REPORT OF THE 2019 SHORTFIN MAKO SHARK STOCK ASSESSMENT UPDATE MEETING

(Madrid, Spain 20-24 May 2019)

The results, conclusions and recommendations contained in this Report only reflect the view of the Shark Species Group. Therefore, these should be considered preliminary until the SCRS adopts them at its annual Plenary meeting and the Commission revises them at its Annual meeting.

Accordingly, ICCAT reserves the right to comment, object and endorse this Report, until it is finally adopted by the Commission.

1. Opening, adoption of agenda and meeting arrangements

The meeting was held at the ICCAT Secretariat in Madrid, 20-24 May 2019. Dr. Enric Cortés (USA), the Shark Species Group ("the Group") rapporteur and meeting Chair, opened the meeting and welcomed participants. Mr. Camille Jean Pierre Manel (ICCAT Executive Secretary) welcomed the participants and highlighted the importance of the work to be developed by the Group for the stock assessment and management advice to the Commission. In particular, he noted the importance of the meeting given the proposal to list Shortfin Mako shark on CITES appendix II. The Assistant Executive Secretary (Dr. Miguel Neves dos Santos) reviewed the meeting logistics. The Chair proceeded to review the Agenda, which was adopted with some changes (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The List of Documents presented at the meeting is attached as **Appendix 3**. The abstracts of all SCRS documents and presentations provided at the meeting are included in **Appendix 4**. The following served as rapporteurs:

Sections	Rapporteur
Item 1	N. Taylor
Item 2	C. Santos, F. Mas, M. Neves dos Santos
Item 3.1 -3.3	C. Palma, M. Ortiz,
Item 3.4	M. Serghini
Item 3.5	E. Cortés
Item 4	R. Coelho, E. Cortés
Item 5	H. Winker, D. Courtney, J.J. Maguire
Item 6	B. Babcock, D. Courtney
Item 7	D. Courtney, M. Kai, B. Babcock
Item 8	D. Rosa
Item 9	S. Biton Porsmoguer, M. Neves dos Santos
Item 10	G. Diaz, M. Neves dos Santos, E. Cortés

2. Review of the activities and progress of the SRDCP

2.1 Habitat use based on electronic tagging

Document SCRS/2019/090 provided an update of the study on habitat use and migrations of shortfin mako, developed within the ICCAT Shark Research and Data Collection Program (SRDCP), based on new tags deployed during 2018-2019. Up to date 43 tags (14 sPATs and 29 miniPATs) were deployed from Brazilian, EU-Portugal, EU-Spain, Uruguayan and United States vessels in the temperate NE and NW, Equatorial and SW Atlantic. Data from 41 out of 43 tags are available, with a total of 1,656 tracking days recorded.

Authors highlighted that shortfin mako behaviour seems to differ between regions as specimens tagged in the SW Atlantic tended to stay in the same general area and sharks tagged in the equatorial region travelled considerable distances throughout the Atlantic. Authors also pointed out that although overall depth and temperature ranges were large, tagged sharks spent most of their time in depths above 90 m and preferred a range of water temperatures from 18 to 22ºC, during both daytime and nighttime.

The Group discussed early tag detachment and tag failure issues. The authors clarified that pop-up satellite tags still suffer from some limitations, specially related to mechanical failure of tag components and species behavior.

Given that most tag deployments lasted two months or less, the Group discussed about programming future tags to remain attached for longer periods of time in an effort to identify possible seasonal movements of shortfin mako.

2.2 Post-release mortality

Document SCRS/2019/096 presented an update on the results of the shortfin mako post-release mortality study of the SRCDP based on new tags deployed during 2018-2019. Up to date 43 tags (14 sPATs and 29 miniPATs) were deployed from Brazilian, EU-Portugal, EU-Spain, Uruguayan and United States vessels in the temperate NE and NW, Equatorial and SW Atlantic. Due to tag failures (2) and premature release with unknown fate (6), only 35 out of the original 43 tags rendered reliable information on individual fate, resulting in 27 survival and 8 mortality events (22.8% post-release mortality).

Although sample sizes were low, the Group noted the effect of size (fork length) on post-release mortality, where larger sharks seem to have lower post-release mortality rates, and how it follows the same trend observed for hooking mortality.

The Group discussed that observer's subjectivity when classifying shark condition (perfect, moderate, severe) should be considered carefully as it could potentially bias post-release mortality rate interpretations.

The correlation between soaking time and post-release mortality was also discussed. The Group highlighted the importance of using hook timers to calculate hooking time since hooking time would represent a better proxy of shark stress than soaking time.

The Group also commented on the rates of tag failure between different tag manufacturers and tag components.

Combined with other tagging initiatives from the Atlantic, post-release mortality of the shortfin mako was 25%. The Group highlighted the fact that this rate matches the rate published for the species in a recent meta-analysis from Musyl & Gilman (2019).

The Group acknowledged the substantial and collaborative work that is being carried out under this ICCAT Research Program and encouraged its continuation and support in the future.

The Group was informed by the Secretariat that between 2018 and 2019 a total of 37 tags were acquired within the SRDCP. Additionally, some tags from previous phases of the project were still available and have been deployed during 2018-2019. Overall, between January 2018 and May 2019, a total of 23 sharks have been tagged within the SRDCP, including: 14 shortfin makos, 4 silky sharks, 3 oceanic whitetips, 1 porbeagle and 1 scalloped hammerhead. Currently, and including tags from previous phases of the project, a total of 39 miniPATs (22 from previous phases + 17 from 2019) are available for deployment. With this information, the Group recommended that the new 17 miniPATs from 2019 should be deployed as a priority on the non-retention ICCAT shark species, including silky sharks, oceanic whitetips and hammerheads.

2.3 Genetic analysis of shortfin mako in the Atlantic Ocean

Regarding the population structure of Atlantic shortfin mako, the whole mitochondrial genome (mitogenome) sequencing was conducted using next generation sequencing (NGS) technology with the 2018 budget. Whole mitogenome sequencing with the Long PCR technique (Cheng *et al.*, 1994, Miya *et al.*, 2003) was planned initially, and two Long PCR primer sets (set1; S-LA16S-H lso and L12321Leu, set2; S-LA16S-L lso and H12293Leu; located in the tRNALeu and 16S rRNA genes of the mitochondrial DNA region) were designed for shortfin mako based on the nucleotide sequence deposited in the DNA database (Accession No. KF361861). Although several conditions about long PCR reaction were tested, the amplification of Long PCR was not successful for many specimens. The main reason for this problem was suggested to be the condition of the template DNA (i.e., the fragmentation of total genomic DNA). Because of the variable preservation level of tissue samples, protocols to obtain mitogenomes from low quality and/or quantity DNA extracts will have to be developed. As an alternative for mitogenome sequencing with the long PCR method, the method proposed by Tilak *et al.* (2015) is being tested.

In addition, the Uruguay samples showed different results according to the past two studies (Taguchi *et al.*, 2016; Nohara *et al.*, 2017) and the study must be revisited. Recently, samples from 35 specimens collected in 2018 were provided by Uruguay and will be analyzed as part of the project in 2019.

2.4 Movements, stock boundaries and habitat use of silky sharks and other species in the Atlantic Ocean

Of the eight miniPATs acquired in late 2018 allocated to silky shark for the United States and EU-Portugal, five tags have been deployed and three are awaiting deployment. Seventeen tags were acquired in 2019, of which eight will be deployed later in the year on silky shark. The other nine tags will be deployed on silky and other species (i.e., oceanic whitetip, threshers, and hammerheads).

2.5 Movements and habitat use of porbeagle in the Atlantic Ocean

Of the miniPATs acquired in late 2018 for porbeagle, three were allocated to EU-Portugal (two already deployed), four to Norway (not yet deployed), and four to EU-France (not yet deployed).

2.6 Workplan for 2020

The following activities were listed as priorities for the SRDCP workplan in 2020. These will be revised during the Shark Species Group meeting in September 2019:

- Age and growth of shortfin mako in the South Atlantic: include samples from Japan and Namibia and conduct final analysis;
- Genetics - analysis of nuclear genome;
- Reproductive biology of porbeagle: update reproductive parameters of porbeagle by comparing size and condition of reproductive organs from existing historical samples and newly collected samples;
- Provide final results of habitat use and post-release mortality of shortfin mako shark;
- Movements and habitat use of porbeagle: provide final results;
- Movements, stock boundaries, and habitat use of silky sharks and other species: provide results for silky and continue tagging of other (no retention) species;
- New project: target-tagging of certain life stages of blue shark in the South Atlantic to answer specific questions (e.g., reproductive aggregations of females);
- Consider the viability of a close-kin mark-recapture study for the North Atlantic stock of shortfin mako shark.

3. Review of updated data from the Secretariat and new data received from National scientists, with special emphasis on shortfin mako and porbeagle sharks

The Group revised the most up-to-date information available in the ICCAT database system (ICCAT-DB) for the three major shark species (BSH: *Prionace glauca*; SMA: *Isurus oxyrinchus*; POR: *Lamna nasus*), namely the fishery statistics data (T1NC: Task I nominal catches; T2CE: Task II catch & effort; T2SZ: Task II size frequencies of the samples) and the conventional tagging data.

The SCRS catalogues on Task I/II data availability of the three species (BSH, SMA, POR) for the northern and southern Atlantic stocks/regions and for the period 1988 to 2017 are presented in the six **Tables 1 to 6**, respectively. The ICCAT scorecards of the six corresponding major shark stocks are shown in **Figure 1**.

3.1 Task I data (nominal catches)

The Secretariat informed the Group that, since the last SCRS annual meeting, no major changes have occurred in T1NC datasets of the three major shark species. Moreover, the CPC-reported shark catches for 2018 are still very incomplete.

For shortfin mako several cases with apparent inconsistencies in T1NC series were discussed. In the Moroccan surface longline fishery in the North Atlantic targeting mostly swordfish (SWO), the shortfin mako catch ratios (SMA/(SMA+SWO)) increased from around 35% before 2015 to more than 50% in 2015 and 2016, and returned back to 30% in 2017. These longline catch increases in 2015 (947 t) and 2016 (1,000 t) and the sharp decrease in 2017 (320 t) are inconsistent with the available shortfin mako nominal CPUE trends (SCRS/2019/084). The Namibian longline shortfin mako T1NC series in some years (2009, 2011, 2013, 2017) has catches below 50% of the ones reported in catch and effort statistics. In addition, the Group also questioned the sharp decrease in shortfin mako catches by Namibia from 2016 (799 t) to 2017 (194 t).

The Group also observed that several other shortfin mako T1NC series in the last two decades for both the North Atlantic (longlines: Belize, China PR, Korea, Mexico, Panama, Senegal; gillnets: Venezuela) and South Atlantic (longlines: Belize, Korea, Panama, Philippines, Vanuatu; gillnets: Côte d'Ivoire) are still incomplete. Representatives of those CPCs at the meeting committed to verify and revise those series.

One of the Group's concerns was the extent to which ICCAT CPCs are reporting dressed weight as opposed to (or instead of) live weight in T1NC, a fact that could potentially result in underestimates of total catches. The availability of official weight/weight conversion factors by species, and how this information should be integrated into the current T1NC data provision templates, was debated in detail. While it is required to submit T1NC in live weight (kg), it is not always possible for an ICCAT CPC to estimate live weight catches from product weight (commonly dressed weight), due to the lack of ICCAT official weight/weight conversion factors for shark species in particular. The Group noted that the main fleets in the North Atlantic (EU-Spain, EU-Portugal, Mexico, United States) already use the same conversion factors published in Mejuto *et al.* (2008), already adopted by ICCAT but not officially and fully published. The Group requested that the Secretariat update the ICCAT field manual with the weight/weight conversion factors of Mejuto *et al.* (2008).

Furthermore, the Group recommended that the Secretariat study a proposal that adds to the current ST02-T1NC form a column to report the conversion factors used to obtain live weight catch estimations. This proposal should be presented to the 2019 meeting of the Sub-Committee on Statistics.

At the Chair's request, the Secretariat presented a summary of how the shortfin mako T1NC series had changed since the ones used in the 2017 shortfin mako stock assessment (Anon. 2018a). The Secretariat informed the Group that the major changes occurred in 2018 with three main revisions: a) A full revision of USA commercial fleet landings between 1981-2016 (Díaz, 2018); b) The elimination of the historical part (before 2003) of the Morocco longline catch series estimated by the Group in 2017 (1961-2010), requested by Morocco as this fishery only started in 2003; and c) The inclusion of the Chinese Taipei (1981-1993) catch series estimated by the Group (which also included the period 1994 to 2015). The details are described in the report of the 2018 shark species group intersessional meeting (Anon, 2018b). At this meeting the Group decided to include the pending shortfin mako catch series of Chinese Taipei (1994-2015) in T1NC, and reiterated the 2018 request made to Chinese Taipei and other CPCs with longline fleets to provide improved T1NC estimates of the three major shark species as soon as possible.

With respect to porbeagle (POR), the assessment in 2008 (Anon. 2009) was done in collaboration with ICES scientists as a significant proportion of catches of porbeagle come from domestic coastal fisheries that are normally not reported to ICCAT. Therefore, for the 2008 assessment total removals represented combined catches from ICCAT reporting Task I and local catches from diverse CPCs. In preparation for the upcoming porbeagle assessment, it was proposed that the catch series used in the 2008 stock assessment (summary in **Table 7**) be adopted as POR Task I nominal catch estimates and stored in the ICCAT databases, with the corresponding source of data (NAFO, FAO, ICES, Group estimates based on catch ratios, etc.). The Group agreed with the proposal. The Group discussed that the Commission has included porbeagle as an official ICCAT species. Therefore, CPCs should report all catches of this species, including in non-traditional ICCAT fisheries.

The Group also recognized the difficulties associated with obtaining accurate porbeagle catches, often due to species identification problems and difficulties in estimating weight of live porbeagle that are released alive.

Finally, the adopted Task I nominal catch series of the three main species by stock/region are presented in **Table 8**, with the corresponding catches figures of BSH, POR and SMA shown in **Figures 1** to **3**, respectively.

3.2 Task II data (catch & effort and size samples)

Task II catch and effort (T2CE)

As part of the ongoing work on continuous Task II data improvements for completeness and harmonization, the Secretariat presented a detailed catalogue of T2CE containing a least one of the three main shark species (BSH, POR and SMA) in the species catch composition of each dataset. It also informed the Group that the T2CE revisions made by CPCs over the most recent years reduced to less than 5% the number of T2CE datasets available in ICCAT not having the level of resolution required by the SCRS in time (month) and area (1x1 grid for surface gears, and 5x5 grid or better for longline). Several CPCs, namely South Africa, Namibia, Mexico, Brazil, Uruguay, Korea, EU-Cyprus, EU-France, have committed to continue improving T2CE. It was noted that other important longline fleets T2CE series (Belize, Canada, Chinese Taipei, China PR, Panama, EU-Portugal, USA) should be revised to recover BSH, POR and SMA catches, recover fishing effort, and complete the species catch compositions with sharks species in particular. The long-term goals are to completely eliminate from T2CE, datasets that were reported by year/quarter, datasets with high area resolutions (10x20, 10x10, and, 5x10), and replace datasets with catch but without reported fishing effort.

The Secretariat also proposed two actions for T2CE: a) to reclassify the species mako sharks (MAK) as SMA (as was done in T1NC); and b) to reclassify catch type "D" (discards generic) as "DD" (dead discards), affecting only years 2003 to 2005, and shortfin mako number of datasets. Both changes were approved by the Group.

The Secretariat informed the Group that the T2CE datasets with BSH and SMA might have sufficient information from 2000 onwards that could allow a preliminary estimation of CATDIS for those two species. The Secretariat will present the preliminary CATDIS estimations of BSH and SMA to the 2019 Meeting of the Sub-Committee on Statistics.

Task II size samples (T2SZ)

The Secretariat made available to the Group all existing size frequencies of SMA (all the other species are available on request). It also informed that no major improvements were observed in T2SZ of three major shark species since October 2018. The six SCRS catalogues of BSH, POR and SMA show that T2SZ data still remain largely incomplete.

3.3 Conventional tagging data

The Secretariat provided the summary of conventional tagging information available at the Secretariat for the three major shark species: blue shark, shortfin mako and porbeagle. Maps of density distributions of releases and recaptures and displacement trajectories were presented for shortfin mako (similar maps for other species are available in STAT. Bull Vol. 44 /Section 5, published at: https://www.iccat.int/sbull/SB44-1-2018/s5.html).

The Group inquired about the sex information for shark tagging data. The Secretariat informed that sex information is provided in the summary files, albeit there is limited information for all species as most of the tagging comes from opportunistic tagging activities. The Secretariat will work with U.S. scientists from the Narragansett Laboratory to recover sex information for sharks from prior scientific tagging activities.

3.4 Indices of relative abundance

Document SCRS/2019/084 provided an updated standardized CPUE of the Moroccan longline fishery in the South of Moroccan Atlantic waters for shortfin mako for the period 2010-2018. The updated standardized CPUEs were estimated using a Generalized Linear Model and Boosted Regression Trees. Unlike previous analysis conducted in (Anon. 2018c), the model takes into consideration the registration number of longliners as a factor. This choice is justified by taking into account the variability of different longliner characteristics, the crew and the fishing areas frequented.

The Group was concerned about what seems to be a mis-match in shortfin mako catch between the reported Task I nominal catches for 2017 and the estimated CPUE for that year. More specifically, while the reported catches dropped from 1,000 t in 2016 to 320 t in 2017, the estimated CPUEs (both nominal and standardized) remained almost constant between those two years. The Group agreed that further investigation of this issue is needed. The Group suggested excluding species from the model and to identifying clusters for each catch composition record to align with the original dataset and treat as a categorical variable.

Document SCRS/2019/097 highlighted the potential effects of deep vs. shallow longline sets, as well as different branch line configurations, on the CPUE and hooking mortality of the shortfin mako, using General additive model (GAM) and Generalized linear mixed models (GLMM).

The Group suggested that for future analysis soak time should be included as a covariate in the models as it may have a great influence, particularly in hooking mortality.

3.5 Life history

Document SCRS/2019/087 presented several population dynamics parameters of interest for use as inputs in stock assessment models for the western North Atlantic population of porbeagle, including the maximum population growth rate, generation time, steepness of the Beverton-Holt stock-recruitment relationship (h), the position of the inflection point of population growth curves (R), and the spawning potential ratio at maximum excess recruitment (SPR_MER).

After the presentation of the document there was a comment about how the life history of the western North Atlantic porbeagle population implied a low lifetime reproductive output given the median age at maturity of 13 years and the lifespan of 25 years with only 4 pups on average being produced every two years. It was also discussed that the lifespan, which is based on ageing of vertebrae, may be an underestimate, but that nevertheless stock rebuilding, if the stock is overfished, will take time given the late age at maturity.

4. Review of results of the Areas Beyond National Jurisdiction (ABNJ) porbeagle assessment for the southern Hemisphere

A summary of the ABNJ porbeagle stock status assessment for the southern Hemisphere was provided (see Appendix 5 for the Executive Summary of the report). The approach used combined a spatially explicit sustainability risk assessment and indicator analyses for different southern Hemisphere fisheries that served to characterize local trends in relative abundance based on commercial catch per unit effort (CPUE) data, and trends in size and sex ratio based on biological data. The assessment considered five subpopulations or regions by longitude: 1) Western Atlantic Ocean, 2) Eastern Atlantic/Western Indian Ocean, 3) Eastern Indian Ocean, 4) Western Pacific Ocean, and 5) Eastern Pacific Ocean. In the Eastern Atlantic/Western Indian Ocean, Eastern Indian Ocean, and Western Pacific regions, where data availability and quality were better, stock status assessment was performed using a quantitative spatially explicit risk assessment. Indicator-based analyses were used to assess stock condition in the eastern Pacific and the western Atlantic, where there was more limited information.

Japanese observer data on catch and effort throughout the southern Hemisphere were used to generate standardized CPUE series, which were then used to predict relative abundance across the entire region and combined with effort to predict surface longline catches. Catch estimates for other fisheries were obtained from the literature. Most catch rate indicators were relatively short, variable, and uncertain, with the majority either stable or increasing. Length indicators were also variable. The eastern Atlantic/western Indian Ocean region, which was the most data rich, was selected as the 'calibration region' and a production model fitted to the estimated catch and the abundance index for the calibration area. The model estimated a catchability parameter for the pelagic longline effort, which was used to estimate fishing mortality for the calibration area and extended to other model areas. These values of fishing mortality were then compared to a Maximum Impact Sustainable Threshold (MIST), a population reference point based on productivity, to determine if overfishing (F > MIST) was occurring. Three MIST values were defined: F_{crash} (instantaneous fishing mortality leading to population extinction), F_{lim} (instantaneous fishing mortality rate that corresponds to the limit biomass B_{lim}), and F_{msm} (instantaneous fishing mortality rate that corresponds to the maximum number of fish in the population that can be killed by fishing in the long term). Results from the risk assessment estimated low fishing mortality rates in the three regions comprising the assessment area, and low risk from commercial pelagic longline fisheries to porbeagle shark over the spatial domain of the assessment. These results were consistent with the trends observed in catch rate indicators over the entire southern Hemisphere range of the porbeagle shark population, which in most cases showed stable or increasing catch rates.

The Group did not fully evaluate the ANBJ porbeagle assessment for the southern Hemisphere at this meeting and therefore is not in a position to endorse or reject that assessment. That decision will be made at the next porbeagle stock assessment meeting when the Group fully evaluates the ABNJ assessment.

5. Examine examples of diagnostics for Stock Synthesis model fit

Document SCRC/2019/088 implemented several key integrated stock assessment model diagnostics identified by Carvalho *et al.* (2017) to evaluate Stock Synthesis model runs for North Atlantic shortfin mako. For improved interpretation, particular emphasis was placed on graphical visualization of these diagnostics. In addition, the set of diagnostic tests was extended by a test to evaluate model-prediction skill. A brief description of each diagnostic, its intended use, and a brief interpretation of its results were provided as an aid to the Group to determine if the Stock Synthesis models fit the data adequately and that the models are well specified. The nine diagnostics (**Table 9**) provide an objective aid to evaluate stock assessment model fit to data and to identify possible model misspecification.

The diagnostics were implemented for three previously completed North Atlantic shortfin mako Stock Synthesis models (model runs 1, 2, and 3) presented to the Group at its 2017 shortfin mako stock assessment meeting (Anon. 2018a). The diagnostics consistently identified that a significant trend in the estimated recruitment deviations (required to fit trend in CPUE in all models) had a large influence on model results and probably contributed to poor sample prediction skill. However, the CPUE fit showed no clear evidence for conflicts among the CPUE indices suggesting that the abundance trend was consistent across the different fleets. The diagnostics did not provide information to distinguish among models in their performance in this instance. Also, although the diagnostics identified some potential problems, they were not severe enough to preclude using these models for management advice. It was noted that the other models used in the 2017 assessment (BSP2JAGS, JABBA) have not yet been evaluated with all these diagnostics.

The Group discussed the use of the term "Root Mean Squared Error", RMSE, to describe the residuals between observed and estimated CPUE. It was suggested that the diagnostic be called Root Mean Squared Residual (RMSR) to avoid confusion with the root mean squared error between predicted and observed data points in cross-validation and machine learning applications.

Document SCRS/2019/098 evaluated the differences between Stock Synthesis and production models for shortfin mako sharks. Shortfin mako sharks are long lived, with an age of maturity of 21 years. However, Stock Synthesis has estimated that all the fleets have dome shaped selectivity, with sharks of age 3-10 being the most vulnerable. Thus, the production models are tracking trends in the subadult exploitable biomass, rather than the spawning stock fecundity, SSF, where SSF is the spawning (pupping) stock fecundity, used here instead of spawning biomass to reflect the reproductive biology of shortfin mako (the shortfin mako/shark proxy for spawning stock biomass). Although production models can track short term trends in abundance (with process error), they provide no information on the trends in SSF, which is lagged by at least a decade. Thus, the authors recommended not using production models for projections for the North Atlantic shortfin mako stock.

The dome-shaped selectivity in the Stock Synthesis model implies that there is a large cryptic biomass of mature animals that are not being caught by the fisheries. Some Group members noted that there is some evidence that these large animals exist, based on research surveys. It was suggested that a future assessment should run a Stock Synthesis sensitivity analysis with a logistic selectivity functional form to evaluate the implications of this cryptic biomass for the perception of stock status. The development of a recruitment index would also be useful for assessment, to evaluate whether the autocorrelation in recruitment that the Stock Synthesis model needed to fit the CPUE data is accurate.

Document SCRS/2019/093 presented a method to approximate the probability density distributions about the stock status, which are required to produce the Kobe phase plot. For shortfin mako, the stock status is defined by SSF/SSF_{MSY} and F/F_{MSY}. The method uses a delta-multivariate log-normal (delta-MVLN) distribution with variances and covariance of SSF/SSF_{MSY} and F/F_{MSY} calculated from the Hessian of the Stock Synthesis model. The approximation seems accurate, and it can be applied in minutes rather than the hours required for MCMC. Comparing the MCMC and MVLN methods may also provide a diagnostic of lack of convergence in the MCMC, as was seen in model 3 when the MCMC chain was short and had not yet converged.

SCRS/2019/085 investigated the reasons for the large difference in stock status estimates between the 2012 (Anon. 2013) and 2017 assessments (Anon. 2018a) and concluded that the 2012 assessment overestimated stock size and underestimated fishing mortality. Steep declines in the stock size indices between 2010, the last data year in the 2012 assessment, and 2015, the last data year in the 2017 assessment, and the introduction of process error in the surplus production models are the main reasons for the change in perception of stock status. Including process error allowed the model to fit the stock size indices much better compared with the flagrant lack of fit in the 2012 model fits.

Document SCRS/2019/086 presented an application of Surplus Production in Continuous Time (SPiCT) to mako shark, which suggested that B/B_{MSY} was above 1.0 for most of the years since the early 2000s but had declined since 2010 to slightly below 1.0 in 2015-2016. The ratio F/F_{MSY} was less than 1.0 for all years since 1999 except in 2012 and 2013. While the relative trends in biomass and mortality ratios can be considered reasonable, the absolute values are one order of magnitude smaller than estimates in the 2017 assessment (Anon. 2018a) and the intrinsic growth rate estimate ($r = 0.7$) is incompatible with the mako shark biology.

While the incorporation of process error in the surplus production model improved considerably the fit to the stock size indices, the Group acknowledges that surplus production models do not fully capture the biological characteristics of shortfin mako shark. Surplus production models assume that the biomass next year is related to the biomass this year, plus growth (including recruitment), minus catch and natural mortality. The median age at maturity for shortfin mako shark is estimated to be 21. While the catch is mostly of immature specimens less than age 10. Therefore, the component of surplus production related to somatic growth of fish already recruited to the fishery is included in surplus production models, but the large lag effect between exploitable phase and reproductive phase is not. For a species like shortfin mako shark that produces 12 pups on average every two to three years, stochastic variation of annual numbers of recruits is expected to be low and closely related to the abundance of mature females. Because production models do not account for the time lag in the dynamics of the mature population, the Group concluded that production models should not be used for projections. Nevertheless, the production models can track short term changes in exploitable biomass, so they can be used to estimate current status, as was done in the 2017 assessment (Anon. 2018a).

Stock Synthesis makes it possible to model the biological characteristics of shortfin mako shark productivity more realistically. However, to have a good fit to the stock size indices, current Stock Synthesis models estimated large, serially correlated recruitment deviations that may not be consistent with the close relationship between the abundance of mature females and recruits mentioned above. While it is possible that these recruitment deviations are aliasing other biological mechanisms (increase in growth, decreased pup mortality, increased litter size, etc.), the Group recognized the possibility that the changes in estimated recruitment could be an artefact of fitting the CPUE indices.

6. Projections

Document SCRS/2019/092 updated the four BSP2JAGS model runs that were used for projections in the 2017 assessment (Anon. 2018a) with revised Task I catches for 2015 to 2017, a TAC every 100 t, and a longer time horizon. The current status (2018) had a lower B/B_{MSY} and higher F/F_{MSY} than the stock status in 2015 estimated in the 2017 assessment because the population continued to decline due to high catch levels. The projections show the population continuing to decline into the future unless the total catches are decreased substantially (**Figure 5**). The Group noted that, because the fishery mainly focuses on juvenile animals, the production model is only tracking juvenile abundance. Thus, the projections are not informative about trends in the mature population, which would lag behind the trends in the exploitable population by 10 years or more.

Document SCRS/2019/061 found that using the updated version of Stock Synthesis (Stock Synthesis 3.30) rather than the version that was used in the 2017 assessment (Stock Synthesis 3.24) had a negligible impact on the results. Thus, the new version could be used for projections. This was useful because the new version can incorporate changes in size selectivity that can be used to evaluate the effect of size limits in projections (See **Section 7**).

Document SCRS/2019/082 presented projections using Stock Synthesis 3.24 for the three Stock Synthesis runs developed in the 2017 assessment, with updated catches in 2015-2018 (**Figure 6**). All three models projected that spawning stock fecundity (SSF), defined as the number of pups produced in each year, will continue to decline until approximately 2035 even with no fishing, because the cohorts that have been depleted in the past will age into the mature population over the next few decades (the median age at maturity is 21 years). For runs 1 and 2, a TAC of between 800 – 900 t, including dead discards, resulted in ≥ 50% probability of being in the Kobe green zone (the joint probability of $F < F_{MSY}$ and $SSF > SSF_{MSY}$) by 2070. Run 3, which assumed a low productivity stock-recruitment relationship, found that only TACs of between 0 and 100 t (including dead discards) resulted in ≥ 50% probability of being in the Kobe green zone by 2070. The Group emphasized that fishing mortality rates had to be well below F_{MSY} to see any rebuilding.

In the 2017 assessment, SS3 models were built by sequentially adding biological realism. Thus, run 3 was considered the best SS3 model based on the belief that the low fecundity stock recruit relationship (LFSR) is most appropriate for this stock. The diagnostics are similar between models, so they provide no reason to change the model selection decision from the assessment. However, having decided not to use the production models for projection(s) due to their inability to capture the time lag between the selected ages in the fishery and age at maturity, the Group was concerned that using only one model for projection would not adequately capture the uncertainty in the population dynamics. Thus, the Group decided to incorporate the uncertainty in the stock recruit relationship between Beverton-Holt (run 1) or LFSR (run 3) by using both runs 1 and 3 to make a combined Kobe probability matrix. Unlike run 3, run 1 was not used to evaluate status in the 2017 assessment but it was thought to be a good model to incorporate the hypothesis that the population is somewhat more productive than the LFSR hypothesis. This alternate hypothesis (SS3 run 1) is consistent with some of the production model estimates of productivity from the 2017 assessment, but the SS3 run 1 can incorporate the necessary time lag effects caused by the selectivity and maturity of the stock.

The Group combined the Stock Synthesis MCMC projection results from Stock Synthesis run 1 and Stock Synthesis run 3 for making projections. The projections show the following: regardless of the TAC (including a TAC of 0), the stock will continue to decline until 2035 before any biomass increases can occur; a TAC of 500 tons has a 52% probability of rebuilding the stock to levels above SSF_{MSY} and below F_{MSY} in 2070; to achieve a probability of at least 60% the realized TAC has to be 300 tons or less; lower TAC achieve rebuilding in shorter time frames (**Table 10**). All the rebuilding projections assume that the TACs account for all sources of mortality - including dead discards.

The Group also conducted projections sampling from the delta-multivariate log normal distribution (SCRS/P/2019/035). The results of this analysis corroborated the findings obtained using MCMC (**Figure 7**).

7. Evaluate, to the extent feasible, the probability of success of the measures contemplated in ICCAT Rec. 17-08 through additional projections

Document SCRS/2019/089 evaluated the effects of a size regulation on the recovery of SSF to the target level by forecasting using the 2017 stock assessment base-case model (Model 3 with Stock Synthesis version 3.30.12 beta) for shortfin mako shark in the North Atlantic Ocean. The models assumed zero mortality for sharks below the size limit. Fixed TAC scenarios with or without size regulation under different TACs were compared. Deterministic TAC projections found that the SSF could not reach the MSY level until 2070 even if the TAC was set to zero with or without size regulation. TAC projections also found that the fixed TAC with size regulation accelerated the recovery of the SSF. These results suggested that a minimum size regulation that is applied to the whole fishery could be a useful tool to increase the speed of the recovery under management by TAC – provided that discard mortality is low. Because of model changes for projections the projection results from this paper may differ slightly from the assessment model results described in Section 6.

The Group discussed if size limits make sense given the biology of the species. The Rec [17-08] size limit of 210 cm FL for females is less than the size at maturity, so it would not protect mature females from being fished. For a long-lived species, a slot limit that protects some mature age groups may be appropriate, but none of the tools available at this meeting were able to evaluate slot limits. It was also noted that larger sharks have a higher mercury concentration, and so are less desirable to fisheries (Biton-Porsmoguer *et al.*, 2018). This set of projection assumes that there is zero mortality for fish below the size limits and therefore these projections could be considered unrealistically optimistic.

Document SCRS/2019/095 summarized future projections developed intersessionally to evaluate the effectiveness of a subset of the 2017 conservation and management measures recommended by ICCAT as applied in SCRS/2019/095, related to TAC and minimum size limits, to reduce North Atlantic shortfin mako shark mortality in association with ICCAT fisheries and to rebuild the stock to the MSY level. For the projections, minimum size limits were applied to all fisheries. All projection scenarios for the base case model (run 3) resulted in population declines until about 2040 regardless of the fixed TAC level used in future projections (including TACs of zero). SSF in the projections continued to decline after F had been reduced because it took many years for the surviving recruits to reach maturity (age at 50% maturity = 21 yr) and begin to contribute to SSF. For the base case, projections of SSF/SSF_{MSY} appeared to stabilize at a stock size below MSY by 2070 with a fixed TAC of 800 t. Fixed TAC levels > 800 t are projected to result in a declining trend of SSF/SSF_{MSY} by 2070, and fixed TAC levels < 800 t are projected to result in an increasing trend of SSF/SSF_{MSY} by 2070. A Kobe II risk matrix for the base case indicated that SSF would be likely to reach SSF_{MSY} by 2070 (around two mean generation times) with greater than 50% probability only at a fixed annual TAC limit of <100 t. For the base case, the recovery of SSF was accelerated by size limit regulations to protect immature shortfin mako.

A limitation of the projection approach implemented with fixed TAC and minimum size regulation was that the approach imposed a change in gear selectivity that implicitly assumed perfect TAC implementation and that sharks below the size limit experienced zero fishing mortality during the projection period (2019-2070). In consideration of the nature of shortfin mako fisheries (i.e., mostly by-catch species), it may be more likely that the TAC and size limits will not be perfectly implemented. In this case, the expectation is that the fixed TAC regulation and the size limit regulation could be less effective at accelerating the recovery of SSF to SSF_{MSY} than reported by the projection scenarios.

The effect of circle hooks was not evaluated with projections.

Document SCRS/2019/101 showed projections from the Decision Support Tool, DST, which is a web-based tool for doing projections based on an existing Stock Synthesis model, with the ability to adjust size limits, fraction of the total catch released, and the fraction of the discards that die. The projections assume that the selectivity of the fisheries does not change, implying that the fishers do not reduce their mako shark catch by avoiding mako sharks; they can only reduce their retained catch by discarding them. The projections were run with specified TACs, which were applied to the retained catch only. With a size limit and discard mortality of 25%, the weight of dead discards was equal to or greater than the weight of the retained catch. A live release policy that caused retention of only 36% of all sharks with a discard mortality of 25% also caused a large volume of dead discards. Thus, in order to rebuild the population, the TAC had to be reduced to about 400 t, so that the total mortality (= retained catch plus dead discards) would be below the level of about 800 t required to cause an increasing trend. Dead discards were higher if the discard mortality rate was higher. In general, the projections showed that, if fishers are unable to avoid catching shortfin mako sharks, and the ones that are discarded have a substantial mortality rate, then it is necessary to greatly decrease the retained catch to allow the population to rebuild. The weight of dead discards is dependent on retention rates and discard mortality rates; thus, it is critical to estimate these parameters accurately for all fleets. It was suggested that the DST tool should add the capacity to put in a maximum size limit or slot limit, since protecting older sharks may be a better strategy than protecting younger sharks for a long-lived species. Allowing the projections to run with a fixed effort in the fisheries targeting other species (e.g. swordfish) would be useful for species like shortfin mako that are caught as by-catch.

Document SCRS/2019/102 implemented Stock Synthesis projections at alternative fixed F rates for the base case (run 3) to evaluate the effectiveness of a subset of the 2017 conservation and management measures, live release, recommended by ICCAT to reduce North Atlantic shortfin mako shark mortality in association with ICCAT fisheries and to rebuild the stock to the MSY level. All projection scenarios resulted in continued short term population declines until the 2030s regardless of the fixed *F* level used in future projections. SSF reached the MSY level by 2070 only for the F equal zero scenario. SSF continued to decline after the 2030s for $F_{current}$ and $F_{reduced}$ by live release ($F_{release}$) scenarios. SSF increased after the 2030s for most scenarios described as a percentage of F_{MSY}. The rate of increase in SSF after the 2030s was higher at reduced F (relative to F_{MSY}).

Projection results for the base case Stock Synthesis model run suggested that live release management measures alone are unlikely to be sufficient to rebuild the stock to the target level within the projected period. However, reduced F (relative to F_{MSY}) is likely to increase the rate of SSF recovery over the projected period. The minimum size regulation also increased the speed of the recovery in SSF after the 2030s, but only if it was assumed that there was no discard mortality. Such limits may have to vary between fleets with different selectivities.

Because shortfin mako is primarily a by-catch species, substantially reducing F may require active measures to avoid catching them in addition to live releases explicitly modelled in this analysis. The fixed TAC projections (model runs 1 and 2) indicated that it is also possible to rebuild the SSF over the projected period if less than 800 t of TAC is taken. However, this TAC would have to be applied to total mortality including dead discards. Under a fixed TAC regulation, fishing mortality is likely to continue to increase after a fleet reaches the allocated TAC due to the accidental catch of shortfin mako shark. Consequently, considering the nature of the fishery, the live release approach (as modeled) may be a practical way to reduce F in addition to other F-related management measures such as reduction of operational time and changes in fishing area.

Model uncertainty should also be considered when interpreting projection results. The use of different model assumptions or the use of different modeling frameworks may lead to different projection outcomes. For example, the range of outcomes obtained from projections of North Atlantic shortfin mako shark ignores large uncertainties in the assumptions of fixed biological parameters within the Stock Synthesis model such as growth, age at maturity, natural mortality, and stock-recruitment relationship, which were not explicitly evaluated in these projections. In addition, alternative model settings for the shape of the selectivity curves by fleet or changes in the proportion of catch rate by fleet may also have a large effect on projection results, and were not evaluated in these projections.

The Group also discussed the possible reasons for SSF not reaching MSY level by the end of the projection period due to the oscillating decreasing and increasing trends in the SSF in the future projections. While SSF_{MSY} would be reached asymptotically, F would need to be reduced below F_{MSY} to increase the rate at which SSF increases to SSF_{MSY}. Froese *et al.* (2018) showed that an $F=F_{MSY}$ scenario is, by definition, not capable of rebuilding stock size above the SSF_{MSY} and the SSF_{MSY} itself is approached asymptotically and reached in infinite time. The Group hypothesized that this may be an effect of imposing fishing at fixed F on a long-lived species with dome-shaped selectivity, which results in pulses of lagged recruitment appearing as SSF 20+ years after, as discussed above.

The Group was unable to fully assess the effectiveness of Rec. [17-08] to reduce shortfin mako fishing mortality because it was only partially implemented by the CPCs in 2018. Per Rec. [17-08], CPCs were required to report their shortfin mako catches for the first six months of 2018. Notwithstanding that the recommendation was not fully implemented during that period, the reported catches were 1,530 t, which suggests that no significant reductions in catch have occurred compared to previous years. Catches for the second half of 2018 were not available to the Group at the time of the meeting. Since 2019 is the first full year during which Rec. [17-08] applies, the Group will not be able to assess the effect of the Recommendation to reduce shortfin mako catches until after 31 July 2020, and noting that it will provide the Group with only one year of data.

The Group had insufficient information to determine which ICCAT recommendations regarding possible conservation measures (Rec. [17-08]) were implemented for what fleet, making it difficult to evaluate the effect of the possible conservation measures by fleet in the projections with Stock Synthesis.

8. Continue to review the effectiveness of potential mitigation measures to reduce by-catch and mortality of shortfin mako

SCRS/2019/091 presented a meta-analysis of retention and at-haulback mortality rates for sea turtles, bony fishes and elasmobranchs that compared different hook, bait, and leader types. With regards to shortfin mako, the results showed that when using circle hooks the retention rate would increase, but at-haulback mortality would decrease compared to J-hooks. Using fish bait (vs squid bait) or wire leaders (vs nylon leaders) did not significantly increase the retention rates of shortfin mako, nor did bait have an effect in at-haulback mortality of shortfin mako.

The Group inquired if the number of hooks was considered, as different experiments have different number of hooks. It was clarified that the relative risk is a ratio that takes into account the number of fish retained compared to the number of hooks, for control and treatment. It was also discussed that the studies considered in the meta-analysis were conducted in different areas and times, using different experimental designs, hooks with different characteristics, etc. This could affect the comparison of the results among the experiments as previous studies have shown that mortality can change with size or temperature and that when using a meta-analysis these studies are all considered the same. It was explained that although all these characteristics were not specifically modelled, the models considered random effects to account for variability between studies. However, it is important to keep in mind these caveats when drawing conclusions from the results. It was also suggested to include interactions in the analysis as at-haulback mortality can come from a combination of different factors, not just one as is being analysed currently. The Group considered the meta-analysis to be an important contribution and it agreed with the authors that the results should be considered preliminary.

9. Summary of Assessment projection results

Combined Stock Synthesis projection results show the following:

- A zero TAC[*] will allow the stock to be rebuilt and without overfishing (in the green quadrant of the Kobe plot) by 2045 with a 53% probability;

- Regardless of the TAC (including a TAC of 0 t), the stock will continue to decline until 2035 before any biomass increases can occur;

- A TAC of 500 t, including dead discards has only a 52% probability of rebuilding the stock to levels above SSF_{MSY} and below F_{MSY} in 2070;

- To be in the green quadrant of the Kobe plot with at least 60% probability by 2070, the realized TAC has to be 300 tons or less;

- Lower TACs achieve rebuilding in shorter time frames;

- A TAC of 700 t would end overfishing immediately with a 57% probability; however this TAC would only have a 41% probability of rebuilding the stock by 2070.

Although there is large uncertainty in the future productivity assumption for this stock, the Stock Synthesis projections show that there is a long lag time between when management measures are implemented and when stock size starts to rebuild. This fact emphasizes the importance of taking immediate action to reduce fishing mortality and rebuild the stock.

The Group explored alternative TAC and size limit measures using two tools. Using the Stock Synthesis projections, the Group examined the combined effects of size limits and different TACs. The results indicated that hypothetically, a minimum size regulation that is applied to the whole fishery could be a useful tool to increase the speed of the recovery under management by TAC - provided that discard mortality is low. Using the DST projections, if fishers are unable to avoid catching shortfin mako sharks, and the ones that are discarded have a substantial mortality rate, then it is necessary to greatly decrease the retained catch to allow the population to rebuild. The weight of dead discards is dependent on retention rates and discard mortality rates; thus, it is critical to estimate these parameters accurately for all fleets.

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[*] All TACs are inclusive of dead discards.

The Group also evaluated alternative F strategies to evaluate the potential impact of a live release measure applied across all fisheries. A live release approach as modelled may be a way to reduce F if discard mortality rates are low, but other management measures such as reduction of soak time and/or time-area closures may also be required.

10. Other matters

10.1 CITES

The Secretariat informed the Group that in early January 2019 it received a proposal for the inclusion of the shortfin mako shark on CITES Appendix II [in accordance with Article II paragraph 2 (a) of the Convention, and satisfying Criteria A and B in Annex 2a of Resolution Conf. 9.24 (Rev. CoP17)]; and longfin mako shark [in accordance with Article II paragraph 2 (b) of the Convention and satisfying Criterion A in Annex 2b of Resolution Conf. 9.24 (Rev. CoP 17)]. In addition, in late January 2019 the Secretariat received a request from FAO to provide additional information to the FAO *Sixth Expert Advisory Panel Report' for the Assessment of Proposals to Amend Appendices I and II of CITES - Including mako shark, Isurus oxyrinchus.* This request focused mainly on the uncertainty of the 2017 shortfin mako stock assessment. Accordingly, the Secretariat provided some additional clarifications, highlighting that the SCRS is the scientific authority at ICCAT so the Secretariat was not in a position to provide a comprehensive response to the request from FAO. In addition, since the Group would only meet in May 2019, the SCRS Chair, the Vice-chair, the Sharks Species Group rapporteur, and the Commission's Panel 4 Chair prepared a document (*Notes on the inclusion of the shortfin mako (Isurus oxyrinchus) and longfin mako (I. paucus) sharks in Appendix II of CITES in relation to the stock status and scientific advice provided to the Commission*) that was sent to FAO in March 2019.

The Secretariat also informed the Group that it has received two invitations to attend side-events during the CITES meeting. After consultations with the Panel 4 Chair, FAO was informed of our acceptance to attend these side-events and that Dr. Fábio Hazin (former Commission Chair, current Chair of Panel 4, and former rapporteur of the Shark Species Group) would be ICCAT's representative. The Secretariat also informed the Group that due to the tragic events in Sri Lanka, the CITES meetings has been postponed *sine die*.

10.2 RFMO-CITES Sharks Conference

The Secretariat informed the Group that it was contacted by an advisor to the German Federal Ministry for the Environment, which informed them that a high-level RFMO-CITES Sharks Conference is being organized. The event will be held in Germany at the end of March 2020 (23/24 or 30/31 March), but for the time being, no additional information has been made available to the Secretariat.

10.3 Tuna RMFO Meeting on By-catch

The Secretariat informed the Group that the Chair of the Kobe Steering Committee has requested that ICCAT organize a new meeting of the Joint t-RFMO By-catch Working Group. The meeting will have a specific focus on sharks and will be held 16-18 December 2019. Currently the Secretariat is making a number of contacts to find a suitable venue for the meeting, and closely working with the t-RFMOs Secretariat on a tentative agenda.

11. Recommendations

11.1 General Recommendations

- The Group recommended that the Secretariat include on the list of published conversion factors on the ICCAT website and the ICCAT Manual, the conversion factors for dressed-weight to whole-weight (live-weight) for blue shark and shortfin mako developed by Mejuto *et al.*, 2008.

- The Group recommended that the Sub-Committee on Statistics discuss and approve the use of the Mejuto *et al.* 2008 conversion factors for application for blue shark and shortfin mako.

- The Group recommended that the Secretariat develop a proposal on potential changes to the ST01-NC form to include information on the conversion factors used by CPCs to report catches in whole weight. Such proposal shall be presented at the 2019 meeting of the Sub-committee on Statistics for its discussion and potential adoption.

- The Group recommended that the Secretariat adopt the time series of catches of shortfin mako by Chinese Taipei estimated by the Group as the official Task I catch statistics.

- The Group recommended that the Secretariat adopt the time series of catches of porbeagle estimated in the 2008 stock assessment (Anon. 2009) meeting as the official Task I catch statistics for this species.

- The Group recommended that the Secretariat contact the Statistical Correspondents of Namibia and Morocco to confirm the 2017 reported shortfin mako catches.

- The Group recommended that all CPCs review their shortfin mako CPUE to identify potential conflicts with catch time series.

- The Group recommended that the Secretariat work with National scientists to recover sex information for the tagging data.

11.2 Recommendations with financial implications

- The Group continues to recommend designing and implementing a study to compare the effects of circle versus J hooks on retention rates, catch rates, and at-haulback mortality of sharks. The experimental design should account for the influence of leader material types (wire versuss nylon) and consider possible regional and fleet operational differences.

- The Group recommend that the Commission continue funding the Shark Research Program (SRDCP).

11.3 Management Recommendations

Southern Atlantic Shortfin mako

- Given that fishery development in the South predictably follows that in the North and that the biological characteristics of the stock are similar, there is a significant risk that this stock could follow a similar history to that of the North stock. If the stock declines it will, like the North stock, require a long time for rebuilding even after significant catch reductions. To avoid this situation and considering the uncertainty in the stock status, the Group recommends that, at a minimum catch levels should not exceed the minimum catch in the last five years of the assessment (2011-2015; 2,001 t with catch scenario C1).

Northern Atlantic Shortfin mako

- The Group conducted new projections using two Stock Synthesis model scenarios that incorporated important aspects of shortfin mako biology. This was a feature that was not possible with the production model projections developed in the 2017 assessment (Anon. 2008a) and, therefore, the Group considers the new projections as a better representation of the stock dynamics. The stock synthesis projections indicated that: a zero TAC* will allow the stock to be rebuilt and without overfishing (in the green quadrant of the Kobe plot) by 2045 with a 53% probability; regardless of the TAC (including a TAC of 0 t), the stock will continue to decline until 2035 before any biomass increases can occur; a TAC of 500 tons, including dead discards has only a 52% probability of rebuilding the stock to levels above SSF_{MSY} and below F_{MSY} in 2070; to be in the green quadrant of the Kobe plot with at least 60% probability by 2070, the realized TAC has to be 300 t or less; lower TACs achieve rebuilding in shorter time frames; a TAC of 700 t would end overfishing immediately with a 57% probability, however this TAC would only have a 41% probability of rebuilding the stock by 2070.

- Considering the results of the projections, the Group agreed that the exceptions in Rec. [17-08] that allow for the retention of some caught shortfin mako will not permit the recovery of the stock by 2070. The K2SM indicates that stock recovery can be achieved by 2070 with a 60% if the TAC is less than 300 t and with a 52% chance with a TAC of 500 t - inclusive of dead discards in both cases. A range of TAC options with a range of time frames and associated probabilities of rebuilding are included in **Table 10**. Given the vulnerable biological characteristics of this stock and the pessimistic findings of the projections, to accelerate the rate of recovery and to increase the probability of success the Group recommends that the Commission adopt a non-retention policy as it has already done with other shark species.

- The Group emphasized that the report of all sources of mortality is an essential element to decrease the uncertainty in stock assessment results, and particularly the report of estimated dead discards for all fisheries. Although the reporting of dead discards is already part of the ICCAT data reporting obligations, the requirement has been ignored by many CPCs. The report of dead discards and live releases is of the utmost importance particularly if the Commission adopts a non-retention strategy.

- The Group indicated that additional measures can potentially further reduce incidental mortality including time/area closures, gear restrictions, and safe handling and best practices for the release of live specimens (since post-release survival can reach 75%).

- The Group emphasized that the K2SM does not capture all the uncertainties associated with the fishery and the biology of the species. In addition, the length of the projection period (50 years) requested by the Commission significantly increases the uncertainty of the results. Therefore, the Group advised that the results of the K2SM should be interpreted with caution.

12. Adoption of the report and closure

The report was adopted by the Group and the meeting was adjourned.

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Table 1. BSH-N SCRS catalogue on Task I/II data availability between 1988 and 2017 (Task II, DSet="T2", colour scheme: "a"= T2CE exists; "b"= T2SZ exists; "c"= T2CS exists).

Species	Stock	Status	FlagName	GearGrp	DSet	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Rank	%	%cum
				T1 Total		1843	1818	3037	4306	3560	9589	8590	8468	7395	29283	26763	26172	28174	21128	20066	23005	21742	22359	23217	26927	30723	35198	37178	38083	36778	37058	36574	39627	44067	39679			
BSH	ATN	CP	EU.España	LL	t1										24497	22504	21811	24112	17362	15666	15975	17314	15006	15464	17038	20788	24465	26094	27988	28666	28562	29041	30078	29019	27316	1	69.1%	69%
BSH	ATN	CP	EU.España	LL	t2										-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	b	b	b	b	b	b	b	b	b	1		
BSH	ATN	CP	EU.Portugal	LL	t1			1387	2257	1583	5726	4669	4722	4843	2630	2440	2227	2081	2110	2265	5642	1751	4026	4337	5283	6164	6248	8256	6508	3725	3694	2994	3808	7679	5610	2	16.6%	86%
BSH	ATN	CP	EU.Portugal	LL	t2			-1	-1	-1	-1	-1	a	a	a	a	a	a	a	a	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	2		
BSH	ATN	CP	Japan	LL	t1							1203	1145	618	489	340	357	273	350	386	558	1035	1729	1434	1921	2531	2007	1763	1227	2437	1808	3287	4011	4217	4460	3	5.7%	91%
BSH	ATN	CP	Japan	LL	t2							-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ab	ab	ab	a	a	a	a	a	a	3		
BSH	ATN	CP	Canada	LL	t1	968	978	680	774	1277	1702	1260	1494	528	831	612	547	624	581	836	346	965	1134	977	843	0	0	0	0	1	0	1	5	16	32	4	2.6%	94%
BSH	ATN	CP	Canada	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	a	a	a	a	a	-1	a	a	a	a	-1	a	a	a	a	a	a	a	a	a	a	a	4		
BSH	ATN	CP	U.S.A.	LL	t1	421	480	742	772	185	1144	580	622	607	181	172	96	137	105	68	55	70	68	47	54	137	106	176	232	123	114	142	82	43	42	5	1.1%	95%
BSH	ATN	CP	U.S.A.	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	b	c	-1	b	b	b	b	b	ab	ab	ab	ab	ab	ab	ab	ab	ab	5		
BSH	ATN	NCC	Chinese Taipei	LL	t1							487	167	132	203	246	384	165	59		171	206	240	588	292	110	73	99	148	107	123	83	238	287	76	6	0.7%	96%
BSH	ATN	NCC	Chinese Taipei	LL	t2							-1	-1	-1	-1	-1	-1	-1	-1		ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	6		
BSH	ATN	CP	Belize	LL	t1																						114	461	1039	903	1216	392	4	6	201	7	0.6%	96%
BSH	ATN	CP	Belize	LL	t2																						ab	ab	ab	ab	a	a	a	a	ab	7		

Table 2. BSH-S SCRS catalogue on Task I/II data availability between 1988 and 2017 (Task II, DSet="T2", colour scheme: "a"= T2CE exists; "b"= T2SZ exists; "c"= T2CS exists).

Species	Stock	Status	FlagName	GearGrp	DSet	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Rank	%	%cum
				T1 Total		0	0	0	8	107	10	2704	3108	4252	10145	8797	10829	12444	14043	12682	14967	14438	20642	20493	23487	23097	23459	27799	35069	26421	20672	26148	22457	25417	28376			c
BSH	ATS	CP	EU.España	LL	t1										5272	5574	7173	6951	7743	5368	6626	7366	6410	8724	8942	9615	13099	13953	16978	14348	10473	11447	10133	10107	11486	1	45.8%	46%
BSH	ATS	CP	EU.España	LL	t2										-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	b	-1	b	b	b	b	b	-1	b	1		
BSH	ATS	CP	EU.Portugal	LL	t1								847	867	1336	876	1110	2134	2562	2324	1841	1863	3184	2751	4493	4866	5358	6338	7642	2424	1646	1622	2420	5609	6663	2	16.4%	62%
BSH	ATS	CP	EU.Portugal	LL	t2								-1	-1	a	a	a	a	a	a	a	a	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	2		
BSH	ATS	CP	Namibia	LL	t1												0			2213	2316	1906	6616	3536	3419	1829	207	2351	2633	1176	1147	2471	2137	2775	1357	3	8.8%	71%
BSH	ATS	CP	Namibia	LL	t2												-1			a	-1	ab	ab	ab	ab	ab	ab	ab	ab	a	ab	a	a	a	ab	3		
BSH	ATS	NCC	Chinese Taipei	LL	t1							1232	1767	1952	1737	1559	1496	1353	665		521	800	866	1805	2177	1843	1356	1625	2142	2074	2257	2240	1854	1992	2053	4	8.6%	80%
BSH	ATS	NCC	Chinese Taipei	LL	t2							-1	-1	-1	-1	-1	-1	-1	-1		ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	4		
BSH	ATS	CP	Brazil	LL	t1									743	1103		179	1683	2173	1966	2160	1568	2520	2533	2309	1625	1268	1500	1913	1607	2013	2551	2420	1334	2177	5	8.6%	88%
BSH	ATS	CP	Brazil	LL	t2									-1	a		-1	ab	a	a	a	a	ab	a	ab	a	ab	ab	ab	ab	a	a	a	a	a	5		
BSH	ATS	CP	Japan	LL	t1							1388	437	425	506	510	536	221	182	343	331	209	236	525	896	1789	981	1161	1483	3060	2255	3232	2236	2127	3115	6	6.5%	95%
BSH	ATS	CP	Japan	LL	t2							-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ab	ab	ab	a	a	a	a	a	a	6		
BSH	ATS	CP	Uruguay	LL	t1				8	107	10	84	57	259	180	248	118	81	66	85	480	462	376	232	337	359	942	208	725	433	130					7	1.4%	96%
BSH	ATS	CP	Uruguay	LL	t2				-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ab	ab	ab	ab	b	ab	ab	ab					7		
BSH	ATS	CP	South Africa	LL	t1											23	21		82	63	232	128	154	90	82	126	119	112	317	158	179	525	402	356	418	8	0.8%	97%
BSH	ATS	CP	South Africa	LL	t2											-1	-1	ab	a	ab	ab	ab	ab	ab	ab	ab	ab	ab	a	ab	ab	ab	ab	ab	ab	8		

Table 3. POR-N SCRS catalogue on Task I/II data availability between 1988 and 2017 (Task II, DSet=”T2”, colour scheme: “a”= T2CE exists; “b”= T2SZ exists; “c”= T2CS exists).

Species	Stock	Status	FlagName	GearGrp	DSet	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Rank	%	%cum
				T1 Total		1123	1088	1374	2054	2658	1952	2770	2173	1640	1877	1516	1471	1555	1081	892	690	842	605	519	522	527	421	119	68	111	156	29	56	20	29			
POR	ATN	CP	Canada	LL	t1	83	73	78	329	813	919	1575	1351	1045	1322	1055	956	899	491	223	130	220	191	184	83	115	50	65	22	29	16	8	3	2	2	1	41.2%	41%
POR	ATN	CP	Canada	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	a	a	a	a	a	-1	a	a	a	a	-1	a	a	a	abc	ab	ab	ab	ab	ab	a	ab	1		
POR	ATN	CP	EU.France	UN	t1	446	341	551	300	496	633	820	565	267	315	219	240	410	361	461	303	194	276	194	83	83	153								0	2	25.8%	67%
POR	ATN	CP	EU.France	UN	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1								ab	2		
POR	ATN	NCO	Faroe Islands	LL	t1	373	477	550	1189	1149	165							13	8	10	14	5	19	21												3	13.3%	80%
POR	ATN	NCO	Faroe Islands	LL	t2	-1	-1	-1	-1	-1	-1							-1	-1	-1	-1	-1	-1	-1												3		
POR	ATN	CP	EU.Denmark	UN	t1	33	33	46	85	80	91	93	86	72	69	85	107	73	76	42	21	20	4	3	2	1		0		2						4	3.8%	84%
POR	ATN	CP	EU.Denmark	UN	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		a		a						4		
POR	ATN	CP	Japan	LL	t1	80	58	63	62	54	35	29	15	15	13	19	41	47	52	21	7	20	27	18	17	10	13	13	14	49	98	0	0	2		5	3.0%	87%
POR	ATN	CP	Japan	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ab	ab	ab	a	a	a	a	a		5		
POR	ATN	CP	EU.España	LL	t1	69	42	26	47	15	21	52	19	41	25	25	18	13	24	54	27	11	14	34	8	41	77		0							6	2.3%	89%
POR	ATN	CP	EU.España	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		-1							6		
POR	ATN	CP	EU.France	LL	t1																	185			271	184	46		1	0			0		1	7	2.3%	92%
POR	ATN	CP	EU.France	LL	t2																	-1			-1	-1	-1		-1	-1			-1		a	7		
POR	ATN	CP	Norway	UN	t1	11	25	43	32	41	24	24	26	28	17	27	32	22			19			1	8	9	6	12	11	17						8	1.5%	93%
POR	ATN	CP	Norway	UN	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			-1			-1	-1	-1	-1	-1	-1	-1						8		
POR	ATN	CP	U.S.A.	LL	t1	0	1	1	4	4	50	108	35	78	56	9	0	1	0	1	0	1	0	0	0	0	0	3	2	0	2	7	34	1	9	9	1.4%	94%
POR	ATN	CP	U.S.A.	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	b	b	b	b	b	b	b	ab	ab	ab	ab	ab	ab	ab	ab	ab	9		
POR	ATN	CP	EU.Portugal	LL	t1	3	2	2	1	0	1	1	1	1	1	1	0	7	4	10	101	50	14	6	0	3	17	7	0	0						10	0.8%	95%
POR	ATN	CP	EU.Portugal	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	a	a	a	a	a	a	a	a	a	a	a			b	b	b	10		
POR	ATN	NCC	Chinese Taipei	LL	t1	7	3	0			4	10	12	27	18	13	27	19	18	22	12	8	7	5	3				0							11	0.7%	96%
POR	ATN	NCC	Chinese Taipei	LL	t2	-1	-1	-1			-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-1							11		
POR	ATN	CP	Canada	GN	t1								2	4	8	11	6	2	7	12	11	10	10	6	10	8	11	18	7	2	0	1	1	0	0	12	0.5%	96%
POR	ATN	CP	Canada	GN	t2								a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	ac	a	a	a	a	a	a	a	12		

Table 4. POR-S SCRS catalogue on Task I/II data availability between 1988 and 2017 (Task II, DSet=”T2”, colour scheme: “a”= T2CE exists; “b”= T2SZ exists; “c”= T2CS exists).

Species	Stock	Status	FlagName	GearGrp	DSet	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Rank	%	%cum
				T1 Total		330	301	301	239	360	207	279	170	311	178	262	178	214	121	182	196	109	133	122	149	85	62	16	21	37	29	38	4	1	0			
POR	ATS	NCC	Chinese Taipei	LL	t1	85	108	142	73	192	85	146	57	168	65	170	73	84	29	93	95	39	43	47	99			2	0	0	1	0	0		0	1	40.9%	41%
POR	ATS	NCC	Chinese Taipei	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			a	-1	a	a	-1	-1		-1	1		
POR	ATS	CP	Brazil	LL	t1	96	102	95	81	128	60	32	49	33	36	38	58	60	67	74	49	37	52	32	23				2							2	25.9%	67%
POR	ATS	CP	Brazil	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	a	-1	-1	-1	-1	a			-1							2		
POR	ATS	CP	Japan	LL	t1	118	15	37	48	12	13	14	6	9	14	1	1	7	4	3	2	11	3	3	9	41	34	8	7	25	15	13	4	1	0	3	10.3%	77%
POR	ATS	CP	Japan	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	a	a	a	a	a	a	a	a	a	3		
POR	ATS	NCO	NEI (Flag related)	LL	t1	23	50	13	8	14	10	22	8	46	23	37	11	15	3	1																4	6.1%	83%
POR	ATS	NCO	NEI (Flag related)	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1																4		
POR	ATS	CP	EU.España	LL	t1			1	13	12	32	35	43	28	27	2	14	7	14	2	9	4	0	3	5	4	13									5	5.8%	89%
POR	ATS	CP	EU.España	LL	t2			-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1									5		
POR	ATS	CP	Uruguay	LL	t1								3		5	14	3	4		8	34	8	28	34	3	40	14	6	12	12						6	4.9%	94%
POR	ATS	CP	Uruguay	LL	t2								-1		-1	-1	-1	-1		-1	-1	-1	-1	a	a	b	a	-1	ab	ab	b					6		
POR	ATS	CP	Panama	LL	t1	1	7	8	14	2	6	24	4	21	3		0	1																		7	1.9%	96%
POR	ATS	CP	Panama	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		-1	-1																		7		
POR	ATS	CP	China PR	LL	t1						0	1	0				13	36	4		5	4	2	2	6											8	1.6%	97%
POR	ATS	CP	China PR	LL	t2						-1	-1	-1				-1	-1	-1		-1	-1	-1	-1	-1											8		

Table 5. SMA-N SCRS catalogue on Task I/II data availability between 1988 and 2017 (Task II, DSet="T2", colour scheme: "a"= T2CE exists; "b"= T2SZ exists; "c"= T2CS exists).

Species	Stock	Status	FlagName	GearGrp	DSet	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Rank	%	%cum
				T1 Total		2926	2170	2389	2296	3233	4114	3659	5306	5306	3534	3845	2858	2587	2677	3426	3987	4000	3695	3574	4158	3800	4541	4767	3718	4431	3595	2852	2991	3351	3115			
SMA	ATN	CP	EU.España	LL	t1	1851	1079	1537	1390	2145	1964	2164	2209	3294	2416	2223	2051	1561	1684	2047	2068	2088	1751	1918	1814	1895	2216	2091	1667	2308	1509	1481	1362	1574	1784	1	53.5%	53%
SMA	ATN	CP	EU.España	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	b	b	b	b	b	b	b	b	b	1		
SMA	ATN	CP	EU.Portugal	LL	t1			193	314	220	796	649	657	691	354	307	327	318	378	415	1249	399	1109	951	1540	1033	1169	1432	1045	1023	817	209	213	257	270	2	17.1%	71%
SMA	ATN	CP	EU.Portugal	LL	t2			-1	-1	-1	-1	-1	a	a	a	a	a	a	a	a	a	a	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	2		
SMA	ATN	CP	U.S.A.	RR	t1	795	670	268	210	250	667	317	1422	232	164	148	69	290	214	248	0	336	282	257	158	156	163	168	178	229	219	201	190	163	189	3	8.3%	79%
SMA	ATN	CP	U.S.A.	RR	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	b	b	3		
SMA	ATN	CP	Japan	LL	t1	113	207	221	157	318	425	214	592	790	258	892	120	138	105	438	267	572			82	131	98	116	53	56	33	69	45	74	89	4	6.2%	85%
SMA	ATN	CP	Japan	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			-1	-1	ab	ab	ab	a	a	a	a	a	a	4		
SMA	ATN	CP	Maroc	LL	t1																147	169	215	220	151	283	476	636	390	380	616	580	807	1000	320	5	6.0%	91%
SMA	ATN	CP	Maroc	LL	t2																-1	-1	-1	-1	-1	-1	-1	-1	-1	a	a	-1	a	ab	ab	5		
SMA	ATN	CP	U.S.A.	LL	t1	160	188	146	176	273	249	269	259	166	179	146	124	123	135	123	105	140	138	95	167	149	171	168	160	152	140	155	100	108	112	6	4.5%	96%
SMA	ATN	CP	U.S.A.	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	b	b	b	b	b	b	ab	ab	ab	ab	ab	ab	ab	ab	ab	6		
SMA	ATN	CP	Canada	LL	t1								93	56	99	55	54	59	60	61	63	69	74	64	64	39	50	39	37	28	35	53	84	82	109	7	1.3%	97%
SMA	ATN	CP	Canada	LL	t2								-1	a	a	a	a	a	-1	a	a	a	a	-1	a	a	a	abc	ab	ab	ab	ab	ab	ab	ab	7		

Table 6. SMA-S SCRS catalogue on Task I/II data availability between 1988 and 2017 (Task II, DSet="T2", colour scheme: "a"= T2CE exists; "b"= T2SZ exists; "c"= T2CS exists).

Species	Stock	Status	FlagName	GearGrp	DSet	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Rank	%	%cum
				T1 Total		1032	1546	1255	1062	1183	1743	2182	3100	2395	2187	2008	1606	2588	2107	2103	3235	2526	3259	3036	2786	1881	2063	2486	3258	2905	2183	3274	2773	2765	2786			
SMA	ATS	CP	EU.España	LL	t1	378	809	552	327	421	772	552	1084	1482	1356	984	861	1090	1235	811	1158	703	584	664	654	628	922	1192	1535	1207	1083	1077	862	882	1049	1	38.8%	39%
SMA	ATS	CP	EU.España	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	b	-1	b	b	b	b	b	b	b	1		
SMA	ATS	CP	Japan	LL	t1	525	618	538	506	460	701	1369	1617	514	244	267	151	264	56	133	118	398			72	115	108	103	132	291	114	182	108	77	96	2	14.3%	53%
SMA	ATS	CP	Japan	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			-1	-1	ab	ab	ab	a	a	a	a	a	a	2		
SMA	ATS	CP	Namibia	LL	t1												1			459	375	509	1415	1243	1002	295	23	306	328	554	9	950	661	799	194	3	13.2%	66%
SMA	ATS	CP	Namibia	LL	t2												-1			a	-1	ab	ab	ab	ab	ab	ab	ab	ab	a	ab	a	a	a	ab	3		
SMA	ATS	CP	EU.Portugal	LL	t1								92	94	165	116	119	388	140	56	625	13	242	493	375	321	502	336	409	176	132	127	158	393	503	4	8.6%	75%
SMA	ATS	CP	EU.Portugal	LL	t2								-1	-1	a	a	a	a	a	a	a	a	a	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	4		
SMA	ATS	CP	Brazil	LL	t1	70	71	103	79	158	122	95	119	83	190	233	27	219	409	226	283	177	426	183	152	121	92	128	179	193	276	256	172	124	275	5	7.6%	82%
SMA	ATS	CP	Brazil	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	a	-1	-1	ab	a	a	a	a	ab	a	a	a	a	a	a	a	a	a	a	a	a	5		
SMA	ATS	CP	South Africa	LL	t1					64	43	23	46	36	29	168	66	103	68	12	115	101	111	86	224	137	146	152	218	108	250	476	613	339	305	6	5.8%	88%
SMA	ATS	CP	South Africa	LL	t2					-1	-1	-1	-1	-1	-1	-1	-1	ab	a	ab	ab	ab	ab	ab	ab	ab	ab	ab	a	ab	ab	ab	ab	ab	ab	6		
SMA	ATS	NCC	Chinese Taipei	LL	t1	35	29	36	80	44	31	65	87	117	139	130	198	162	120	146	83	180	226	166	147	124	117	144	204	158	157	161	154	95	88	7	5.2%	93%
SMA	ATS	NCC	Chinese Taipei	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	7		
SMA	ATS	CP	China PR	LL	t1						34	45	23	27	19	74	126	305	22	208	260	68	45	70	77	6	24	32	29	8	9	9	5	3	1	8	2.2%	96%
SMA	ATS	CP	China PR	LL	t2						-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	a	a	a	a	a	a	a	a	a	a	a	8		
SMA	ATS	CP	Uruguay	LL	t1	23	19	26	13	20	28	12	17	26	20	23	21	35	40	38	188	249	146	68	36	41	106	23	76	36	1					9	1.9%	98%
SMA	ATS	CP	Uruguay	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ab	ab	ab	a	-1	ab	ab	ab					9		

Table 7. POR nominal catches (t) series included in Task I (source: 2008 POR stock assessment).

		ATN																		ATS												
		NE											NW							SW												
		EU.DEU	EU.DNK	EU.IRL	EU.PRT	EU.SWE	EU.UK		FRO	ISL	NOR		BRB	CUB	FR.SPM	JPN	KOR	TAI	VEN	ARG	BRA	CHN	CUB	EU.ESP	EU.PRT	JPN	KOR	NEI.MIX	PAN	PHL	TAI	VEN
Decade	Year	ICES	ICES	ICES	ICES	ICES	ICES	*	ICES	ICES	ICES	RSCE	ratios	ratios	FAO	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios	ratios
1920	...											2179																				
1930	...											23927																				
1940	...											9351																				
1950	1950		1900								1358																					
	1951		1600								778																					
	1952		1600								606																					
	1953		1100						100		712																					
	1954		700						300		594																					
	1955		600						100		897																					
	1956		400								871																1						
	1957		600						100		1097																1						
	1958		900					7	300		1080										7					0						
	1959		600					9	600		1183									14	25					2						
1960	1960		400					10	500			1929								19	20					13						
	1961		600					9				1053								27	22					4						
	1962		400					20				444				1				53	8					21						
	1963		200					17				121				30				109	11					34						
	1964		300					5				89				28				86	8					69						
	1965		200					8				204				57				74	4					68						
	1966		200					6				218				36				11	3					23	1					
	1967		200					7				305				57				8	4					14	1				0	
	1968		100					7				612		0		153		1		18	4		1			23	15				3	
	1969		100					3				909		1		223		9		10	3		2			329	16				31	
1970	1970		200					5				269				714		7		9	5		0			296	11				142	
	1971		400					7				211		0		322		9		6	3		0			25	11				60	
	1972		500					15		6		206		0		16	1	28		23	2		0			81	27		0		37	
	1973													0		50	1	41		20	3		0			3	28		13		41	
	1974													0		51	1	36		10	8		1				32		7		60	
	1975													0		18	6	40		20	8		0			0	24		3		26	
	1976					3								0		82	20	63		26	7		0				20		5		33	
	1977															79	40	62		24	15		0			0	55		2		33	
	1978															60	14	54		3	68		0			1	15		2		58	
	1979						1							0		96	24	49			74		0			0	13		1		74	
1980	1980															122	1	30		0	59		0			18	16		4		57	
	1981									1						149	0	21		1	103		0			57	14		2		52	
	1982													0		45	1	33			98		1			9	12		4		50	0
	1983									1				0		62	1	38			85		1			1	11	1	5		35	1
	1984													0		51	0	66	0		56		1			0	10	1	5		20	1
	1985									1				0		61	0	57			50		2			35	12	1	15		27	1
	1986									1				1		69	2	96			141		0			122	6	2	12		60	1
	1987									1				0		90		41	7		95		1	1		92	5	9			72	0
	1988									1						80		7	11		96		0			118	6	23	1		85	0
	1989									1						58		3	13		102		0			15	19	50	7		108	0
1990	1990															63		0	2		95		1	1		37	3	13	8		142	
	1991															62			1		81			13		48	3	8	14		73	
	1992															54			2		128		0	12		12	1	14	2		192	
	1993	1			1											35		4	2		60	0		32		13	1	10	6		85	
	1994				1											29		10	4		32	1		35		14	2	22	24		146	
	1995				1										7	15		12	1		49	0		43		6	1	8	4		57	
	1996				1										40	10		27	7		33			28		6	6	46	21		168	
	1997				1								0		13	9		18	2		36			25	1		1	23	3		65	
	1998	2			1								0		20	19		13	8		38					1		37		0	170	
	1999												1			41		27	9		58	13		12		1		11	0	0	73	
2000	2000								13				0		13	47		19	6		60	36				7		15	1	0	84	
	2001								8				0		2	52		18	2		67	4		13	1	4		3		0	29	
	2002								10				0		1	21		22	0		74				1	3		1		0	93	
	2003	5	21				25		14				0		2	7		12	0		49	5			1	2				0	95	
	2004	7	20			5	24		5		24		0	1	4	20		8			37	4				11				1	39	
	2005	5	4	3		0			19				0	1		27		7			52	2				3				3	43	
	2006	0	3						21				1	1		18		5			32	2			1	3				1	47	
	2007		2			1							0			5		3			23	6			2	4	3				99	

Table 8. Final Task I nominal catches of the three major shark species by stock/region.

	Sharks (major)												
	BSH (Prionace glauca)				POR (Lamna nasus)				SMA (Isurus oxyrinchus)				Sharks
Year	ATN	ATS	MED	Total	ATN	ATS	MED	Total	ATN	ATS	MED	Total	(other)
1950					3262			3262	106			106	
1951					2381			2381	71			71	
1952					2209			2209	71			71	
1953					1916			1916	88			88	
1954			6	6	1595		6	1601	22			22	22
1955			9	9	1599		7	1606	45			45	14
1956			11	11	1272	1	6	1279	27			27	20
1957			13	13	1800	1	6	1807	73			73	19
1958			9	9	2290	8	3	2300	61			61	28
1959			5	5	2395	42	3	2440	80			80	23
1960			3	3	2841	52	1	2894	53			53	19
1961			11	11	3591	53	2	3646	124			124	26
1962			8	8	3888	82	2	3972	168			168	22
1963			5	5	6934	154	1	7089	73			73	34
1964			17	17	9702	162	5	9869	132			132	20
1965			13	13	5624	146	8	5778	105			105	28
1966			10	10	2583	37	3	2623	219			219	12
1967			10	10	1166	28	2	1196	197			197	14
1968			7	7	1814	64	2	1880	260			260	28
1969			5	5	2120	392	2	2514	256			256	34
1970			6	6	1410	463	0	1872	231			231	33
1971			9	9	1737	104	0	1842	359	97		457	23
1972			16	16	2045	171	2	2218	350	60		410	24
1973			13	13	1326	107	4	1436	341	212		553	20
1974			10	10	823	116	2	942	518	67		586	30
1975			11	11	1259	82	3	1344	618	76		694	26
1976			11	11	1660	91	2	1753	290	30		320	27
1977			7	7	1309	129	3	1441	478	252		730	50
1978	4		8	12	1284	146	3	1433	417	168		585	45
1979	12		9	21	1749	163	2	1914	234	299		533	59
1980			11	11	1759	153	1	1913	525	324		848	38
1981	204		11	215	1553	229	1	1783	1097	375		1472	49
1982	9		7	15	677	174	1	851	1332	974		2306	91
1983	613		6	619	1271	140	1	1412	1248	512		1760	102
1984	121		5	126	844	93	1	938	1591	745		2336	129
1985	380		8	388	807	144	1	952	3781	786		4567	133
1986	1493		6	1499	901	343	0	1245	3689	609		4297	161
1987	1629		26	1656	983	275	1	1260	3243	386	12	3641	698
1988	1843		3	1846	1123	330	0	1453	2926	1032		3958	1121
1989	1818		2	1820	1088	301	1	1390	2170	1546		3716	1004
1990	3037		1	3039	1374	301	0	1676	2389	1255		3645	1918
1991	4306	8	3	4318	2054	239	1	2293	2296	1062		3358	1756
1992	3560	107	1	3668	2658	360	0	3019	3233	1183		4416	3594
1993	9589	10	0	9600	1952	207	0	2159	4114	1743		5856	3008
1994	8590	2704	6	11300	2770	279	0	3049	3659	2182		5841	7981
1995	8468	3108	8	11584	2173	170	0	2343	5306	3100		8406	9036
1996	7395	4252	2	11650	1640	311	1	1952	5306	2395		7701	10967
1997	29283	10145	150	39578	1877	178	0	2055	3534	2187	6	5727	8851
1998	26763	8797	63	35623	1516	262	1	1779	3845	2008	8	5861	14643
1999	26172	10829	22	37023	1471	178	0	1649	2858	1606	5	4469	10417
2000	28174	12444	45	40664	1555	214	1	1769	2587	2588	4	5179	12630
2001	21128	14043	47	35219	1081	121	1	1203	2677	2107	7	4792	21930
2002	20066	12682	17	32765	892	182	0	1075	3426	2103	2	5531	16581
2003	23005	14967	11	37983	690	196	0	887	3987	3235	2	7225	16018
2004	21742	14438	125	36305	842	109	3	954	4000	2526	2	6528	27585
2005	22359	20642	72	43072	605	133	2	740	3695	3259	17	6970	33458
2006	23217	20493	178	43888	519	122	1	642	3574	3036	10	6620	15575
2007	26927	23487	50	50464	522	149	0	671	4158	2786	2	6946	23806
2008	30723	23097	81	53901	527	85	2	613	3800	1881	1	5682	22921
2009	35198	23459	185	58842	421	62	1	485	4541	2063	1	6605	17662
2010	37178	27799	216	65193	119	16	1	136	4767	2486	2	7254	18986
2011	38083	35069	40	73192	68	21	0	90	3718	3258	2	6979	17451
2012	36778	26421	42	63241	111	37	1	149	4431	2905	2	7338	12251
2013	37058	20672	100	57830	156	29	0	185	3595	2183	0	5778	20421
2014	36574	26148	235	62956	29	38		67	2852	3274	0	6127	5442
2015	39627	22457	665	62749	56	4		60	2991	2773	0	5764	4032
2016	44067	25417	729	70213	20	1	1	22	3351	2765		6116	3056
2017	39679	28376	105	68160	29	0	1	30	3115	2786		5901	3267

Table 9. Summary of diagnostics results for 2019 Shortfin mako shark Stock Synthesis assessment models.

Diagnostic-1 (JABBA-residual plot and RMSE of CPUE residuals)
All three models passed this diagnostic.
Diagnostic-2 (Runs test of CPUE residuals)
The results for this diagnostic were mixed.
Diagnostic-3 (Runs test of size composition residuals)
All three models passed this diagnostic.
Diagnostic-4 (Runs test of recruitment deviations)
All three models failed this diagnostic.
Diagnostic-5 (Retrospective patterns and Mohn's Rho test)
All three models passed this diagnostic.
Diagnostic-6 (R0 likelihood component profile)
The results for this diagnostic were mixed.
Diagnostic-7 (ASPM)
The results of this diagnostic were mixed.
Diagnostic-8 (MCMCs)
The results for this diagnostic were mixed.
Diagnostic-9 (Hind-cast cross-validation)
The results for this diagnostic were mixed.

Table 10. Stock Synthesis model runs 1 and 3 combined Markov Chain Monte Carlo (MCMC, long chain) Kobe II risk matrix for North Atlantic shortfin mako projection results: Probability that the fishing mortality (F) will be below the fishing mortality rate at MSY ($F < F_{MSY}$; top panel), probability that the spawning stock fecundity (SSF) will exceed the level that will produce MSY ($SSF > SSF_{MSY}$; middle panel), and the probability of both $F < F_{MSY}$ and $SSF > SSF_{MSY}$ (bottom panel).

A. Probability that $F < F_{MSY}$

TAC (t)	2019	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
0	100	100	100	100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100	100	100	100	100
200	100	100	100	100	100	100	100	100	100	100	100	100
300	100	100	100	100	100	100	100	100	100	100	100	100
400	100	100	100	100	100	100	100	100	100	100	100	100
500	96	99	100	100	100	100	100	100	100	100	100	100
600	81	89	99	99	98	96	95	97	97	97	96	95
700	57	69	93	92	88	82	80	83	84	85	82	82
800*	32	45	76	77	70	63	62	64	67	67	65	63
900	15	24	57	58	51	46	44	47	51	49	49	48
1000	5	11	37	38	31	27	26	28	30	31	30	30
1100	2	4	19	21	17	13	11	13	14	14	14	13

*Largest TAC interval with ≥ 50% by 2070

B. Probability that $SSF > SSF_{MSY}$

TAC (t)	2019	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
0	46	42	24	14	11	33	53	60	63	67	72	81
100	46	42	24	13	10	29	49	56	59	61	66	73
200	46	42	24	13	9	26	47	54	55	57	61	66
300	46	42	24	12	9	22	42	50	52	53	56	60
400	46	42	24	12	8	19	39	47	49	50	52	55
500*	46	42	24	12	7	17	34	42	45	47	49	52
600	46	42	24	12	7	14	28	37	40	41	43	47
700	46	42	24	11	6	11	23	31	34	35	37	41
800	46	42	23	11	6	10	19	26	27	28	30	32
900	46	42	23	11	5	8	16	20	21	21	23	24
1000	46	42	23	11	5	7	12	16	16	15	15	17
1100	46	42	23	10	5	6	10	12	12	11	10	10

*Largest TAC interval with ≥ 50% by 2070

C. Probability of both $F < F_{MSY}$ and $SSF > SSF_{MSY}$

TAC (t)	2019	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
0	46	42	24	14	11	33	53	60	63	67	72	81
100	46	42	24	13	10	29	49	56	59	61	66	73
200	46	42	24	13	9	26	47	54	55	57	61	66
300	46	42	24	12	9	22	42	50	52	53	56	60
400	46	42	24	12	8	19	39	47	49	50	52	55
500*	46	42	24	12	7	17	34	42	45	47	49	52
600	45	42	24	12	7	14	28	37	40	41	43	47
700	41	41	24	11	6	11	23	31	34	35	37	41
800	27	34	23	11	6	10	19	26	27	28	30	32
900	14	21	23	11	5	8	15	20	21	21	23	24
1000	5	10	20	10	5	7	12	15	15	14	14	16
1100	2	4	14	9	4	5	7	9	9	8	8	8

*Largest TAC interval with ≥ 50% by 2070

SCORECARD on Task I/II availability for the main shark fisheries (final year: 2017)										
				SCORES (by time series)			N. flag fisheries ranked			
FisheryID	Species group	Species	Species/stock	10 yr (2008-17)	20 yr (1998-17)	30 yr (1988-17)	10 yr (2008-17)	20 yr (1998-17)	30 yr (1988-17)
21	Major sharks	BSH	BSH-N region	6.58	4.58	3.30	3	4	5
22			BSH-S region	6.91	5.40	3.70	7	6	6
23		POR	POR-N region	3.30	1.91	1.32	13	15	10
24			POR-S region	2.85	1.08	0.58	4	6	6
25		SMA	SMA-N region	5.80	3.52	2.47	7	6	5
26			SMA-S region	7.32	5.50	3.25	7	8	7

Figure 1. Scorecard on Task I/II data availability for the six major shark fisheries (final year: 2017).

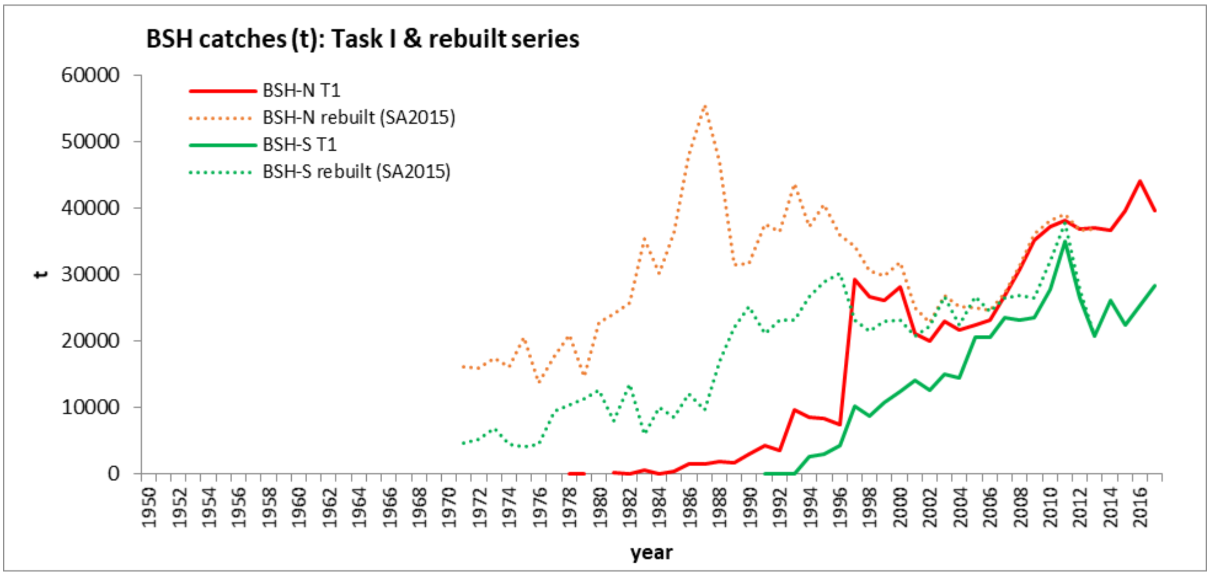

Figure 2. BSH catches (t) in Task I by stock (includes the two dotted series rebuilt in the 2015 stock assessment).

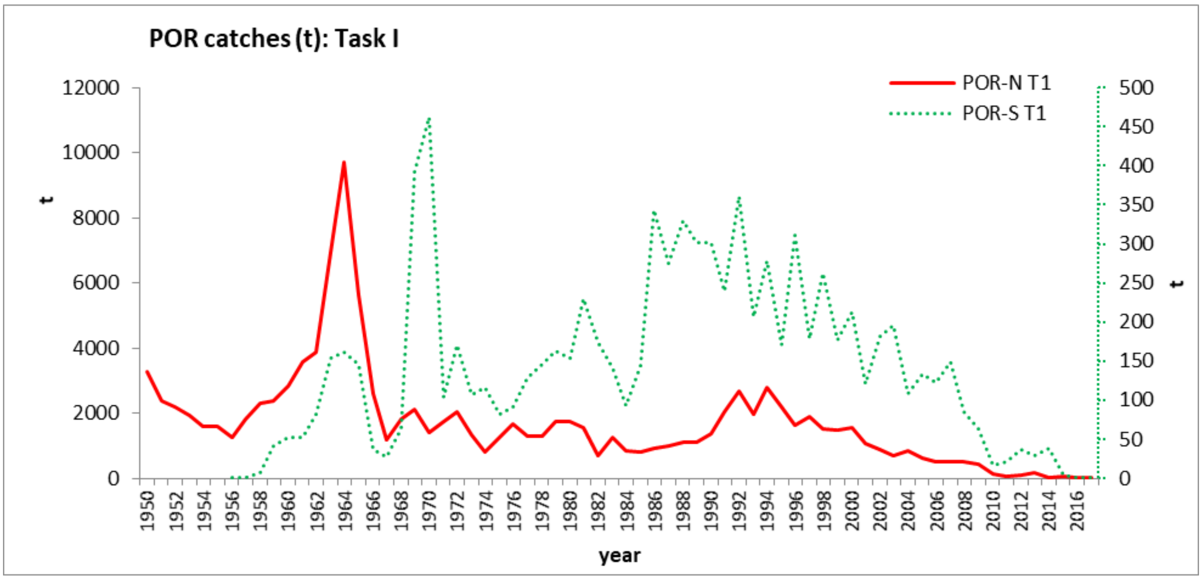

Figure 3. POR catches (t) in Task I by stock (BSH-S catch series, dotted, is plotted on the right vertical axis).

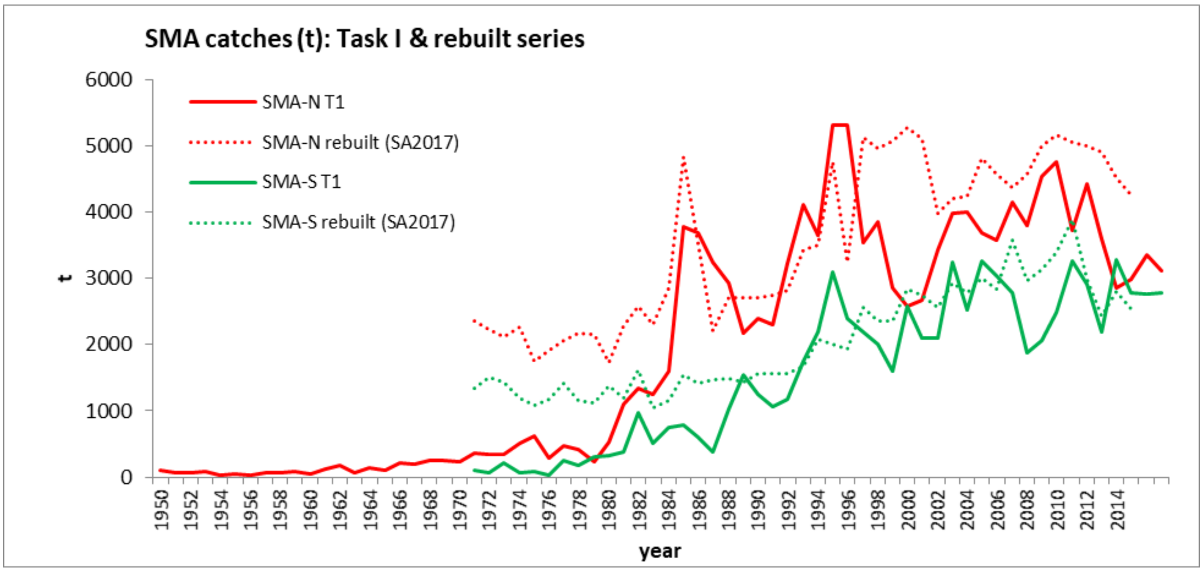

Figure 4. SMA catches (t) in Task I by stock (includes two dotted series rebuilt in the 2017 stock assessment).

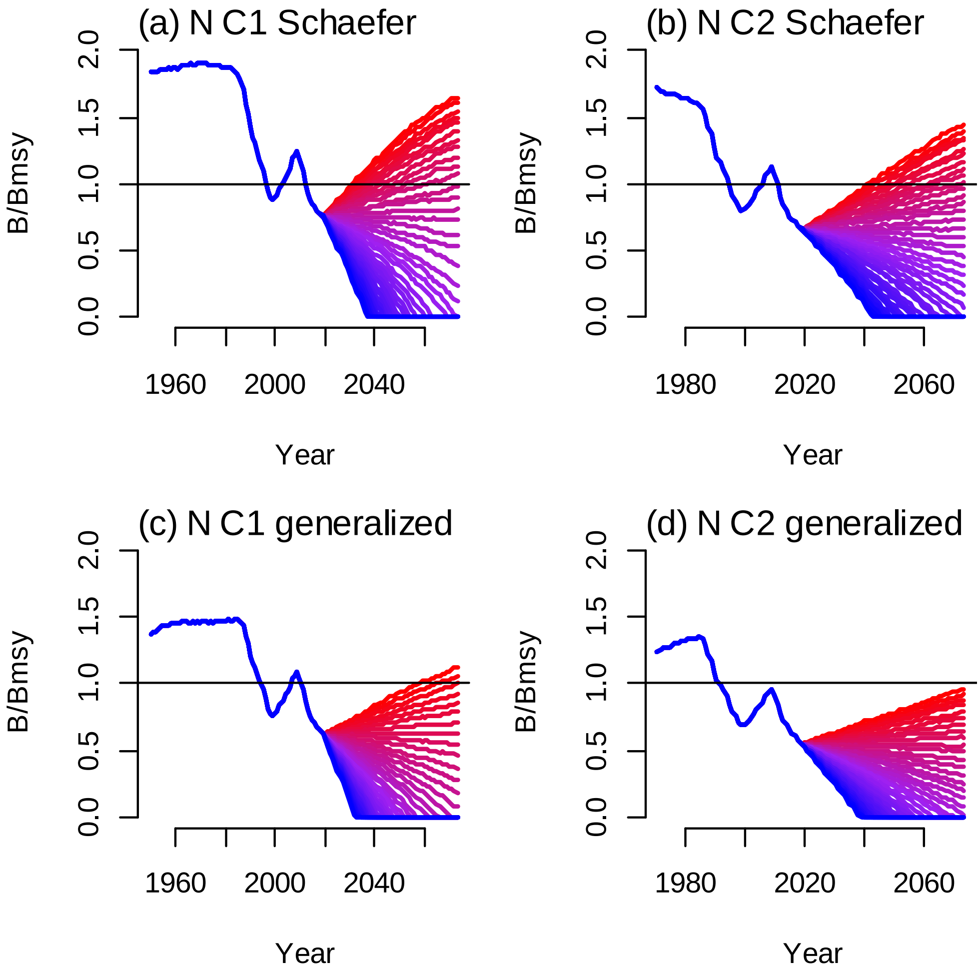

Figure 5. Projections for North Atlantic shortfin mako shark for the four BSP2JAGS models from the 2017 assessment. Lines are TACs from 0 to 4000 mt in 100 mt increments. First projection year is 2019, last year is 2073 (**SCRS/2019/092**).

(a) Run 1

(b) Run 2

(c) Run 3

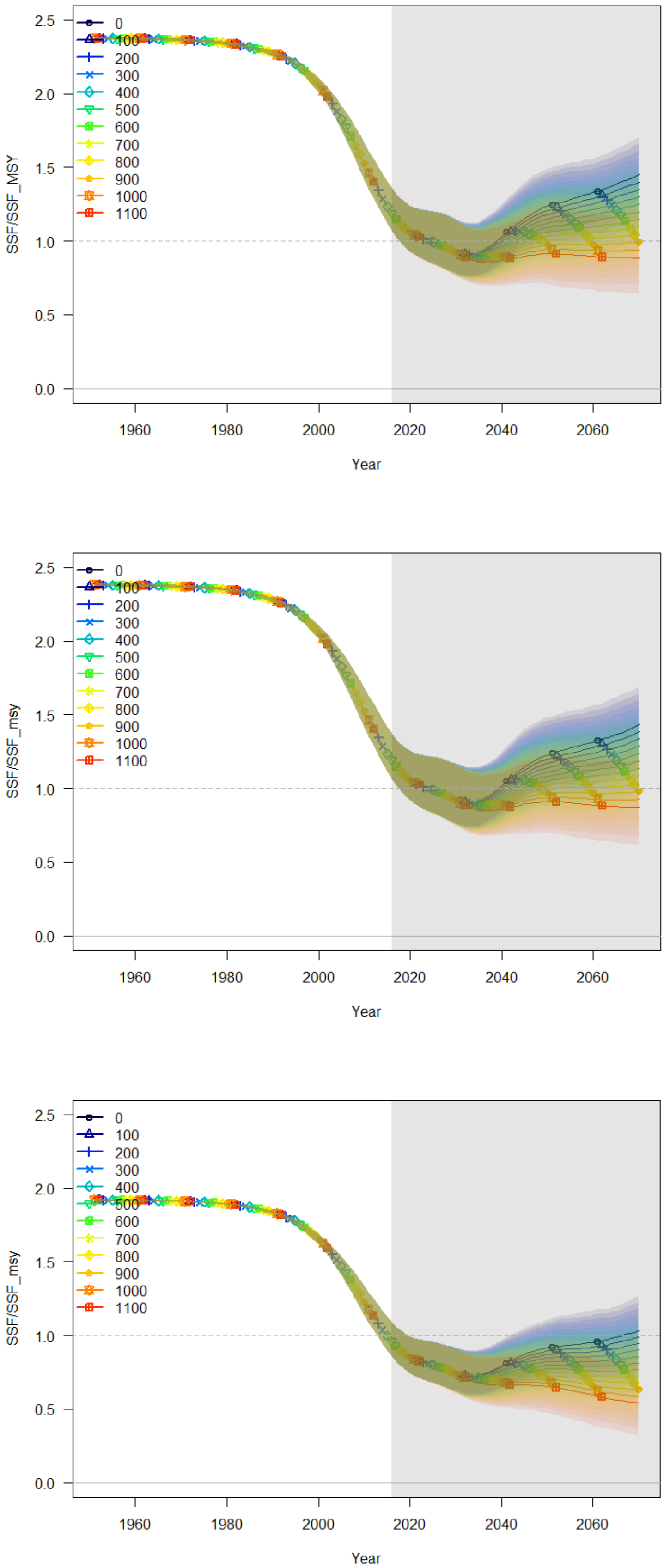

Figure 6. Projections from three Stock Synthesis model runs (SCRS/2019/082).

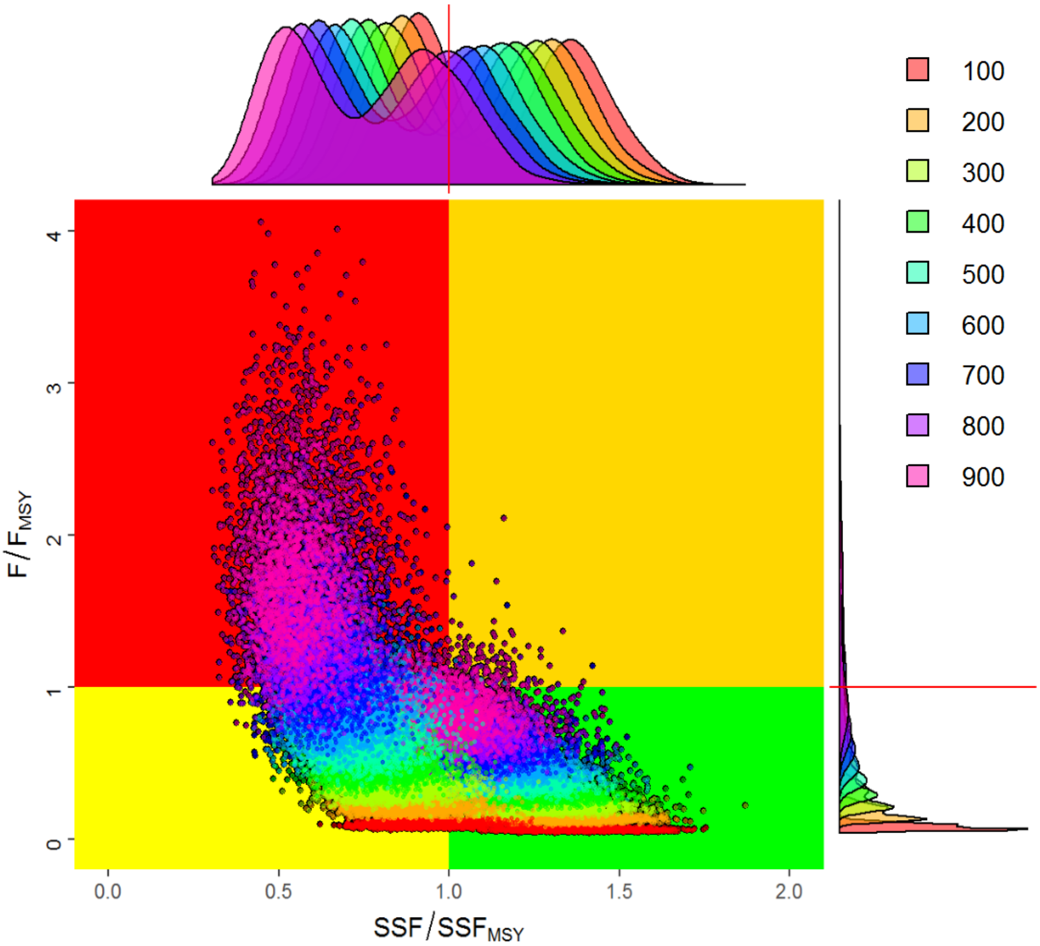

Figure 7. Delta-multivariate log normal distribution of Stock Synthesis model runs 1 and 3.

Appendix 1

Agenda

1. Opening, adoption of Agenda and meeting arrangements
2. Review of the activities and progress of the SRDCP
   - 2.1. Habitat use based on electronic tagging
   - 2.2. Post-release mortality
   - 2.3. Genetic analysis of shortfin mako in the Atlantic Ocean
   - 2.4. Movements, stock boundaries and habitat use of silky sharks and other species in the Atlantic Ocean
   - 2.5. Movements and habitat use of porbeagle in the Atlantic Ocean
   - 2.6. Work plan for 2020
3. Review of updated data from the Secretariat and new data received from national scientists, with special emphasis on shortfin mako and porbeagle sharks
   - 3.1. Task I data (nominal cathes)
   - 3.2. Task II data (catch & effort and size samples)
   - 3.3. Conventional Tagging data
   - 3.4. Indices of relative abundance
   - 3.5. Life history
4. Review of results of the ABNJ POR assessment for the Southern Hemisphere
5. Examine examples of diagnostics for Stock Synthesis model fit
6. Projections
7. Evaluate, to the extent feasible, the probability of success of the measures contemplated in ICCAT Rec. 17-08 through additional projections
8. Continue to review the effectiveness of potential mitigation measures to reduce by-catch and mortality of shortfin mako
9. Summary of Assessment projection results
10. Other matters
11. Recommendations
12. Adoption of the report and closure

Appendix 2

List of Participants

CONTRACTING PARTIES

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Appendix 3

List of Papers and Presentations

Reference	Title	Authors
SCRS/2019/008	Report of the Shortfin Mako Stock Assessment Update Meeting	Anon.
SCRS/2019/061	Impact of a stock synthesis version update on the outputs of assessment for shortfin mako in the north Atlantic Ocean	Kai M., and Courtney D.
SCRS/2019/082	Example of a stock synthesis projection approach at alternative fixed total allowable catch (TAC) limits implemented for three previously completed north Atlantic shortfin mako Stock Synthesis model runs	Courtney D., and Rice J.
SCRS/2019/083	Shortfin mako (*Isurus oxyrinchus*) fishery in the South of the Moroccan Atlantic waters	Baibbat S.A., Serghini M., Abid N., Ikkiss A., Joundoul S., and Houssa R.
SCRS/2019/084	Standardized catch per unit effort (CPUE) of shortfin mako (*Isurus oxyrinchus*) for the Moroccan longline fishery	Serghini M., Moustahfid H., Habiba H., Aziza L., Abid N., and Baibat S.
SCRS/2019/085	A comparison of the 2008, 2012 and 2017 assessments of the north Atlantic shortfin mako shark	Maguire J.-J., and Cortés E.
SCRS/2019/086	A SPiCT assessment of the north Atlantic shortfin mako shark	Maguire J.-J., and Berg C.W.
SCRS/2019/087	Preliminary estimates of population dynamics parameters of porbeagle shark in the western North Atlantic Ocean	Cortés E.
SCRS/2019/088	Examples of diagnostic methods implemented for previously completed North Atlantic Shortfin Mako Stock Synthesis model runs	Courtney D., Carvalho F., Winker H., and Kell L.
SCRS/2019/089	The effect of size regulations to protect immature north Atlantic shortfin mako	Kai M., Semba Y., Courtney D., and Rice J.
SCRS/2019/090	Updates on the habitat use and migrations patterns for shortfin mako in the Atlantic using satellite telemetry	Santos C.C., Domingo A., Carlson J., Natanson L., Travassos P., Macías D., Cortés E., Miller P., Hazin F., Mas F., Ortiz de Urbina J., and Coelho R.
SCRS/2019/091	Assessing the effects of hook, bait and leader type as potential mitigation measures to reduce bycatch and mortality rates of shortfin mako: a meta-analysis with comparisons for target, bycatch, and vulnerable fauna interactions	Rosa D., Santos C.C., and Coelho R.
SCRS/2019/092	Updated projections for the Bayesian Production model (BSP2JAGS) from the 2017 shortfin mako shark assessment	Babcock E.A., Cortés E., and O'Farrell H.
SCRS/2019/093	A rapid approach to approximate Kobe posteriors from Stock Synthesis assessment models with applications to north Atlantic shortfin mako	Winker H., Kell L., Fu D., Sharma R., Courtney D., Carvalho F., Schirripa M., and Walter J.

SCRS/2019/094	An overview of Namibian pelagic longline fishery for shortfin mako (*Isurus oxyrinchus*) in the southeast Atlantic Ocean	Jagger C.E., Kimoto A., and Frans E.
SCRS/2019/095	Summary of intersessional work completed with stock synthesis projections to evaluate a subset of the 2017 conservation measures recommended by ICCAT, related to TAC and size limits, to reduce mortality for north Atlantic shortfin mako	Courtney D., Kai M., Semba Y., and Rice J.
SCRS/2019/096	Updates on post-release mortality of shortfin mako in the Atlantic using satellite telemetry	Miller P., Santos C.C., Carlson J., Natanson L., Cortes E., Mas F., Hazin F., Travassos P., Macias D., Ortiz de Urbina J., Coelho R., and Domingo A.
SCRS/2019/097	CPUE and hooking mortality of shortfin mako (*Isurus oxyrinchus*) caught by longliners in the southwestern Atlantic	Mas F. , Forselledo R., Jimenez S, Miller P., and A. Domingo
SCRS/2019/098	Age-structured biomass dynamics of north Atlantic shortfin mako with implications for the interpretation of surplus production models	Winker H., Carvalho F., and Kerwath S.
SCRS/2019/101	Summary of intersessional work completed with the decision support tool to evaluate 2017 conservation measures recommended by iccat to reduce mortality for North Atlantic shortfin mako	Vaughan N., Babcock E. A., and Courtney D.
SCRS/2019/102	Stock synthesis projections at alternative fixed fishing mortaltity rates to evaluate the effect of live release	Courtney D., Kai M., and Rice J.

SCRS/P/2019/034	The pelagic longline fisheries from Vigo (Spain)	Biton-Porsmoguer S.
SCRS/P/2019/035	MVLN: A rapid approach for projections, too? Applications to North Atlantic Shortfin mako	Winker H.

Appendix 4

SCRS Documents and Presentations abstracts as provided by the authors

SCRS/2019/061 This document paper evaluates the effects of a Stock Synthesis version update from 3.24 to 3.30 on the outputs of the stock assessment base-case (Model 3) results for shortfin mako shark in the North Atlantic Ocean. The same values were compared between old and new versions for the biological parameters, fisheries data, and model parameters except for some new features only available in the new version. All results including the outputs of likelihood components, biological reference points, annual biomass, annual spawning stock fecundity, annual fishing mortality, and annual recruitment were almost identical between two versions. We also evaluated the effects of changes we made to the forecast settings by implementing them in the original model. The changes we made to the forecast settings had a minor impact on the recruitment likelihood (reduced by 0.76 likelihood units) due to turning on the estimation of late and forecast recruitment deviation from 2013 to 2016, which resulted in a small change in the main biological reference point model outputs (< 0.01% change) in the original model. We therefore concluded that there is no impact of the version update on the stock status of North Atlantic shortfin mako and recommend using the new version of SS (3.30.12 beta) with new settings of parameters for Model Run 3 in the future projection.

SCRS/2019/082 Stock Synthesis projections at alternative fixed total allowable catch (TAC) limits were implemented here for three previously completed North Atlantic shortfin mako shark Stock Synthesis model runs presented to the ICCAT Shark Working Group (Group) during the 2017 ICCAT Shortfin Mako Assessment Meeting. Model runs 1 and 2 were preliminary Stock Synthesis model runs presented during the 2017 meeting. Model run 3 was the base Stock Synthesis model run resulting from the 2017 meeting. The main difference between the 2017 Stock Synthesis model runs was that model run 3 utilized a low fecundity stock recruit relationship, while model runs 1 and 2 utilized the Beverton-Holt stock recruit relationship. Kobe II risk matrix probabilities produced here with MCMC for preliminary model runs 1 and 2 indicated that a fixed annual TAC limit of between 800 – 900 t resulted in ≥ 50% probability of being in the Kobe green zone (the joint probability of F < FMSY and SSF > SSFMSY) by 2070 (two generations). In contrast, a fixed annual TAC limit of 800 t for model run 3 indicated that the spawning stock size would likely stabilize below the level required to return the stock to a size that could support MSY by 2070. Model run 3 had a relatively lower initial ratio for SSF/SSFMSY and a relatively lower rate of recovery in SSF/SSFMSY over time during the projection period as a result of utilizing the low fecundity stock recruit relationship, which may explain the observed differences in the Kobe II risk matrix probabilities obtained for model run 3. All MCMC projection scenarios resulted in continued short term population declines regardless of the fixed TAC level used in future projections. Spawning stock size in the projections continued to decline after fishing pressure had been reduced because it took many years for the surviving recruits to reach maturity (female age at 50% maturity = 21 yr) and begin to contribute to the spawning stock size.

SCRS/2019/083 As in other parts of the world, in Morocco, the shortfin mako is caught mainly as bycatch by longliners targeting swordfish in the south of the Moroccan Atlantic waters. The research activities carried out to monitor shortfin mako fishery were based on biological sampling at landing ports and onboard longline vessels targeting this species. A total of four surveys were conducted during the period from April 2018 to April 2019 during which 1366 individuals were sampled. The results of this monitoring are presented in this paper.

SCRS/2019/084 Shortfin mako shark, *Isurus oxyrinchus* is harvested as bycatch by the Moroccan longliners targeting swordfish Xiphias gladius in the south of Moroccan Atlantic waters. A time series of standardized catch per unit effort (CPUE) for shortfin mako was estimated by first analyzing the fleet dynamic and identification of fishing tactics using multi-table method, and then using two statistical models, including Generalized Linear Models (GLM) and Boosted Regression Trees model (BRT) with main effects and two-way interactions. BRT with two-way interactions was selected as the best model to estimate CPUE with less RMSE and high PDE. The standardized CPUE analysis indicates a declining trend since the early years and slight increase and stability in the last four years of the time series.

SCRS/2019/085 The 2017 ICCAT stock assessment for north Atlantic shortfin mako suggested a substantial deterioration of the estimated stock status compared with the 2008 and 2012 stock assessments. ICCAT is updating catch projections in May 2019 to evaluate if further management measures are needed to ensure the sustainability of the North Atlantic shortfin mako fishery. This paper compares the data, methods and results of the three most recent assessments as background to the discussions to be held during the Shortfin Mako Stock Assessment Update Meeting in May 2019.

SCRS/2019/086 The 2017 ICCAT stock assessment for north Atlantic shortfin mako shark suggested a substantial deterioration of the estimated stock status compared with the previous assessments in 2008 and 2012. The ICCAT stock assessments were based on surplus production models (ASPIC and several implementations of Bayesian surplus production models) and Stock Synthesis 3 (SS3) was also used in the 2017 assessment. In this paper, we have applied a newly developed surplus production model in continuous time that the International Council for the Exploration of the Sea (ICES) has used to provide advice on stocks where only catch and one or more indices of stock size are available.

SCRS/2019/087 Vital rates and population dynamics parameters for use as inputs in stock assessment models were computed for the western North Atlantic population of porbeagle (*Lamna nasus*) based on existing and very recently published biological information. Vital rates included reproductive schedules and mortality schedules calculated with multiple estimators. Population dynamics parameters included the maximum population growth rate (rmax), generation time ($\overline{A}$), steepness of the Beverton-Holt stock-recruitment relationship (h), the position of the inflection point of population growth curves (R), and the spawning potential ratio at maximum excess recruitment (SPRMER). I used multiple methods to compute rmax: four age-aggregated methods and two age-structured methods. I used the age-structured Leslie matrix approach to incorporate uncertainty in growth parameters, maturity ogive, natural mortality, and lifespan to generate estimates of all quantities of interest. Estimated productivity ranged from rmax=0.046 to 0.059 yr-1for the six deterministic methods. For the stochastic Leslie matrix method, mean rmax was 0.051 yr-1(IQR=0.034 – 0.068), mean h was 0.36 (IQR=0.29 – 0.43), mean R was 0.66 (IQR=0.61 – 0.73), mean $\overline{A}$ was 16.9 years (IQR=16.2 – 17.3), and mean SPRMER was 0.68 (IQR=0.58– 0.79). These estimates can be used to formulate informative priors of rmax and the shape parameter in production models, steepness in age-structured/integrated stock assessment models, to inform the time horizon for projections in all models, and for potential use in data-limited stock assessment approaches.

SCRS/2019/088 This paper presents a range of model diagnostics for three Stock Synthesis assessment models (model runs 1, 2, and 3) of North Atlantic shortfin mako shark that had previously been presented to ICCAT's Sharks Species Working Group during its 2017 meeting. The objectives of this paper were to evaluate stock assessment model fit to data, identify possible model misspecifications, and evaluate model prediction skill by implementing the following nine diagnostic approaches. (1) Simultaneous visualization of residuals from multiple catch per unit effort (CPUE) indices using JABBA residual plots indicated comparable goodness of fits for all three model runs. (2) Runs tests applied to individual CPUE and (3) runs tests applied to size composition data showed no evidence for undesirable, systematic patterns in residuals. (4) Runs tests applied to estimated recruitment deviations suggested rejecting the hypothesis of randomly distributed recruitment deviations in model runs 1, 2, and 3 ($p < 0.05$). (5) Retrospective analyses showed no evidence of strong retrospective patterns and were fairly consistent among scenarios. (6) Inspection of likelihood component profiles for the influential virgin recruitment parameter R0 pointed towards some conflict between size composition data and the CPUE indices, with implications for data weighting. (7) A deterministic age-structured production model diagnostic analysis showed that the estimated catch-at-age and fixed productivity parameters (growth, mortality, and stock-recruitment relationship implemented without annual recruitment deviates) were not able to explain trends in the CPUE indices, which indicated that the abundance information contained in the CPUE indices could not be interpreted without accounting for the fluctuations in recruitment. (8) MCMC diagnostics indicated that the chains mostly converged, but suggested that the shorter MCMC chains used for run 3 may not have been sufficient to achieve full convergence. (9) A hind-cast cross-validation diagnostic identified that all three models had poor prediction skill for two of the five indices. An explanation may be that either the indices are not proportional to relative abundance or that there are processes that are not being accounted for in the model structure. In the latter case this could be due to recruitment dynamics, or changes in spatial and temporal distribution or catchability. This could be investigated by considering a range of scenarios based on alternative datasets and model structures using hindcasting which is not possible using traditional methods such as AIC.
SCRS/2019/089 This document evaluates the effects of a size regulation on the recovery of spawning stock fecundity to the target level using the forecast of stock assessment base-case model (Model 3 with Stock

Synthesis version 3.30.12 beta) for shortfin mako shark in the North Atlantic Ocean. We compared the scenarios with and without size regulation under different total allowable catches. We found that the spawning stock fecundity (SSF) could not reach to the MSY level until 2070 even if the TAC was set to zero with and without size regulation. We also found that the TAC with size regulation accelerated the recovery of the SSF. These results suggested that the size regulation is a useful tool to increase the speed of the recovery under the management by TAC.

SCRS/2019/090 This paper provides an update of the study on habitat use for shortfin mako, developed within the ICCAT Shark Research and Data Collection Program (SRDCP). A total of 43 tags (29 miniPATs and 14 sPATs) have been deployed by observers on Portuguese, Uruguayan, Brazilian, Spanish and US vessels in the temperate NE and NW, Equatorial and SW Atlantic. Data from 41 tags/specimens is available, and a total of 1656 tracking days have been recorded. Results showed shortfin mako sharks moved in multiple directions, travelling considerable distances. Shortfin mako sharks spent most of their time above the thermocline (0-90 m), between 18 and 22 °C. The main plan for the next phase of the project is to continue the tag deployment during 2018 in several regions of the Atlantic.

SCRS/2019/091 A meta-analysis of 24 publications was conducted to assess effects of hook, bait and leader type on retention rates of target, bycatch and vulnerable species of the pelagic longline fishery. Retention rate and at-haulback mortality rate analyses considered hook type, bait type, the combination of both variables and leader type. Turtles and swordfish had a lower retention rate with circle hooks. In contrast, retention rates of 3 sharks and 2 tuna species were greater with circle hooks. Bait type alone did not seem to significantly influence the retention rates of most of the species examined. Results were mixed when considering the combined effects of hook and bait type. Wire leader lead to a decrease in retention rates of bony fishes and a mix for elasmobranchs. For at-haulback mortality, hook type was the most influential, while bait type only influenced blue shark at-haulback mortality. Leader type did not have a significant effect. The results presented here should be considered preliminary. Future work will consider information on at-haulback mortality rates for bony fishes and sea turtle and expanded information on fishery characteristics.

SCRS/2019/092 The Bayesian Surplus Production (BSP) using JAGS (BSP2JAGS), which was used for the north Atlantic population in the 2017 ICCAT shortfin mako assessment was revised to include updated catch data through 2017, a wider range of TACs used in the projections and a longer projection time period. The current year was updated to 2018. The model found that the population has probably decreased over the last two years, and the projections are more pessimistic than they were in the 2017 assessment.

SCRS/2019/093 The Kobe phase plot provides probabilistic statements about the stock status and is a prerequisite for formal scientific advice in tuna RFMOs around the world. In this paper, we present a detailed documentation of the delta-multivariate log-normal (delta-MVLN) method that enables to rapidly produce Kobe posteriors from the complex Stock Synthesis stock assessment model runs. We evaluate the performance of the method by comparing Markov Chain Monte Carlo (MCMC) Kobe posteriors from Bayesian surplus production models with the delta-MVLN Kobe posteriors for four tuna and billfish stocks. The results suggest that MVLN method can provide, in principle, reasonable approximation of the within-model uncertainty about the stock status. Applications of the delta-MVLN method to Stock Synthesis outputs for North Atlantic shortfin mako produced comparable results to MCMC for Run 1, but showed notably increased divergence between the Kobe posterior distributions for the current base-case model Run 3, with somewhat differing inference about the stock status. In this specific case, this difference points towards convergence issues of the MCMC. We suggest that comparing results from delta-MVLN and MCMC can provide a useful diagnostic for validation of assessment models as differences can be indicative of data conflicts and problems caused by data conflicts and model specifications. While our results provide support for the utility of the delta-MVLN, we recommend further comparisons between delta-MVLN and MCMC and bootstrap approaches should be conducted and preferably complimented with simulation-testing experiments.

SCRS/2019/094 The catch and effort data for shortfin mako caught by the Namibian pelagic longline fleet for the period of 2004-2017 were retrieved from logbooks and analyzed. Various information were provided in this document including the nominal CPUEs. Main tuna longline fishing seasons are from November to May however catches of shortfin mako occurred all year round and there is no closing season as compared to other fisheries in Namibia. The longliners mostly operated in and close to the Namibian EEZ, but also in international waters. The overall nominal CPUEs showed an increasing trend from 2004 to 2017.

After the peak in 2011, the nominal CPUEs remained at a higher level in the recent 7 years compared to the one before 2010. It was also observed the CPUEs were much smaller in the offshore water than in the EEZ. The next step is to standardize this CPUE by taking into account various factors. This will be a good contribution to the stock assessment of shortfin mako in the South Atlantic.

SCRS/2019/095 Stock Synthesis projections were developed intersessionally to evaluate the effectiveness of a subset of the 2017 conservation and management measures recommended by ICCAT, related to TAC and size limits, to reduce North Atlantic shortfin mako shark mortality in association with ICCAT fisheries and to rebuild the stock to the MSY level. All projection scenarios for the base case model (run 3) resulted in continued short term population declines regardless of the fixed TAC level used in future projections. Spawning stock size in the projections, spawning stock fecundity (SSF), continued to decline after fishing pressure had been reduced because it took many years for the surviving recruits to reach maturity (age at 50% maturity = 21 yr) and begin to contribute to the SSF. For the base case, projections of SSF/SSFMSY appeared to stabilize at a stock size below MSY by 2070 with a fixed TAC of 800 t. Fixed TAC levels > 800 t are projected to result in a declining trend of SSF/SSFMSY by 2070, and Fixed TAC levels < 800 t are projected to result in an increasing trend of SSF/SSFMSY by 2070. A Kobe II risk matrix for the base case indicated that SSF would be likely to reach the level required to return the stock to a size that could support MSY by 2070 (around two mean generation times) with greater than 50% probability only at a fixed annual TAC limit of <100 t. For the base case, the recovery of SSF was accelerated by size limit regulations to protect immature shortfin mako. However, the SSF did not reach the MSY level by 2070 even with size limit regulations and a fixed TAC set to zero. These results suggest that while the TAC and size limit regulation are useful to reduce the mortality, these management measures may be insufficient to rebuild the stock to the target level within the ICCAT time frame. In consideration of the nature of the fisheries for shortfin mako (i.e. bycatch species) and recent high level of the annual catches (around 3000 t), other proposed management measures, such as live release, may be practical measures to reduce fishing mortality. However, the effects of implementing live release management measures were not evaluated intersessionally with projections due to time constraints. The effect of circle hooks was also not evaluated intersessionally. Model uncertainty should also be considered when interpreting these projection results. The use of different model assumptions or the use of different modeling frameworks may lead to different projection outcomes.

SCRS/2019/096 This paper provides an update of the study on post-release mortality of the shortfin mako, Isurus oxyrinchus developed within the ICCAT Shark Research and Data Collection Program (SRDCP). Up to date, 43 tags (14 sPATs and 29 miniPATs) have been deployed by observers on Brazilian, Portuguese, Spanish, Uruguayan, and US vessels in the temperate NE and NW, Equatorial and SW Atlantic. Data from 35 out of 43 tagged specimens could be used to obtain preliminary information regarding post-release mortality, resulting in a total of 8 mortality and 27 survival events.

SCRS/2019/097 This document presents preliminary results comparing shortfin mako CPUE and hooking mortality between longline fishing vessels with different gear configurations, namely: deep vs. shallow sets, and fishing sets using reinforced stainless-steel branch-lines vs. simple monofilament branch-lines. All data analyzed was gathered by the Uruguayan National observer Program form DINARA. Comparisons of CPUE between deep and shallow fishing sets was assessed by analyzing Japanese and Uruguayan longline fishing vessels operating in the southwestern Atlantic Ocean. Within the Uruguayan longline fleet, the use of reinforced branch-lines in some vessels and the use of nylon monofilament branch-lines in others also allowed the comparison of both CPUE between these different configurations of shallow longline fishing sets. General additive model (GAM) results suggests that shortfin mako CPUE is considerably lower in deep fishing sets from Japan compared to shallow fishing sets from Uruguay. Among Uruguayan fishing vessels, those fishing with reinforced stainless-steel branch-lines yielded slightly higher (although significant) catch rates than those using monofilament branch-lines. Model results also indicated higher catch rates at intermediate sea surface water temperatures (21-22°C) and close to the external continental shelf and shelf break. Generalized linear mixed models (GLMM) results suggests that hooking mortality of the shortfin mako was affected by size and mean sea surface temperature but not by sex. Hooking mortality did not differ among Uruguayan fishing vessels using different branch-line types but was considerably lower in deep-water fishing sets from the Japanese fleet compared to shallow water sets form Uruguay. Although these results should be considered preliminary and further analysis are needed, this document highlights the potential effects of deep vs. shallow longline sets, as well as different branch line configurations, over the CPUE and hooking mortality of the shortfin mako.

SCRS/2019/098 The development of a Stock Synthesis model for North Atlantic shortfin mako (*Isurus oxyrinchus*) in 2017 has resulted in substantially more pessimistic inference about stock status and future projections when compared to previous assessments for this stock. Here, we aim to uncouple the key drivers of the underlying age-structured population dynamics of the 2017 Stock Synthesis base-case model. The population dynamics reveal an unusual combination of steep dome-shaped selectivity and very late maturation, resulting in a strong lag-effect between the exploitable and reproductive component of the stock. Fisheries mortality predominantly impacts on the sub-adults, whereas fishing mortality is expected to be low for larger adults, in particular the mature females. The dome-shaped selectivity represents a mechanism to propagate the stochastic recruitment variation into the observed CPUE trends, which can lead to biased results when using age-aggregated surplus production models (SPMs). By ignoring the lag effect, earlier SPM assessments have probably contributed to false perception about the long-term sustainability of the fishery. Even the 2017 state-space SPM implementation with informed priors likely overestimated the rebuilding potential. Continuity runs carried out in SPMs JABBA and BSP2 provide a useful tool to track the rebuilding of sub-adult biomass in response to potential intervention measures, but but SPMs cannot be used for future projections and related scientific advice for stocks where vulnerable biomass and 'Spawner' biomass are disjointed.

SCRS/2019/101 DST projections were developed intersessionally to evaluate the effectiveness of a subset of the 2017 conservation and management measures recommended by ICCAT to reduce North Atlantic shortfin mako shark mortality in association with ICCAT fisheries and to rebuild the stock to the MSY level. All projection scenarios where run for the Stock Synthesis base case model (run 3). The projections included a size limit and a policy of live releasing a fraction of the catch. Because these policies caused dead discards, the retained catch had to be reduced to reduce total mortality. The effectiveness of the policies depended on the assumed discard mortality and fraction retained. Accurate estimates of these values for each fleet are needed.

SCRS/P/2019/034 Blue shark (*Prionace glauca*) and shortfin mako *(Isurus oxyrinchus*) are species exploited by the Spanish and Portuguese longline fleet. They land sharks in the fish market at Vigo (Spain). The number of longliners decreased between 2004 and 2016 (less 15 boats). Landings of shortfin mako have decreased and those of blue shark increased between 2001 and 2016. In accordance with ICCAT informs, the blue shark stock is not overexploited. But it is for shortfin mako in the North-eastern Atlantic Ocean. The sharks landed in a fish market are mainly juvenile, the maturity age being late for both species. The authorities must establish measures to reduce fishing pressure. Pelagic sharks (blue shark *Prionace glauca* and shortfin mako *Isurus oxyrinchus*) caught by long-line Spanish and Portuguese fleets in the NE Atlantic, were sampled at Vigo fish market (Spain) for total mercury (Hg) analysis. Hg concentration in white muscle increased with size and weight in both species, but at a higher rate in shortfin mako than in the blue shark. No difference was found with sex, year and season. Spatial variation was observed in the blue shark with higher Hg values in the North of the Azorean archipelago, but not in the shortfin mako. These high-level predators are particularly susceptible to bioaccumulate contaminants (Hg) in their tissues (muscle). However, a significant positive relationship between Hg concentration and trophic level (δ15N) of individuals was observed only in the shortfin mako. Most sharks landed were juveniles which presented Hg concentration lower than the maximum limit allowed by the European Union (1 mg kg−1 wet weight) for marketing. However, concentrations above this threshold were most recorded in blue sharks larger than 250 cm total length (TL) and in shortfin makos larger than 190 cm TL, raising the question of the commercialization of large-sized individuals.

SCRS/P/2019/035 Abstract not provided by the author

Appendix 5

Executive Summary of the Southern Hemisphere porbeagle shark (*Lamna nasus*) stock status assessment

WCPFC-SC13-2017/SA-WP-12 (rev. 2)

This report presents the results of a Southern Hemisphere stock status assessment of porbeagle shark. The study, along with associated regional studies, was a collaborative one involving many countries with Southern Hemisphere fisheries that catch porbeagles. Participating scientists from Argentina, Chile, Japan, New Zealand and Uruguay contributed data analyses and abundance indices. Our approach combined indicator analyses and a spatially-explicit sustainability risk assessment. Indicator analyses were performed independently for different Southern Hemisphere fisheries and served to characterise local trends in relative abundance based on commercial catch per unit effort (CPUE) data, and trends in size and sex ratio based on biological data.

We limited our analyses to the region south of 30 oS which provided most of the available data, although the porbeagle shark's range extends slightly north of this latitude. Porbeagle sharks are taken in fisheries at least as far south as 56 oS. Southern Hemisphere population structure is not well understood, and we considered it unlikely that the population comprises a single well-mixed stock for management purposes. We subdivided the spatial domain of the assessment into five subpopulations or regions by longitude: 1) Western Atlantic Ocean; 2) Eastern Atlantic/Western Indian Ocean; 3) Eastern Indian Ocean; 4) Western Pacific Ocean; and 5) Eastern Pacific Ocean.

We applied different assessment methods by region, depending on data availability and quality. In the Eastern Atlantic/Western Indian Ocean, Eastern Indian Ocean, and Western Pacific regions, stock status assessment was performed using a spatially-explicit risk assessment. Indicator-based analyses were used to assess stock condition in the Eastern Pacific and the Western Atlantic, where there was limited information. We compared results from areas with varying levels of information, for greater insight into the status of the stock, levels of uncertainty, and data requirements for future studies.

Public domain surface longline data were obtained at a resolution of 5 x 5° grid by month by flag from regional fishery management organisations. Catch and effort data were also obtained from other trawl and longline fisheries known to take porbeagle sharks. Japanese observer data on catch and effort throughout the Southern Hemisphere were analysed to determine relationships between catch rates and the covariates year, quarter, latitude, hooks between floats, hooks, and sea surface temperature. These relationships were then used to predict relative abundance across the entire spatial domain, and combined with effort to predict surface longline catches. Catch estimates for other fisheries were obtained from the literature.

Most catch rate indicators were relatively short, variable, and uncertain, with the majority either stable or increasing. Length indicators were also variable. Only the Argentinian size and sex indicators showed temporal trends, with a small decline in sizes for both sexes, and a slight trend towards less female bias in the sex ratio index.

The indicator analyses, in addition to providing time series to monitor population change, revealed spatial patterns in size and sex distributions, and relationships with environmental variables. Such analyses are critical inputs to stock status assessments, because they help to determine model structure.

The risk assessment uses a quantitative framework to estimate spatially-explicit fishing mortality. It derives sustainability status as the ratio of total impact to a maximum impact sustainable threshold (MIST) reference point. The quantitative framework quantifies and propagates uncertainty throughout the assessment process. The risk assessment served to integrate selected CPUE indicators in the evaluation of risk from commercial pelagic longline fisheries to porbeagle shark, within an area subset of the Southern Hemisphere. The spatial domain of the risk assessment covered three regions: Eastern Atlantic/Western Indian Ocean, Eastern Indian Ocean, and Western Pacific Ocean, bounded at 30 oS and 60 oS. The Eastern Atlantic/Western Indian Ocean region was selected as the 'calibration region', being the most data-rich. A biomass dynamic model was fitted to the estimated catch and the abundance index for the calibration area. The model estimated a catchability parameter for the pelagic longline effort, which was used to estimate fishing mortality for the calibration area, and extended to other model areas.

Annual fishing mortalities (F) were greatest in the Eastern Atlantic/Western Indian Ocean, slightly lower in the Eastern Indian Ocean, and lowest in the Western Pacific Ocean. Median F decreased from the mid-1980s to 2014 in both the Eastern Atlantic/Western Indian Ocean and Eastern Indian Ocean regions. In the assessment area (three regions combined) in the last decade (2005 to 2014), median F values ranged from 0.0008 to 0.0015 (mean 0.0010).

Risk was determined from the relationship between total impact and the MIST limit reference point for the stock. We reported against three MIST values: Fcrash, which is the instantaneous fishing mortality that will in theory lead to population extinction; Flim, the instantaneous fishing mortality rate that corresponds to the limit biomass Blim; and Fmsm, instantaneous fishing mortality rate that corresponds to the maximum number of fish in the population that can be killed by fishing in the long term. Risk values were calculated both as an F-ratio (Impact/MIST) and the probability that F exceeds the MIST, for the period from 1992 onwards (the first year of Japanese CPUE data).

F-ratios for the assessment area declined by half from a 1992–2005 mean for the Fcrash MIST of 0.068 (range 0.051–0.088), to a 2006–2014 mean of 0.032 (range 0.023–0.042). For the Flim MIST the equivalent numbers were 0.090 (range 0.068–0.118) in 1992–2005 and 0.043 (range 0.031–0.056) in 2006–2014. For the Fmsm MIST the F-ratios were 0.135 (range 0.102–0.176) in 1992–2005, and 0.063 (range 0.046–0.083) in 2006–2014.

The probability of F exceeding the Fcrash MIST decreased by 95% from a 1992–2005 mean of 0.0084 (range 0.0015–0.0205), to a 2006–2014 mean of 0.0004 (range 0.0000–0.0013). The probability of F exceeding the Flim MIST similarly decreased from a 1992–2005 mean of 0.0183 (range 0.0073–0.0358), to a 2006–2014 mean of 0.0016 (range 0.0005–0.0040). The probability of F exceeding the Fmsm MIST decreased from a 1992–2005 mean of 0.0452 (range 0.0213–0.0778), to a 2006–2014 mean of 0.0066 (range 0.0023–0.0133).

In the last 10 years, the southern bluefin tuna (SBT) and albacore/SBT fisheries combined contributed about 75–80% of the fishing mortality in the Western Indian Ocean/Eastern Atlantic Ocean, 70–90% in the Eastern Indian Ocean, and 70–85% in the Western Pacific Ocean.

Thus, results from the risk assessment indicate low fishing mortality rates in the three regions comprising the assessment area, and low risk from commercial pelagic longline fisheries to porbeagle shark over the spatial domain of the assessment. These results are consistent with the trends observed in catch rate indicators over the entire Southern Hemisphere range of the porbeagle shark population, which in most cases show stable or increasing catch rates. Concern has previously been expressed about reduced catch rates in the Western Atlantic Ocean in the Uruguay longline fishery after 1993, but this concern is allayed by the re-analysis undertaken in collaboration with this project.

The population catchability was calibrated assuming that capture mortality was 100% (i.e., post- release survival is zero). Allowing for post-release survival would reduce these fishing mortality estimates, and reduce the estimated risk.

The catch rate indicators are the most important factors driving the results of the status assessment, and their reliability determines its reliability. The indicator trend in the calibration area is the most important factor determining the relatively low estimate of risk.

The risk assessment assumes that population density from 45 to 55 oS is the same as at 40 to 45 oS, and that density south of 55 oS is zero. We have evidence from fisheries and surveys that porbeagles occur south of 45 oS, but we do not have Japanese longline observer data with which to estimate density. This is an important assumption, because it implies that the low fishing effort south of 45 oS provides a refuge from fishing mortality for the population. Biological data, and estimated relationships between size and sea surface temperature, suggest that a high proportion of the adult population occurs at these latitudes.
Continued data collection by observers will improve the time series and provide better evidence about abundance trends. Maintaining collection and analysis of indicators from observer data is a key recommendation from this project. The following analyses could be carried out with currently available data:

- Explore assumptions about population density distribution and their effects on risk estimates, by rerunning the assessment with alternative density estimates.
- Explore selectivity at age in the Japanese pelagic longline data, which may permit estimation of the availability at age of the population to fishing. This analysis may permit two further developments: an age-structured analogue of the biomass dynamic risk assessment; and direct estimation of the proportion of the population south of 45 oS, removing the need to assume constant density from 45 to 55 oS.
- Further explore available biological data, to understand why patterns differ among areas. For example, it would be useful to model the effects of SST on size and sex patterns in the Chilean swordfish fishery.

The following recommendation would require further data collection:

- Compile biological and catch rate data from fisheries occurring south of 45 oS, such as the Chilean demersal longline fishery. Some data from this fishery are currently available, and data collection is ongoing.

The following recommendation would require additional, separate studies:

- Study porbeagle distribution using various tool (genetics, microchemistry, stable isotopes, parasites, conventional and electronic tags) to identify biologically-based boundaries.

The multiple indicators/risk assessment approach used in this study served to 1) source and synthesise available information on porbeagle shark at the scale of the Southern Hemisphere; 2) identify important data gaps (e.g., density distribution and life-stage specific vulnerability and overlap with fishing activities); 3) define a productivity-based reference point for the species; and 4) prioritise fishery areas for monitoring and management. This project has filled important information gaps by both directly analysing available life history information, and providing statistical support to the analyses by participating national fisheries scientists.

The project has provided the first assessment of the sustainability of the impact of fishing on the Southern Hemisphere porbeagle shark stock, and laid a foundation for future work. Results indicate that the impact of fishing is low across the entire Southern Hemisphere range of the porbeagle shark population.