

## REPORT OF THE 2016 MEDITERRANEAN SWORDFISH STOCK ASSESSMENT MEETING

(Casablanca, Morocco, 11-16 July 2016)

### 1. Opening, adoption of agenda and meeting arrangements

The Meeting was held at the *Institut National de Recherche Halieutique* (INRH) in Casablanca from 11-16 July 2016. Mr. Jilali Bensbai (INRH) opened the meeting welcoming the participants (“the Group”). Dr. Laurence Kell, on behalf of the ICCAT Executive Secretary, thanked the INRH for hosting the meeting and highlighted the importance of the work to be developed by the Group during the meeting, aiming the provision of management advice to the Commission. Dr. Georges Tserpes, meeting Chairperson, proceeded to review the Agenda, which was adopted with a slight modification for the inclusion of the review and update of the species Executive Summary and work plan for 2017 under item 5 (Other matters) (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The List of Documents and Presentations presented at the meeting is attached as **Appendix 3**. The following participants served as rapporteurs:

<i>Section</i>	<i>Rapporteur</i>
Item 1	M. Neves dos Santos
Item 2	S. Saber, D. Macias, J. Ortiz de Urbina
Item 3	L. Kell, G. Tserpes
Item 4	R. Coelho, G. Tserpes, D. Die, M. Neves dos Santos
Item 5	G. Tserpes, R. Coelho, M. Neves dos Santos
Item 6	M. Neves dos Santos

### 2. Summary of available data for assessment

#### 2.1 Biology

During the meeting three documents were presented exploring questions related to the biology of the species.

Document SCRS/2016/112 presented length-weight relationships for the Mediterranean swordfish based on a large time series of data from several fisheries operating in different areas of the Mediterranean Sea. Differences among areas were found to be statistically significant, which should be considered when adopting Mediterranean-wide equations. However, results were considered to be preliminary due to the fact that not all available data were used and the structure of certain data sets was not properly clarified. The Group suggested the accomplishment of the study, and for the purposes of the current assessment, agreed on employing the length weight relationship (Mejuto and De la Serna, 1993) used in the previous Mediterranean swordfish stock assessment session.

Document SCRS/2016/117 presented a length-weight relationship for the Mediterranean swordfish caught by the Algerian longline fishery in 2015 and 2016. The Group recognized that although it is a small sample with a narrow length distribution range, it represents a highly valuable source of information and should be included in the on-going length-weight revision mentioned in SCRS/2016/112.

Document SCRS/2016/114 presented the results of stomach contents of juvenile swordfish from the middle Aegean Sea of Turkey. Prey categories by order of importance were teleosts, cephalopods and crustaceans. Anchovy had the highest frequency of occurrence, percentage abundance and index of relative importance (IRI) whereas; sardine had the highest percentage by weight. The secondary food preference group was cephalopoda, especially *Loligo vulgaris*. This squid species was the third option in terms of IRI. Crustaceans showed low values for all the feeding indices examined in the analysis. Additionally, *Cepola macrophthalmia* and *Sardinella aurita* are reported for the first time from the content of swordfish stomach in the Aegean Sea. Other studies on feeding habits of swordfish in the Mediterranean Sea reported that cephalopoda species is the main prey and teleost the second one. This difference in food preference can be due to some specimens from the present study caught by purse seine targeting anchovy and sardine.

The Group has noted that research results have demonstrated the possible occurrence of a high mixing rate between the Mediterranean and North Atlantic stocks west of the 05°W boundary separating the two stocks. It is very likely that part of the fish caught in this area belong to the Mediterranean stock but further studies are needed to identify the degree of mixing among stocks.

As no new information was presented for other biological parameters, the Group adopted the same values that were used in the 2010 and 2014 stock assessments (see list below) (Anon. 2011 and 2015).

<i>Parameter</i>	<i>Mean</i>	<i>CV</i>	<i>Distribution</i>	<i>Description</i>	<i>Source</i>
M	0.206	0.25	lognormal	Natural mortality (1/year)	McAllister (2014)
L <sub>inf</sub>	238.58	0.1	lognormal	Von Bertalanffy asymptotic length	Mean: ICCAT Manual CV: Working Group
K	0.185	0.1	normal	Von Bertalanffy growth parameter	Mean: ICCAT Manual CV: Working Group
t <sub>0</sub>	-1.404	0.2	normal	Von Bertalanffy age at zero length	Mean: ICCAT Manual CV: Working Group
a	8.90E-07	0.1	lognormal	Weight at length parameter	Mean: ICCAT Manual CV: McAllister (2014)
b	3.554738	0.1	normal	Weight at length parameter	Mean: ICCAT Manual CV: McAllister (2014)
L <sub>50</sub>	142	0.2	lognormal	Length at 50% maturity	Mean: ICCAT Manual CV: McAllister (2014)
d	0.2	0.2	lognormal	Parameter of the logistic maturity ogive	Working Group
h	0.83	0.14	beta	Steepness $h=0.2 + 0.8 \text{ Beta}$ (5.86. 1.59)	McAllister (2014)

## 2.2 Catch, effort, and size

### 2.2.1 Description and evolution of the Mediterranean swordfish fisheries

Mediterranean swordfish fisheries are characterized by high catch levels. It should be noted that annual reported catches (on average about 13,802 t from 1988 to 2015) are similar to those of the North Atlantic, though the Mediterranean has a much smaller body of water. However, the potential reproductive area in the Mediterranean is probably relatively larger than that in the Atlantic. Furthermore, it has been suggested that the biological and oceanographic conditions prevailing in the Mediterranean favor the high productivity of large pelagic fish.

Swordfish fishing has been carried out in the Mediterranean since the Roman times. Currently, with a high demand for swordfish for fresh consumption, swordfish fishing is carried out all over the Mediterranean Sea. The biggest producers in the recent years (2003-2015) are EU-Italy (45%), EU-Spain (13%), Greece (10%), Morocco (14%), and Tunisia (7%). Also, Algeria, Cyprus, Malta, and Turkey have fisheries targeting swordfish in the Mediterranean. Incidental catches of swordfish have also been reported by Albania, EU-Croatia, EU-France, EU-Portugal, Japan, Libya and Syria.

Mediterranean total swordfish landings showed an upward trend from 1965-1972, stabilized between 1973 and 1977, and then resumed an upward trend reaching a peak in 1988 (20,365 t). The sharp increase between 1983 and 1988 may be partially attributed to improvement in the national systems for collecting catch statistics. Since 1988 and up to 2011, the reported landings of swordfish in the Mediterranean Sea have declined fluctuating mostly between 12,000 to 16,000 t. In the last four years, following the implementation of the three-month fishery closure and the requirement for vessel authorization, overall fishing effort has been decreased and catches are around 10,000 t. Based on the available information during the assessment, the catches in 2015 amounted to 9,966 t catches were 9,966 t (**Table 1**).

In the period 2003-2011, the main fishing gears used were longlines and gillnets. Since 2012 the main gear employed by the swordfish targeting fisheries is longline. **Figure 1** presents the evolution of the catches according to the fishing gear. Swordfish is also caught with harpoons and traps, and also as by-catch in other fisheries (longlines targeting albacore, purse seines, etc.).

There have been several important management initiatives by ICCAT in recent years, and a summary of these measures is provided here. ICCAT first signaled its intention to protect juvenile Mediterranean swordfish in 2003, when it stated that “In order to protect small swordfish, Contracting Parties, Cooperating non-Contracting Parties, Entities or Fishing Entities shall take the necessary measures to reduce the mortality of juvenile swordfish in the entire Mediterranean” [Rec. 03-04]. The Recommendation was made more explicit in Rec. 07-01, where a one month closure was established: “Fishing for Mediterranean swordfish shall be prohibited in the Mediterranean Sea during the period from 15 October to 15 November 2008. Rec. [08-03] extended the closure period from 1 October to 30 November. The period of closure was extended in Rec. [11-03], which stated “Mediterranean swordfish shall not be caught (either as a targeted fishery or as by-catch), retained onboard, transhipped or landed during the period from 1 October to 30 November and during an additional period of one month between 15 February and 31 March.” Most recently, Rec. [13-04] reaffirmed this closure period. It has been reported, however, that other large pelagic fisheries, such as those of albacore, are capturing large numbers of small swordfish, particularly during the autumn and winter months (Tserpes *et al.*, 2014).

Concerning minimum sizes, Rec. [11-03] and Rec. [13-04] established a minimum size that prohibited the retaining on board, transhipping, landing, transporting, storing, selling, displaying or offering for sale Mediterranean swordfish measuring less than 90 cm LJFL or, in alternative, weighing less than 10 kg of round weight or 9 kg of gilled-gutted weight, or 7.5 kg of dressed weight. However, the CPCs may grant tolerances to vessels that have incidentally captured small fish below the minimum size, with the condition that this incidental catch shall not exceed 5% by weight or/and number of pieces per landing of the total swordfish catch of said vessels.

A ban on the use of driftnets within the Mediterranean was established in 2003 [Rec. 03-04], but full compliance with the regulation occurred several years later. Rec. 09-04 established a list of fishing vessels allowed to fish for Mediterranean swordfish. Most recently, there have also been restrictions on the number of hooks carried by individual longliners, hook size and longline length. These restrictions were established for 2012 [Rec. 11-03] and remain in force since 2013 [Rec. 13-04].

### 2.2.2 National fishery descriptions from Working Group participants

Scientists participating in the Working Group provided a summary of the recent fishery developments, including domestic management measures (which are in addition to the ICCAT measures described above). Catches associated with these countries represent about 89% of the 2015 provisional total Mediterranean swordfish catch.

#### *EU-Greece*

The Greek swordfish fleets operate throughout the eastern Mediterranean basin exclusively using drifting surface longlines. The swordfish fishing season follows the established temporal closures by ICCAT and a special license is required for a commercial fishing boat to be allowed to fish for swordfish.

In 2015, about 200 vessels were licensed to fish swordfish, but not all of them were regularly involved in the swordfish fishery. Most of them entered the fishery occasionally. A reduction of the effort has been observed in 2015, mainly due to the low prices of the swordfish and the high costs of the longline swordfish operation (expensive bait, gear losses, light-sticks). Many of the licensed boats have changed fishing gear during the swordfish fishing season, targeting other species. A large number of these boats was involved in the albacore fishery, during the summer months of 2015. The albacore fishery during the summer, is a quite new activity for the Greek fishing fleets and has started about three-four years ago in the area of Crete by a small number of boats, which followed the Italian large pelagic fishing vessels targeting albacore in the Libyan and Cretan Seas and landing their catches in the Cretan ports. In 2015, a large part of the Greek swordfish fishing fleet has been involved in the albacore fishery during the summer months, from June to August, in various areas of the S. Aegean, depending on the availability of the resource.

Consequently, a reduction of the swordfish production has been recorded. Swordfish production during the 2015 fishing season was estimated to be up to 691 t, which is the lowest of the last twenty years. The CPUE rates were also among the lower ones observed in the last decade.

#### *EU-Italy*

Italy has a long historical tradition in the swordfish fishery which is currently reflected by the development of several fishing strategies and gears in more recent times. As a matter of fact, Italy has an important fleet of longliners which provides the bulk of the catches, while minor catches are obtained by the few harpoon vessels still active in the Strait of Messina, the tuna traps, the purse seines and sport fishery. The structure of the Italian

fleet has undergone major changes after the total UN driftnet moratoria to driftnet longer than 2.5km which entered into force in 1992. Italy had the most numerous driftnet fleet in the Mediterranean and it was not easy to apply and enforce the new regulation, due to a strong tradition. The gradual process of fleet dismantling has led to a gradual reduction of fishing units in the period from 1992 to 2002, when, an EU ban to the use of driftnet to catch highly migratory species entered into force

Italy has transposed the ICCAT management measures described earlier, with the DM 03 June 2015 and DD of 29 February 2016, establishing measures for the professional longline swordfish fishery including a new list of the authorized vessels, which substantially reduced the number of the licensed boats compared to what was previously reported in the ICCAT database. Also, the recently adopted regulation is more restrictive than recommendations in place in ICCAT. Indeed, vessels are authorised to keep onboard only 2800 hooks maximum also in case of trips longer than two days.

The longline fleet is widespread all over the various seas around Italy, with a higher concentration in the southern Italian regions (over 65% of the fleet). Most of the vessels are small-medium longliners. According to the DD of 29 February 2016 the Italian fleet licensed for the professional swordfish fishery is now made up of 849 boats, mostly small-medium sized units, (45% less than 12 meters LOA and 10 GT, 78% less than 15m LOA), with an average length of 12.5m and 15.6 GT., distributed in a great number of harbours, usually exploiting local fishing grounds. Some of the smaller boats in the list have licenses for different gears (longline, trammel net, bottom gillnet, etc.) and show a strictly seasonal activity, switching from one gear to the other according to the seasons and fishing opportunities. Vessels medium-large in size usually carry out a more focused activity, alternatively targeting swordfish and albacore or bluefin tuna and covering various areas in the Mediterranean Sea. The fishing grounds show moderate yearly variability, depending mostly on oceanographic factors. Some fleets are active all the year round, while the majority of the vessels are active from spring until early autumn.

The longline fishery has changed considerably in the last five years. From 2009-2010, the mesopelagic longline has been gradually introduced in almost all Italian swordfish fleets, which has led to an increase in catches of individuals of larger size and decreases in the catches of juveniles, at least in the first years (see SCRS/2016/120). This new approach is now incorporated in the majority of the Italian longliners that use alternatively surface and meso-pelagic according to the season. The majority of vessels use both gears depending on the sea condition, season and fishing opportunity. The mesopelagic longline gear is set deeper and for longer periods of time compared to the traditional approach for the Italian fisheries and is mainly operated during the summer months due to better weather conditions. Surface longline is easier to manage and faster in the fishing activity (smaller size and shorter soaking time); it can be used by smaller boats and much closer to the coast (fishing in the surface layers) and produces its main effort only during night hours. This is particularly noteworthy, as these changes in fishing patterns can have implications in the use of catch rates as indices of abundance in the stock assessment.

SCRS/2016/120 presented nominal indices of relative abundance for swordfish caught by the Ligurian longline fishery updated with 2014 and 2015 data. The trend in CPUE for the mesopelagic longline indicates that relative abundance for 2014 has strongly increased from 2013 levels, but dropped during the following season 2015. Average sizes of fish, after the drop of the previous years, remain quite constant. During the winter months fishing is active using the American Type longline: a comparison of the two gears in terms of catches, CPUEs and size frequency distributions is reported.

#### *EU-Spain*

The Spanish longline fleet targeting swordfish in the western Mediterranean operates using several gears which cover a wide range of depths. From the beginning of the fishery until year 2000, the fleet operated by using only a surface gear: the traditional or home based longline (LLHB). About 2000, part of the fleet began to use a weighed gear (*pedras*) and floats (*bolas*), having access to deeper waters, close to the sea bottom. The gear was termed *piedra-bola* or bottom longline (LLPB). After 2002, the fleet began to use the American longline (LLAM): a surface gear that introduced some new elements such as the spool, a thicker main-line, and larger distance between hooks. Finally, in 2007 a semi-pelagic longline (LLSP) began to be used.

LLSP operates in mesopelagic waters, fishing in a zone of the water column different than the previous ones. All these new elements have been implemented by the fleet probably due to improvements in profitability (increasing yield or diminishing the cost of the activity).

Some of the factors that could explain the above referred changes in fishing practices would be the reduction of the by-catch of vulnerable species, reduction of immature swordfish in the catch, as well as the increase in yield. The implementation of management measures by the Spanish legislation, such as seasonal closure in months with high yields (October-November) and the imposition of a minimum legal size (90 cm LJFL), probably has also played an important role.

The surface longline fishery has remained quite stable regarding total fishing effort. As regards effort distribution between gears, it is highly variable from year to year. Currently the main gears used by the fishery are LLSP (in summer months), and LLHB (in winter months). In addition, swordfish is also caught seasonally, in small quantities, as a by-catch species on the longline fisheries targeting bluefin tuna and albacore.

#### *Morocco*

The Moroccan swordfish fishery in the Mediterranean Sea has been in operation since 1983. With the introduction of the driftnet in the area in the early 90s, the fishery has had an important expansion during the 1990s. Since 2008, the Mediterranean catches have been significantly reduced due to the implementation of the national plan for banning the driftnet, following the ICCAT recommendation (Rec. 03-04).

After the total ban of driftnet use in Moroccan waters since 2012, swordfish is mainly targeted by longliners in the Mediterranean, particularly in the Strait of Gibraltar. The fishing season occurs mainly in August-September and from December to January, with a peak in December. Minor catches of this species are also taken occasionally by traps and purse seines.

After the peak landings of 4,900 tons recorded in 1997, the swordfish catches have shown a steady decline since 2005 and were only 480 tons in 2015. The average catch during the period 2012-2015, was about 705 tons, which represented a decrease of about 49% with respect to the period 2009-2011. This important reduction in the total catches is due to the complete ban of driftnet since 2012. Over the last decade, the average size of the landed fish has slightly increased, reaching 150 cm in 2013-2015.

In addition to the ICCAT management measures already described, Morocco has established a freeze on fishing effort through the suspension of the investments for vessel construction since 1992 (Circular note No. 3887 of 18 August 1992). Morocco also implemented a minimum size of 125 cm up to and including 2011, but the new ICCAT minimum size (Rec. 11-03) has been implemented for 2012 and later.

#### *Tunisia*

Swordfish is of high economic importance for Tunisia. National production is around 1000 t (average 2003-2012). The main fishing season is the summer (July-August). Surface longline is the most commonly used gear type with sardinella as bait. Fish are landed in round weight. There are 466 vessels allowed to catch swordfish (year 2013). This fleet is attached to 20 landing ports. The main port is in the north. However, the eastern region has the main part of the fleet (62%). Vessels range in length between 5 to 20 m, (GRT) tonnage range 1.7 and 49 t and engine power (HP) from 30 to 500 CV.

#### *Turkey*

The Turkish swordfish fishery in the Mediterranean dates back to the early 17th Century. The fishery in Turkey has been carried out in the Aegean Sea and eastern Mediterranean Sea. While harpoon gear has been used in the northern Aegean Sea, longlines have been used in the Aegean Sea and the eastern Mediterranean Sea. However, some swordfish are also caught incidentally by purse seines as by-catch. About 61 vessels were involved in the swordfish fishery and most of them are smaller than 20 m LOA. This fishery is carried out 6-7 months per year due to the closed seasons and meteorological conditions.

Regarding potential of Mediterranean swordfish fishery in the eastern Mediterranean in the context of far-reaching driftnet banning by GFCM/ICCAT, driftnet has been recognized to be used conventionally in the past as the foremost effective fishing gear in Turkey. However, Turkey has prohibited utilization of all types of driftnet as from 2011, to comply with the relevant GFCM/ICCAT decisions.

Since then, total catch of Mediterranean swordfish in Turkish waters, as well as in the high-seas of the Mediterranean, has decreased substantially over the years since 2011 (i.e., from 330 metric tons in 2010 down to 96 metric tons in 2014) due to inefficiency and limited catch capacity of some other alternative gears that have been tried by the coastal fishers.

In this regard, the large scale driftnet banning has evidently registered quite a negative impact especially on the small-scale coastal fishermen owing to the lingering social and economic value of this type of fishery over the livelihoods of many small-scale fishers in Turkey. At present, no efficient alternative fishing gear to compensate the effectiveness of the eliminated drift-nets could be adopted by the Turkish fishermen with respect to the Mediterranean swordfish fisheries.

#### *Summary of national fisheries*

It is clear from the fishery descriptions presented here that the Mediterranean swordfish fishery supports a number of important national fisheries with significant numbers of active vessels.

#### *2.2.3 Task I catches*

The complete Mediterranean swordfish summary table is presented in **Table 1**. The Group noted that the available catch data appeared to be generally complete. In 2015, the provisional total yield for the stock was 9,966 t, an increase of about 2% compared to 2014 (9,794 t).

**Figure 1** shows the T1NC catches by year and major gear. In the previous stock assessment, it was noted that the Mediterranean swordfish stock is among the stock with largest T1NC catches with “unclassified” gear. While such catches are not a major component of the contemporary years, there remain ranges of years where significant catches are designated as gear “unclassified”. Efforts should be made by the national scientists of the relevant CPCs to discriminate T1NC catches by gear for the time periods in question. **Figure 1** also illustrates the increase in importance of the longline gear component.

#### *2.2.4 Task II (catch-effort and size samples)*

The detailed catalog of T2CE is presented in **Table 2**. Although there are some significant gaps regarding size data (for example, EU-Italy in 2013), the Group noted a general improvement in data availability for the most recent years.

### **2.3 Relative abundance estimates (CPUEs)**

Four documents including information on the temporal evolution of the abundance indices of different Mediterranean swordfish fisheries were presented to the Working Group.

Document SCRS/2016/096 reported standardized catch rates for the Spanish longline fishery in the western Mediterranean, for the period 1988-2015. Swordfish catch rates expressed in terms of number of fish were analyzed by means of a General Linear Modelling approach assuming a negative binomial error distribution. The standardized index showed notable annual fluctuations without any definite trend for the period under study.

Document SCRS/2016/113 reported annual standardized catch rates from the Greek drifting surface longline fisheries targeting swordfish in the eastern Mediterranean for the period 1987-2015. Annual standardized indices were estimated by means of Generalized Linear Modelling techniques, and the explanatory factors included 'Year', 'Month', 'Gear type' and 'Area of fishing'. Catchability changes that took place in the fisheries were also taken into account. As regards to the trend, the standardized annual index from year 2000 onwards was generally lower than that estimated for the years preceding 2000.

Document SCRS/2016/119 showed standardized catch rates from the Moroccan fleet targeting swordfish in the Strait of Gibraltar for the period 1999-2015. Catch rates were analyzed using General Linear Modelling techniques, under lognormal error assumption. The relative abundance index showed a relative stable trend over the period 1999-2011, following an increase in year 2012, and remaining stable thereafter. The Group discussed the fact that the reported standardized index included information on two dissimilar fisheries: driftnet fishing for the period 1999-2011, and longline for the period 2012-2015. Given the disparate nature of the gears involved, it was recommended to estimate a single standardized index for each fishing gear. This document was finally revised taking into account the aforementioned comment.

Document SCRS/2016/120 presented the available longline CPUE time series for several fisheries in the Ligurian Sea for the period 1990-2015. Nominal catch rates for swordfish caught by the Ligurian longline fishery were updated for the years 2014 and 2015. The trend in nominal CPUE for the mesopelagic longline indicated a high increase in relative abundance for 2014 as compared to 2013, following a decline for year 2015.

It remains as a matter of concern the depletion of the fraction of the population made by spawners (fish larger than 140cm). The American Type longline (LLAM) which was introduced in 2011, is actively used in winter months. A comparison of the two gears in terms of catches, CPUEs and size frequency distributions is reported. Harvest rates of the young-of-the-year (YOYs) are higher in the winter months.

Given the availability of data in the last five years, three standardized CPUE indices were used in the assessment; those referring to the Greek, Spanish and Moroccan longlines. When scaled to the mean of each index and compared, the ensemble of indices did not show a clear trend of change in biomass (**Figure 2**).

### 3. Stock assessment

The stock was assessed using an age structured population model (XSA) as used in the previous assessment. In the previous assessment although biomass dynamic models had also been used the age structured model (XSA) was chosen to develop the stock status advice and to develop projections. This was because the lack of contrast in the relative abundance indices make production model results rather uncertain because stock productivity (estimates of  $r$  and  $K$ ) is poorly defined by the data. Particularly due to the lack of relative abundance indices for the period when the stock is expected to have declined in abundance (1975-1985), as catch increased.

#### 3.1 Methods

##### 3.1.1 XSA

The age structured assessment was conducted using XSA in R using the FLXSA package (part of the FLR-project, Kell *et al.*, 2007; <http://www.flr-project.org/>). The catch at age (CAA) data were generated using a statistical mixture distribution analysis that was shown during the previous assessment to provide statistically more robust results than deterministic age slicing. The estimates of CVs also showed that there was little information in the length distributions to justify splitting CAS into ages greater than 6. Therefore, in line with the Atlantic swordfish assessments XSA runs were conducted with a plus group of 6, (see Kell 2015 for full documentation of methodology used).

Biological parameters used for maturity and natural mortality-at-age were the same as in the last assessment, i.e. fish first mature at age 3 (when 50% are mature) and are fully mature at older ages; natural mortality was assumed equal to 0.2. Weights-at-age were derived from the mixture analysis and were consistent with the CAA.

Seven CPUE data sets were available for tuning the XSA: i.e. Moroccan longlines and gillnetters (SCRS/2016/119), Spanish longliners (SCRS/2016/096), Sicilian longliners (Tserpes *et al.* 2015), Sicilian gillnetters (Tserpes *et al.*, 2011), Greek longliners (SCRS/2016/113) and Ligurian longliners (SCRS/2016/120). The standardized CPUE indices were not differentiated by age. These indices in the XSA were considered to be representative of the 2-4 age-group abundances (the plus group is not used for calibration within XSA) as assumed in the last assessment. Fleet catchability was assumed to be independent of year-class size for all terminal years and ages. Only the Greek, Moroccan and Spanish longline series covered the recent period (i.e. allowed the terminal Ns in the recent years to be estimated), so these indices were the ones used for calibration of XSA.

XSA estimates the survivors (i.e. terminal Ns by age and year) for each observed value of CPUE. This is done by calibration regression to predict population numbers-at-age by year for each series and then projecting along the cohort to the oldest age or most recent year. In addition shrinkage to the mean is performed, where the terminal Ns also including a term related to recent  $F_s$  or  $F_s$  at younger ages (shrinkage to the mean  $F$ ) and numbers-at-age for recruiting age classes are estimated from the geometric mean of recent recruitments (shrinkage to the mean  $n$ ). Time series weights can be applied to discount past values.

The catch-at-size (CAS) data are shown in **Figure 3**, the 2016 dataset (blue) is overlaid on the 2014 data set (pink), differences are only seen for 2012 and 2013. The differences are small. The catch-at-size are summarized by *lustrum* in **Figure 4**.

The CAS are used to construct Powell Weatherall plots (**Figure 5**) and to estimate  $Z$  (**Figure 6**), the black points are estimates for each 5 year period and blue line is a loess smoother fitted through these.

The estimation of the catch-at-age (CAA) are shown in **Figure 7**, which shows the CAS (green), the modes by age (red) and the fitted distribution (black). **Figure 8** plots the standardised residuals of the proportion of numbers-at-age from the deterministic age slicing procedure (red negative and black positive residuals), in order to look for evidence of cohort effects.

Next age based catch curves are plotted to examine differences in selection pattern. Selection pattern is determined by the vulnerability of different age classes to fishing, and is affected by availability (horizontal overlap), encounterability (vertical overlap), fishing behavior and the dynamics of the targeted stock. **Figure 9** shows estimates of selectivity by *lustrum*, **Figure 10** estimates by gear and **Figure 11** by gear and *lustrum*.

Three XSA runs were conducted, i.e. that based on the 2014 settings and two alternative scenarios: i) the continuity run; ii) Lorenzen natural mortality vector; and, iii) estimation of discards.

Lorenzen (1996) developed a set of empirical relationships for natural mortality as a function of body weight (W). The general relationship natural mortality and weight (g) is of the form

$$M(W)=M_u W^b$$

Where,  $M_u$  is the natural mortality at unit weight and b is an allometric scaling exponent. Lorenzen's estimates of b for temperate systems was  $b=-0.309$ , while  $M_u$  was derived so that M at age 3 (where fish are mature for the 1st time) was equal to 0.2 (**Figure 12**).

In the continuity run the XSA settings were the same as applied in 2014 (**Table 3**). While for the discards scenario the catch-at-age matrix was inflated by assuming that for every ton of catch, four 0-age fish were discarded (Tserpes *et al.*, 2014; **Figure 13**).

### 3.1.2 Production model

A biomass dynamic model was used to reconstruct the biomass time series back to 1950. This was done because prior to 1985 no catch-at-size and hence catch-at-age were available to fit XSA. The estimates of  $r$  and  $K$  from XSA were used with the catch data (i.e. Task I) to estimate stock biomass.

## 3.2 Diagnostics

### 3.2.1 XSA

The CPUE series used in the calibration of XSA are shown in **Figure 14**; and the goodness fits based on the CPUE residuals are shown next. **Figure 15** plots the residuals against fitted values to check the variance, **Figure 16** plots the residuals against year to check for systematic patterns that may indicate a poor fit; **Figures 17 to 19** compares the fits to the observations for ages 2, 3 and 4, respectively; a good fit is indicated by the points falling along the  $y=x$  line (black line); the blue line is a linear regression fitted to the points. **Figure 20** checks for autocorrelation that may introduce bias and **Figure 21** are QQ plots to check for log normality. **Figure 22** show the relative weighting for each terminal year  $N_s$  by CPUE observation (columns are ages) and shrinkage.

**Table 4** shows the spawning stock biomass by each of the XSA scenarios.

**Figure 23** shows the fits to 1 index at a time. Retrospective analyses are performed in **Figures 24** for the 3 time series used in 2016 and in **Figure 25** for the 6 time series used in 2014. The stock numbers at age, fishing mortality and full diagnostics for the XSA are available in **Appendix 4**.

### 3.2.2 Production model

The fact that available data are not useful to fit a production model does not necessarily mean that the dynamics of this stock could not be explained by such model. It is possible that the relative abundance indices that are currently available do not track abundance well. Alternatively, these indices may represent a period of time when changes in stock size are relatively small and therefore there is not enough contrast in the data to estimate productivity and model parameters.

Similar conclusions, regarding production models, were reached in the past for other stocks and it has often been necessary to assume that stock productivity parameters ( $r$ ,  $F_{MSY}$ ) were known from other studies so as to fit the production model. Bayesian production models do this formally by defining a prior distribution for the value of  $r$  and other model parameters. During the 2014 Mediterranean Swordfish Stock Assessment meeting stock a prior distribution for  $r$  with mean of 0.47 and CV of 0.49 were obtained by simulation on the basis of combining estimates of von Bertalanffy growth, weight/length relationship, logistic maturity ogive, natural mortality and steepness parameters (Anon., 2015).

There have been a number of studies of swordfish stocks reporting estimates of  $F_{MSY}$  and  $r$  from production models (table below). All these studies report relatively high values of  $r$ , between 0.4 and 0.6 suggesting values of  $F_{MSY}$  range between 0.2 and 0.3 for logistic production models where  $r$  is twice  $F_{MSY}$ .

<i>Stock</i>	<i>Assessment</i>	<i>Model</i>	<i>Estimate</i>	<i>80% percentile/ (CV of posterior)</i>	<i>Reference</i>
SWO Med.	2010	ASPIC	0.52	0.36-0.68	Anon. 2011
N Atl. SWO	2013	ASPIC	0.42	0.34-0.51	Anon. 2014
S Atl. SWO	2013	ASPIC	0.49	0.21-0.77	Anon. 2014
SWO Med.	2014	Bayes Prod model	0.59	0.30	Anon. 2015

Moreover the current assessment with XSA implies a value of  $r = 0.45$ , similar again to the values obtained from production models.

Assuming these values of  $r$  truly represent the dynamics of the Mediterranean swordfish stock it is possible to use production models to reconstruct the biomass of the stock and the fishing mortality it has suffered. The only additional assumption required is that the reported catches are a precise measure of removals. For a given value of  $K$ , the virgin biomass, the logistic production model would predict yearly biomass and fishing mortality under the condition that  $r = 4 MSY/K$ . In other words for a given value of  $K$  and  $r$ ,

$$MSY = r * K / 4$$

We used ASPIC to implement these calculations and calculate values of  $B$  and  $F$  from 1950 to 2015 given the catch and values of  $r$  in the range between 0.2, 0.6 and values of  $K$  from 60,000 to 300,000 representing a range that largely encompasses estimates of  $r$  and  $K$  obtained in previous attempts to evaluate this stock with production models. We assume that the “best” estimate of  $r$  for this stock is 0.45.

Of course not all combinations of parameters can reproduce observed catches, but there are a number of them that do. Many such combinations lead to the biomass crashing and the stock not being able to sustain itself. The smallest stock with an  $r$  value of 0.45 that would be able to sustain itself until 2015 would have a  $K = 120,000$  and an  $MSY$  of 13,500. Larger stocks and less productive stocks ( $r < 0.45$ ) would also have been sustainable but would not have led to the current state of overfishing/overfished predicted by XSA. Conversely smaller and more productive stocks ( $r > 0.45$ ) could also be sustainable but would led to a more pessimistic view of the stock status. The relative decline in biomass as a ratio of  $B_{MSY}$  can change depending on the value of  $r$  and  $K$  (**Figure 26**).

When estimates of biomass from such production models are overlayed with the nominal CPUE of Demetrio *et al.* (1999) they seem to have a similar trend suggesting that the catch rates from Demetrio *et al.* (1999) are consistent with the changes in biomass for the 1970s-1980s predicted by production models (**Figure 27**).

In conclusion, these production models may not be useful to estimate current stock status, because the most recent relative abundance indices are not consistent with the biomass trends that they predict. These models, however, seem to provide an explanation for why the biomass of the stock declined during the 1980s. These results are not inconsistent with the estimates of stock biomass obtained in the XSA model. XSA estimates that by the mid to late 1980s  $SSB$  was already well below  $SSB_{MSY}$ . Production models, on the other hand, predict that total biomass started to fall below  $B_{MSY}$  in the late 1980s or early 1990s. It is to be expected that total biomass in a production model will decline at a lower rate than  $SSB$ , and thus than the production model’s calculations of when the stock become overfished would lag the estimates from XSA.

### 3.3 Stock Status relative to benchmarks

#### 3.3.1 XSA

Estimates of recruitment, SSB, catch and fishing mortality for the three scenarios are shown in **Figure 28**. Stock number and F-at-age estimates by year are provided in **Appendix 4**. The main effect is to increase the estimated recruitment by a constant factor, the other time series are little changed. A bigger effect is seen in the equilibrium curves (**Figure 29**) and reference points (**Table 5**) where biomass reference points are increased and F reference points decreased for the Lorenzen M scenario. **Figure 28** presents an equilibrium analysis with reference points and **Figure 30** presents the same curves with the observations and fits. The net result is that for the Lorenzen M scenario the level of overfishing and over fished is increased as seen in the Kobe Phase Plots (**Figure 31**).

#### 3.3.2 Synthesis of the stock status

The current assessment of Mediterranean swordfish confirms that the stock is overfished and suffering overfishing. The stock has been on this state since the late 1980s, because of the large catches in that period and the selection pattern which captures many immature fish.

Catches of immature fish remain high and the greatest mortality is suffered by fish of age 3. Recruitment has been declining for the last 15 years, and recent recruitments have been lower than the level expected to be available given recent levels of the spawning stock biomass (SSB).

There is considerable uncertainty in regards to the possible levels of future recruitment. It is unclear whether the most recent levels are associated with a change in stock productivity, if they are an artefact of the estimation process, or if they are a random occurrence that could be reverted naturally by a series of positive recruitment anomalies. The consequences of having one of these three scenarios are as follow:

- 1) If recruitment can naturally come back to the levels of recruitment observed in the 1980s and 1990s, then the stock is severely overfished and will require long recovery times before it reaches again  $B_{MSY}$  (this scenario is the one assumed for the projections).
- 2) If the tendency of recruitment is an artefact of the estimation process (such as severe underestimation of small fish killed by the fishery (as a consequence of discarding), then current recruitment may be underestimated. The stock could recover to the level of  $B_{MSY}$  faster than in case a, if undersized fish mortality is reduced.
- 3) If recruitment has changed because of a regime shift or changes in ecological conditions, then current stock productivity may be lower than in the 1990s and current reference points do not represent current stock conditions.

### 3.4 Projections

The scenario including estimates of discards was chosen to perform projections in order to provide advice on the response of the stock to management. Biological parameters (growth, fecundity, M) were the same as in historical assessment and selection patterns (landings and discards) were the average from the most recent three years. For recruitment, a Beverton and Holt stock recruitment relationship was fitted to the historical data. There was little evidence of a decline in recruitment at low population size (i.e. steepness was high). There was strong autocorrelation in the residuals (**Figure 32**), therefore when running the projections the recruitment deviates were simulated with autocorrelation ( $\rho=0.6$ ,  $\sigma=0.2$ ) (**Figure 33**). Projections were performed for F values relative to  $F_{MSY}$  in **Figure 34** and for  $0.8F_{sq}$  relative to  $F_{MSY}$  in **Figure 35**. **Tables 6a to 6c** show the Kobe II Strategy matrix of probabilities of not over fishing, not being overfished and being in the green quadrant, respectively, by year for each level of fishing mortality.

## 4. Recommendations

### 4.1 Statistics and research

#### 4.1.1 Recommendations with financial implications

- *Stock mixing and management boundaries:* The Group noted the need to further improve the current knowledge about stock boundaries between the Mediterranean and North Atlantic swordfish stocks. For this purpose, it was recommended to conduct collaborative and multidisciplinary research, including population genetics, electronic tagging, life history, and to use fine-scale (e.g. 1° squares) and quarterly sampling strata.

- *Data recovery plan:* The Group noted that the catch and CPUEs time series currently in use in the stock assessment models start in 1985. Therefore the early period of the fisheries, which accounted to increasing catches is not being accounted in the model. As such, the Group recommended conducting a recovery of historical data, so that the entire history of the fishery is taken into account in the stock assessment models. Particular effort should be dedicated to collecting available information from the major fisheries of the early years, especially Italian fisheries.
- *Size and age at maturity:* As there may be spatial differences between the east and west Mediterranean swordfish, the Group recommended that future work is conducted to determine region specific size and age at maturity.
- *Habitat use and availability to the different gears:* The Group recommended the use of satellite tagging to provide information on habitat use for comparison of the availability of swordfish to the various fisheries, including comparisons between traditional and meso-pelagic longlines.

#### 4.1.2 Recommendations without financial implications

- *L-W relationships:* Ongoing work and preliminary results shown to the Group indicate that the length-weight relationships currently in use in ICCAT for the entire Mediterranean might not be the most appropriate, as there may be spatial differences between the east and west Mediterranean. Therefore the Group recommended this revision to continue, and an effort to be made to incorporate all available data sets into the analysis, including data from different Mediterranean regions and fisheries.
- *Gear selectivity:* Further research on gear design and use is encouraged in order to minimize catch of juvenile swordfish and increase yield and spawning biomass per recruit from this fishery. The Group recommended further studies to be conducted on the mesopelagic longlines fisheries developed during the mid-2000's, due to the impact these fisheries may have in terms of catch composition, CPUE series, size distribution of the catches and consequently on the assessment of the stock status and provision of management advice.
- *CPUEs:* The Group recommended the collection and recovery of historical data to increase the period covered by the time series. For example, the nominal data presented in De Metrio *et al.* (1999) should be recovered and evaluated for possible standardization. The Group recommended mesopelagic longlines and traditional drifting surface longlines to be considered different gear, and separate CPUE series be developed in the future. The Group reiterated the need for CPUE to take into account the geographic stratification of the catch by gear and month using standard measures of effort for each gear (e.g. number of hooks for longline, length of nets for gillnet), on as fine a scale as possible (5° rectangles for longline, and 1° rectangles for other gears). In addition the Group also recommended considering other gear characteristics (i.e. use of light attractors, hook style, bait type, etc.) during CPUE standardization. Although CPUE by age is the usual input for the age-structured analyses, the Group recognized that this must be based on an increased level of sampling, not merely substitution of the current data. Therefore, it is recommended that increased sampling take place so that CPUEs can be developed by age. To achieve this goal, the Group noted that it is important to collect size data together with the catch and effort data to provide meaningful CPUEs.
- *Discards.* Recently adopted management measures may have increased discard levels, therefore the Group noted that participating countries should improve their estimates of discards of juvenile swordfish, when applicable, and submit such information to the ICCAT Secretariat.
- *Monthly spawner - recruit proportion in the catches:* Though the monthly probability to catch undersized swordfish, or the monthly discard rate has been examined in some Mediterranean swordfish fisheries, there is no estimation of the monthly proportion of recruits and spawners in the Mediterranean swordfish catches. The Group recommended that monthly estimation of spawner and recruit proportion in the catches could facilitate management decisions for seasonal closures.

#### Related with statistics

- *Data recovery and reconstruction:* The Group requested that Sub-Committee on Statistics works in collaboration with the Mediterranean swordfish to evaluate the use of other methodologies in historical reconstructions for future Mediterranean swordfish stock assessments.

- *Task I and II.* The Group recommended mesopelagic longlines and traditional drifting surface longlines to be considered as different gears by the ICCAT Secretariat, and separate Task I and II series be developed in the future, and that CPCs report data using those different gear codes.
- *Next stock assessment:* The Group recommended that the next stock assessment for Mediterranean swordfish should be carried out four years from now (2020) in order to give more time for additional data to be collected and prepared. Additionally, a data preparatory meeting should be conducted the year before (2019), to analyze and prepare data for the stock assessment. If there is a change in stock status indicators during the interim period, as for example a large change in nominal catches or in average sizes, then the stock assessment should be carried out before 2020.
- *Reference points:* The Group recommended looking into alternative indicators and appropriate reference points (e.g., *L*<sub>opt</sub> or measures based on reproductive potential).
- *List of recreational and commercial vessels:* The Group noted that the authorized list of vessels for Mediterranean swordfish currently groups recreational and commercial vessels. The Group requested the Secretariat to separate those two categories as per [Rec. 13-04].

#### **4.2 Management advice**

Over the last 25 years biomass levels appear to be rather stable at low levels. This situation has remained the same since the last assessment. However, fishing mortality levels have shown a declining trend since 2010. Assessment of stock status and reference points were done under the assumption that recruitment levels can come back up to the levels seen in the past (1980's and 1990's). Under such assumption the stock is currently overfished and suffering overfishing. According to the Commission objectives the stock requires rebuilding and fishing mortality has to be reduced. The level of the stock to be rebuilt to is contingent on the assumption on future recruitment which is highly uncertain. In order for rebuilding to start to take place there will be a need for substantial reductions in harvest so that responses from the population can be detected. Additionally, for the SCRS to be able to reduce uncertainty in regards to future recruitment, there will be a need to increase monitoring of landings and discards.

The Group noted that since the establishment of minimum landing sizes, the discard levels of undersized swordfish may have increased. Additionally, it has been shown that high swordfish by-catches composed mostly of undersized individuals exist in albacore fisheries operating in the autumn and winter months coinciding with the swordfish closing season. As the swordfish fishery closure aims to the protection of recruits, the impact of those fisheries needs to be taken into account, which was not possible to do in the current stock assessment. In addition, the impact of those fisheries should be considered in future management recommendations.

#### **5. Other matters**

The Group revised and updated the Executive Summary and workplan for 2017. The Group agreed that only the catch table needs to be updated during the forthcoming swordfish Species Group meeting.

#### **6. Adoption of the report and closure**

The report was adopted during the meeting. The Chairman thanked the hosts for their hospitality and participants and the Secretariat for their work during the week. The meeting was then adjourned.

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