is occurring, but that recruitment overfishing is not. Although in two cases (wahoo in the southern Atlantic and little tunny in the North Atlantic) recruitment overfishing has increased in the recent period.

2.5 Harvest strategies

Harvest control rules and harvest strategies are not in place yet, but these are under development for a number of stocks/fisheries (Rec. 15-07: Recommendation by ICCAT on the Development of Harvest Control Rules and of Management Strategy Evaluation).

2.6 Management measures in place

ICCAT has adopted a number of Conservation and Management Measures (CMM) to address specific problems of overfishing. It should be noted that these CMMs are compromises to address the problems while minimising the impacts of fisheries for other species that are fished sustainably. Tuna fisheries are generally multi-specific, catching various species at the same time, and CMMs should also address the issue of multiple fleets fishing for a specific species.

Rec. 16-01: Recommendation by ICCAT on a Multi-Annual Conservation and Management Program for Tropical Tunas addresses the issues concerning the major tropical tunas. Amended by Rec. 18-01: Recommendation by ICCAT Supplementing and Amending Rec. 16-01 on a Multi Annual Conservation and Management Programme for Tropical Tunas
Concerning bigeye [Rec. 16-01]:

- Total allowable catch for 2016-2018 is set at 65,000 t for Contracting Parties and Cooperating non-Contracting Parties, Entities or Fishing Entities.
- Be restricted to the number of their vessels notified to ICCAT in 2005 as fishing for bigeye tuna.

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- Specific limits of number of longline boats; China (65), Chinese Taipei (75), Philippines (5), Korea (14), EU (269) and Japan (231).
- Specific limits of number of purse seine boats; EU (34) and Ghana (17).
- No fishing with natural or artificial floating objects during January and February in the area encompassed by the African coast, 20º W, 5ºN and 4ºS.
- No more than 500 FADs active at any time by vessel.
- Use of non-entangling FADs.

Concerning yellowfin tuna [Rec. 16-01]

- Revised time-area closure for FAD associated surface fishing
- TAC of 110,000 t (since Rec. 11-01).
- Specific authorization to fish for tropical tunas for vessels 20 meters or greater
- Specific limits of number of longline and/or purse seine boats for a number of fleets
- Specific limits on FADs, non-entangling FADs required

Concerning skipjack [Rec. 16-01]: the measures adopted above have an effect on skipjack fisheries although this stock is most likely fished sustainably.

Rec. 17-02: Recommendation by ICCAT Amending the Recommendation for the Conservation of North Atlantic Swordfish, Rec. 16-03. Establishes a TAC of 13,200 t for the years 2018, 2019, 2020 and 2021, as well as the 125/119 cm LJFL minimum size.

Rec. 16-11: Recommendation by ICCAT on Management Measures for the Conservation of Atlantic Sailfish. Limits Atlantic sailfish catches of either stock to the level of 67% of MSY.

Rec. 18-04: Recommendation by ICCAT to Replace Rec. 15-05 to Further Strengthen the Plan to Rebuild Blue Marlin and White Marlin Stocks. Reduce the total harvest of White marlin to 400 t in 2016, 2017, and 2018. Reduce the total harvest of Blue marlin to 2,000 t in 2016, 2017, and 2018.

Rec. 16-12: Recommendation by ICCAT on Management Measures for the Conservation of Atlantic Blue Shark Caught in Association with ICCAT Fisheries. Blue shark catches should remain below the observed during the period 2011-2015 (i.e. 39,102 t) or further measures will be adopted.

Rec. 17-08: Recommendation by ICCAT on the Conservation of North Atlantic Stock of Shortfin Mako Caught in Association with ICCAT Fisheries. Stipulates various efforts to improve the available data.

Other shark related recommendations concerning shark fishing, finning, discarding and data collection. [Rec. 04-10], [Rec. 07-06], [Rec. 10-06], [Rec. 14-06].

3 Mauritania and Senegal

Given that the Mauritania and Senegal share many species and stocks and that regional level assessment is carried out within the context of CECAF (FAO), the review of stock assessment methods for the two case studies is presented for the two case studies together.

3.1 Mauritania

The current four-year (16-11-2015 to 15-11-2019) Protocol to the Fisheries Partnership Agreement (FPA) allows the EU fleet to fish for shrimp, black hake, demersal fish, tuna and small pelagic fish, up to a total of 287 050 tonnes/year. As shown in Table 5, this is a multispecies agreement, covering a variety of species and fishing gear. It is the most costly EU fisheries protocol (59.125 million EUR per year), with an additional 60 million EUR of license fees. Up to 261 500 tonnes of non-tuna species can be caught by a maximum of 58 European fishing vessels. Up to 40 fishing vessels can fish for tuna species (20,000 tonnes per year).

Fishing accounts for an important part of economy of Mauritania, with total catches in the Mauritanian EEZ of approximately 800,000 tonnes in 2014 and 2015 (Marti, 2018). Almost half of the catches (363,000 tonnes and 389,000 tonnes in 2014 and 2015, respectively) were accounted for by 4,000 national industrial and small-scale fishing vessels. In addition to the SFPA, vessels from other non-EU countries such as Russia, Ukraine and China are also licensed to fish in the Mauritanian EEZ (Marti, 2018).

<u>Defining the main species of interest</u>

A large number of species are exploited in Mauritania by the national and foreign fleets. The small pelagics caught by the industrial, artisanal and coastal fleets are mainly clupeids such as the sardine (*Sardina pilchardus*), sardinellas (*Sardinella* sp.), and bonga (*Ethmalosa fimbriata*) while the industrial fleet focuses additionally on horse mackerel (*Trachurus* sp.) and mackerel (*Scomber* sp.). Other schooling species caught by purse seines used for small pelagics include croakers (Scianidae), mullets (Mugilidae) and bluefish (*Pomatomus saltatrix*). *Brama brama* is caught by Spanish longliners fleet as well as demersal fish.

Although octopus, shrimp and black hakes are the most important demersal species, a large number of commercial demersal species are caught in Mauritanian waters. These include species of sea bream (Sparidae), sole (Soleidae), croaker (Scianidae), grouper (Serranidae) and elasmobranchs (sharks and rays) (Erzini et al., 2005; Stobberup et al., 2005; FarFish, 2017).

The most important crustacean species are the prawn (langostino) (*Farfantepenaeus notialis*), and deep-sea rose shrimp (gamba) (*Parapenaeus longirostris*). Other shrimp species include the coastal species *Melicertus kerathurus*, and the deep-water species *Aristeus varidens*, *Plesionika heterocarpus* and *Aristaeopsis edwardsiana*.

Table 5: Allowable catches (tonnage and maximum live weight) and rates of use by EU vessels

Categories	Species	Gear	tonnes (max/yr) 2012-2014	Utilization 2014 (%)	tonnes (max/yr) 2015-2019	Utilization 2016 (%)	Utilization 2017 (%)
1. MTR_CRU	Crustacea, except spiny lobster and crabs	Trawl	5,000	35	5,000	19	12
2. MRT_HKM	Black hake	Trawl & bottom longline	4,000	76	6,000	101	57
2. bis (2017)	Black hake	Trawl (freezer)			3,500	-	
3 MRT_NTO_DEM	Demersal other than black hake	Other than trawl	2,500	64	3,000	93	36
4. MRT_SP	Tunas	Purse seine	5,000	225	12,500	44	2
5. MRT_LP	Tunas	Pole & line & Longline	10,000	22	7,500	44	26
6. MRT_PRL_Congelé	Small pelagics	Trawl (freezer)	300,000	73	225,000	60	9
7. MRT_PEL_Frais	Small pelagics	Trawl (fresh)	15,000	0	15,000	0	0
8. MRT_CEPH	Cephalopods	Trawl	0	-	0	-	-

Source: Marti, 2018

3.2 Senegal

The current SFPA, initialized on 25 April 2014 covers the five-year period from November 20, 2014 to November 19, 2019 and in mainly a tuna fishery agreement (TAC of 14,000 tonnes/year), with a limited demersal component (TAC of hakes of 2000 tonnes/year). The agreement covers 28 EU tuna purse seiner s (16 from Spain and 12 from France), 8 pole and line vessels (7 Spanish and 1 French) and 2 demersal trawlers from Spain.

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Senegal has a large fishing fleet accounting for annual landings of more than 400,000 tonnes/year. The artisanal fleet employs purse seines, gillnets, and hook and line gear, while the industrial fleet consists of trawlers, tuna pole and line vessels and sardine purse seiners (FarFish, 2017).

Defining the main species of interest

Yellowfin (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*) and bigeye tuna (*Thunnus obesus*) are the main tropical species targeted by the EU fleet. Other tuna species caught largely as by-catch by the industrial fleet include little tunny (*Euthynnus alletteratus*), bonito (*Sarda sarda*), Spanish mackerel (*Acanthocybium solandri*) and Atlantic sailfish (*Istiophorus platypterus*) (FarFish, 2017). Of the tunas contemplated in the SFPA, utilization of the 14,000 tonnes/year TAC was 100% on average for the period 2015 to 2018 for the purse seiners (FarFish D4.3), while that for the pole and line vessels was 77% (FarFish, 2019a).

Coastal, small pelagics account for the majority of the landings in Senegal (FarFish, 2017). As reported in D2.1 (FarFish, 2017), these consist mainly of species from four families: Clupeidae (sardines and sardinellas), Engraulidae (anchovies), Carangidae (jacks, scads and horse mackerels) and Scombridae (mackerals and tunas). The main species are round sardinella (*Sardinella aurita*), flat sardinella (*Sardinella mad*erensis), West African ilisha (*Ilisha africana*), bonga (*Ethmalosa fimbriata*), European anchovy (*Engraulis encrasicolus*), black horse mackerel (*Trachurus trecae*), Atlantic horse mackerel (*Trachurus trachurus*), scad (*Caranx rhonchus*), chub mackerel (*Scomber japonicus*), and mackerel (*Scomber scombrus*).

Coastal demersal resources are largely high value species and account for 65% and 90% of the exports in volume and in value, respectively (FarFish, 2017). These resources are caught mainly on the continental shelf (depths of less than 200 m) by the artisanal fleet using a range of different gears and also by the industrial fleet.

These deep-water species, caught mainly by trawlers, include deep-water rose shrimp (*Parapenaeus longirostris*), striped red shrimp (*Aristeus varidens*), black hakes, scorpion fish, sharks, rays and monkfish. Of lesser importance are deep-water pink lobster *Palinurus mauritanicus* and deep red crab Geryon (*Chaeton maritae*). Of the 2,000 tonnes/year TAC for black hake, the average utilization for the 2015 to 2018 period was 66% (FarFish, 2019a). It should be noted that in this fishery, the SFPA stipulates an allowed by-catch of 7%, 7% and 15% for cephalopods, crustaceans and fish, respectively.

Coastal demersal fish species include groupers, soles, croakers, mullet, and sea breams. The main coastal cephalopod species are the common octopus (*Octopus vulgaris*) and cuttlefish (*Sepia officinalis hierreda*), while the main coastal crustaceans are the white shrimp (*Penaeus notialis*) and the green spiny lobster (*Panilurus regius*).

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3.3 Responsibility for data collection and stock assessment

In Senegal, data on fishing effort and catches are collected by the Oceanographic Research Centre of Dakar Thiaroye (CRODT) both for artisanal and industrial fisheries. Data on fleets

and fisheries infrastructures are also collected. Biological data (e.g. growth parameters, weight-length relationships, maturity) is available for some of the main stocks and species. Research vessel surveys are carried out by CRODT.

In Mauritania, annual research vessel surveys are carried out by IMROP. IMROP is responsible for biological sampling of demersal fish, shrimps and cephalopods as well as collecting data on catch and effort for all the stocks included within the SFPA protocol (FarFish, 2017).

Given that the assessment and management of the highly migratory / large pelagics species is co-ordinated through ICCAT and this is covered in the section on Cape Verde of this deliverable, in the case of Mauritania and Senegal, this deliverable will focus mainly on the assessment and management of small pelagics and demersal species. In the case of demersal species, joint assessments are carried out by the FAO/CECAF Working Group on the Assessment of Demersal Resources (Table 6). For small pelagics, joint assessments are carried out by the FAO Working Group on the Assessment of Small Pelagic Fish off Northwest Africa.

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Table 6: Total catches (t) of major demersal species analysed in 2017

Target species	Catch contributions 2015 (%)	Catch contributions 2016 (%)	Catches 2015 (t)	Catches 2016 (t)	Percentage difference	Average catches (2012-2016) (t)
Octopus vulgaris	45	38	85,319	76,521	-10%	71,620
Sepia spp.	17	15	32,210	29,534	-8%	29,550
P. longirostris	4	4	7,255	8,743	21%	9,955
Pseudotolithus spp.	1	2	2,161	3,147	465	2,346
Loligo vulgaris	6	9	10,673	18,665	75%	11,859
Merluccius spp.	6	8	10,601	16,972	60%	9,668
Pagrus caeruleostictus	2	2	2,980	3,937	32%	3,886
Pagellus belotti	3	5	6,536	9,440	44%	6,193
Arius spp.	3	3	5,630	5,162	-8%	5,304
Merluccius merluccius	3	3	4,946	5,381	9%	5,293
Sparus spp.	2	2	3,800	4,138	9%	5,204
P. mediterraneus	3	4	6,044	7,708	28%	7,013
Pagellus spp.	2	1	3,070	2,701	-12%	3,423
D. macrophthalmus	2	2	3,160	3,594	14%	2,841
Penaeus notialis	1	1	1,226	1,324	8%	1,768
Epinephelus aeneus	1	2	2,161	3,147	46%	2,346
Pagellus acarne	1	1	1,191	1,598	34%	1,136
TOTAL DEMERSAL	**100**	**100**	**188,963**	**201,717**	**7%**	**179,395**

Source: FAO/CECAF, 2018.

3.4 Stock assessment

The FAO/CECAF Working Group on the Assessment of Demersal Resources in the Northern Area of CECAF (Northern Morocco to Southern Senegal) carries out joint stock assessment of demersal species from the five countries in the sub-region. In 2017, 26 stocks and groups of demersal species (shrimps, cephalopods, hakes and other demersal fish) species were assessed (FAO/CECAF, 2018; FAO, 2018).

Data are annual or quarterly estimates of total catches and indices of abundances based on demersal surveys or commercial catch per unit effort (CPUE). In the case of black hake, CPUE from the Spanish fresh hake trawl fishery is used along with data on abundance from Mauritanian research surveys (FAO, 2018).

Stock assessment for most demersal species is mainly carried out using the Surplus production models (FAO, 2018). For black hake, in addition to the Schaefer dynamic production model, the Fox dynamic

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production model within a Bayesian framework is also used, allowing estimation of the reference points and associated uncertainties (FAO, 2018). A new data limited method, Catch MSY (CMSY), developed by Martell and Froese (2013), was also used. This approach is based on catches and basic parameters of the Schaefer model and allows estimation of MSY and related fishing reference points (see section 4.7).

In addition to the Schaefer dynamic surplus production model, the Fox Bayesian model, length-based cohort analysis (LCA) (Jones, 1984) is also used for some species to estimate current fishing mortality (F) and recent fishing exploitation. These estimates are then used in yield per recruit models to calculate F_{max} and F0.1 (FAO, 2018).

Projections are made with the dynamic surplus production models using the last year of data available as a starting point and considering two scenarios: 1) F constant (remains unchanged) and 2) changes in F based on recommended catches for the next year (FAO/CECAF, 2018; FAO, 2018).

The FAO Working Group on the Assessment of Small Pelagic Fish off Northwest Africa also uses the same stock assessment methods as the FAO/CECAF Working Group on the Assessment of Demersal Resources in the Northern Area of CECAF (FAO, 2017).

3.5 Stock status and reference points used

The Biological Reference Points (BRP) adopted by CECAF used by the Working Group are:

– Target reference points (TRP): B0.1 and F0.1
– Limit reference points (LRP): BMSY and FMSY

To assess the current situation with respect to the LRPs, Bcur/BMSY and Fcur/FMSY are used. To assess the situation relative to the TRPs, Bcur/B0.1 and Fcur/F0.1 are used. The CECAF scientific Working Groups assign the results in three categories (FAO/CECAF, 2018):

- "Non-fully exploited: The stock is in good condition and fishing pressure can be increased without affecting the sustainability. All increases must be seen in the context of the general environmental situation."
- "Fully exploited: The fishery operates within the limits of sustainability. Current fishing pressure seems sustainable and can be maintained." But without increase of effort.
- "Overexploited: The fishery is in an undesired state both in terms of biomass and fishing mortality. Fishing pressure should be reduced to allow the stock to grow."

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Of the 26 stocks or groups of species assessed, satisfactory results were obtained for 19, with nine classified as over-exploited, seven fully exploited and three not fully exploited. Inconclusive results were obtained for seven stocks. However, or the latter stocks, additional information from fisheries and scientific surveys suggests that many are overexploited (FAO/CECAF, 2018; FAO, 2018). A summary of the 2017 stock assessments and management recommendations for demersal species is given in Table 7. Only species or groups of species from Mauritania and Senegal are included.

Of particular interest, it can be seen that black hakes (two species assessed as one) is considered over-exploited at the regional level. For octopus, the most important cephalopod species, no assessment was possible in Senegal. The deep-water rose shrimp was considered not fully exploited in Mauritania but over-exploited in Senegal.

A summary of the 2017 stock assessments and management recommendations for pelagic species is given in Table 8 (FAO/CECAF, 2018; FAO, 2018). Only species or stocks from Mauritania and/or Senegal are included. As can be seen, no assessment results are available for *Sardinella* species due to insufficient data in the case of surplus production models or inconclusive results for the data limited CMSY approach. The two species of horse mackerel are considered over-exploited, while the chub mackerel is considered fully exploited. It should be noted that these assessments are on a regional basis.

In a recent publication (Ba et al., 2018) a global diagnosis of demersal fish stocks was carried out using data from national (Senegal) fisheries data bases as well scientific trawl survey data. Time series since 1971 were analysed for trends, abundance indices were estimated for 10 stocks and stock assessments carried out using pseudo-equilibrium Fox and Pella-Tomlinson models and a Biomass dynamic production model fitted in a Bayesian framework. The results indicate that most stocks have declined over time, with three fifths of the stocks over-exploited.

Table 7: Summary of 2017 stock assessments and management recommendations for demersal species (FAO/CECAF, 2018; FAO, 2018). Only species or stocks from Mauritania and/or Senegal are included.

Stock Countries	Catch (t) 2016 (avg. 2012-2016)	*Bcur / B0.1	*Fcur / F0.1	LCA and YPR	Assessments	Management recommendations
Black hake: *Merluccius* spp. (*M. polli* and *M.senegalensis*) Morocco, Mauritania, Senegal and Gambia	5,381 (5,293)	88%	126%	The model gives a very high exploitation rate because of the exploitation of the juveniles.	Overexploited	It is recommended to reduce the current fishing mortality of coastal trawlers targeting juveniles in order to minimize the proportions of juveniles observed in the catches of the last years analysed.
Arius sp. Senegal and Gambia	8,703 (7,613)			N/A	Fully exploited based on CPUE	The available data would not allow assessments of this stock, for this purpose, as a precautionary measure, the Working Group recommends not to exceed the level of fishing mortality that would allow catches that are average recent years (7 600 tonnes).
Pseudotolithus spp. Senegal and Gambia	7,410 (7,231)				Inconclusive	As the assessment is not conclusive, the Working Group recommends, as a precaution, not to exceed the fishing mortality level of 2016.
Epinephelus aeneus Mauritania, Senegal and Gambia	6,263 (4,566)	85%	144%	189%	Overexploited	Taking into account the results of the assessments, the Working Group recommends reducing the current fishing mortality.
Pagrus caeruleostictus Mauritania, Senegal	11,715 (7,653)	116%	114%	N/A	Fully exploited	Based on the results of the assessments, the Working Group recommends not to exceed the current level of fishing mortality.

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Stock Countries	Catch (t) 2016 (avg. 2012-2016)	*Bcur / B0.1	*Fcur / F0.1	LCA and YPR	Assessments	Management recommendations
Dentex macrophthalmus Morocco, Mauritania and Senegal	4,398 (4,225)	160%	27%	N/A	Not fully exploited	The Working Group emphasized that this stock could support a slight increase in fishing mortality.
Pagellus bellottii Mauritania, Senegal and Gambia	9,456 (6,164)	113%	82%	93%	Fully exploited	As a precautionary approach, the Working Group recommends not to exceed the current fishing mortality.
Parapenaeus longirostris Mauritania	350 (790)	-	-		Not fully exploited (2013 assessment)	Given the exceptionally low levels of fishing mortality during the 2012-2016 period, the Working Group considered that an increase could be possible, up to the 2011 catch level, when the fishery was considered sustainable (WG, 2013).
Parapenaeus longirostris Senegal and Gambia	1,401 (1,918)	56%	85%	-	Overexploited in terms of biomass but current F is less than $F_{0.1}$	Considering the past overexploitation of biomass in the stock and current fishing mortality below F0.1 target fishing mortality, the Working Group recommends not to increase the current level of fishing mortality (2016).
Penaeus notialis Mauritania	343 (314)				Fully exploited (2013)	Considering the exceptionally low level of fishing mortality during the 2012-2016 period, the Working Group considers that an increase in catches at the 2011 level would be possible, when the fishery was considered sustainable (WG, 2013).
Penaeus notialis Senegal and Gambia	981 (1,076)				Overexploited (2013)	Given that the last assessment (2013) shows overexploitation, the Working Group recommends not to increase the current level of fishing mortality (2016).
Octopus vulgaris Senegal and Gambia	34,142 (29,109)			N/A	No assessment	Given the reduction in fishing effort in Morocco and Mauritania in recent years and the improvement in the abundance of both stocks (Dakhla and Cap Blanc), the Working Group recommends: For Senegal-Gambia, as a precaution, not to exceed the current fishing mortality.

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Stock Countries	Catch (t) 2016 (avg. 2012-2016)	*Bcur / B0.1	*Fcur / F0.1	LCA and YPR	Assessments	Management recommendations
Sepia spp. Senegal and Gambia	2,280 (3,147)	-	-	N/A		As a precaution, the Working Group recommends not to exceed the current fishing mortality.
Loligo vulgaris Senegal and Gambia	148 (132)					This species with high commercial value is caught incidentally by the fleets that target the octopus. The improvement observed should not be an opportunity for an unregulated increase in fishing effort. The Task Force recommends: Close monitoring of catches and effort applied to squid. A maintenance of fishing mortality at its current level (2016).

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Table 8: Summary of 2017 stock assessments and management recommendations for small pelagics (FAO/CECAF, 2018; FAO, 2018). Only species or stocks from Mauritania and/or Senegal are included

Stock Region	2016 catch in1000 t (2012–2016 average)	Bcur / B0.1	*Fcur / F0.1	Assessment	Assessments
Sardinella *S. aurita* *S. maderensis* *Sardinella* spp Whole subregion.	502 (526) 224 (201) 725 (726)				The production model could not be used due to lack of continuous series of abundance indices. Despite the fact that length frequency data seem insufficient to represent the total stock, the LCA and yield per recruit models were applied. The exploration for different combinations of length structures according to different periods indicates that these are sensitive to the change in the analysis period thus giving different interpretations. Thus, no reference point was retained for deciding on the state of this stock for this year. The CMSY model was also tested, but this model which is based on a very good knowledge of this stock a priori and is very sensitive to the initial assumptions did not provide conclusive results. This recurrent situation of insufficient data to assess this stock is of great concern to the WG. To be able to make more reliable management recommendations, the WG insists on the need to improve the basic data for the models (sampling, acoustic surveys, etc.). Currently and as a precaution the Working Group recommends to retain last year's recommendation.
Horse mackerel *Trachurus. trachurus* *Trachurus trecae* Whole subregion	160 (105) 236 (195)	74% 76%	208% 121%	Overexploited Overexploited	The two species *T.trecae* and *T.trachurus* are overexploited. Thus, the Working Group recommends to reduce both effort and catch for the two species in the different zones and fleets.
Chub mackerel** *Scomber colias* Whole subregion	401 (320)	62% (Biodyn) 123% (XSA)	243% (Biodyn) 68% (XSA)	Fully exploited	The Working Group concluded, based on the results of the production model and the analytical model that the stock is fully exploited. Thus, any increase in catches could reduce the catch levels of this stock whose catch in 2016 exceeds the level recommended in 2015.The Working Group recommends to retain the recommendation made last year for a maximum catch of 340 000 tonnes in the whole sub-region.

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4 Seychelles

The Seychelles is of crucial importance to the EU fishing fleet for two main reasons; a) it is a productive fishing ground and b) the Port of Victoria has strategic importance for the landing, transshipment and processing of the catches, as well as providing services and maintenance to the fishing vessels.

During the period 2014-2018, an average of 27 EU tuna purse seiners (PS) have drawn fishing authorisations to fish in the Seychelles EEZ, which represents almost all EU tuna purse seiners active in the Indian Ocean, but only one longline vessel made use of fishing possibilities in 2016 and 2017 (none in 2018) (Goulding *et al.* 2019).

4.1 Defining the main species of interest

Tropical tunas such as yellowfin, skipjack and bigeye tuna are the main targets of the industrial purse seine (PS) fisheries, including the EU PS fleet. It should be noted that EU PS fleets are active over vast areas of the tropical Indian Ocean, although mostly in the western part of this ocean. Catches of the EU PS fleet in the Seychelles EEZ have been on average 48,000 tonnes in the period 2014-2018 (Table 9). This constitutes about 23% of all the catches taken by EU purse seiners in the Indian Ocean (Goulding *et al.* 2019).

Table 9: Total EU tuna catches (tonnes) in the Seychelles EEZ. A breakdown of EU catches is also given on PS catches inside the Seychelles EEZ and in the whole Indian Ocean. (Unit: tonnes)

Species	**2014**	**2015**	**2016**	**2017**	**2018**	**Avg.**
Yellowfin tuna	23,384	17,205	30,095	24,579	16,610	22,375
Skipjack tuna	15,160	12,656	28,206	19,971	33,457	21,890
Bigeye tuna	3,416	2,075	3,452	4,062	5,249	3,651
Other species	56	49	179	121	39	89
Total	**42,016**	**31,985**	**61,932**	**48,733**	**55,355**	**48,004**

Source: DGMARE & Goulding et al. 2019

There is also a fleet of 13 industrial purse seiners under the Seychelles flag that follow the same fishing strategy as the EU vessels, and this is because most of these vessels are under Spanish beneficial ownership.

Note that in Table 9 above bycatches are minor quantities which consist of the species listed in Table 10. An important component is albacore tuna, but these are small quantities as the main fishing grounds are further south in the IO. Bycatches include undetermined species (e.g. billfish and tunas), neritic tunas, and dolphinfish.

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Table 10: Breakdown of bycatch species (other species) in EU catches

Code	Species	2014	2015	2016	2017
ALB	Albacore	56.4	49.3	95.7	111.9
BIL	Billfish			1.8	
BLM	Black Marlin			0.6	1.8
DOL	Dolphinfish			1.0	0.4
FRI	Frigate tuna			3.0	3.3
LTA*	Kawakawa				3.1
TUN	Tuna nei			76.2	
WAH	Wahoo			0.8	0.2
Total		**56.4**	**49.3**	**179.1**	**120.8**

(Source: DGMARE)

Note*: This is presumably *Euthynnus affinis* so this would be a misidentification and the code should be KAW.

Species such as Swordfish and Blue shark are important target species of the EU longline fleet, but it should be noted that these do not appear in the estimates presented above. The fishing grounds for these species are further south in the Indian Ocean, particularly in the southwest for the EU fleet. Hence, the lack of interest by EU longliners in taking licences to fish in the Seychelles EEZ.

On the other hand, there are numerous longline vessels active in the Seychelles EEZ that fish for bigeye tuna as the main target for the sashimi market. This consists of vessels under the Seychelles flag as well as a number of other countries. The number of vessels with licenses have varied greatly but this was 158 vessels in 2015, including 45 under the Seychelles flag, 85 Taiwanese, and 19 from China, as well as a few other vessels from other countries such as Oman, Philippines, Tanzania and Thailand (SFA 2016). Most are reported to be still operating (Goulding *et al.* 2019).

Bigeye tuna accounts for roughly 50% of catches by these longliners, but catches of yellowfin tuna and swordfish are substantial, while there are lesser catches of unspecified marlin and shark (SFA 2016). Blue shark is presumed to be the dominant species caught as bycatch. Catches of the referred longliners were estimated to be 14,200 tonnes in 2015, of which about 36% was taken in the Seychelles EEZ (SFA 2016).

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4.2 Responsibility for data collection and stock assessment

All of the above-mentioned species are under the management mandate of the Indian Ocean Tuna Commission (IOTC), of which the Seychelles is a member since 1995. Although the formal list of species/stocks managed by IOTC are tuna and tuna-like species (Table 11), data is collated on non-target, associated and dependent species affected by tuna fishing operations, i.e. marine turtles, marine mammals, seabirds, sharks and fish species caught incidentally (bycatch).

Table 11: List of species under the management mandate of IOTC

FAO English name	**FAO French name**	**Scientific name**	**FAO Code**
Yellowfin tuna	Albacore	*Thunnus albacares*	YFT
Skipjack	Listao; Bonite à ventre rayé	*Katsuwonus pelamis*	SKJ
Bigeye tuna	Patudo; Thon obèse	*Thunnus obesus*	BET
Albacore tuna	Germon	*Thunnus alalunga*	ALB
Southern Bluefin tuna	Thon rouge du sud	*Thunnus maccoyii*	SBT
Longtail tuna	Thon mignon	*Thunnus tonggol*	LOT
Kawakawa	Thonine orientale	*Euthynnus affinis*	KAW
Frigate tuna	Auxide	*Auxis thazard*	FRI
Bullet tuna	Bonitou	*Auxis rochei*	BLT
Narrow barred Spanish Mackerel	Thazard rayé	*Scomberomorus commerson*	COM
Indo-Pacific king mackerel	Thazard ponctué	*Scomberomorus guttatus*	GUT
Blue Marlin	Makaire bleu	*Makaira nigricans*	BUM
Black Marlin	Makaire noir	*Makaira indica*	BLM
Striped Marlin	Marlin rayé	*Tetrapturus audax*	MLS
Indo-Pacific Sailfish	Voilier de l'Indo-Pacifique	*Istiophorus platypterus*	SFA
Swordfish	Espadon	*Xiphias gladius*	SWO

Source: IOTC

Responsibility for the collection of fisheries data lies with the flag state national authorities or institutions and it is an obligation for members and cooperating non-members to report these data to the IOTC Secretariat.

The main types of data collected are catches, discards, bycatches, and effort by species/fleet/gear by 1º squares (purse seine) or by 5º squares (longline). This is supplemented by data from tagging (e.g. growth, mortality, movement), and any other data available for scientific research in the various countries or at regional level. In practical terms, many coastal countries struggle with being able to provide complete data for their tuna fisheries and there is often the issue of data quality. A Regional Observer Scheme was established for this purpose, but this is a process involving capacity development for data collection using a variety of means/methods.

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Stock assessment is carried out by specific Working Parties (WP) using the best available data, including data compiled by the Secretariat, ancillary data from other sources, and possible estimates of data to fill known gaps. There are currently the following WP established under the IOTC[4]:

- WP on Billfish (WPB)
- WP on Data Collection and Statistics (WPDCS)
- WP on Ecosystems and Bycatch (WPEB)
- WP on Methods (WPM)
- WP on Neritic Tunas (WPNT)
- WP on Temperate Tunas (WPTmT)
- WP on Tropical Tunas (WPTT)

The results of stock assessment are reported to the Scientific Committee which takes this into consideration and provides the Commission with the information it needs to manage fish stocks under the IOTC mandate, as well as the ecosystems in which the fisheries operate.
The science process of the IOTC can be summarised as a three-step approach:

1. Collection of information on fisheries and scientific analysis to supply advice as needed.
2. Decision-making on the basis of the advice received.
3. Implementation and monitoring of compliance with the actions agreed.

Scientists from Member States are invited to participate in the meetings of the WP to carry out stock assessment. However, in order to strengthen the work of WP, the Secretariat contracts experienced stock assessment specialists to assist and guide in the process.

4.3 Stock status and reference points used

The main species of interest are yellowfin, skipjack and bigeye tuna which are the main targets of the EU purse seine fleet. Bigeye and skipjack tunas are being fished sustainably, but the stock of yellowfin tuna is considered to be overfished as well as being subject to overfishing (Table 12).

In the Seychelles EEZ, substantial catches of Swordfish and Blue shark are taken by the Seychelles and other foreign fleets (non-EU). These two species are being fished sustainably according to IOTC (Table 12). The other billfish species are included as these may be taken as bycatches in longline fleets. The situation appears to be of general overexploitation.

Note that the reference points relate to fishing mortality and biomass in relation to maximum sustainable yield (MSY), defined as the largest average catch that can be taken continuously from a

[4] www.iotc.org

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stock under existing environmental conditions. There are two related reference points: F_{MSY} is the fishing mortality rate that eventually results in the largest yield on average (MSY) and B_{MSY} is the corresponding average stock size. The following definitions have been set in relation to these reference points:

- Subject to overfishing ($F_{year}/F_{MSY} > 1$)
- Not subject to overfishing ($F_{year}/F_{MSY} \leq 1$)
- Overfished ($B_{year}/B_{MSY} < 1$)
- Not overfished ($B_{year}/B_{MSY} \geq 1$)

Table 12: Stock status of selected species under management by the IOTC

Species	Catch in 2017 (unit: 1000 t.)	MSY estimate (unit: 1000 t.)	Relative Biomass	Relative Fishing Mortality	Overfished	Overfishing	Kobe colour codes	Year of full assessment
Tropical tunas								
Bigeye tuna	90.1	104 (87-121)	1.29 (1.07-1,51)	0.76 (0.49-1.03)	No	No		2016
Skipjack tuna	524.3	≈ 510.1 (455.9-618.8)	≈ 0.40 (0.35-0.47)	≈ 0.88 (0.72-0.98)	No	No		2017
Yellowfin tuna	409.6	403 (339-436)	0.83 (0.74-0.97)	1.20 (1.00-1.71)	Yes	Yes		2018
Billfish								
Swordfish	34.8	31.59 (26.30-45.50)	1.50 (1.05-2.45)	0.76 (0.41-1.04)	No	No		2017
Black marlin	21.3	12.93 (9.44-18.20)	1.68 (1.32-2.10)	0.96 (0.77-1.12)	No but uncertain	No but uncertain		2018
Blue marlin	12.2	11.93 (9.23-16.15)	1.11 (0.90-1.35)	1.188 (0.80-1.71)	No	Yes		2016
Striped marlin	3.1	4.73 (4.27-5.18)	0.33 (0.18-0.54)	1.99 (1.21-3.62)	Yes	Yes		2018
Indo-Pacific sailfish	33.3	25.0 (16.18-35.17)	1.13 (0.87-1.37)	1.05 (0.63-1.63)	No	Yes		2015
Sharks								
Blue shark (*Prionace glauca*)	≈ 56.9	33.1 (29.5-36.6)	1.50 (1.37-1.72)	0.90 (0.67-1.09)	No	No		2017

Note: Stock status definitions and colour code

Source: IOTC

Biomass (B) Fishing Mortality (F)	Overfished (Byear/BMSY< 1)	Not overfished (Byear/BMSY≥ 1)
Subject to overfishing (Fyear/FMSY> 1)		
Not subject to overfishing (Fyear/FMSY≤ 1)		
Not assessed / Uncertain		

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4.4 Stock assessment

It is important to bear in mind that the models used for stock assessment (Table 13) depend on the available data, and in some cases, it is not considered possible to carry out a full formal assessment such as in the cases of various neritic tuna species and other bycatch species[5]. Various indicators are used instead (e.g. catch, CPUE, size, etc.), or catch-based methods, when the data does not provide for a formal assessment.

Table 13: List of models commonly used, indicating the general type (family) of model

Acronym	Name	Type
ASAP	Age-Structured Assessment Program	Age/size structured population model
ASPIC	A Stock Production Model Incorporating Covariates	Biomass model
ASPM	Age Structured Production Model	Structured biomass model
BDM	Biomass Dynamic Model	Biomass model
BSP	Bayesian Surplus Production Model	Biomass model
BSP-SS	Bayesian state-space production model	Biomass model
C-MSY	Catch at MSY	Biomass model
ERA	Ecological Risk Analysis	Framework for qualitative to quantitative assessment
JABBA	Just Another Bayesian Biomass Assessment	Biomass model
OCOM	Optimised Catch Only Method	Model based on catches
PSA	Productivity-Susceptibility Analysis	Semi-quantitative rapid risk assessment
SCAA	Statistical catch-at-age	Age/size structured population model
SRA	Stock Reduction Analysis	Model based on catches
SS3	Stock Synthesis	Age/size structured population model

Source: IOTC

The general approach to stock assessment of tunas is to run different modelling approaches in order to have a good basis for a comparison. Discrepancies and/or inconsistencies, when comparing the results of various model types, is used to focus attention on what are the key parameters (sensitivity analysis) that affect outputs and identifying ways of reducing the uncertainty inherent in the data. Age structured models are capable of a more detailed representation of complicated population and fishery dynamics, and these provide for the possibility of integrating several sources of data and biological research, which cannot be considered in simple production (biomass) models. In the end, the choice of model(s) depends on the data available and its quality.

[5] Of the small or neritic tunas, only Kawakawa was assessed formally and found to be fished sustainably.

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The following information was extracted from supporting information on the assessments, which are available on the IOTC website[6]. More details on each assessment model are provided separately in section 4.7.

Bigeye tuna: in 2016, the bigeye tuna was assessed using a range of quantitative modelling methods (ASAP, ASPIC, BDM, BSPM, SCAA, SS3; see Table 12).
Skipjack tuna: skipjack tuna was assessed with Stock Synthesis (SS3) in 2017 using a range of exploratory models to explore the impact of key data and model assumptions on the outputs.

Yellowfin tuna: The Stock Synthesis (SS3) modelling approach used for determining stock status in 2018.

Swordfish: various models (SS3, ASPIC, SCAA, and BSP) were used for assessment in 2017.

Blue shark: in 2017, new information became available and stock assessment was conducted using four stock assessment models, specifically a data-limited catch only model (SRA), two Bayesian biomass dynamic models (JABBA with process error and a Pella-Tomlinson production model without process error) and an integrated age-structured model (SS3).

Bycatch species
Referring back to the bycatch typically caught by the EU purse seine fleet, formal assessments were carried out for albacore and kawakawa and were found to be fished sustainably.
In the case of kawakawa, three modelling methods were used; Optimised Catch-Only Method (OCOM), Catch-MSY and SS3 (Stock Synthesis) were used to assess the status of the stock in 2015. The final results were based on the OCOM model.
Attempts were made at assessing Black marlin and frigate tuna, but the results were considered uncertain. It was not possible to undertake a formal assessment of species such as frigate tuna, dolphinfish and wahoo.

4.5 Harvest strategies

Harvest control rules and harvest strategies are generally not in place, but the first steps have been taken in relation to skipjack tuna (Resolution 16/02 On harvest control rules for skipjack tuna in the IOTC area of competence; Resolution 16/09 On establishing a Technical committee on management procedures).

[6] www.iotc.org

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4.6 Management measures in place

4.6.1 IOTC

IOTC has adopted various Conservation and Management Measures (CMM) which are specified in the following:

Bigeye (note that these are not specific for bigeye tuna only and some are generic for all)

- Resolution 15/01 on the recording of catch and effort by fishing vessels in the IOTC area of competence
- Resolution 15/02 mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPC's)
- Resolution 15/06 on a ban on discards of bigeye tuna, skipjack tuna, yellowfin tuna and a recommendation for non-targeted species caught by purse seine vessels in the IOTC area of competence
- Resolution 15/10 on target and limit reference points and a decision framework
- Resolution 15/11 on the implementation of a limitation of fishing capacity of Contracting Parties and Cooperating Non-Contracting Parties
- Resolution 14/02 for the conservation and management of tropical tunas stocks in the IOTC area of competence.
- Resolution 14/05 concerning a record of licensed foreign vessels fishing for IOTC species in the IOTC area of competence and access agreement information
- Resolution 10/08 concerning a record of active vessels fishing for tunas and swordfish in the IOTC area

Yellowfin (apart from generic CMMs stated above, there is a specific rebuilding plan)

- Resolution 18/01 (supersedes 17/01 & 16/01) on an interim plan for rebuilding the Indian Ocean Yellowfin tuna stock in the IOTC Area of Competence. Specifies limits and reductions in catches, as well as a limit on the number of FADs.

Skipjack (same as above)

- Resolution 16/02 On harvest control rules for Skipjack tuna in the IOTC Area of Competence

Swordfish (no specific CMMs apply)

Billfish: (Striped Marlin, Black Marlin, Blue Marlin and Indo-Pacific Sailfish)

- Resolution 18/05 On Management Measures for the Conservation of the Billfishes: Striped Marlin, Black Marlin, Blue Marlin and Indo-Pacific Sailfish specifies that CPCs should endeavour to maintain or reduce catches to MSY levels, as well as a minimum size of 60 cm LJKL (Lower Jaw Fork Length).

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Blue shark

- Resolution 17/05 On the conservation of sharks caught in association with fisheries managed by IOTC includes minimum reporting requirements for sharks, calls for full utilisation of sharks and includes a ratio of fin-to-body weight for frozen shark fins retained onboard a vessel and a prohibition on the removal of fins for sharks landed fresh.

4.6.2 National level

At the national level The Seychelles Fishing Authority reviewed its National Plan of Action for the Conservation and management of Sharks (NPOA) 2007-2011 and developed a new 5 years plan for the period 2016-2019. The NPOA (NPOA) 2007-2011 had 11 work programmes. In general, the implementation of the NPOA was patchy at best and in some sections entirely absent. One of the finding of the review was that the key shortcoming for the implementation of the NPOA was the weak functioning of its Steering Committee – in terms of not being given sufficient priority in the Fisheries Portfolio, insufficient secretariat support, a lack of strategic approach and insufficient and irregular meetings. These shortcomings need to be addressed as a priority in NPOA 2.

In regard to research, data gathering and educations and awareness, some progress were made particularly in regard to species identification, education and awareness, surveys for data collection by species; tagging to look at ecology and movement.
The following has been achieved;

a). A shark identification booklet to identify shark species caught in the Seychelles waters.

b). Artisanal shark fishery survey was undertaken to collect species specific data to determine abundance, diversity and seasonality of species.

c). A database and species-specific morphometric models developed, based on intact specimens model was developed to identify and collect size measurement from dressed carcasses.

d). A cartoon book (Shark fin soup) was published which depict the bad practice of shark fining and its consequences on shark population and the marine ecosystem was produced.

For fisheries having MSC or other certification the Fishing Boat Owners Association (FBOA), with financial support from the SFA, continued the implementation of their hook and line local labelling programme. The main aim of the programme is to promote the traditional sustainable ways of fishing, to add value to the catch and to maintain the resources availability for future generations. The principle of the programme is to guarantee the origin of the fish and strengthen the link between fishers and consumers.

MSC pre-assessment of the Seychelles purse seine fishery targeting tuna was undertaken in 2015/2016. The fishery did not pass the pre assessment phase and various measures have been proposed for improving the sustainability of the fishery. The main issue was the lack of harvest control rules for the Indian Ocean Tuna Fishery. Seychelles in collaboration with various stakeholder including vessels owners and operators have developed a Fishery Improvement Programme for this fishery with the aim of meeting standard for future MSC certification.

At sea deployment of observers on the Seychelles purse seine fleet continued in 2015/2016 under the framework of the Seychelles National Observer programme. A total of 84 deployments were completed only of Seychelles purse seiners in 2015 covering a total of 3,541 observed days (84% coverage). SFA is also providing observer services to other purse seine fleet and Table 14 summarizes deployment for 2015.
The programme is in phase three of its implementation which is focusing on data compilation, analysis and dissemination.

Table 14: Observer deployments for 2015 (Seychelles)

Country	Number of trips observed	Number of days observed
France	17	1,028
South Korea	8	324
Mauritius	1	70
Seychelles	84	3,541
Spain	120	5,277
TOTAL	**230**	**10,240**

Source: SFA.

SFA in collaboration with FAO (under the Global Tuna Project) and with OPAGAC is implementing a pilot Electronic monitoring system on two Seychelles Flagged purse seiners. The purpose of the project is to assess the data collected via the electronic system with data collected from other sources such as human observers, port sampling, logbooks and landing. If successful, the system will be deployed on more vessels to complement human observer data as well as on industrial longline vessel where logistic for human observer deployment is much more complex.

As per the requirement of IOTC resolution 16/01, Seychelles is required to reduce catches of yellowfin tuna by its Purse seine fleet by 15% base on the 2014 catch level of approximately 23, 500 Mt. The new catch level for yellowfin for this fleet would come to 19,932 Mt.

4.7 Stock Assessment Models used in Tuna Fisheries

The methodologies used in both the IOTC and ICCAT are similar. In many cases various models are used for comparative purposes, ranging from more simple surplus production models to age structure integrated statistical models that use a variety of data sources, including results from tagging studies, etc. Simple models have less data requirements than other more detailed assessment methodologies,

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which make them more suitable for data-poor situations. Because of their simplicity, they do not necessarily reflect the true dynamics of the stock/fishery such as age-specific processes, but this does not necessarily reduce their value. In principle, simple models should give results consistent with more complex models, or at least, it should be possible to identify and explain the inconsistencies. This is in itself a valuable modelling exercise which should include sensitivity analysis of parameters and an assessment of the quality of the data fed to the models.

When possible, the preferred methodology is to use Stock Synthesis (SS), which is a sophisticated tool which can be used with simplified parameterization, applicable to moderate-data species. SS is designed to accept both size and age structured data so, it can capture changes in age- or size specific processes over time and can also provide area-disaggregated analyses. However, it needs catch and CPUE data (or other abundance index) and, even in its simplified form, it usually requires considerable tuning and more time to run than production models.

Based on Table 13 which lists the models commonly used, the following gives a short description of these models/software. These are based on sources such as the NOAA Assessment Toolbox[7] and Coelho *et al.* (2019).

The Age Structured Assessment Program (**ASAP**) is an age-structured model that uses forward computations assuming separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and indices of abundance. Discards can be treated explicitly. The separability assumption is relaxed by allowing for fleet-specific computations and by allowing the selectivity at age to change smoothly over time or in blocks of years. The software can also allow the catchability associated with each abundance index to vary smoothly with time. The problem's dimensions (number of ages, years, fleets and abundance indices) are defined at input and limited by hardware only. The input is arranged assuming data is available for most years, but missing years are allowed. The model currently does not allow use of length data nor indices of survival rates. Diagnostics include index fits, residuals in catch and catch-at-age, and effective sample size calculations. Weights are input for different components of the objective function and allow for relatively simple age-structured production model type models up to fully parameterized models.

ASPIC (A Stock Production Model Incorporating Covariates) is a software that allows fitting catch and abundance indices data to a biomass dynamic model (Logistic or Fox). ASPIC is a non-equilibrium implementation of the well-known surplus production models of Schaefer and Pella-Tomlinson. ASPIC can fit data from up to 10 data series of fishery-dependent or fishery-independent indices, using bootstrapping to construct approximate non-parametric confidence intervals and to correct for bias. In addition, ASPIC can fit the model by varying the relative importance placed on yield versus measures

[7] https://www.nefsc.noaa.gov/nft/

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of effort or indices of abundance. This model has been used extensively, particularly in the context of ICCAT.

ASPM (Age Structured Production Model) is a model that falls somewhere between simple biomass-based production models and the more data-demanding sequential age-structured population analyses. ASPM estimate similar parameters to production models but make use of age-structured computations internally, rather than lumped-biomass ones, and directly estimate parameters of a stock-recruitment relationship. Their main advantage over simpler production models is that they can make use of age-specific indices of relative abundance.

BDM (Biomass Dynamic Model) refers to the original model which models biomass (based on the Logistic, Schaefer or Fox functions). They only require a time series of relative or absolute abundance and of removals to estimate two model parameters: the carrying capacity, K, and the maximum rate of population increase, r, for a stock. This can easily be implemented, for example in Excel, without the need for specific software.

BSP-SS (Bayesian state-space production model) was adapted from the Bayesian Surplus Production Model (**BSP**) to allow using multiple CPUE time series as calculated based on different fleets. BSP is a lumped biomass model, which does not require catches for separate fleets. In addition, it is possible to use available biological information about fish stocks to set up a Bayesian informative probability density function for the rate of population increase, which constrains the model to estimate parameter values that are biologically plausible. This can be useful when abundance index data are not very informative. This model has been used in tuna RFMOs because it is not as data demanding as more sophisticated models. BSP requires catch and at least one CPUE index of abundance.

Catch MSY: Abundance estimates can be difficult and costly to obtain and therefore, methods that require only a time series of removals are sometimes necessary. Without abundance estimates, Schaefer models output a range of r-K combinations which can be used to approximate MSY. This method can be applied to obtain plausible MSY estimates and other biological parameters from catch only data, based on assumptions on resilience (corresponding to the intrinsic growth rate r in the stock production model). For each plausible r-K pair, an estimate is obtained as MSY=1/4 r K. This MSY estimation algorithm has been validated against analytical fish stock assessment estimates of MSY.

Optimised Catch Only Method (OCOM): This method relies on a catch time series dataset without necessary knowledge of prior distributions (Zhou *et al.* 2013). The idea behind this approach is to use unconstrained priors on both r (maximum rate of population increases) and K (carrying capacity), that is $0 < K < \infty$ and $0 < r < \infty$. Because the two parameters are negatively correlated, the maximum K is constrained by r = 0 and maximum r is constrained by the minimum viable K. The aim of this approach

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is to identify the likely range of both r and K and the most likely r ~ K combination on the curve which retain a viable population over time (i.e. where $B_t > C_t$, $B_t \leq K$ and $B_t > 0$ always hold true). This approach produces results from a number of trials and the improbable values are then excluded, so the method is referred to as a posterior-focused catch-based method for estimating biological reference points (Zhou *et al.*, 2013). The approach uses an optimisation model to estimate the feasible r value corresponding to a fixed final depletion level and a sampled K value by minimising the difference between the final biomass and the given depletion level.

Ecological Risk Assessment (**ERA**) analysis has been used as an alternative methodology which assesses the risk associated with exploitation based on two factors: biological productivity and susceptibility to a particular type of fishery. Its application can make use of different type of data from pure qualitative to quantitative depending on the level of ERA. Level 1 (Scale, Intensity, Consequence Analysis) evaluation of the risk is mostly based on perception from interaction with stakeholders, while a semi-quantitative approach relying on sound scientific research forms the basis of level two (Productivity Susceptibility Analysis, **PSA**). Level 3 is fully quantitative (Full stock assessment and Analysis of uncertainty).

JABBA (Just Another Bayesian Biomass Assessment) is a further development of the Bayesian State-Space Surplus Production Model (BSP-SS) framework. JABBA presents a unifying, flexible framework for biomass dynamic modelling, runs quickly, and generates reproducible stock status estimates and diagnostic tools. Specific emphasis has been placed on flexibility for specifying alternative scenarios, achieving high stability and improved convergence rates.

SCAA is a statistical catch-at-age model. It is a likelihood-based assessment model for joint analyses of age-specific fishery and survey data. Age-structured population stock dynamics are modelled using standard forward-projection methods for statistical catch-at-age analyses. The population dynamics model is fit to observed fishery and survey data using an iterative maximum likelihood estimation approach.

Stock Synthesis (**SS3**) provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. It is designed to accommodate both age and size structure in the population and with multiple stock sub-areas. Selectivity can be cast as age specific only, size-specific in the observations only, or size-specific with the ability to capture the major effect of size-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. Some SS features include ageing error, growth estimation, spawner-recruitment relationship, movement between areas. SS is

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most flexible in its ability to utilize a wide diversity of age, size, and aggregate data from fisheries and surveys.

The Productivity-Susceptibility Analysis (**PSA**) is a semi-quantitative and rapid risk assessment tool that relies on the life history characteristics of a stock (i.e., productivity) and its susceptibility to the fishery in question. First used to classify differences in bycatch sustainability in the Australian prawn fishery in 2001, this assessment has a long history of use in evaluating fisheries and is recommended by several organizations and work groups as a reasonable approach for determining risk. The productivity and susceptibility of a stock is determined by providing a score ranging from 1 (low) to 3 (high) for a standardized set of attributes related to each index (productivity = 10; susceptibility = 12). When scoring these attributes, the user has the ability to also assess the data quality associated with each attribute score and customize the analysis by weighting these attributes according to the fishery. The scores for the productivity and susceptibility indices are then automatically calculated and graphically displayed on an x-y scatter plot. Stocks that receive a low productivity score and high susceptibility score are considered to be at a high risk of becoming depleted, while stocks with a high productivity score and low susceptibility score are considered to be at low risk of becoming depleted.

Stock Reduction Analysis (**SRA**) is a family of models that use a Schaefer biomass dynamic model (or other similar function) and an algorithm for identifying feasible r-k combinations to estimate biological and management quantities (r, K, MSY, BMSY, FMSY) as well as time series of biomass, fishing mortality, and stock status benchmarks (B/BMSY, F/FMSY). OCOM (above) is one such example of SRA.

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5 Southeast Atlantic (FAO major fishing area 47)

The South East Atlantic Fisheries Organisation (SEAFO) was established to ensure the long-term conservation and sustainable use of all living marine resources in the South East Atlantic Ocean (outside the national EEZs), and to safeguard the environment and marine ecosystems in which the resources occur.

According to the Convention[8], the mandate of SEAFO concerns all fishery resources including fish, molluscs, crustaceans and other sedentary species within the Convention Area, excluding sedentary species subject to the fishery jurisdiction of coastal States pursuant to article 77 paragraph 4 of the 1982 Convention; and highly migratory species listed in Annex I of the 1982 Convention. In other words, the Convention does not cover coastal resources nor does it cover highly migratory species which are under the mandate of ICCAT. Note also that the Convention area is beyond the EEZs of coastal States.

The SEAFO Convention Area (CA) is a large area with several seamount chains, isolated seamounts, guyots and banks, beyond national jurisdictions. All fishing in SEAFO occurs on or around seamounts, but fishing activity is in general at low levels. Nowadays vessels have mainly concentrated fishing operations on three distinct areas: Valdivia Bank seamounts complex, Meteor, and Discovery Seamounts.

Scientists from Contracting Parties contribute to the assessment of marine resources in the SEAFO Convention Area and provide their scientific advice to the Commission through the Scientific Committee. Information related to the main SEAFO marine living resources (Species summaries) are updated annually, and include catch and effort information as well as additional information relevant to the stocks e.g. spatial and temporal distributions of fishing, length-frequency distributions, life history parameters and other population information, and incidental mortality (sea birds, mammals and turtles) and by-catch of fish and invertebrates.

5.1 Fishing Areas and Commercial Species

The main commercial target species caught in recent years by fleets of members in the SEAFO CA are: deep sea red crab (mainly *Chaceon erytheiae*); alfonsino (*Beryx splendens*); Patagonian toothfish (*Dissostichus eleginoides*); and pelagic armourhead/southern boarfish (*Pseudopentaceros richardsoni*).

[8] www.seafo.org

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The orange roughy (*Hoplostethus atlanticus*) was the target species of an important fishery conducted between 1995 and 2005; also a recent fishery targeting the Tristan da Cunha rock lobster (*Jasus tristani*) took place until 2006 at Vema Seamount.

Fish by-catch is dominated by the blackbelly rosefish (*Helicolenus mouchezi*) in the Valdivia Bank trawl fishery; and macrourid species (*Macrourus* sp.) in the Patagonian toothfish fishery.

5.2 Stock assessment and management

Table 15 presents an overview of the assessment of key fish stocks in the SEAFO area. It is noteworthy that in various cases, fishing has literally stopped for these species and scientists are forced to use historic data in combination with empirical methods in order to provide advice for management.

Table 15: Assessment and management of the five key stocks in the SEAFO Convention Area

Species	Scientific name	Catches	Available data	Assessment method	Advice	Comment
Orange roughy	*H.atlanticus*	None in SEAFO area; 1-2 tonnes taken in the Namibian EEZ	No fisheries data since 2005	Not possible	Continue closure until 2020 and develop criteria for exploratory fishing in 2021	Closed fishery since 2008
Patagonian toothfish	*D.eleginoides*	58 t taken by Japanese longliners in 2018	Fisheries-dependent data	Y/R analysis, length cohort analysis and ASPIC (production model); inconclusive	Harvest Control Rule adopted based on slope of CPUE	Managed according to set TACs per area
Alfonsino	*B.splendens*	None in the SEAFO area	No fisheries data since 2013;	Not possible	Empirical Harvest Control Rule adopted based on last observed catches	Managed according to set TACs per area
Pelagic armourhead/ Southern boarfish	*P.richardsoni*	Negligible catches by one Namibian trawler in 2017	No fisheries data since 2000; Korean observer data on lengths available	CPUE as indicator and Gulland method to estimate MSY	Empirical Harvest Control Rule adopted based on last observed catches	Managed according to set TACs per area
Deep sea red crab	*C.erytheiae*	Carried out by Japanese and Namibian vessels; 140-170 t in 2017/2018	Fisheries-dependent data (observers)	CPUE as indicator	Harvest Control Rule adopted based on slope of CPUE	Managed according to set TACs per area

Source: SEAFO

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As noted in the above in Table 15, the five key stocks in the SEAFO area are managed by TACs which are set for specific areas/fishing grounds. These TACs are defined in Conservation Measure 32/16 on Total Allowable Catches and related conditions for Patagonian Toothfish, Deep-Sea Red Crab, Alfonsino, Orange Roughy and Pelagic Armourhead for 2017 and 2018 in the SEAFO Convention Area. Specific TACs are:

1) Patagonian toothfish: 275 tonnes for Sub-area D and zero tonnes for the remainder of the SEAFO CA;
2) Deep-sea red crab: 171 tonnes in Division B1 and 200 tonnes in the remainder of the Convention Area;
3) Alfonsino: 200 tonnes for the SEAFO CA of which a maximum of 132 tonnes may be taken in Division B1;
4) Orange roughy: zero tonnes and a 4 tonnes bycatch allowance in Division B1, and 50 tonnes in the remainder of the SEAFO CA subject to exploratory fishing protocols, and
5) Pelagic amourhead: 135 tonnes for the SEAFO CA.

Fisheries for Patagonian toothfish and deep-sea red crab continue and appear to be well managed, albeit based on poor data and considerable uncertainty.

In a broader sense, SEAFO has put in place a framework for continuous monitoring of deep-sea fisheries and strict guidelines on procedures when encountering Vulnerable Marine Ecosystems (VMEs), defined by the presence of VME indicator species. This was in response to UNGA Resolution 61/105 on the management of deep-sea fisheries.

SEAFO has defined its fishing footprint, closed 11 areas to bottom contact gears, implemented exploratory and encounter fishing protocols. Furthermore, new fishing areas (areas outside existing fishing areas) are subject to scientific assessment by the SEAFO Scientific Committee, prior to approval. Procedures and standards have also been developed for exploratory fishing in the SEAFO area.

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6 Southwest Atlantic (FAO major fishing Area 41)

FAO Statistical Area 41 covers almost 18 million km^2 off the eastern coast of South America. The high seas fisheries take place mainly in FAO sub-areas 3.1 and 3.2, beyond the EEZ of Argentina and Falkland/Malvinas conservation Zones (FICZ and FOCZ) (FarFish, 2017). The EU fleet consists mainly of Spanish vessels, with peak reported catches of 200,460 tonnes in 2014 (Eurostat). Since 2014 catches have been in decline with total EU reported catches of 132,000 tonnes in 2017 (Table 16). Spanish demersal trawlers > 40m accounted for 87% of the total landed weight reported for FAO 41 and 66% of the value, followed by Spanish pelagic trawlers 24-40m with 5% of the landed weight and 14% of the value, Spanish pelagic trawlers >40m with 2% of the landed weight and 8% of the value and UK demersal trawlers > 40m with 2% of the landed weight and 6% of the value (Scientific, Technical and Economic Committee for Fisheries (STECF), 2018).

The EU fleet is far outnumbered by fishing vessels from other nations such as Taiwan and Russia. For example, according to Ivanovic et al. (2018), an estimated 250 squid jigging vessels from different nations were operating beyond the EEZ of Argentina and south of 44° S, in international waters of FAO Area 41. There is no RFMO for the international waters of FAO Area 41. From 1990 to 2005, there was bilateral international collaboration between the UK and Argentina through the South Atlantic Fisheries Commission (SAFC), with exchange of fisheries data, joint research cruises, joint scientific analysis, and recommended coordinated conservation advice to respective governments. Although Argentina withdrew from the cooperation in 2005, renewed scientific cooperation is currently being negotiated.

Table 16: EU Catches in the SW Atlantic 2009-2017

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bulgaria	*	*	*	*	*	*	*	*	*
Estonia	*	1,609	2,127	3,206	*	*	*	*	*
Spain	82,699	91,484	90,308	11,6879	122,948	200,460	128,309	109,330	121,846
France	4,134	970	127	715	304	187	62	77	1,193*(p)*
Latvia	*	*	*	*	*	*	70	*	*
Lithuania	*	*	*	*	*	*	*	*	*
Poland	*	*	*	*	*	*	*	*	*
Portugal	4,204	5,165	5,303.7	3,325	2,238	1,877	2,440	4,460	6,171
UK	*	3,622	2,505	5,594	*	3,806	4,282	2	3,405
EU (28 countries)	**91,037**	**102,849**	**100,370**	**129,719**	**125,491**	**206,330**	**135,162**	**116,209**	**132,616 *(p)***

Source: EUROSTAT (= not available; p = provisional)*

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6.1 Defining the main species of interest

The main target species are hakes (Argentine Hake, *Merluccius hubbsi* and Australian hake, *M. australis*), cephalopods/squid (Argentine shortfin squid, *Illex argentinus* and *Loligo gahi*), Patagonian grenadier (*Macruronus magellanicus*), red cod (*Salilota australis*), southern blue whiting

(*Micromesistius australis*), kingclip (*Genypterus blacodes*), and skates (*Raja* spp). Some negligible quantities of toothfish (*Dissostichus eleginoides*) are also taken, representing less than 1% of the total catch. By-catch species include the Patagonian squid (*Loligo* spp.), flying squid (*Martialia hyadesi*), grenadier (*Macrourus whitsoni*), Antarctic cod (*Notothenia rossii*), rockcods (*Notothenia* spp.), and various elasmobranchs (FAO, 2016).

6.2 Responsibility for data collection and stock assessment

Given that there is no RFMO, data collection and stock assessment for the high-Seas fishery is a major problem. Spain, the main EU country exploiting these resources has been carrying out multidisciplinary research cruises, with the main objective of habitat mapping, identification of sensitive habitats and estimation of abundance and density of commercially important species (FarFish, 2017). The stock assessment of many of the species of the high seas fisheries is further complicated by the fact that most are straddling stocks with a wide distribution, extending into the EEZs of countries such as Argentina and Uruguay. The fisheries institutes of these coastal countries carry out research cruises, collect fisheries data and carry out stock assessment of a number of species.

6.3 Stock assessment and management

For some species such as Argentine hake (*Merluccius hubbsi*), stock assessment has been carried out for the Argentinean–Uruguayan Common Fishing Zone (AUCFZ; 34°30'–39°30'S) fishery using dynamic surplus production models for the period from 1980 to 2000 (Gutiérrez and Defeo, 2013). Results indicated a decrease in biomass of 43% over this period and a MSY of 91,430 t. According to Maguire et al. (2006, cited in Bensch et al. (2009), Argentine hake was considered overexploited or depleted, with signs of recovery in recent years. Furthermore, as noted by Gutiérrez and Defeo (2013), the Argentine hake has a wide distribution beyond the area fished by the Uruguay and Argentine fleets where it is fished by other fleets and undertakes seasonal migrations. Thus, stock adequate stock assessment requires incorporating data from other fleets and areas where the Argentine hake is fished.

For southern hake (*Merluccius australis*), which is mainly found south of 50ºS, in the SW Atlantic and SE Pacific, Giussi and Zavatteri (2016) carried out a stock assessment using a statistical catch-at-age model for the period from 1986 to 2015, concluding that spawning stock biomass in 2015 was 30% of the spawning biomass in 1986, with a strong decrease in abundance in the initial years of the fishery.

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According to Maguire et al. (2006, cited in Bensch et al. (2009), Argentine short-fin squid (*Illex argentinus*), was considered fully exploited. Chen and Chiu (2009) standardized catch per unit effort (CPUE) and reported an increasing trend in abundance from 1995 to 1999 and a subsequent sharp decline from 1999 to 2003. However, as with all short-lived species, environmentally driven recruitment variability plays a major role in the population dynamics of the short-fin squid. Wang et al. (2018) used and environmentally dependent surplus production model to evaluate the southern Patagonian stock of *I. argentinus* and estimated a MSY ranging from 351,600 to 685,100 t and a biomass of 1,322,400 to 1,803,000 t, with instantaneous fishing mortality (F) less than $F_{0.1}$ and F_{MSY}. According to Wang et al. (2018) the Argentine short-fin squid is not currently overfished.

Southern blue whiting (*Micromesistius australis*) was considered fully to overexploited (Maguire et al., 2006). These findings were supported by cohort analysis carried out for the 1987 to 1999 period by Wohler et al. (2002) who used catch data from the Argentinian and other fleets operating around the Malvinas Islands as well as data from Argentine-British surveys. Results indicated decreasing trends in biomass and recruitment and a spawning biomass of 34% of the virgin biomass. This species is also considered overexploited by FAO (2016).

By-catch species such as the Patagonian grenadier (*Macruronus magellanicus*), Patagonian squid (*Loligo* spp.) are considered fully exploited, pink cusk eel (*Genypterus blacodes*) is considered overexploited, while the status of other by-catch species such flying squid (*Martialia hyadesi*), tadpole mora (*Salilota australis*), grenadier (*Macrourus whitsoni*), Antarctic cod (*Notothenia rossii*), rockcods (*Notothenia* spp.), sharks and rays are not known (FAO, 2016).

A summary of the stock assessment and management for the main target and by-catch species fished in FAO Area 41 is provided in Table 17.

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Table 17: Summary of main species, sources of data, stock assessment and management for the main species target and by-catch species of FAO Area 41

Target species	Who carries out stock assessment	Source of data	Stock assessment methods	Management measures	Harvest control rules
Argentine Hake (*Merluccius hubbsi*),	*International Council for the Exploration of the Sea (ICES), Intituto Español de Oceanografia (IEO) (Bellido et al 2002, Wang et al 2007) *Fisheries Research Institute in Taiwan, Taiwan Universities	*Spanish fleet * Tawaian jigging	*Scientific Observers onboard (hauls observed, length distribution- catch/discard, performing biological samples) (Bellido et al, 2002) *Observers deployed onboard (total catch estimated from processed fish, fishing effort, hauls observed) (Wang et al., 2007) * Observers onboard (size categorized catch/kg, geographic position, jigging depth, bottom depth, daily catch per unit effort (CPUE) – index of population abundance, fishing efforts for each individual vessels (Method estimates the daily effort effectiveness based on a comparison of the nominal CPUE values from pairs of vessels that fished on the same day and at the same site ($0,5^0$ x $0,5^0$ grid-cell) – Methods from Chen and Chiu, 2009., geostatistical method (Chang et al, 2016)	EU vessels fishing in subarea 41.3.1 and 41.3.2 need a special fishing permit (time limited, species, zone, fishing gear and depth). EU vessels not allowed to fish in unassessed areas. Spain has adopted to a comprehensive set of measures and standards with are binding on the shipping company (vessel owner), including mandatory presence on board of an observer. (Portela, et al. 2012) Restrictions due to existing trawlir identified VMEs area not accepte fishing fleets, mainly Asian countries and South Korea)	11 areas closed for bottom trawling by EU fleet, according to UN Resolution 65/105 2006. Spain closed 9 areas for BT in 2011 due to identified VMEs. Two additional areas are closed for EU fleet due to existing ting trawling footprint. EU fleet restrictions apply for EU fleet, but not adopted by other foreign fleet or Argentina. There are some bycatch regulations from Brazilian government that apply both within EEZ and in international waters for the Brazilian fleet. (Brazil, 2011)

Target species	Who carries out stock assessment	Source of data	Stock assessment methods	Management measures	Harvest control rules
Austral hake (*Merluccius australis*),	*International Council for the Exploration of the Sea (ICES), Intituto Español de Oceanografia (IEO) (Bellido et al 2002) *INIDEP (Giussi et al, 2016)	*Spanish fleet *INDEP cruise	*Scientific Observers on board (hauls observed, length distribution- catch/discard, performing biological samples) (Bellido et al, 2002) *Abundance index was obtained directly from trawl surveys using the swept area method (Alverson and Pereyra, 1969). The stock assessment was performed using the statistical catch at age model (Giussi and Zavaretti, 2016) implemented in the AD Model Builder platform (Fournier et al., 2012). The model was tuned with annual catch data, catch at age composition and the CPUE derived using data obtained from the commercial fleet in the period 1992-2015		
Argentine shorfin squid (*Illex argentinus*),	International Council for the Exploration of the Sea (ICES), Intituto Español de Oceanografia (IEO) (Bellido et al 2002)	Spanish fleet Asian countries	*Scientific Observers on board (hauls observed, length distribution- catch/discard, performing biological samples) (Bellido et al, 2002)		
Southern blue whiting (*Micromesistius australis*).	International Council for the Exploration of the Sea (ICES), Intituto Español de Oceanografia (IEO) (Bellido et al 2002)	Spanish fleet	*Scientific Observers on board (hauls observed, length distribution- catch/discard, performing biological samples) (Bellido et al, 2002)		

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Target species	Who carries out stock assessment	Source of data	Stock assessment methods	Management measures	Harvest control rules
Bycatch species					
Patagonian grenadier (*Macruronus magellanicus*) ,	International Council for the Exploration of the Sea (ICES), Intituto Español de Oceanografia (IEO) (Bellido et al 2002)	Spanish fleet Falkland Islands Fisheries	*Scientific Observers on board (hauls observed, length distribution- catch/discard, performing biological samples) (Bellido et al, 2002)		
Patagonian toothfish (*Dissostichus eleginoides*),	International Council for the Exploration of the Sea (ICES), Intituto Español de Oceanografia (IEO) (Bellido et al 2002)	Spanish fleet	*Scientific Observers on board (hauls observed, length distribution- catch/discard, performing biological samples) (Bellido et al, 2002)		
Longtail southern cod (*Patagonotot hen ramsayi*),	International Council for the Exploration of the Sea (ICES), Intituto Español de Oceanografia (IEO) (Bellido et al 2002)	Spanish fleet	*Scientific Observers on board (hauls observed, length distribution- catch/discard, performing biological samples) (Bellido et al, 2002)		

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7 Conclusions

This review of stock assessment carried out in each of the CS has shown that there is a wide range of methods and models used, ranging from simple surplus production models to state-of-the-art catch-at-age methods. The application of different models is limited by the data available and for many of the non-target or by-catch commercial species there is no stock assessment. However, the recent development of data-limited methods for stock assessment of data-limited or data-poor species has opened up new possibilities for stock assessment of species and stocks that up to now have not been assessed. In this context, DLM tools developed in FarFish provide a wide range of methods that can be used for data-limited species, as shown by examples for by-catch species from the Seychelles and Cabo Verde CS.

Reviews of available data for application of the DLM tools have shown that there are a number of sources of suitable data that could be used. Of particular interest are national and international research survey data that can provide time series of catch and effort and length frequency distributions for species that have to date not been assessed. Data collected by scientific observers on board EU vessels can also be a valid source for assessment by DLM.

However, it should be understood that the actual assessment of all the data-limited species or stocks in the different CSs was never an objective of FarFish. The role of FarFish is to provide the tools for assessment of data-limited species and identify sources of data that could be used to assess data-limited species that are currently not assessed e.g. in the multispecies demersal trawl fisheries of Senegal and Mauritania, the by-catch species of the pelagic fisheries of the Seychelles and Cabo Verde, and the high seas fisheries of the SW and SE Atlantic. FarFish provides examples of data sets for the DLM that are used to illustrate the approaches that are available. It is up to the CS partners to apply the DLM tools to their species and stocks using data that they have, namely national and international research cruise surveys that only they have access to.

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