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PLAUSIBILITY AND UNCERTAINTY OF BASIC DATA AND PARAMETER SELECTION ON STOCK ASSESSMENTS: A REVIEW OF SOME INPUT DATA USED IN THE 2017 ASSESSMENT OF THE SHORTFIN MAKO (*ISURUS OXYRINCHUS*) OF THE NORTHERN ATLANTIC STOCK

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SUMMARY

Three key-elements for the case of shortfin mako used in 2017 assessment of North Atlantic stock are reviewed. The catch scenarios implemented indicate that historical T1 considered in base case scenario (C1) have greatly underestimated the level of catches during several of the initial decades, taking into consideration the history of the fisheries, fleet's capacity and fishing effort by fleet. A hypothetical catch scenario also used (C2) probably overestimated in an important amount the catch levels of some fleets and fleets combined for the most recent period of that series. The review of CPUE series suggests that there may be qualitative and/or quantitative limitations in some of them which would likely affect some series being considered as indicators of abundance. Some key biological parameters considered in the assessment are also reviewed and discussed, such as the growth model implemented and the age of first reproduction of the females, within a context compared to other studies, preliminary estimations from tagging-recapture data and those parameters applied in other stock of the same specie, and in other species from the same family.

RÉSUMÉ

Trois éléments clés utilisés dans l'évaluation de 2017 du stock de requin-taupe bleu de l'Atlantique Nord sont révisés. Les scénarios de capture mis en œuvre indiquent que la tâche 1 historique considérée dans le scénario de base (C1) a largement sous-estimé le niveau des captures pendant plusieurs des premières décennies, compte tenu de l'historique des pêcheries, de la capacité des flottilles et de l'effort de pêche par flottille. Un scénario de capture hypothétique également utilisé (C2) a probablement surestimé de manière importante les niveaux de capture de certaines flottilles et de flottilles combinées pour la période la plus récente de cette série. L'examen des séries de CPUE suggère qu'il peut y avoir des limitations qualitatives et/ou quantitatives dans certaines d'entre elles, ce qui affecterait probablement quelques séries considérées comme des indicateurs d'abondance. Certains paramètres biologiques clés pris en compte dans l'évaluation sont également examinés et discutés, tels que le modèle de croissance mis en œuvre et l'âge de la première reproduction des femelles, en comparaison avec d'autres études, des estimations préliminaires issues de données de marquage-recapture et ces paramètres appliqués à d'autres stocks de la même espèce et à d'autres espèces de la même famille.

RESUMEN

El caso de tres elementos clave usados en la evaluación del 2017 del marrajo dientuso del stock de Atlántico Norte son revisados. La revisión de los escenarios de captura indica que la T1 histórica considerada (escenario C1) ha estado muy subestimada durante varias décadas iniciales, considerando la historia de las respectivas pesquerías, la capacidad de las flotas y el esfuerzo de pesca histórico. Un escenario hipotético de capturas usado (C2) probablemente sobreestimó de forma importante el nivel de capturas de algunas de las flotas y de las flotas combinadas para los años más recientes de esa serie. La revisión de las series de CPUE sugiere que algunas de ellas probablemente no reunían suficientes meritos cualitativos y/o cuantitativos como para ser considerados indicadores de abundancia de este stock. Se revisan y

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discuten algunos de los parámetros biológicos básicos considerados en la evaluación, tal como el crecimiento y la edad de primera reproducción de las hembras; dentro de un contexto comparado con otros estudios, nuevas aproximaciones preliminares de datos de marcado-recaptura, aquellos parámetros de crecimiento aplicados en recientes evaluaciones de otros stocks de esta misma especie, así como de otras especies de la misma familia.

KEYWORDS

Shortfin mako, uncertainty, input data, catch, effort, standardized CPUE, growth, reproduction

1. Introduction

Uncertainties surrounding stock assessments are regularly described in the literature as ranging from the collection of basic data and processes implemented by the respective CPC to the selection and assumptions of a variety of parameters, assessment models and their interpretation for the management advice. However, the uncertainties may also be caused in some cases by working protocols and decisions taken during the assessment process on the limited data available and some parameters assumed as unique and reliable. Misspecification of key parameters or assumptions in assessments can strongly impact the estimates of quantities of management interest, such as stock depletion and biomass at maximum sustainable yield (Mangel *et al*. 2013). These misspecifications could include some incorrect assumptions of important basic data and parameters implemented (Carvalho *et al*. 2021). Base cases and assessment outlooks should be defined based on robust pre-analyses and deep discussions of those main key-elements. However, main emphasis could have been placed in some cases on statistical refinement procedures rather than on the previous analysis and verification of the most basic elements to achieve plausible assessments.

Fisheries science manuals indicate three main key-elements for the assessment of exploited fish stocks assessment[2]. "*A*": those related to the estimation of the ***A**bundance* over the years -or indicators of relative abundance over time-; "*B*": the variables that define the ***B**iology* of the species-stock and "*C*": the ***C**atches* taken by the fleets so that a certain relationship can be established between the fishing intensity applied to the stock and the catch obtained over the years, although this last relationship is more difficult to be sustained in bycatch species. In order to achieve each of these three key-elements combined strategies and robust methods have to be implemented to obtain reliable data in addition to establishing duly supported research programs. To ensure high quality stock assessments the data used must be accurate, representing the degree of approximation to the true values. Regardless of the assessment models applied in each species-stock and their adaptation to each species, these three elements cited are usually the basis on which the assessment of tuna and tuna-like stocks has been undertaken in ICCAT. The plausibility of the scientific assessments (diagnoses on the status of the stocks, management recommendations and recovery plans) has depended in many species on the reliability to keep the fish stocks (targeted, bycatch or mixed) in equilibrium. The implemented management actions also largely depend on these three elements. Obtaining the right diagnoses of the state of the stocks from a solid basis is no minor matter nor a mere mathematical or academic exercise since it depends not only on the sustainability of the fish stocks and ecosystems but also on the healthy food production and economic and social subsistence of many fishing communities.

In the case of assessments of bycatch fish species, assumptions identical or similar to those applied for the target species are usually considered. This has been a source of old scientific debates that has extended to the present day, especially in the case of some bycatch fish species of low or medium prevalence such as some of large pelagic highly-migratory sharks for which ICCAT has been recently responsible for the study, assessment and management; given that it is not easy in many cases to estimate e.g. maximum population growth rates using traditional methodologies and historical catch levels are in some cases highly uncertain. The resulting general conclusion, that only extremely low fishing mortality can be tolerated in all these species and that a modest level of bycatch may lead to stock collapse and possible extinction, could be untenable in some cases due to data limitations or the fact that the analysis is logically flawed (Gedamke *et al*. 2007).

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[2] https://www.fisheries.noaa.gov/topic/population-assessments#fish-stocks

A fourth element that should also be pointed out within an assessment process are the model/s selected in each case, their respective methodological assumptions, the internal configuration of the processes and the weighting criteria applied to each data; as well as the necessary accuracy in the adaptation to the biological characteristics and behavioral dynamics of these highly migratory shark species that are usually different in relation to many others, such as in the case of many bony fish. The type of models selected should be adapted to the characteristics of the species as well as to the available data considered as plausible and reliable. Models can shed light on some aspects that intuition or experience alone may not detect, but in no case should they go beyond what reliable data allows except to test hypotheses, analyze sensitivities or be regarded as numerical exercises; but acknowledging limitations that may exist in the conclusions reached on those exercises or in projections made under uncertain data, hypothetical assumptions or unrealistic time scenarios.

In some species assessed by ICCAT and other tRFMOs, and specifically on bycatch species, there may have been limitations of knowledge insofar as basic data and biological parameters are concerned due to difficulties inherent in these highly migratory species and/or because of the lack of studies, very diverse results or a lack of full validations. Conclusions on basic biological parameters of a stock may be subject in some cases to methodological debate, by having used samples from restricted geographic areas or with few representative sample sizes trying to generalize results achieved, or for not having robust or validated methods and results, with effects on the diagnoses of the assessment models according to whether one or other parameters are assumed. For these reasons, the order of priority of the three “ABC” key-elements may be different in some species-stocks assessed by ICCAT. Assessment models currently used from the sixties of last century have first considered as main input data the reliable catch levels, the nominal effort applied by the fleets over the years and the size-frequency distribution of the catches. Subsequently, age-structured models and production models also focused on "*indices of relative abundance*" have been also incorporated whose indices considered were generally obtained in fleets with a large space-time coverage and considered representative in relation to the stock distribution and/or their representative fractions. Based on these premises, these indices may or may not be included in the assessment models or weighted according to the qualitative-quantitative merits they provide in order to be considered "*representative*" of the stock’s abundance. More recently, ICCAT has incorporated in the assessment, amongst others, Bayesian production models (BSP or similar) and Stock Synthesis models with currently a more restricted number of potential users, with more demanding input data and assumptions and on a very urgent work dynamic. A little discussion upon uncertain or implausible input data, or upon estimates under preliminary or uncontested hypotheses, could be assumed in some cases.

It is a desirable premise in an assessment process to positively value what is considered most plausible and representative from a quantitative and qualitative point of view. Indicators of relative abundance, when obtained from reliable data with wide area-temporal coverage and/or through intensive scientific monitoring, are probably one of the best and most reliable data on the trend of a stock or its fractions over the years; regardless of the fit that these indices later show in relation to the models that could be built in some cases from simple untenable or contradictory data. The CPUE data which are considered representative and qualitatively robust can directly be very informative about the trends of a stock over time and serve to validate those results obtained from previous models built, instead of considering these CPUE the object of validation based on the result of a model built with untenable data or incorrect assumptions. But sometimes standardized CPUE series that would probably not meet the conditions as to be considered "*indicators of relative abundance*" of the whole stock or its fractions could also be applied within models. Regularly, "*indicators of relative abundance*" and the weight assigned to each were usually assessed before the implementation into models (e.g. Anon. 2020[b]), but not always. The results of an assessment may be influenced by uncertain or even implausible catch data or by a set of contradictory CPUE indicators quantitatively and qualitatively very diverse which can be considered indicators of abundance and weighted according to different criteria or prioritizations. Indicators obtained from few data and/or with important limitations could in some cases have a better fit -or allow greater flexibility- within models tested and considered useful and more informative than those with much greater representativeness of the stock as a whole. The results of the models should be also subject to rational interpretation and empirical validation in the context of species biology, the history of the fisheries and their reliable historical catch levels, not just based on a mere statistical interpretation or model diagnosis. Bearing the above in mind, the knowledge of the biology of the species, the fisheries and their history are essential elements in order to focus assessments and to discern the plausibility of the diagnoses of those other less plausible numerical products.

Under the different assessment scenarios and models used in ICCAT -without entering into other very relevant decisions that must be assumed a priori such as the stock structure, etc. - it seems that nowadays the order of prioritization "*CAB*" of the three key-pillars persists in many ICCAT species. "*C*": good catch data series (T1-catches) so that they can be considered plausible and related to fishing mortality over time, "*A*": indicators that represent the relative abundance of the stock over the years, so that in some cases they can be assumed to be representative of the trend of relative abundance when they reach merit, "*B*": to have basic biological parameters (growth, reproduction, etc.) so that they accurately describe the biology of the species, sometimes would allow for more complex models to be also applied and/or alternative ones to be interpreted.

A conceptual *process flow of interconnected diagnostics* to achieve a plausible base-case model for the stocks assessment based on realistic data available, the biology of species and the history of their fisheries is proposed in Carvalho *et al.* (2021). In some species that have been assessed by ICCAT for decades, this process could be relatively consolidated throughout the long history of the working groups and there is usually an agreement on the level of the quality of the basic data used and biological parameters implemented in the assessment models; valuing or adjusting the approaches according to improvements, new contributions or new models developed and testing the results achieved to the previous ones to verify consistency. However, in stocks that are more recently incorporated into the ICCAT assessment process due to very recent mandates, as is the case for some bycatch species, the base case model plausibility may be lacking, weaker or merely incipient in some cases. High uncertainty regarding the most basic key elements or time periods considered in the assessment could occur under a very short-term assessment process as well as the temptation to provide management advice from poorly consolidated or highly uncertain assessments. In those cases, the most basic data and parameters may be subject to high uncertainty, not be consolidated, or even some specific periods or biological parameters may be selected without being sufficiently contrasted against each other nor taking into consideration their effects on the models. The consolidation of these assessment processes may require time of study and evaluation before providing management advice with a minimally solid basis. But in the meantime, the assessment should probably be considered preliminary until they are consolidated and endorsed based on data that are considered plausible and a base-case model selected according to the criteria of plausibility e.g. such as indicated above Carvalho *et al.* (2021). But the process of verifying plausibility and uncertainty of the most basic key input data and parameters could also be incorporated at the top of the flow chart proposed by those last authors. These types of exercises are time-consuming, require considerable work and historical reviews, and are rarely positively valued but rather some times criticized.

The present paper reviews and discusses as a case, following the order "*CAB*", the plausibility and the uncertainty o**f** some of the basic input data selected from an assessment of the Northern stock of *Isurus oxyrinchus* (SMA) carried out at the ICCAT meetings in 2017 and 2019, yet without forgetting other possible elements (e.g. Semba *et al.* 2018, Courtney *et al.* 2019, Carvalho *et al.* 2021, Kell in press) that may also affect the assessments carried out or other possible analytical approaches (e.g. Anon. 2018) which were applied to assess other stock of the same species.

2. Methods

Several sources of public information (reports) available to open access on the ICCAT web page was consulted (Anon. 2017^{a,b}, Anon. 2020^{a}). It was not possible to access some procedures regarding how some of the estimates in the assessment were obtained nor to tables not included in the reports. Therefore, there are some limitations regarding the interpretation of some aspects that would probably explain decisions taken but not fully detailed in reports due to space constraints, working protocols or other reasons. Furthermore, the reports are brief making it difficult in some cases to interpret some of the arguments, figures and scales used as well as some results achieved.

Available SCRS papers submitted to the SMA 2017 and 2019 working groups (WG) and to the SCRS were also consulted. Papers submitted on standardized CPUE series were specifically reviewed. However, some SCRS draft-papers also consulted on other important matters were not available in the ICCAT Collection of Scientific Papers on the date of preparation of this present paper or were withdrawn from publication, although considered in some cases as key-inputs or relevant bases for the assessment.

Various scientific papers specifically referenced within each section of the present paper were also reviewed, as well as the *ICCAT Stat. Bull*. from initial historical periods. Current T1-SMA data (2020) and those used in the 2017 assessment (scenarios C1 and C2) were also consulted, compared and reviewed. Data available in ICCAT for T2-effort and also various SCRS documents and other literature that provide information on fisheries, historical fishing effort, catch rates and catches of the different fleets were also taken into consideration.

Records of our tagging-recapture program were also analyzed to obtain preliminary approximation to growth rates of females of this species as well as for applying preliminary linear fit (Sparre and Venema 1998) and maximum likelihood approaches (Francis 1988) for comparison to other growth rates and models described in literature for females. Moreover, the tagging-recapture ICCAT data base (Anon. 2017[a]) was reviewed. Growth rates and growth models were also inferred from this data set using both linear fit and maximum likelihood approaches. FL_{max} values obtained by observers at sea was also reviewed and discussed. The growth rates were discussed and their impacts on some other key biological parameters also assessed.

3. Results and discussion

3.1 Catch scenarios: "C"

Background: A review of the SMA-T1 data reported by CPC was performed at the March 2017 data preparatory meeting (Anon 2017[a]). At that meeting, new additional historical data on T1 of some fleets was provided for that of previously unavailable years 1990s (e.g. González-González *et al.* 2017) because that species was not included in the ICCAT mandates until the mid-nineties. Some revisions were also carried out for some fleet-years (e.g. Japan 2014, 2015), with correction of errors in the ICCAT database of specific years (e.g. 2004), etc. These additional data led to some updated information and some changes in the catch matrix for years prior to 1996 (see Anon 2017[a]-Fig. 1). The resulting "*new*" T1 series was deemed "*acceptable*" by the Group for use in the June 2017 assessment, while acknowledging that T1 data from many relevant contracting parties were missing for the years prior to 1997. Subsequent to these revisions and updates of the T1 data, a new revision occurred in one fleet (e.g. Díaz 2018-SCRS/2018/117[3]) which could not be incorporated into the 2017 SMA assessment meeting. Most of the available T1 data came from commercial longline fleets targeting tuna and tuna-like species in which SMA is mainly reported as a bycatch species, but some records of rod and reel from some CPC are also available. Recreational SMA fisheries and their mainly unreported catches could have also been very important historically in some areas because around 46% of the recaptures reported from important tagging programs carried out in the NW Atlantic had been submitted by recreational fisheries (Kolher *et al.* 2002). Other coastal-artisanal fisheries (handlines, driftnets, etc.) in some areas on both sides of the North Atlantic may also have had SMA bycatches or targeted catches, yet were probably very few or not reported at all.

The group Anon (2017[a]) concluded that calculations for alternative catch scenarios of estimated catch from ratios between species was not carried out in that case-species as had previously been done for the blue shark assessment cases. However, new catch estimates were incorporated for some fleets applying constant ratios between species for each fleet, but with very different ratios (e.g. SMA/SWO ratios of 0.66 and 0.06 for the Moroccan and Brazilian fleets, respectively). The preparatory WG (Anon 2017[a]) did not recommend replacing reported T1 series with hypothetical series estimated by indirect methods. The working group considered "*acceptable*" the T1 reported to be implemented in the 2017 assessment, and the estimations based on ratios among species carried out in a previous assessment of other species such as blue shark were not recommended in that case. But in the subsequent assessment meeting (Anon 2017[b]) an additional paper was submitted and an alternative hypothesis proposed for a reconstruction of time series of SMA catches for the period 1971-2015 based on applying ratios between catches of sharks and the main-target species. As deduced from Anon (2017[b]) there were two scenarios of total catches finally assumed in the North stock assessment (**C1**: base case according to T1 catches reported 1950-2015, **C2**: sensitivity analysis based on a hypothesis of catches 1971-2015), considering in the last case ratios among species, and null discards in both cases as described for this species for some of the fleets studied.

A detailed review and discussion of each catch scenario (C1 and C2) is included in the following paragraphs, but main conclusions are summarized in paragraph 3.1.3.

3.1.1 Scenario C1

Scenario C1 of catches considered for the period 1950-2015 assumed the T1 data reported by the CPC or those provided by national scientists using scientific records or estimations. The WG Anon (2017[a]) recognized that "*T1 data from many contracting parties for the period 1950-1996 was missing*". The reported T1 data varied greatly among fleets in terms of the year in which their respective reports began and evidently also in the amounts reported by year/fleet/gear throughout their series.

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[3] Document is not available in Collect. Vol. Sci. Pap. Document withdrawn.

Although the T1 series considered in scenario C1 began in 1950, the review in the present paper on the historical fishing activity by fleet (**Table 1**) shows that the available T1-catch information really was very scarce or even non-existent for many of the most active fleets during the initial decades of that series, even for highest relevant longline fleets with high fishing intensity in the North Atlantic between the 1950s-1980s; some of them with documented high fishing intensity and high catches of "target species" during those periods. Only in the case of one fleet (EU-Spain) retrospective T1 estimates were available from 1950 onwards. In other fleets, the corresponding T1 reports began much later: in 1971 (Japan), 1981 (Taipei), 1982 (USA), 1986 (Venezuela), 1995 (Canada), 2000 (China People's Republic), 1982 (Other fleets combined), etc. However, many of them were the main or the most relevant actors with longline gears during at least the 1950s-60s-70s-80s from which relatively high positive catches of SMA would also be expected, from at least the fifties or sixties of the last century merely considering the respective longline fishing histories, fishing areas and gear styles (**Table 1**).

In contrast, the only fleet with data available from 1950 considered in scenario C1 was nevertheless a minor or incipient actor in the initial decades of that series. Therefore, those fleets with assumed zero catches in the initial decades of the series were the ones with the greatest fishing capacity and applied the greatest fishing intensity within the North Atlantic, with highly relevant catches in both commercial and recreational fisheries in which SMA could represent a significant percentage. Some NW Atlantic recreational fisheries may have been also important at least during those periods since SMA could account for up to 90% of the recorded catch of shark species as described by several studies (e.g. Anderson 1985, Casey and Hoey 1985, Hoff and Musick 1990).

The most relevant commercial offshore pelagic longline fisheries would be those mostly targeting tuna species in which positive catches of SMA in a significant amount would be expected before the start of their respective T1 reports. Among them, probably those targeting BFT/ALB/BET/YFT tunas (e.g. Japan, Taipei, Korea, etc.) and/or swordfish, tunas, sharks and other species (USA, Canada, Venezuela, Cuba, Mexico, etc.), acting some of them since the beginning of the 1960's or even before (Bonfil 1994). As noted, only in the case of one fleet was T1 data available with retrospective estimates up to 1950, although their authors recommended caution when using the estimates prior to 1983 for the purpose of assessment due to the assumptions in the retrospective calculations back to 1950 (González-González *et al.* 2017).

Therefore, scenario C1 assumed international catches for many years/decades after 1950 as being the same as those described for a single fleet that was at that time a minor player in the longline activity of the North ATL. In subsequent periods, the total catches assumed under C1 were very partial as catch reports from other fleets were progressively incorporated in T1 data, although they would have even had very relevant fishing activity many years or decades before the start of their respective T1 reports even if the species identification was uncertain in some cases (**Table 1**).

Capacity: Since at least the mid-1960s the ICCAT Stat. Bol. has been available, which includes some data on fleet capacity per flag (number of longline units and size-category of boats operating). Capacity information has historically been very poorly reported to ICCAT. Capacity is not an indicator of the nominal fishing effort in itself, neither of the fishing intensity. However, it allows us to identify, along with other information, some of the main longline fleets that started their fisheries within the Atlantic in the 1950s-60s, as well as those that started reporting of their respective fisheries many years later (see ICCAT Stat. Bol.). Despite this, the partial information available on capacity allows for identifying some of the most relevant actors in the longline fisheries during the initial ICCAT decades, with some records available since the 1960s in some cases. Even considering all these limitations, the capacity information - regardless of the size and fishing power of the vessels- shows the huge importance of some "*long-distant*" actors during the initial decades of the ICCAT series, among which are those targeting various species of temperate and/or tropical tunas according to their respective historical periods described in scientific literature. The partial data do not provide total capacity nor discriminate it between the North and South Atlantic during those initial periods. However, in view of the T1 data of the target species per stock for the tuna species such as ALB/BFT/BET/YFT during those periods, it seems to confirm some of the main actors in the longline fisheries within the North ATL during the initial decades of the C1 series, starting from 1950 (**Figure 1**).

Some information on the number of longline vessels in some of the most relevant fleets is also described in Bonfil (1994). Another author also describes the activity in year 1974 of 132 long-distant longliners (average 10-year-old) operated by Korean fishermen with Korean or foreign-country flags vessels which were active in the Atlantic at least during the 1970s and likely years before. An effort of 2.6 thousand hooks per fishing operation - probably with a multifilament style- and a mean CPUE of *Lamnidae* of 12.4 kg RW per thousand hooks was described for the eastern tropical Atlantic areas studied (Choo 1976). However, a lower abundance of SMA is regularly described in tropical compared to temperate waters by most studies reviewed. Therefore, according to the CPUE described in that study a simple calculation suggests that catches of only those 132 longliners could have likely reached around 1,500 tons year^{-1} during those periods, considering that these fishing units would be just a minor part of the total number of longliners fishing in the whole Atlantic at that time and a large amount of them likely fishing in the Northern areas targeting ALB/BFT/BET/YFT/SWO.

Nominal fishing effort: The T2-effort data available in ICCAT provides an approximate view of the trend in nominal fishing effort applied over the years by some oceanic longline fleets targeting tuna and tuna-like species in the area distribution of the northern SMA stock. This information is likely to be partial or incomplete for some fleets, or even non-existent in some cases or periods, especially in the initial ones and in some years/fleets in particular. It also does not include some data on other fishing gears, including recreational fisheries or coastal artisanal fisheries. It is also possible that the nominal effort data for some fleets would have been reported to ICCAT and aggregated at the time, but probably without the level of detail required by the current T2-effort compliance or that available longline effort, or was not raised to total catch. So that information could be considered as a minimum estimation. On the other hand, some effort data has been provided in different units other than number of hooks yet they could not be summarized.

In the present exercise, an attempt has been made to extend and complement the ICCAT T2-effort series of longliners (when reported in number of hooks) with other information available in the scientific literature consulted for those periods in which that information was not available in T2-effort. For some longline fleets and years in which these effort data could not be recovered from any source, whilst having knowledge about the longline fishing activity of those fleets, effort levels have been assumed considering each case to obtain a general picture of the probable trend of nominal effort over the years as well as of the different active fleet components (see **Annex** 1 for detailed information about sources). For that exercise we have had to consider an approximation start-end year for some respective longline fisheries within the areas cited based on information available in the literature, historical descriptions, reports, etc. (**Figure 2**). The activity of some fleets could have been even prior to that considered in the present exercise, based on personal information or the memory of the authors. But in some cases it has not been possible to find any references making detailed descriptions of the beginnings of some fisheries, and whether or not they were dependent on the mainland or islands.

Therefore, the reconstructed series just provides an approximation to the nominal effort that was probably applied by only oceanic longline fleets (mostly high seas) during the period 1950-2018 within the North SMA stock areas. However, it has not been ruled out that the series of effort was greatly underestimated or partially reported at least for the initial periods, so the picture probably is a minimum estimation for at least the initial decades. The series does not have a direct translation into fishing intensity applied by each fleet or group of fleets in relation to SMA, however it allows to identify the relative importance between fleets or group of fleets during old historical periods between 1950-2018; especially during initial decades of that series when T1 of the North Atlantic SMA was not reported in the case of many important fleets despite highly relevant fishing activity during those decades in temperate waters.

In summary, a sustained increase in total nominal effort seems to have occurred from 1950 to the end of the last century, followed by a substantial and sustained decrease (-53%) from that year until reaching in recent years a level of nominal effort similar to that reported in the 1980s. This reconstruction would indicate that, from the point of view of the nominal effort, the longline fleets targeting tuna species would have been very important actors in the longline fisheries within areas the North Atlantic SMA stock as early as the 1960s. It also points out the start of some important longline fisheries targeting some shark species, swordfish and tunas in NW Atlantic areas during the initial 1960s or even earlier in some cases. Regardless of any year in the series in which the reported data could be incomplete, the trend of the set of fleets considered to be targeting tuna species determines the general pattern obtained for the combined longline fleets within the areas of distribution of the North Atlantic SMA stock, and also pointing out the beginning of important longline fisheries in NW Atlantic since at least the beginning of the 1960s.

For the purposes of the C1 catch scenario, the nominal effort applied by the various longline fleets during the periods prior to 1990 seems to have been very high, especially that of the fleets targeting tunas. During the initial periods of the C1 series those fleets used relatively shallow longlines targeting temperate tunas such as BFT/ALB in temperate waters, or tropical tuna species such as BET/YFT in subtropical and inter-tropical areas. In later periods, its activity progressively shifted towards lower latitudes, using in some cases deeper longlines and mainly targeting BET/YFT and secondarily also other species in some cases. As indicated above, the catch scenario C1 assumed for the period 1950-1970 total catches from the North stock equal to those made mostly by a single fleet that was a minor player in the longline fisheries during those decades. Although somewhat more complete T1-SMA data began to be available from 1971 for some other fleets, the truth is that until approximately the period 1981-1986 the T1-SMA reports of the most important longline fleets were not documented despite their fisheries being developed and expanded since the sixties or even before (**Table 1**).

3.1.2 Scenario C2

Background: During the SMA stock assessment meeting held in June 2017 (Anon 2017[b]) one paper proposed a hypothesis for the reconstruction of the time series of SMA catches during the period 1971-2015 (Coelho and Rosa 2017). The paper provided a hypothetical estimation of total catch levels assuming ratios between shark catches and catches of the main-target species of the respective fleets, applying ratios obtained from different sources (observers, literature reviews and/or personal communications). The procedures and assumptions applied to each fleet-period for the specific case of SMA are not detailed, although the method was based on previous work (Murua *et al.* 2013) to hypothetically estimate catch levels of shark species under various target species capture scenarios and ratios between both. The authors describe that "*mean nominal catches were calculated for target species groups (main sharks species, major tunas including billfish but excluding swordfish, other sharks small tunas, etc.)". "Two scenarios of "low estimate" and "high estimate" were implemented according to those records with null capture reported*." This reconstruction hypothesis was applied for the period 1971-2015 both for the fleet-years with reported data and for those other fleet-years with unreported or partially reported data, as was the case for many of the active fleets but with catches expected positive from SMA although not reported. The document does not describe ratios applied by fleet in the case of SMA so it was not possible to replicate procedures to explain some of the results achieved in the case of some fleets and those specifically analyzed in the present paper.

3.1.2.1 Period 1971-1990

The evident conclusion inferred from Coelho and Rosa (2017) when applying ratios between species is that the main differences between T1 catches reported (C1) and estimated (C2) would have occurred during the earliest decades of the series 1971-2015 considered in that C2 case. The deduced estimated average of underreporting would have been up to 84% for the period 1971-1979. Starting in 1971, a possible progressive decrease was estimated in the proportion of underreporting until year 1986 as T1 data reports were progressively incorporated into the T1 ICCAT series from some fleets with well-known important fishing activity from many years or decades before the start of their SMA catch reports. Based on those estimations, the T1 reported data could already approach full reporting for at least the most relevant set of fleets in the North Atlantic after 1985. Thus, for the year 1986 and immediately thereafter, the ratio between the total reported and those total estimated catches using ratios was already equal to or greater than 1 (**Figure 3**) and for some years, in particular of the period 1986-2015, the total catches reported in T1 turned out to be up to 66% higher than the one hypothesized based on ratios between species.

Therefore, based on those hypotheses, the SMA catches, reported or unreported, from some fleets could have been much higher than those available in ICCAT as T1 for decades prior to the mid eighties, and would also be greatly underestimated for the combined fleets as a whole (international T1) for some of those decades. According to this hypothesis, scenario C1 would have systematically underestimated the level of catches for decades prior to the mid-eighties with progressively higher retrospective underreporting rates until reaching underreporting levels of up to 84% in the early years of the series (**Figure 3**).

Without going into the assessment of the estimated catch levels achieved under C2 scenario based on the hypotheses implemented, the trend to systematically underestimate total catches available during the initial periods from 1971 to mid-eighties -and therefore surely before- seems plausible and consistent if we take into account the SMA T1 data reported by many fleets versus the arguments put forward in the previous chapters of the present paper considering the history of the respective longline fisheries within the Atlantic, the capacity of the fleets, the fishing effort reported for longliners or estimated by the most relevant fleets within the North Atlantic areas -especially during decades prior to 1990s- versus the reported T1 catches by fleet. The C2 hypothesis probably offers one of the multiple possible views on what the profile of historical catches could have been during the period 1971-1985, which would be completely different from the one assumed in the base case C1 scenario, starting in the C2 case from a level of catches above 2,000 tons as early as 1971, although for only the group of fleets considered "*other*" those estimates reached quite a constant catch of around 1,500 t year^{-1} during the complete period 1971-2015 considered. Consequently, catches during those initial decades since 1971 and probably before could be expected well above 2000 t year^{-1} for all fleets combined based on that assumption.

However, the estimated figures of catch amount in C2 are not easily verifiable because of the assumptions applied over the years. In fact, some relevant fleets during these initial periods mainly until eighties used relatively shallow longlines targeting various species of temperate tunas such as ALB/BFT (Uozumi 1996), it has not been be ruled out that they may have had relatively high SMA bycatch rates-ratios similar to those obtained during the same periods by other shallow longline fleets fishing in those temperate regions of North

Atlantic (Bonfil 1994, Goodyear 2021) with ratios between species that would be expected to be higher and very different from those obtained during subsequent, or in more recent periods mainly targeting BET in warmer areas. In other longline fleets targeting YFT a negative correlation was observed between the abundance of the target species and that of the sharks which ranked second in terms of fishing performance in number of individuals (Rodríguez-Rodríguez *et al.* 1988). It had been also described that species composition of the catches in longliners would change with the catch rates of the target species. For example, a decline in percentage of shark catches was observed as tuna catch rates increased and there was little evidence in this type of fleets that sharks were positively associated with the presence or abundance of tuna species targeted (Au 1985). Neither a positive correlation could be found between the increase in the catch rates of swordfish and catch rates of SMA - or shark species combined- in areas near Grand Banks since, among other things the thermal requirements among species were found to be different in those areas-times (Mejuto and Iglesias 1988). A negative correlation between catch rates of SWO and some shark species was also pointed out and considered a significant target effect in some CPUE standardization. Therefore, the assumption of a positive and directly proportional relationship between the catch levels of the target species and the catch levels of a bycatch such as SMA may not be plausible in many cases.

It should also taken into consideration the fact that many of these longline fleets targeting tunas changed their target species and their fishing areas substantially over the years, moving from temperate zones of the North Atlantic to the warmer ones and modified the gear configuration and fishing strategy towards mid-deep and deeper longline since eighties targeting mainly BET. In these cases, it may be weak to assume the use of equal ratios between species between such diverse fishing periods, or have assumed constancy of ratios between species and fleets despite having applying such different fishing strategies over time. Neither would possible improvements in catchability occurred in the longline fishing gear for the targeted tuna species be assumed with a proportional equivalent effect on a bycatch species such as SMA. This relationship would not seem plausible if we look at the studies previously cited and recent ones describing the transition from shallow longlines to the very efficient deeper longlines for their respective targeted tuna species (e.g. Semba *et al.* 2017), since the major availability of SMA has been generally described in temperate areas of the North Atlantic and regularly in shallow layers according to the regular horizontal movements of this species described by some electronic tagging studies. Moreover, management recommendations implemented in the recent periods on some of the target species may have had an impact on the inter-species ratios during the different periods. The average species composition over short periods are not regularly reflecting the temporal changes in fishing grounds, target species and gear changes over decades which could affect bycatch estimations inferred from ratios among species. It is also evident that the possible changes in abundance over time between the different species, and therefore on the changes in prevalence-ratios between species, can not be considered in this or other hypothetical exercises.

3.1.2.2 Period 1991-2015

According to the results of the C2 hypothesis for periods after 1990 it could be inferred that T1 reported for the fleets as a whole could have been generally underreported around -12% on average during the 1991-2015 period. However, in the said hypothesis it was estimated that between 1992-1996, and also in some subsequent years, the estimated total catches based on ratios already turned out to be lower than those reported in T1 (**Figure 3**). Due to the limited information available, it was not possible to identify in the present paper the reasons which would justify a different hypothetical amount of under-reporting suggested for some fleets for recent years (e.g. Venezuela, EU-Spain, Others) and the hypothetical over-reporting suggested for some other fleets (e.g. USA, Portugal, Morocco) (**Figure 4**). However, it was possible to validate this hypothesis by comparing the estimated catch based on ratios for one of these fleets (EU-Spain) and to contrast the result with those provided by national scientists through direct scientific monitoring of the catches and landings of the longline fishery over several decades (González-González *et al.* 2017). This last data set was scientifically reviewed, contrasted and considered as SMA T1 for the assessment of the year 2017 under scenario C1.

The result of comparing the scientific estimates considered as T1 for the EU-Spain fleet (González-González *et al.* 2017) with the estimates obtained for this fleet using ratios under the hypotheses considered in scenario C2 (Coelho and Rosa 2017) suggested an underestimation of the estimated catches using ratios compared to the T1 reported during the period 1997-2009 at an average of 257 tons yr^{-1} in favor of the reported T1 catches. On the contrary, the estimated catch hypothesis for scenario C2 during the period 2010-2015 suggested a progressive and increasing overestimation of the estimated catches using ratios over the reported T1 at an average of +803 t yr^{-1} reaching only in this fleet, in the most recent years analyzed, an overestimation of up to +1,284 t in 2015. However, looking at the T2-nominal effort data of that particular longline fleet during the period 2000-2015 in this species a scenario of increasing bycatch during said period does not seem plausible as a suggested scenario

C2. On the contrary, a relatively stable or decreasing bycatch trend would be more plausible as reported, based on scientific T1 considered in the C1 scenario (**Figures 5**). Moreover, there was a slight decrease in standardized CPUE of SMA during that short final period (Fernández-Costa *et al.* 2017). Therefore, a hypothetical huge and sustainable increasing trend of the catches of SMA is neither supported nor plausible in this fleet for that period. As a result, an assumption of progressive increasing of SMA bycatch during the period 2010-2015 would appear untenable as estimated for this fleet by scenario C2. Null or negligible accidental interactions that could occur in fishing gears also reviewed other than longline in no way could justify the huge systematic positive bias between the catches hypothetically estimated using ratios and those based on direct and scientifically verified field observations, and even less for only the most recent years of that series.

On the other hand, the review of the catch estimates for the different fleets analyzed for the period 1997-2015 (Coelho and Rosa 2017) suggested a type of *compensation effect* between the estimates of each fleet on the overall result for fleets combined, that is, considering both the underestimated and the overestimated catches using ratios in relation to those respectively reported (**Figure 4**). However, that difference for fleets combined was not neutral neither quantitatively irrelevant because their respective magnitudes are very different among fleets. For the period 1997-2015, the average differences for fleets combined would reach +1,119 t yr^{-1} in favor of the estimated catches using ratios, which would represent an average of +31% in relation to the T1 reported by the group of fleets during that same period. But this large amount is approximately equivalent and probably mainly produced by the overestimation that occurred when applying the ratio procedure to only one single fleet (EU-Spain) for the most recent years of that series (**Figure 4**). As indicated above, the scarce information available does not allow us to elucidate in the present work the assumptions/ratios applied to each fleet-period to be able to estimate the hypothetical SMA catch level of scenario C2 and specifically for the most recent years. However, it is likely that the estimated level in C2 was the result of applying substitutions of ratios between fleets-periods-species. The available information of various studies recommends caution when assuming ratios between species and when applying them to different fleets and/or periods, as well as when considering different units in which these ratios could be described (e.g. in number of individuals or by weight, in which units of weight, with what coverage of information, changes in targeting, etc.).

In this context, a comparative test was performed taking into account ratio information from T1 available from ICCAT and from the literature for two longline fleets acting on the North SMA stock to which similar fishing strategies and species composition of their catches a priori could have been assumed. Ratios SMA/SWO were obtained in round weight. (a): SMA/SWO ratio by year obtained from the reported T1-LL of EU-Spain (González-González *et al.* 2017) also available in ICCAT data base (t1nc_20200115). (b): SMA/SWO ratio by year obtained from the reported T1-LL of EU-Portugal available in the ICCAT database (t1nc_20200115). (c): SMA/SWO ratio by year for EU-Portugal obtained from those observations in weight of SMA and SWO considered for the standardized CPUEs of the respective species, from the same fishing gear, the same source of information and identical fishing effort observed in both data sets analyzed (Coelho *et al.* 2017[a]-SCRS /2017/049, Coelho *et al.* 2017[b] -SCRS/2017/053). The SMA/SWO ratio (a) of the EU-Spain fleet obtained from T1 has remained quite stable since 1990 with an average of around 0.40. The SMA/SWO ratio (b) of the EU-Portugal fleet obtained from its updated T1 was initially quite similar to that of the Spanish fleet, but only until approximately year 2002 and subsequently it was increased until reaching values greater than 1.0 or even up to 2.0, and later dropping to low values. The SMA/SWO ratio (c) of the EU-Portugal fleet obtained from the records used to obtain standardized CPUEs of both species was very low throughout the series, with an average of 0.09 (**Figure 6**).

Regardless of the conclusions that can be drawn from this simple comparison and previous comments about the unlike premise of assuming a positive and proportional relationship between the catches of the target-main species and SMA, it is evident that the selection and application of one or the other ratios among species and periods could have huge impact on the hypothetical estimates of catches of SMA based on catch levels of the species/s considered as main or target, or when substituting ratios between fleets and/or periods. Estimates of catches from ratios depend not only on the available sources of information, their plausibility and representativeness, but also on the selection criteria applied by the respective authors.

3.1.3 Conclusions on catch scenarios

According to Anon. (2017[a]) conclusions, the C1 scenario of total reported catches of the Northern stock used as base case assessment provided an underestimated view of the real catch levels of several initial decades of the series 1950-2015. But the revision made in the present paper indicates that the level of such underestimation was really huge and it would affect among others those fleets with the highest fishing intensity during decades 1950s, 1960s, 1970s and even the 1980s, for which in many of those periods zero catches were assumed for most under the base case C1 scenario; including those longline fleets which were the most developed in NW Atlantic fishing areas at least since the beginning of the 1960s and whose probably very relevant catches of SMA occurred but assumed to be null until the start of their respective T1 reports in the 1980s or even later; as well as for some recreational fisheries in those areas. Subsequent to the initial periods of high fishing activity, but without considering positive SMA catches in many fleets, some data from various fleets and gears have been progressively incorporated reports in the T1 series (**Table 1)** (see also Anon 2017[a,b] and a summary in Appendix b of Courthney *et al.* 2020). The present review also pointed out that for those initial decades considered in the C1 scenario a total catch of fleets combined was assumed for the whole of the Northern stock equal to that of a single fleet whose estimates had been the only ones available since 1950, but which was a minor or incipient actor during those periods. But zero or very minor catches were assumed for many of the most relevant fleets at least for periods prior to 1971, 1981 or even later for many important fishing actors.

Scenario **C1** is not only implausible from the point of view of the assumed historical catch levels, but also in relation to the catch profile of the series, giving a false image of very low catches during several of the initial decades and an abrupt increase in total catches occurred since the 1980s, which was simply the result of the starting point of reporting for some relevant fleets that had been actively fishing during several previous decades within the North Atlantic but with SMA catches assumed to be null. Therefore, that apparent increase in catches is not related to fishing intensity or mortality.

On the other hand, scenario **C2** used an assumption -when applying ratios among species- which considered a probably false positive and directly proportional relationship between the catch levels of the target species and the bycatch SMA species, as well as probably applying ratios between species for different fleets-periods. However, C2 could provide a somewhat more realistic view than C1 of what might have been one of the possible profiles of total SMA catches throughout the periods prior to 1986 for fleets that may have had positive and probably relevant catches of SMA within the North Atlantic stock. Based on that hypothesis, there was proposed by those authors an important systematic underestimation of the historical catches used in the assessment under the base case C1 scenario that could reach, or probably exceed, 84% in the initial decades of that series. Therefore, it should not completely ruled out that in 1971 –the first year considered in the C2 series- and probably before, the total catches of SMA were of at least above 2000 tons yr^{-1} as estimated by scenario C2, or more likely above this level if we look at the fishing intensity applied and the type of fisheries developed during those periods, the species targeted, the gears-styles used and main areas of fishing; in addition to the catches that would be expected from other fishing gears such as gillnets, recreational and coastal, etc. The exercise C2 would just support one of the hypothetical scenarios of underreporting rates of the total catches during the period 1971-1985 and likely even earlier.

Yet the method based on ratios among species appears weak when estimating or validating the level of catches in recent years, at least in the case of the fleet specifically analyzed and likely for fleets combined. With this in mind, the level of apparent underreporting of catches of scenario C1 in relation to C2 hypothesis for those recent years of the series analyzed as a result of combining the estimates of the different fleets was similar or mainly to the overestimation of catches that was verified when applying the ratio method to a single fleet has contributed to date the longest series and the highest part of the reported T1-SMA of the Northern stock. The use of ratios applied for scenario C2 probably produces a sustainable overestimation of up to +31% for the most recent years of the series considered. This overestimation seems to be confirmed not only in the case of the fleet with highest catches reported based on scientific records, but in view of the trend of the nominal effort and CPUE trend of that fleet; as well as from the decreasing trend of the nominal effort of the order of -53% since the beginning of the 21st century for the set of all longline fleets combined, operating within the areas in which the North Atlantic SMA stock is distributed, along with the aforementioned data.

Within this context, and considering previous information, an attempt was made in the present work to identify some of the main active oceanic longline fisheries in the North Atlantic from 1950 onwards and their fishing effort. Various simulation-exercises could be carried out from the present approach suggesting some plausible catch profiles for periods before 1986 (**Figure 7**). However, only with the study carried out by national experts the estimates of historical catches of most important fleets-gears can be improved, especially for the period 1950-1985. Nevertheless, this exercise could be also largely improved by incorporating updates and other fishing gears with also expected positive catches of SMA, including the recreational and artisanal coastal fisheries. In any case, evidently under no circumstances can the base case scenario C1 be considered plausible in terms of total catches for assessment neither likewise the profile of the historical catches throughout the entire 1950-2015 period.

The important source of uncertainty in historical catch levels does not only affect the assessment of the North and South Atlantic SMA stocks, but also seems to be a common problem in the assessment of other stocks of the same and other bycatch species due to the fact that they were historically not well recorded and/or reported and/or they were not identified at the species level in many fleets (e.g. Anon. 2018, Bonfil 1994, Semba *et al.* 2012) and because some of them were not included in mandates of the tRFMOs until recently. The bid to reduce the existing level of uncertainty surrounding the catch levels considered in the assessment models seems like a "*sine qua non*" task that probably requires hard work by national scientists as well as experimenting with more diverse and realistic scenarios to be implemented within appropriately selected models and time periods.

3.2 CPUE scenarios: "A"

Background: Five SCRS papers provided standardized CPUE series of North Atlantic SMA stock and were presented at the preparatory and assessment meetings (Anon 2017^{a,b}): U.S. longline (Cortés 2017), Chinese-Taipei longline (Tsai and Liu 2017), Japanese longline (Semba *et al.* 2017), UE-Portugal longline (Coelho *et al.* 2017), UE-Spain longline (Fernández-Costa *et al.* 2017).

Despite quantitative and qualitative differences and limitations in some of the indices, the WG (Anon. 2017^{a,b}) recommended using all CPUE presented: Indices of the United States (logbook), EU-Portugal, Japan, Chinese-Taipei and EU-Spain. There was a "*strong general agreement regarding the selected indices".*

A brief conclusion of the review and discussion is included below. A summary figure of the main standardized CPUEs and a table with some quantitative details for each index reviewed are also included (**Figure 8** and **Table 2**) as well as a summary table specifically required for one of the index (**Table 3**). However, a detailed discussion on each of the CPUE series is included in the present paper considering possible strengths and weaknesses of the respective series (see Chapters from **3.2.1. to 3.2.5** under **Annex 2** for details**).**

3.2.1 Conclusions on CPUE scenarios

Full stock assessments commonly require at least catch data series and "*indices of abundance*" that should be standardized. The catches per unit of effort (CPUE) are in some cases assumed to be reliable indicators of relative abundance for large pelagic species in view of the lack of direct abundance indicators or independent fishery data in most cases. CPUE indicators must be evaluated on a case-by-case basis taking into account -among other diagnoses- the empirical knowledge of each fishery, the quality and quantity of the data used, the spatial coverage of each fleet data in relation to the stock area-distribution, as well as the biological plausibility of the inter-annual CPUE variability obtained in the analyses for this species since abrupt changes in the total abundance-biomass should not be biologically plausible in this species during short time scenarios (Ramos-Cartelle *et al.* 2011).

Minimum data required for some stock assessment models of these species should include accurate information on a regular basis upon catches and indices of relative abundance (Braccini *et al.* 2011, Martell 2008). The latest information in the North Atlantic SMA case was obtained or estimated from very different styles of commercial longline fleet data as catch-per-effort (CPUE) to infer trends in the "*relative abundance*" regularly assumed as proportional to stock abundance. This assumption is possible because of a proposed relationship between effort and the probability of capture as well as the observed trend with successive catch events. The CPUE are standardized to "*remove*" some factors other than "*abundance*" that could affect the interpretation of the CPUE trends over time, but assuming reliable and representative catch and effort information.

Decisions for selecting and weighting CPUE series into models are not easy in SMA because it is not a targeted species in most commercial fleets described –it is a bycatch in at least all CPUE series presented- and the relative importance on occurrence of this species and the catch levels reported by fleet are in some cases very different among those fishing actors-styles and time periods (**Table 2**). The decision for selecting representative CPUEs could mainly be based on scientists involved in the fisheries and with knowledge of the history of these fisheries. Detailed revisions are regularly regarded as an important step in the ICCAT assessment processes (e.g. Anon. 2020^{b}) but in some cases-species they are omitted or are all assumed by default. Time constraints, the current workload and working procedures could explain in some cases limitations for revisions on selecting data, CPUEs series, weighting criteria or parameters used in some stocks. Therefore, the selection of CPUE series is in some cases based on an *ad-hoc* decision rather than based on an in-depth discussion considering quality and representativeness of data used in each series. Certainly, the analysis of CPUEs of SMA is not easy because it is a bycatch in many commercial fisheries and with currently low or even minor occurrence in some cases, affected over time by lacks of information or even misinformation when reporting (or over-reporting), species misidentification, etc. The standardized CPUEs series have been developed in these cases from six different sets of data and from very different fishing strategies among fleets and even in the same fleet over time in some cases.

However, the CPUE standardization had to be done and selected on sets of data with relevant positive annual catches and enough area-time coverage to avoid fleets with minor or just sporadic occurrence of SMA with misinformation in the reporting, etc.; or from those fleets where the relationship between effort and catches is weak or non-existent at all. The catch coefficient is a function of the interaction of the fish with the fishing gear and the environment. This assumption is regularly weak in case of many bycatch species but even weaker or nonexistent in the case of rare or sporadic catch events described in some fleets/gears/styles. But there is no way to assess the assumption of homogeneous catch coefficients with rare or minor fishing events, low coverage of information, minor area-time coverage or low availability of this species as indicators of the general abundance of a broadly distributed stock such as SMA. Even under the circumstance of a very different coverage and representativeness of the CPUEs in terms of occurrence, areas covered and/or the levels of catch that each fleet represents, equal weighting criteria are in some cases applied to all indices within models.

From the review of the CPUE series presented at the 2017 assessment for the Northern stock (**Table 2**, **Figure 8, Annex 2**, subsections from 3.2.1 to 3.2.5 for details) we could conclude that probably the indices of the USA (Series 1, complemented or corrected with the Series 2 from observers) and EU-Spain longline fleets based on scientific records could be both considered quantitatively and qualitatively the most representative as for indicators of the relative abundance of the broad stock within their respective regions of North Atlantic fishing activity, and probably both should be assumed in the base cases of the assessment models tested. Despite some limitations described in one of those indices in terms of underreporting in recent years in the mandatory logbook data used and other possible limitations about changes in gear configuration, fishing practices and target species over time (see **Annex 2**, subsection 3.2.1.); both indices have very high levels of catch-effort data coverage in relation to other analyzed fleets and also in relation to the total effort applied by their respective fleets, which cover a period of three decades and most distribution areas of the North Atlantic stock. Both indices represent pelagic-surface longlines with a significant occurrence of this species (**Table 2**) and they complement each other in terms of spatial coverage covering between the two a large part of the areas of distribution of this stock based on the current definition of stock structure. The U.S. index Series 1 (complemented or corrected with Series 2) represents the westernmost regions of the North Atlantic areas generally longitude > 45ºW and preferably> 60ºW, which are probably more closely related to environmental events related to the Gulf Stream patterns and, therefore, with the seasonal migratory behaviors of SMA related to this current that have been described by fishermen, scientists and by the available tag-recapture data. The EU-Spain index represents from the easternmost areas to the central-western North ATL, reaching approximately 45ºW. Together both indices probably represent the abundance -or availability- of the stock according to the migratory processes that have been described between the different areas of the North Atlantic stock based on the abundant tag-recapture records collected at least since 1962 (Kohler *et al.* 2002, Anon. 2017[b]). On the other hand, both fleets are fishing those fractions of the stock mainly available in the pelagic layers, which within this species seems to preferentially perform its life and the vertical migration patterns as indicated by electronic tagging studies (Sepulveda *et al.* 2004; Vetter *et al.* 2008; Stevens *et al.* 2010; Abascal *et al.* 2011, Anon. 2018), providing information on very stable size-fractions tracked over three decades. In addition, the U.S.-Series 2 index, despite the limitation in coverage indicated by the author, provides additional information confirming that during the years analyzed it also did not detect symptoms of stock depletion and supporting the thesis on the probable underreporting of SMA catches in their mandatory logbooks during recent periods, as suggested by the author.

The *Japanese longline* index (**Figure 8, Annex 2** subsections 3.2.3 for details) could provide useful information for some years of the series analyzed, especially during the temperate-area periods targeting some tuna species. The authors tried to minimize the artificial CPUE drop suggested in a previous work by applying a slight modification in the areas defined within the GLM run. However, this limitation is probably not the main problem for this index to be assumed as an index of abundance throughout the complete series analyzed. The *filtering* procedure used to estimate catch rates of SMA as well as the changes in the fishing areas over time, with different targeted tuna-species and fishing style-gears (and maybe different daily patters) introduces uncertainty about the catch coefficient and the representativeness and interpretation of this index as a trend of abundance throughout the complete period analyzed. Moreover, the high variability observed and specifically the picks estimated in years 2008-2009-2010, around double that of previous and posteriors years, suggests that this index is probably not representing stock abundance. Probably the two different periods that the authors had already defined, warned of and discussed in a similar sense are really not comparable, and therefore this index cannot be interpreted as a trend in the abundance of this stock from the complete period 1994-2015, and even less so considering the values obtained for some years that are biologically implausible as a change in the abundance of this species. This index probably represents roughly how all changes in the fishing patterns of this fleet over the years after 1994 have affected their own SMA catch rates -after applying filtering processes on the raw data-, but resulting in a very minor bycatch species in the most recent periods/areas/gear style targeting tropical tunas and probably also considering different fractions of the stock (size-sex) of the SMA stock throughout the different fishing periods considering the biological information described in literature.

The *EU-Portugal* logline index (**Figure 8, Annex 2** subsections 3.2.4. for details) represents an advance in the study of this species in that fleet. The coverage of the data on total SMA catch represented between 1.2% and 9.3% (mean 4.11% of annual coverage) according to the authors. Nominal CPUE for year 2007 presented a variation of around +/- 200% over the previous and subsequent years, respectively, which seems biologically unlikely to be due to a change in biomass in this stock in only one year. Although standardized CPUE modeled somewhat softens that view, nonetheless the standardized series as a whole gives a "round-trip" picture that is probably a contrivance from the available data of some of the years and the large mass and high variability of zeros in catches per trips modelled**.** The observations used and their possible relationship with over-reporting or under-reporting catches of this and/or other species should be considered. Some existing uncertainties should probably be elucidated for some year-periods as well as for the differences in SMA/SWO ratios, depending on the source of information considered, that could have an effect not only on T1 data estimated but probably also on some records used to run the standardized CPUE series. Observations, areas and period of coverage are relatively limited, very restricted, and minor to that available in other previously described surface longline series.

The *Chinese-Taipei* longline index (**Figure 8,** see **Annex 2** subsections 3.2.2.) could represents a laudable scientific effort and an advance in the study of the low occurrence of this species in a very small part of this fleet during only the most recent years. The authors pointed out the poor accuracy of the SMA catch (T1) data historically reported to ICCAT. The methodology for estimating retrospective annual catches could be inappropriate in these cases considering the low coverage and the few observations used from the brief period 2007-2015. The important changes occurred in that fleet over the years in terms of fishing areas, target species and gear style during periods prior to 2007, would not support a retrospective implementation of those ratios between species over 25 years.

But an important limiting factor inferred from this study is the scarcity of SMA information probably used to estimate standardized CPUE and the difficulty to assume this series as an indicator of annual abundance of a stock with such a wide distribution. Due to the limitations in logbooks data for developing standardized CPUE, the authors used data from a 2007-2015 scientific observers' program with a mean effort observed of around 424.8 thousand hooks per year, that it is probably equivalent to only one trip per year, during the period 2007-2015. The standardized CPUE series could probably have been obtained from a catch average of around 80 fish per year (about 4 tons of catch per year) to represent the huge SMA Northern stock; resulting in an average of about 26 positive sets per year. The minimum number of positive observations would have been obtained in year 2007 with probably around 7 fish caught (0.3 t of observed in annual catch) in the set of all positive observations obtained for that year. The maximum number of observations would have occurred in year 2009 with only around 215 fish caught (about 11 t of annual catch) among all the positive observations for that year, most of them within only one of the areas considered (**Table 3**). The standardized CPUE obtained in year 2009 represented a change of approximately 300% over the value obtained in the immediately preceding and subsequent years, which is biologically implausible in this species. The low number of observations used and the very low number and fish observed -for some years in particular- as well as for the areas covered by these few observations in relation to the vast historical activity of this fleet since the 1960s, suggests that in no case would this series meet conditions -at least in quantitative and representativeness- as to be incorporated into the assessment models as an indicator of the abundance of the Northern stock, under any scenario, and even less considering the relative minor catch contribution estimated for this fleet to the total T1 catch fleets combined of this stock, as was estimated by those authors (**Table 2**).

3.3 Biology scenarios: "B"

Background: Several documents on growth and reproductive biology of SMA were presented to the preparatory and assessment WGs (Anon. 2017[a,b]) in addition to considering others available in the literature. It was not easy for an external reader to identify in Anon (2017[a]) the growth and reproduction parameters finally considered in the assessment (Anon. 2017[b]). The table, "*life history parameters for mako (North and South) stocks*", was included that a priori could be assumed as those selected parameters. In the specific case of females, among other, some reference values were initially cited: FL_{inf} = interval 366-393 cm, T_{max}= 32 years of life and

$FLMat_{50\%}$= interval 275-298 cm, according to the respective literature. However, additional information suggests that growth parameters other than those included were finally selected in some assessment models.

A detailed review and discussion is included in the following paragraphs, but main conclusions are summarized in paragraph 3.3.3.

3.3.1 Growth model

A preliminary paper Rosa *et al.* (2017^{a}-SCRS/2017/051[4]) discussed progress on the age and growth of the North Atlantic SMA using vertebrae readings (Anon 2017^{a}). The WG also discussed growth analysis that had used both vertebrae-age readings and tag-recapture data, but very limited conventional tagging-recapture had been included. The method on interpretation of the "*bands*" formed on the SMA vertebrae replicated the criteria of a previous work (Natanson *et al.* 2006) that had used 118 and 140 samples of males and females respectively and proposed a validation of the growth from 22 records of tag-recapture and length-frequency data for the first ages. This last work concluded that "*the tag-recapture curves and the length frequency modes indicate a much faster growth for the young mako sharks as the vertebral growth indicates*". But it is important to underline that the term "*young mako*" was applied in that study to fish below 200 cm in size. The validation of "*one band pair per year hypothesis"* was further based in a single tetracycline-injected adult male recaptured after one year at liberty and aged at 18 years old.

Probably for these reasons Anon (2017^{a}) recommended that a more complete tag-recapture data set should be used since even seemingly very high growth rates could be real in this species –as reported in other literature- and that apparent negative growth rates shown in some of the tag-recapture records would introduce an observation error. The WG also discussed issues related to the validation of the estimated age and the periodicity in the formation of the deposit-bands (*deposition rates*) considered for the interpretations of the vertebrae. However, at the assessment meeting in (Anon. 2017^{b}) a complementary contribution was presented on growth, based on the same method and interpretation of the "bands" formed (Rosa *et al.* 2017^{b}-SCRS/2017/111[5]) and it was proposed and accepted to be considered in that assessment as unique growth model. A sample of 379 individuals of both sexes was analyzed in that case for sizes between 52-366 cm - that is, an average around 1.2 fish for each size class of 1 cm- although the number of available specimens of FL > 200cm was very scarce according to its authors. That final growth model fixing FL_0= 63 was the one finally implemented in the assessment and also in subsequent works (Anon. 2017^{b}, Anon. 2020^{a}, Courtney *et al.* 2017, 2019). The considered growth model was based on several premises. (a): Three laboratories-readers counted the *band pairs* (consisting of one opaque and one translucent band) as one year. (b): The inter-calibration of three laboratories-readers to ensure consistency between readers, but under the previous agreed hypothesis of *one band pair per year*. (c): The annual deposition rate assumed was based on the criteria of a previous coauthor's work (Natanson *et al.* 2006) previously described.

The authors have already pointed out one of the key problems existing in the study of the growth of this species when interpreting marked "*bands*" on hard parts-vertebrae, persisting in the case of SMA much uncertainty among other regarding the pattern on the band deposition rate: "*with some studies using a one band pair per year hypothesis while others assume a deposition of two band pairs per year*" providing very different growth rates and growth models among studies. However, other studies propose *mixed deposition rates* according to which deposition rates would depend on age of the fish "*on having a band pair deposition rate that changes from 2 to 1 band pairs per year after age 5"* (e.g. Anon. 2018) -a brief discussion about this issue is available in the report of last reference-. Other authors postulate or discussed differences between individuals according to the origin of the sample or a variable deposition rate according to the experiences -migrations and areas of presence over time- occurred to each individual throughout its life. But considering the huge intra-ocean migrations that have been described for this species within the Atlantic and in other oceans according to the tag-recapture data (e.g. Kohler *et al.* 2002, de Bruyn *et al.* 2015, Anon 2017^{a}) it is plausible that the band deposition rate depends more on age and/or on individual vicissitudes not necessarily related to time than the sampling areas considered in each study. Moreover, the selection of habitats and their high migratory capacity probably depend on size-body biomass therefore the environmental conditions, areas and behavior (e.g. for reproduction, etc.) would not necessarily be the same throughout their life. The regionally specific oceanography events over time could be also taken into consideration because they could play a role in the vertebrae growth, deposition rates and growth rates achieved by each fish and also in posterior age-validations suggested (Wischniowski *et al.*2015). So, a common and constant deposition rate, or equal temporal pattern, should not be assumed a priori

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[4] Document is not available in Collect. Vol. Sci. Pap. The paper was withdrawn.

[5] Document is not available in Collect. Vol. Sci. Pap. The paper was withdrawn.

and even less from the few samples regularly analyzed and from restricted areas in most studies or reviews consulted (see e.g. Barreto *et al.* 2016, Bishop *et al.* 2006, Cailliet *et al.* 1983, Cerna and Licandeo 2009, Cortés 2000, Chan 2001, Doño *et al.* 2015, Groeneveld *et al.* 2014, Hsu 2003, Liu *et al.* 2018, ICES 2017, 2018; Natanson *et al.* 2006, Pratt and Casey 1983, Ribot-Carballal *et al.* 2005, Rosa *et al.* 2017ª-SCRS/2017/51[4], Rosa *et al.* 2017ᵇ-SCRS/2017/111[5], Rosa *et al.* 2018, Semba *et al.* 2009, Valeiras and Abad 2009, Wells *et al.* 2013).

If a conclusion can be drawn from the review of the literature previously cited on SMA growth of different areas and oceans from the interpretation of the bands on hard parts, it is that, in addition to the different methodological approaches mentioned above and the difficulty or absence, or contradictory validation between many of them, most do not reach or exceed a sample size of 200 individuals per sex and regular samples are taken from relatively restricted areas. The performance of the methods is regularly poor when sample sizes are small, age-reading error is correlated among readers, when all readers are biased and for ages that are poorly represented in the samples (Punt *et al.* 2008). Values of L_{inf} for the same sex and for the same type of size (FL, CFL, TL, PCL, etc.) vary considerably between such studies, sometimes indicating the low number of fishes used –and in some key largest sizes even less- and the great difficulty in estimating this parameter especially for females, some of them being very untenable based on field-size records or with resulting biologically aberrant values in other cases due to the difficulties for fitting those "age" interpretations. A broad range of K values are in some cases suggested for the same sex in the same study depending of the fit type implemented (e.g. Liu *et al.* 2018).

Growth is in fact one of the most important and problematic biological parameters for its study in most fish species in any of its distribution areas. It is especially complex in the case of highly migratory fish species because they have the capacity to search for the most suitable habitats for the development of each life stages of respective individuals and sexes over time. It is perhaps one of the most studied and at the same time most debated parameters, being one of the main sources of uncertainty in the study of population dynamics. Age allocation criteria often involve a lot of subjectivity when based on the interpretation of "*bands*" on hard structures. In this sense not only the interpretation criteria is important, but also the methods to carry out the selection, preparation and reading of the hard parts present various alternatives that may have an effect on the growth interpretation and estimates (e.g. Quelle *et al.* 2019, Natanson *et al.* 2018). Additionally, sharks lack bony parts and often exhibit tremendous growth rates and variability in their cartilaginous structure thus making aging extremely more difficult (Hoff and Musick 1990).

So, the problem in the case of SMA previously summarized is not only to standardize the interpretations of the hard parts among the different readers involved in a study and based on an already agreed or pre-established criterion on *band pairs per year*, but to elucidate whether the formation of the interpreted bands is really of such a nature that there can be considered a stable pattern in the hard structure, throughout the life of the fish and whether these are significantly related to its age. In that sense, Natanson *et al.* (2018) summarize some relevant issues related to the interpretation of the hard parts (vertebrae) in SMA and in some other shark species pointing out the subjectivity within vertebral band interpretation in age and growth studies because that band pair interpretations are subjective and contingent on several factors, including the preparation method, microscope quality, computer hardware, image analysis programs and reader experience among others cited. They also pointed out that the relationships between band pair deposition to time in SMA must be considered *loosely correlated* over the span of the studies because they have shown that SMA have varying band pair counts along the vertebral column and ontogenetic changes in band pair deposition rates observed. As a result, it is worth critically examining past studies on vertebral ageing, and they suggest that future studies should perhaps assume that band pair deposition is not triggered by a time-related event. Therefore, band pairs are not necessarily linked to time and some of the techniques suggested for validations could neither provide a real validation.

With all this in mind, and based on previous studies, the Anon. (2017ᵇ) recommendation seems to be very reasonable regarding facing growth estimates based on tag-recapture data sets compiled at least from 1962 onwards through international cooperation for the provision of recaptured data. Those records could help to elucidate mainly the growth of the Northern stock since most of them probably come from tag-recapture activities occurring within and between North Atlantic areas (e.g. Kohler *et al.* 2002). These latter authors indicated in year 2001 that 608 recaptures of SMA out of a total of 5,333 releases were already registered at that time thanks to international cooperation. Some tag-recapture records had been selected to preliminarily estimate growth rates versus those obtained using "*bands*" formed on hard parts (Natanson *et al.* 2006) concluding in that case that "*tag-recapture curves indicate a much faster growth for the young mako sharks than vertebral growth indicates*", considering "*young*" those sizes below 200 cm and the data of 22 recaptured fish between 0.08 and

2.56 years at liberty. A much larger number 1,258 tag-recapture records of SMA are already in the ICCAT tag-recapture data base, but sex information is not currently available (Anon. 2017[a]).

As an example, several growth estimates are plotted for only SMA females obtained from different band reading criteria, applying different types of fits or those obtained from data already available in the literature. Some growth models were estimated from length-frequency of females (e.g. Mejuto and Garcés 1984) and assuming fixed values for FL_{inf} or FL_0 considering as constant those described by Rosa *et al.* (2017[b]-SCRS/2017/111[5]) or other values reported in literature. The Rosa *et al.* (2017[b]-SCRS/2017/111[5]) growth model was also considered, previously estimating a t_o parameter or assuming the reported FL_0= 63 cm (Anon. 2017[b]). Other growth models such as Pratt and Casey (1983) and Barreto *et al.* (2016) were also considered and plotted. The growth model implemented for females in the assessment of the Northern Pacific SMA stock (Anon. 2018) was also included in FLcm units, but original PCLcm unit was also plotted for comparison. Additionally, preliminary growth models inferred from some tagging-recapture records of females obtained in our tagging-recapture program (see next paragraphs) were also considered assuming FL_0= 63 cm and fitting the data by linear (Sparre and Venema 1998) or maximum likelihood methods (Francis 1988), (**Figures 9, 10**).

In the assessment of the North Pacific SMA stock (Anon. 2018), a very different growth model was used than that assumed for the North Atlantic stock assessment (Anon. 2017[b]). However, the reason was not to support the thesis that the two stocks of the same species present different growth rates, but rather to apply alternative methodological approach which produces very different growth rates and models. The growth model by sex obtained and used in SS3 in the assessment of the North Pacific stock was based "*on having a band pair deposition rate that changes from 2 to 1 band pairs per year after age 5*" as some authors had pointed out and validated. Sex-specific estimates of growth were based on that case, on a meta-analytic approach of age and growth data provided by different studies compiling vertebrae interpretation and size frequency analysis (Takahashi *et al.* 2017). In a similar sense, some pioneer studies had used different methods for estimated growth: temporal analysis of length–month information, results of tagging data, length–frequency analysis and combined with ring counts on vertebrae. The last estimates using those rings and interpretations agreed quite well with results from other methods tested and large growth rates of around 50 and 32 cm yr^{-1} were even obtained for the two initial ages in both sexes (Pratt and Casey 1983). Extensive size-frequency distributions obtained from broad Atlantic and Pacific areas also suggest as very plausible growth rates of around 30-40 cm FL $year^{-1}$ for the initial ages in both sexes (García-Cortés *et al.* in press).

Moreover, the longest period recorded in our tagging-recapture data (Mejuto *et al.* 2005) was a female 13.53 years at large, increasing form 105 cm to 325 cm FL during that period. The mean growth rate of this longest at large female was 16.25 cm yr^{-1}, more than double the estimated growth rate when considering the model Rosa *et al.* (2017[b]-SCRS/2017/111[5]) for females.

Additionally, a preliminary analysis was carried out for the seven tag-recapture records for the case of those females whose sex was equally identified at the time of tagging and recapture and which were at large during at least 3.5 years. The growth model estimated for these females using linear fit or maximum likelihood approaches were, respectively: K = 0.1385, FL_{inf} = 334 cm; K= 0.124, FL_{inf}= 350, assuming FL_0=63 cm in both cases (**Figure 9**). Growth rates of these females were also much faster than those assumed for females in the North Atlantic assessment and closer to those assumed for the same sex and length type in the North Pacific assessment case (Anon. 2018).

On the other hand, a total of 1,258 tag-recaptures of SMA were available in the ICCAT data base (Anon. 2017[a]). The conclusions achieved by the 2017 WG on tagging-recapture and the review carried out in the present paper are consistent and mostly suggest restricted tagging areas in NW regions, short time at-large periods of most tagged-recaptured fish and an mostly apparently relative short horizontal-straight migrations from the tagging to the recapture position regularly between quite restricted North Atlantic areas. Apparent negative growth rates, which are biologically implausible (Anon. 2017[b]) can be deduced in some records due to estimations at release or errors in the data records. Some information was found to be lacking in that available data set to develop sex-specific analysis. In fact, only 51 fish-records available have been more that 3.0 years at large and 47 of them have shown positive growth rates, but sex information is omitted. The percentage of individuals of each sex which contribute to the set of these available ICCAT tagged-recaptured data would likely be quite balanced in small and medium sizes, but more females than males should be expected in the case of the very scarce o rare number of available largest recaptured individuals assuming true the differential growth described in the literature, and considering the sex ratio data by size classes and the FL_{max} values observed at sea (García-Cortés *et al.* in press-2021).

Despite the limitations in the available tag-recapture ICCAT data set, the preliminary analysis of those 47 tagged-recaptured fish -considered sex unidentified- was carried out and also considering 45 remaining records after rejecting two possible outliers. The simple linear fits and maximum likelihood approaches suggested K values between 0.1202 and 0.1485 and FL_{inf} between 314 and 290 cm for "unidentified-sex" individuals considering the respective data sets and the type of fit implemented (**Table 4**). The values from ICCAT tagging-recapture data also suggest much higher growth rates and a much faster growth model for that assumed for either sex in the North Atlantic assessment case (**Figure 11**). These tag-recapture results support previous studies including comparative tag-recapture data. Higher growth rates and faster growth models were regularly obtained from tag-recapture and size data than from those estimates using marked bands on the vertebrae assuming "*one band pair per year hypothesis for all sizes-ages"*.

FL_{max} values recorded so far in our observer at sea program from Atlantic areas were 297 cm and 320 cm for males and females, respectively (García-Cortés *et al.* in press). These values are very consistent to those FL_{max} observed during landings in the 1980's of 293 cm and 326 cm for males and females, respectively (Mejuto 1985). Therefore, the FL_{inf} values obtained for the preliminary tagging-recapture data seem to be quite consistent with those FL_{max} observed in North Atlantic. Preliminary growth models obtained for unidentified-sex from ICCAT tagging-recapture data were not included in comparisons with some other growth models described in the present paper (**Figures 9 and 10**), which only consider females in those particular plots.

Therefore, it does not seem plausible to assume in the case of the North Atlantic SMA stock a preliminary and unique growth model -among the slowest documented in literature- to be implemented, especially in a scenario in which the different interpretative criteria of the rings can produce such different growth rates and models (**Figure 9, 10, 11**) and whose growth rates are not probably related to age and neither supported by the tag-recapture data available to date.

A similar dilemma occurred in the case of the European hake (*Merluccius merluccius*) which is a bony fish and not at all a highly migratory species. Due to its demersal nature, it suffers seasonal environmental contrasts in the areas where it lives. Perhaps a relatively regular annual pattern of bands on its hard parts should be expected in this species and some validations had been suggested. Extensive and comprehensive samplings and readings were done during decades involving different laboratories. However, seven decades after the debate on "*slow growth*" vs. "*fast growth*" in this species based on interpretation on hard parts, a paradigm shift occurred, as was demonstrated by means of tag-recapture data, showing that in fact the species is fast growing, twice that which had traditionally been considered in the models from the interpretation of the rings on hard parts (De Pontual *et al.* 2006). The new growth paradigm had important implications on the number of age classes in the stock and in the catch, on the age of first maturity, on the biomass of the spawning stock, etc. The length-age keys used in the ICES WG for its assessment from its inception in 1992 to 2009 were not valid, nor were the resulting evaluations reliable throughout all those years (Bertignac and Pontual 2007, Piñeiro-Álvarez *et al.* 2009, Piñeiro-Álvarez 2011).

3.3.2 Age of first reproduction in females

A conclusion is evident in the case of SMA depending of which of the growth models is assumed, as well as regarding the effect when estimating the age of first maturity of the females ($AgeMat_{50\%}$), even starting from a possible range of $FLMat_{50\%}$ values considered (275-298 FL cm) (Anon. 2017[a]) within which -or in its proximity- it would be considered feasible to ascertain the first litter-parturition processes in females, considering the sporadic occurrence of pregnant females observed in oceanic areas and the few records analyzed in most studies reviewed (see e.g. Bass *et al.* 1975, Bigelow and Schroeder 1948, Bustamante and Bennett 2013, Campana *et al.* 2005, Cliff *et al.* 1990, Conde-Moreno and Galván-Magaña 2006, Francis and Duffy 2005, García-Cortés *et al.* in press, Gilmore 1993, Groeneveld *et al.* 2014, Gubanov 1978, Joung and Hsu 2005, Maia *et al.* 2007, Mollet *et al.* 2000, Semba *et al.* 2011, 2017; Sims 2005, Snelson *et al.* 2008, Stevens 1983, 2008). However, in the assessment of the North Pacific stock a somewhat lower $FLMat_{50\%}$ value ($FLMat_{50\%}$= 254 cm, equivalent to $PCLMat_{50\%}$= 233 cm) was found than that assumed in the North Atlantic stock assessment.

Critical information on the biology of SMA necessary for the SS3 and other assessment models is related to sex-specific growth, natural mortality, reproductive cycle, maturity and fecundity. The selection of one growth parameter or another is not a minor issue in the case of those models that incorporate these parameters. The natural mortality could be inferred in some cases from the growth model assumed. The estimate of size at first maturity of females ($FLMat_{50\%}$) is transformed into age at first maturity ($AgeMat_{50\%}$) in many assessment models from growth. Under that hypothesis of growth and reproduction as slow as that assumed in Anon. (2017[a,b]) the females of the North stock would reach a longevity (T_{max}) of around 29-32 years, yet it was assumed at 31 years

(Ardizzone 2006), and $AgeMat_{50\%}$ for females between 21-18 years, respectively, according to the unique preliminary growth study that was considered in the North Atlantic assessment case (Anon 2017[b]). That is, an $AgeMat_{50\%}/T_{max}$ ratio would be assumed between 0.68-0.58 according to the values respectively considered (Rosa *et al.* 2017[b,5] or Anon. 2017[a]). However, the $AgeMat_{50\%}$ = 21 years was finally implemented (Anon. 2017[b], Anon. 2020[a], Courtney *et al.* 2019). On the contrary, considering other growth models (**Figure 9**) $AgeMat_{50\%}$ values for females would be around 7-13 years of age, with $AgeMat_{50\%}/T_{max}$ values between 0.23-0.42 according to the growth model considered (**Table 5**).

As previously pointed out, a very different growth model to that used for the North Atlantic were assumed form females in the assessment of the North Pacific SMA stock. A value of T_{max}= 31 years (Ardizzone 2006) was also considered in that case, but the $AgeMat_{50\%}$ was around 10.5 years based on the growth model estimated form females (Anon. 2018) -versus 21 year assumed in the North Atlantic case-, and a $FLmat_{50\%}$= 254cm (equivalent to the $PCLmat_{50\%}$= 233cm). This would represent in the case of the North Pacific a ratio $AgeMat_{50\%}/T_{max}$= 0.34 that seems more plausible for this species as suggested by other growth models of females, including the preliminary tag-recapture approximations or in comparison with that described for porbeagle or large pelagic-highly migratory species.

Comparatively, we can consider the case of the porbeagle (*Lamna nasus*) belonging to the same family. This species is described as less abundant than SMA, as well as being a slower-growing and later-maturing species, and typically (or mostly) restricted to some cold waters of both hemispheres; with probably lower growth rates and with a relatively later female first reproduction than SMA. A median age of maturity $AgeMat_{50\%}$ for females of 13 years was estimated in that species for longevity (T_{max}) of at least 25 years (Natanson *et al.* 2019, Cortés 2020). Therefore, according to these authors, the female porbeagle would have an $AgeMat_{50\%}/T_{max}$ value that it is probably below 0.52. It would seem biologically plausible for the $AgeMat_{50\%}/T_{max}$ value of SMA females to be lower than that of the porbeagle. Hence, a value of around 0.7 deduced when applying the growth postulated for SMA females by Rosa *et al.* (2017[b])[5] –assumed for the assessment- would seem unlikely. According to this assumption of age and $AgeMat_{50\%}$, subsequent work under SS3 has been carried out also considering that $AgeMat_{50\%}$ of the females would be reached at 21 years old, for T_{max} longevity of 31 years (Ardizzone 2006, Anon. 2020[a], Courtney *et al.* 2019), while other growth models suggest for the same size of first maturity of females a range of around 7-13 years old.

As already indicated, an $AgeMat_{50\%}/T_{max}$ value of 0.7 for females does not seem typical of a highly migratory large pelagic species such as SMA, which has a very wide geographical distribution, high biomass and great abundance in both hemispheres, especially in temperate and subtropical areas but also to a lesser extent in the tropical ones, presenting a relative high prevalence within the pelagic ecosystem. Furthermore, under such an unfavorable reproductive strategy in relation to other large pelagic species present in the same ecosystem, this species would probably have become extinct millions of years ago as a result of competitive processes at the highest levels of the food chain. On the other hand, we must consider that the availability of reproductive individuals is usually very rare event in the oceanic longline fisheries of several oceans. Pupping and/or nursery areas of SMA are regularly described along the continental margins of the oceans and into EEZ (Gibson *et al.* 2021, Liu *et al.* 2018) and so information about nursery areas, pregnant females and presence of litters is very scarce in most studies using samples from high-seas longline fisheries.

On the other hand, the M values were also different between the two assessed stocks, with M values = 0.08 and 0.128 (for both sexes) in the North Atlantic and North Pacific, respectively. In the north Pacific case, the M value was estimated from Hoening (1983) approximation using the same T_{max}=31 year (Ardizzone 2006). The application of Hoening's methodology in the case of the North Atlantic stocks would imply obtaining the same M value as that of the North Pacific stock given the same T_{max} assumed in both cases-stocks. Alternatively, the resulting M values would have been 0.14 and 0.15 for females and males, respectively if Hoening's approximation were applied to the T_{max} values of males and females suggested by Rosa *et al.* (2017 [b])[5] for the North Atlantic.

Considering the reproductive strategy of SMA, it is assumed that the levels of recruitment are closely related to the biomass-abundance (SSF) or to the number (SAF) of the reproductive females. In other words, it does not seem feasible to keep the abundance of recruits and pre-breeders relatively high and stable over several decades - as the catch, size data and standardized CPUEs of fleets with the longest and most robust data have shown- while neither assuming a stable trend of the breeders during those periods, with the corresponding time span that defines a tenable growth model. In this species, considering its reproductive strategy, it is unlikely that environmental factors have as much relevance on annual recruitment levels as in the case of many bony fish in which even, with very low levels of spawning biomass, high levels of recruitment may occur for environmental causes or phases that are favorable to them, or the opposite. In the case of SMA, stable levels of juveniles and pre-breeders could only be likely justified from stable SSF or SAF levels.

3.3.3 Conclusions biological parameters

Biological parameters currently include some uncertainty in many fish stocks. But in many species this uncertainty is within a reasonable range whereupon the effect on the assessment outcomes is assumed to be low, moderate or even relatively negligible in the long term. However, in the case of the North Atlantic SMA, the level of uncertainty is enormous at least in terms of growth parameters as well as on the implications when estimating $\text{AgeMat}_{50\%}$ of females, productivity, etc. which could determine the results of some base case models applied and influence the interpretation of others. Inaccurate age estimates can lead in this case to serious errors in stock assessment and projections.

The SMA growth model assumed in the 2017 assessment of Northern stock and the age of first maturity of the females seems to be unlikely in view of the existing evidences. Therefore, caution is advisable when selecting unique and preliminary parameters over others described in literature that appear probably more plausible, considering the different results achieved depending on the interpretation of the bands on the vertebrae, the limited number of samples analyzed in most growth studies, and of the almost mimetic use of methodologies and interpretative criteria among readers involved. Considering the available results, recent studies and in the absence of validation, tag-recapture is postulated as a good approach to elucidate some of these uncertainties and for suggesting which growth models would be plausible, or to rule out those others empirically untenable.

The selection of some biological parameters over others could have important effects on the results of some assessment models used in the case of SMA and projections, as well as on the modeler's vision in relation to the dynamics of the stock over the years and the interpretation of diagnosis provided by those other models tested. Reviewing the growth approaches applied in the assessment of other stocks of the same species and what other available growth model estimates suggest, it seems advisable to at least try out alternatives to these pre-established parameters and to propose various scenarios that consider diversity. This will probably make assessments harder and more time consuming (e.g. Anon. 2018), and/or it will likely require a longer period of work and/or other type of solid approaches before taking decisions, and probably more effort to improve basic data and quality of reports. But, it will probably be scientifically more ethical and responsible to assume and recognize the existing doubts or uncertainties than to propose a unique scenario of biological parameters and model results which are probably untenable or without solid scientific bases. The review of the literature and the available tagging-recapture data does not support growth rates nor the growth model implemented for the 2017 North Atlantic stock assessment.

Undoubtedly, it is necessary to also improve studies on the reproduction of this species despite the difficulties in finding representative samples of breeding females from oceanic areas. The size of maturity, the reproductive cycle, breeding frequency and the number of fecundity, etc., are some of the parameters which currently encompass large uncertainties and which are regularly inferred from small sampling sizes in this species. Reviewing the previously-cited literature, it can be concluded that the availability of observations for the different studies on the reproduction of SMA females was regularly scarce probably due to not having access to observations from those areas or females where reproductive processes could be more intense and/or to the escape-release of the large females from oceanic longliners. Studies on size-distribution of the catch in commercial longline fleets carried out in the different oceans (Anon. 2018, Coelho *et al.* 2017[c], García-Cortés *et al.* in press.) have found that larger sizes tend to occur in equatorial and tropical regions and smaller sizes in higher latitudes. But predominant pre-breeding records in most oceanic longliners and the occurrence of fish larger than 200 cm FL are regularly very scarce in the most studies describing catches in high-seas longline fleets targeting tuna and tuna-like in the different oceans.

3.4 Other matters

Both the JABBA models conducted in the 2017 assessment using the C1 or C2 catch scenarios, the selected CPUE series and the weighting criteria assumed for them, predicted overfishing since around the 1980s or before the 1990s, respectively. In other words, from the time when levels of T1 catches were considered incipient under scenarios C1 and C2. They also estimated median MSY values between 1,147-1,832 tons according to the type of model implemented (Schaefer or Pella and Tomlinson) and the catch scenario C1 or C2 selected (Anon 2017[b]). The values in term of relative biomass and F trends differed from those estimated in previous ICCAT assessments or those obtained through other type production models using equivalent catch data sets for the same periods with reliable catch data considered. It was argued that production models could not be appropriate for estimating realistic MSY or other reference points in the case of SMA. In fact, the median age at maturity for females was assumed at 21 years considering the growth model implemented for females and T_{max}= 31 years in the 2017 North Atlantic assessment. Therefore, based on such arguments, it was then argued that the bycatch component in most fleets would be of immature fish less than 10 years old and that a "*very large lag effect",* between exploitable phase and reproductive phase starting at 21 years old, would occur in such a case (Anon. 2020[a], Maguire and Berg 2020). However, the perception of such a "*long lag effect"* would dramatically change if other growth models were assumed (see section 3.3.1*).*

During at least the entire period 1971-2015, the reported and the estimated catches would have been largely higher than the estimated MSY levels. Furthermore, the total annual catches reported from the 1980s to 2015 have proven to be several times higher than the MSY estimated by those base case production models and F > Fmsy was predicted from the 1980s-1990s. But all this while the longest, broadest and most robust abundance indicators did not show signs of depletion of stock -nor decreases in the mean size of the catches which would suggest a stressed stock (Shuter 1990)- in those fleets specifically analyzed over several decades after the start of the alleged overfishing period based on JABBA predictions. However, results obtained from other production models tested suggested a different outlook in terms of production curves, MSY, F and biomass trajectories.

Productivity estimates for the Northern stock under the JABBA models tested were relatively much lower than for the Southern stock and also lower than those obtained in previous North stock assessments. For the southern stock, the estimates of r_{max} give much higher values, basically twice the estimate of the North stock. In that sense, Cortés (2017[b]) estimated that in the case of SMA the productivities ranged from r_{max}=0.031 to 0.060 yr^{-1} for the Northern Atlantic stock but r_{max}=0.066 to 0.123 yr^{-1} for the South Atlantic stock. In the case of the restricted NW porbeagle stock the same author (Cortés 2019) estimated a productivity which ranged from r_{max}=0.046 to 0.059 yr^{-1} using six deterministic methods. For the stochastic Leslie matrix method, the mean r_{max} of porbeagle was 0.051yr^{-1}. Additionally, Cortés and Semba (2020) estimated productivity for the western North Atlantic porbeagle assuming an equally probable 1- or 2-year breeding frequency and the estimated productivity was 0.045-0.068 $yr^{-1}$for the six deterministic methods tested. For the stochastic Leslie matrix, mean values r_{max}= 0.059 yr^{-1}(CIs95%=0.037–0.081) were estimated for the Northwest Atlantic porbeagle stock. So r_{max} estimates for a relatively restricted porbeagle stock were generally higher than those predicted for the broad and abundant North Atlantic SMA stock (Anon. 2017[b]). Taking into consideration the respective biological characteristics of both species, their respective areas of distribution, the history of the fisheries and the abundance-biomass described for the respective stocks; a relatively much higher r_{max} value could be plausible in the case of North Atlantic SMA. The resulting conclusion about r_{max} in the case of the assessment of North Atlantic SMA stock should probably be investigated in the context already suggested by other authors for this type of bycatch species while also taking into consideration the effect of the catch scenarios previously assumed and other decisions consequently taken for assessment.

In other hand, caution must be exercised by scientists when considering some upward revisions or hypothetical estimations in some historical catch data, which may on occasion not be accurately documented or justifiable in relation to fleet intensity reported and/or in relation to catches of other species. In some cases, when forthcoming regulatory measures are envisioned for a species, a sudden interest may appear in some cases to revise upward historical catch reports, or to suddenly report high increases in catch data for those recent years potentially considered as reference for future regulations. We refer to this "*phenomenon*" as "*the pre-quota effect*", previously identified in past catch reports in some actors as in the case of some highly valuable tuna species.

4. General conclusions

The stock assessment outcomes of SMA 2017-2019 could be -among other elements- very sensitive to the unlikely catch scenarios selected, the decision-rules for selecting and weighting CPUE series and probably mainly to the biological parameters considered in some of the models or those taking into consideration for the interpretation of results achieved by other models tested. The preliminary growth model considered in 2017 could be an especially important issue regarding the uncertainty and plausibility of that assessment and projections. More appropriately and weighted CPUE series could be probably selected considering qualitative and quantitative merits of each series and their relative contributions to the areas of distribution and catches covered. Due to the high uncertainty in all these key-items, models implemented and runs should be tested with a variety of scenarios considering more plausible historical catch levels according to the history of the respective fisheries and the gears involved as well as more diverse and plausible scenarios of key biological parameters.

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Table 1. An overview of the historical fishing activity by flag and year of some ICCAT commercial longline fleets operating in areas of the North Atlantic SMA stock during the period 1950-2015 targeting tuna and/or tuna-like species and their respective T1 reported-available assumed in the base case C1-catch scenario in assessment carried out in year 2017. **F codes**: No fishing activity carried out or not identified= "-". Fishing activity carried out or assumed based on literature= "1". Fishing activity carried out but data affected by mercury restrictions= "2". **T1 codes:** No T1-catch reported for the fishing activity carried out = "0". T1-catch reported for the fishing activity carried out and data assumed in the C1 scenario= "1".

YearC/Fleet	ESP		PRT		JPN		TWN		USA		CAN		VEN		MAR		CHN		KOR		CUB		MEX		BLZ		PAN	
	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1	F	T1
1950	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	1	1	-	-	-	-	-	-	-	-	-	-	1	0	-	-	-	-	-	-	-	-	1	0	1	0	-	-
1955	1	1	-	-	-	-	-	-	-	-	-	-	1	0	-	-	-	-	-	-	-	-	1	0	1	0	-	-
1956	1	1	-	-	1	0	-	-	-	-	-	-	1	0	-	-	-	-	-	-	-	-	1	0	1	0	-	-
1957	1	1	-	-	1	0	-	-	-	-	-	-	1	0	-	-	-	-	-	-	-	-	1	0	1	0	-	-
1958	1	1	-	-	1	0	-	-	-	-	-	-	1	0	-	-	-	-	-	-	-	-	1	0	1	0	-	-
1959	1	1	-	-	1	0	-	-	-	-	-	-	1	0	-	-	-	-	-	-	1	0	1	0	1	0	-	-
1960	1	1	-	-	1	0	-	-	-	-	-	-	1	0	-	-	-	-	-	-	1	0	1	0	1	0	-	-
1961	1	1	-	-	1	0	-	-	-	-	-	-	1	0	1	1	-	-	-	-	1	0	1	0	1	0	-	-
1962	1	1	-	-	1	0	1	0	1	0	1	0	1	0	1	1	-	-	-	-	1	0	1	0	1	0	-	-
1963	1	1	-	-	1	0	1	0	1	0	1	0	1	0	1	1	-	-	-	-	1	0	1	0	1	0	-	-
1964	1	1	-	-	1	0	1	0	1	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	-	-
1965	1	1	-	-	1	0	1	0	1	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	-	-
1966	1	1	-	-	1	0	1	0	1	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	-	-
1967	1	1	-	-	1	0	1	0	1	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	-	-
1968	1	1	-	-	1	0	1	0	1	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	-	-
1969	1	1	-	-	1	0	1	0	1	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	-	-
1970	1	1	-	-	1	0	1	0	2	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1971	1	1	-	-	1	1	1	0	2	0	2	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1972	1	1	-	-	1	1	1	0	2	0	2	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1973	1	1	-	-	1	1	1	0	2	0	2	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1974	1	1	-	-	1	1	1	0	2	0	2	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1975	1	1	-	-	1	1	1	0	2	0	2	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1976	1	1	-	-	1	1	1	0	2	0	2	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1977	1	1	-	-	1	1	1	0	2	0	2	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1978	1	1	-	-	1	1	1	0	2	0	2	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1979	1	1	1	0	1	1	1	0	1	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1980	1	1	1	0	1	1	1	0	1	0	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1981	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1982	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1983	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1984	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1985	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1986	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1987	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1988	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1989	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1990	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1991	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1992	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1993	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	-	-	1	0	1	0	1	0	1	0	1	0
1994	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0
1995	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	1	0
1996	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0
1997	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0
1998	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0
1999	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	1
2000	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1
2001	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	1	0
2002	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0
2003	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	1	0
2004	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	1	0
2005	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	1	0
2006	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0	1	1
2007	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1
2008	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	-	-	1	1	1	0	1	1
2009	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	-	-	1	1	1	1	1	1
2010	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	-	-	1	1	1	1	1	0
2011	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	0
2012	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	0
2013	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
2014	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
2015	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	0

Table 2. Summary-table of the main CPUE series selected as valid for the 2017 assessment of the North Atlantic shortfin mako stock (see annex 2 for details about each series).

Fleet / CPUE series	**USA (S1)**	**UE-ESP**	**UE-POR**	**JAP**	**TAI**
LL category	SWO	SWO	SWO	TUN	TUN
SCRS Source	SCRS/2017/056	SCRS/2017/108	SCRS/2017/049	SCRS/2017/054	SCRS/2017/071
Data Type	M_LBOOK	SCI_TRYP	SCI_COMB	M_LBOOK (5)	OBS
Period	1986-2015	1990-2015	1999-2015	1994-2015	2007-2015
# Years	30	26	17	22	9
% Coverage	4-90 (1)	71.0	4.1	?	11.4
CPUEn	0.60	1.81	1.03 (4)	0.13	0.06
CPUEw (kg RW)	21.6 (2)	42.9	30.9	6.5 (2)	3.1 (2)
Mean W (kg RW)	36 (3)	37	30	50 (6)	50
Mean Task I (t) 1990-2015	475	1196	688	238	32
% Task I vs. Total 1990-2015	**13.02**	**55.12** (7)	**18.47** (7)	**6.35**	**0.58**

CPUEn:	Number of fish per thousand hooks
CPUEw:	Kg round weight per thousand hooks
Note[1]:	The coverage in logbooks of around 90% was assumed for recent years but it was variable through the years. Range is included.
Note[2]:	CPUEw estimated from CPUEn and mean weight of catch
Note[3]:	A mean weight approximation from figure included in the document
Note[4]:	CPUEn estimated from CPUEw and mean weight described in the document
Note[5]	Mandatory logbooks filtered for species composition by record
Note[6]	Assumed mean weight of Japan = mean weight of Taipei (50 kg RW)
Note[7]:	Reported Task I of UE-MMEE = 73.64% of international Task I reported 1990-2015

Data type:

M_LBOOK:	Mandatory logbook (Note: A series 2 was obtained from observers and also implemented)
SCI_TRYP:	Scientific information by trip obtained during landings
SCI_COM:	Scientific information by trip (combination of landings, logbooks and port sampling)
M_LBOOK (5):	Mandatory logbooks filtered for species composition
OBS:	Observer at sea

Table 3. Summary-table inferred from the data included in the CPUE standardization of Taipei and estimated total Task 1 during this period (Tsai and Liu 2017). Quantitative diagnosis of data used was obtained from information included in that paper for CPUE standardization and T2-effort extracted from ICCAT database.

	Task II_effort	**Effort GLM**	Coverage	Task I	Task I	**Data used in GLM**		
Year	Effort Atl-N	Effort observ.	%	T1 Nº	T1 W(t)	Mean W(kg)	Nº fish	W fish (t)
2007	5227184	288793	5.52	126	6	47.6	7	0.33
2008	3949808	226049	5.72	530	27	50.9	30	1.55
2009	3524685	426490	12.10	1774	89	50.2	215	10.77
2010	5419712	419197	7.73	278	14	50.4	22	1.08
2011	4593175	643722	14.01	1083	54	49.9	152	7.57
2012	3750793	763769	20.36	703	35	49.8	143	7.13
2013	4135281	233317	5.64	263	13	49.4	15	0.73
2014	1351877	247759	18.33	309	16	51.8	57	2.93
2015	4238512	574711	13.56	N/A	N/A	N/A	N/A	N/A
2016	5755115	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mean	4194614	424867	11.4	633	31.8	50.0	80.0	4.01

Table 4. Growth parameters obtained from preliminary runs of the conventional tagging-recaptured SMA ICCAT data base (Anon. 2017^{b}) for those fish (sex-unidentified) at least 3.0 years at large. L_0 was assumed at FL= 63 cm in all cases (see figure 11 for comparison).

Data set	**Fit type**	**# M-R fish**	**K**	**FL$_{inf}$ (cm)**	**FL$_0$ (cm)**
Set 1	Linear	47	0.1202	314.8	63.0
Ser 2	Linear	45	0.1485	292.0	63.0
Set 1	Max. likelihood	47	0.1410	290.0	63.0
Set 2	Max. likelihood	45	0.1450	292.0	63.0

Table 5. Longevity (T_{max}, in years), size of first litter ($AgeMat_{50\%}$ in years) and the relationship between both parameters in case of females of two Lamnidae species (shortfin mako and porbeagle). (1): Values used in the SMA North Atlantic stock assessment case, based on the size of first reproduction of females and the growth model implemented (Anon. 2017^{b}). (2): Range of values achieved based on other SMA growth models of females obtained for the North Atlantic stock using hard parts, size information or tagging-recapture data (see figures 9, 10, 11and chapter 3.3.). (3): Values used in the North Pacific SMA stock assessment case based on the size of first reproduction of females and the growth model implemented (Anon. 2018). (4): Values used for females in porbeagle POR (*Lamna nasus*) (Natanson *et al.* 2019, Cortés 2020).

Species	Case-Growth model	Tmax (yr)	AgeMat50% (yr)	AgeMat50%/Tmax
SMA	North Atlantic 2017 (1)	31	21	0.68
SMA	North Atlantic (2)	31	7-13	0.23-0.42
SMA	North Pacific 2018 (3)	31	10.5	0.34
POR	(4)	25	13	0.52

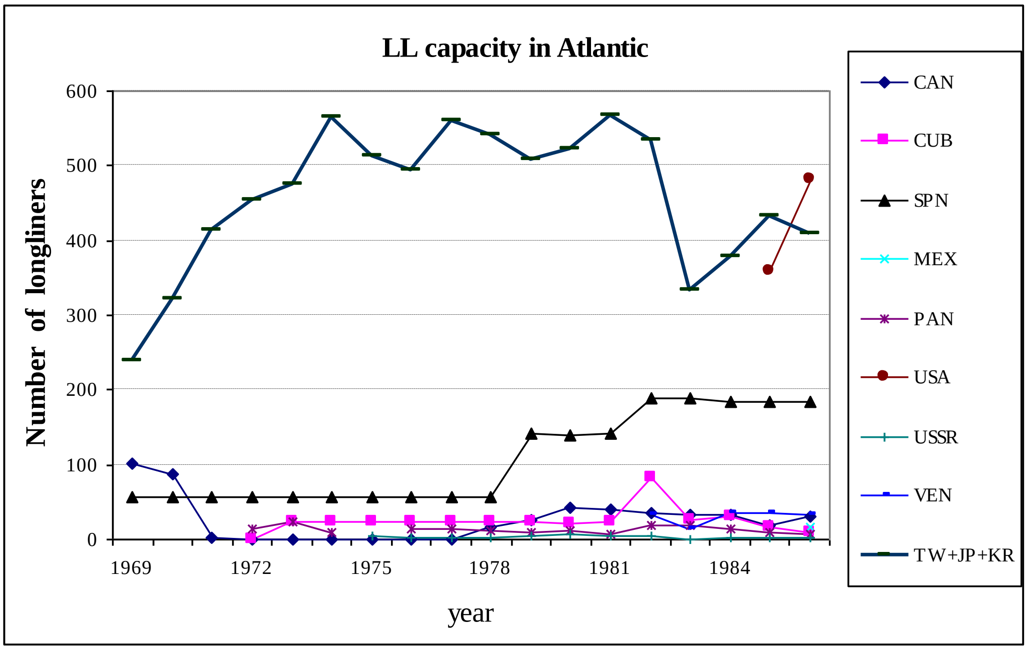

Figure 1. Capacity: Number of longliners for some of the active fleets fishing in the Atlantic Ocean between years 1969-1986 as it was reported by the CPCs to the ICCAT Stat. Bol. The reported data is incomplete from many fleets-years. Data of fleets TW+JP+KR are the number of long-distant longliners reported by the CPCs Taipei+Japan+Korea. Data from U.S. was not reported until 1985 but longline fisheries started at least at the beginning of the 1960s. The period of mercury regulations is not well reported in the case of Canada. Data of UE-Spain before 1978 were approximated from scientific information. Data of other longline fleets can be very incomplete or unreported at all, so the figure is just a partial overview.

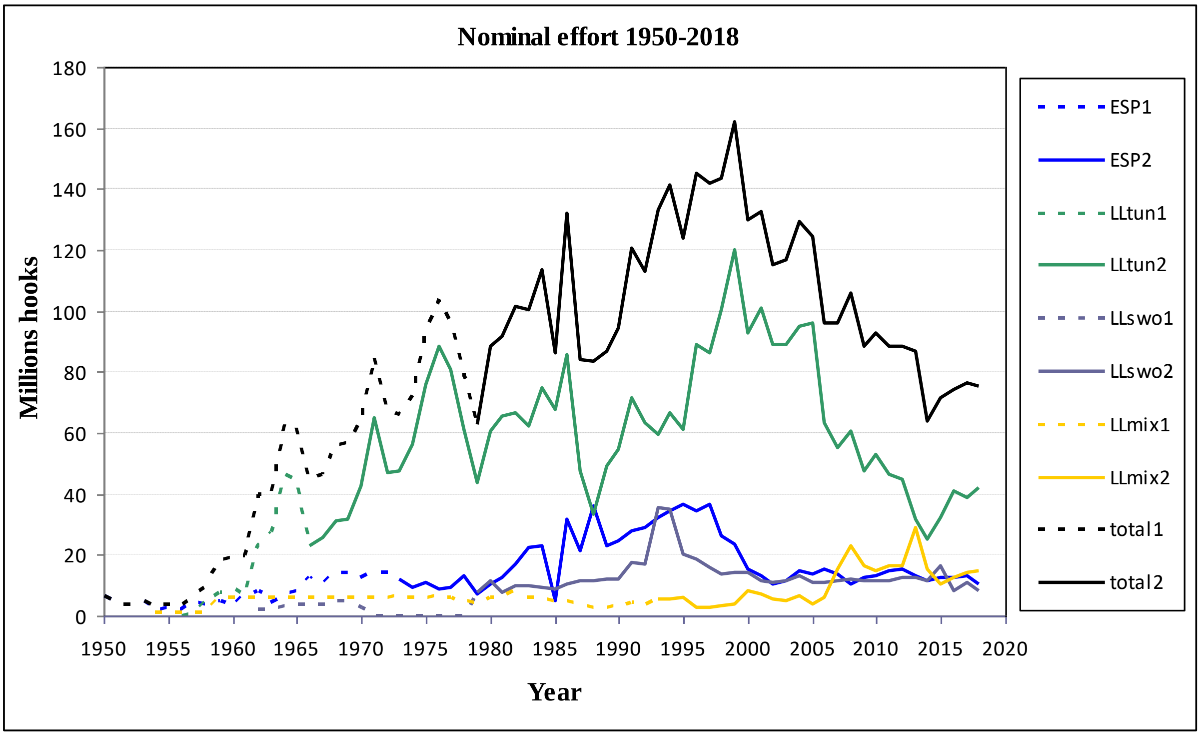

Figure 2. Nominal effort (million of hooks) of the longline fleets fishing in the area of distribution of the Northern stock of the shortfin mako. Task-2-effort reported to ICCAT (vers. Januaruy 2020) was complemented with information obtained in scientific papers (continuous lines). The effort estimated for old years with no information found was estimated from assumptions applied to each fleet (see **annex 1** for details) and those periods are indicated (dashed line). The series of effort are summarized: ESP= UE-España. LLtun= JPN+TWN+KOR+CHN. LLswo= PRT+USA+CAN+MAR. LLmix= VEN+MEX+CUB+PAN+BLZ.

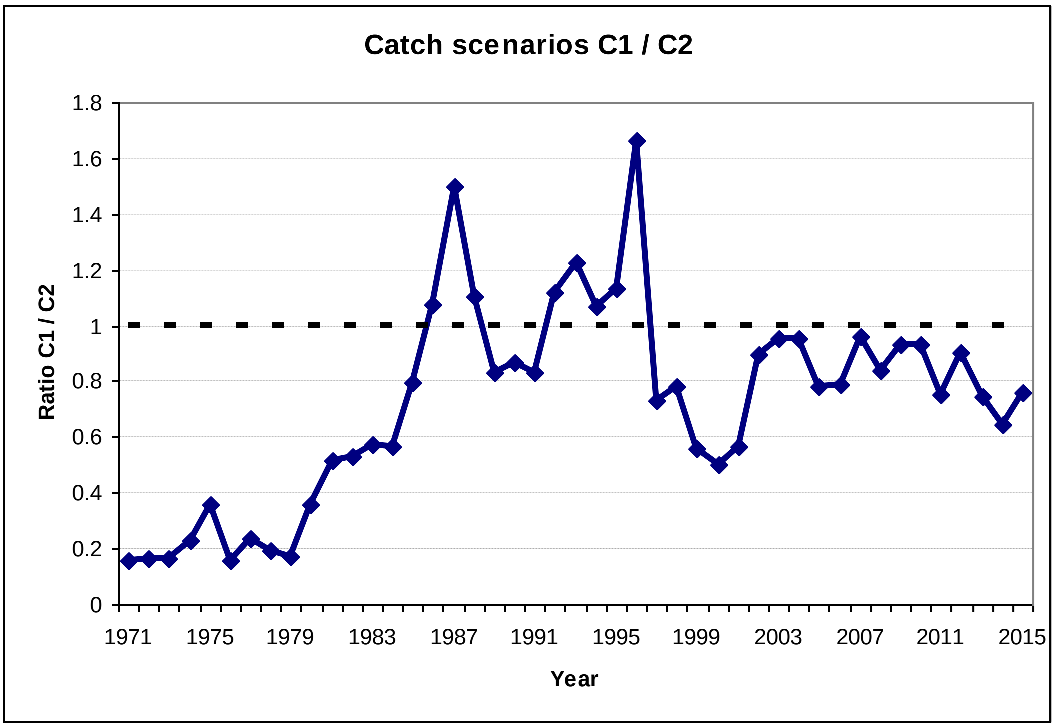

Figure 3. Scenario C2 vs. C1: Ratio between Task1 (T1) reported to ICCAT and used in the base case models of the 2017 assessment of the Northern shortfin mako (scenario C1) and the hypothetical catch estimated based on ratios between species (scenario C2) for the period 1971-2015 (Coelho and Rosa 2017).

Main conclusions: (a): An average level of underreporting of up to 84% was suggested for the period 1971-1979 (this level could be assumed to be that also relating to years 1950-1970). (b): A progressive decrease in the level of underreporting was suggested for most active fleets during 1979-1986 as T1 was progressively reported by the active CPC although their fishing activities were carried out from years-decades earlier. (c) The ratio in 1986 is close to 1 and in years immediately after 1986 ratio > 1 reaching a value up to 1.6 in year 1996. It was considered that after 1985 T1 data could approach full reporting at least for the set of the most relevant fleets in the North Atlantic. An overestimation of catches based on ratio between species is plausible for the most recent period in scenario C2 (see discussion of the present paper).

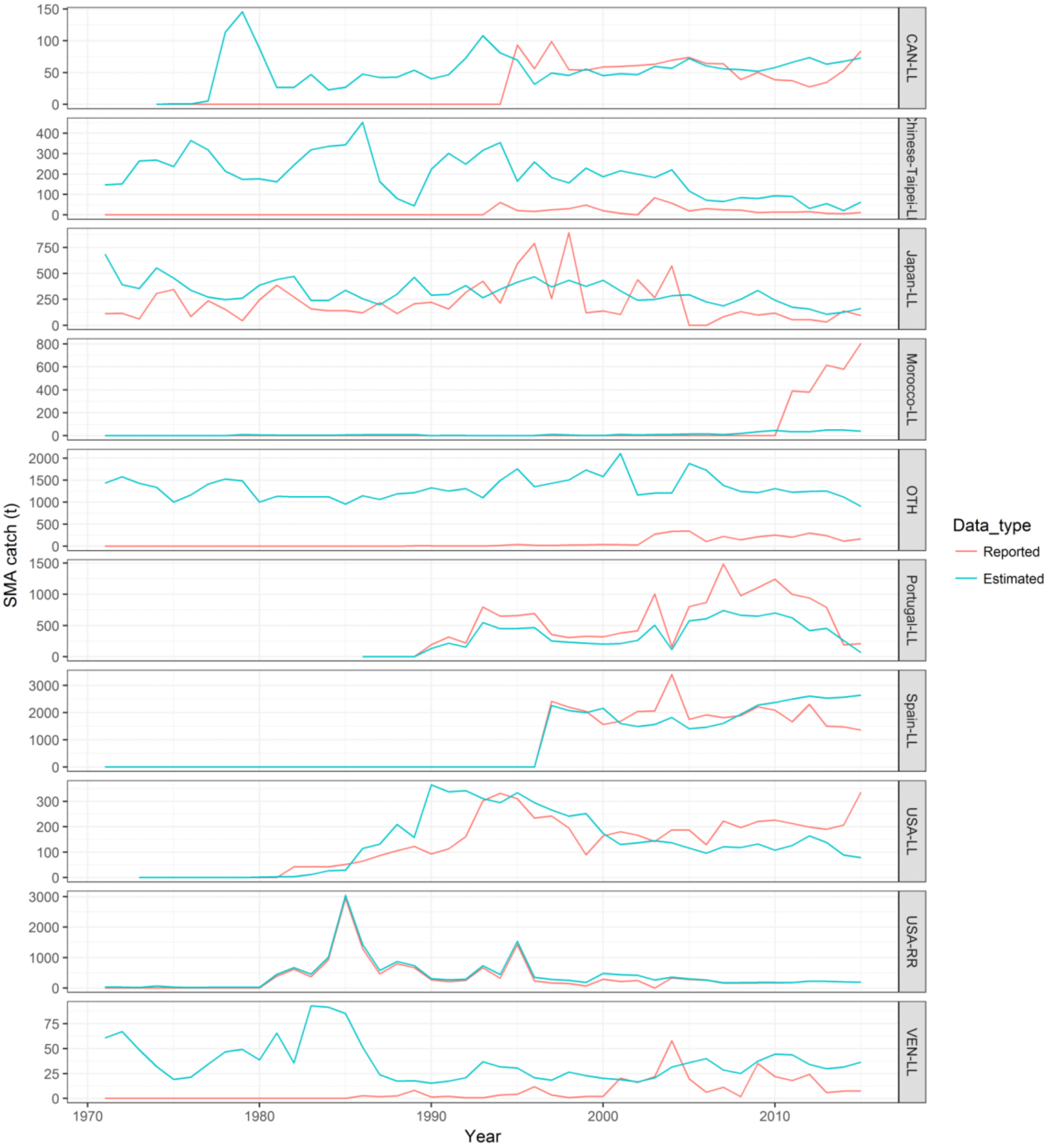

Figure 4. Comparison between the reported ICCAT catches (T1) by flag or group of fleets and the estimated hypothetical catch series based on ratios among species for the Northern shortfin mako stock, during the period 1971-2015 (figure was taken from the presentation of Coelho and Rosa, 2017).

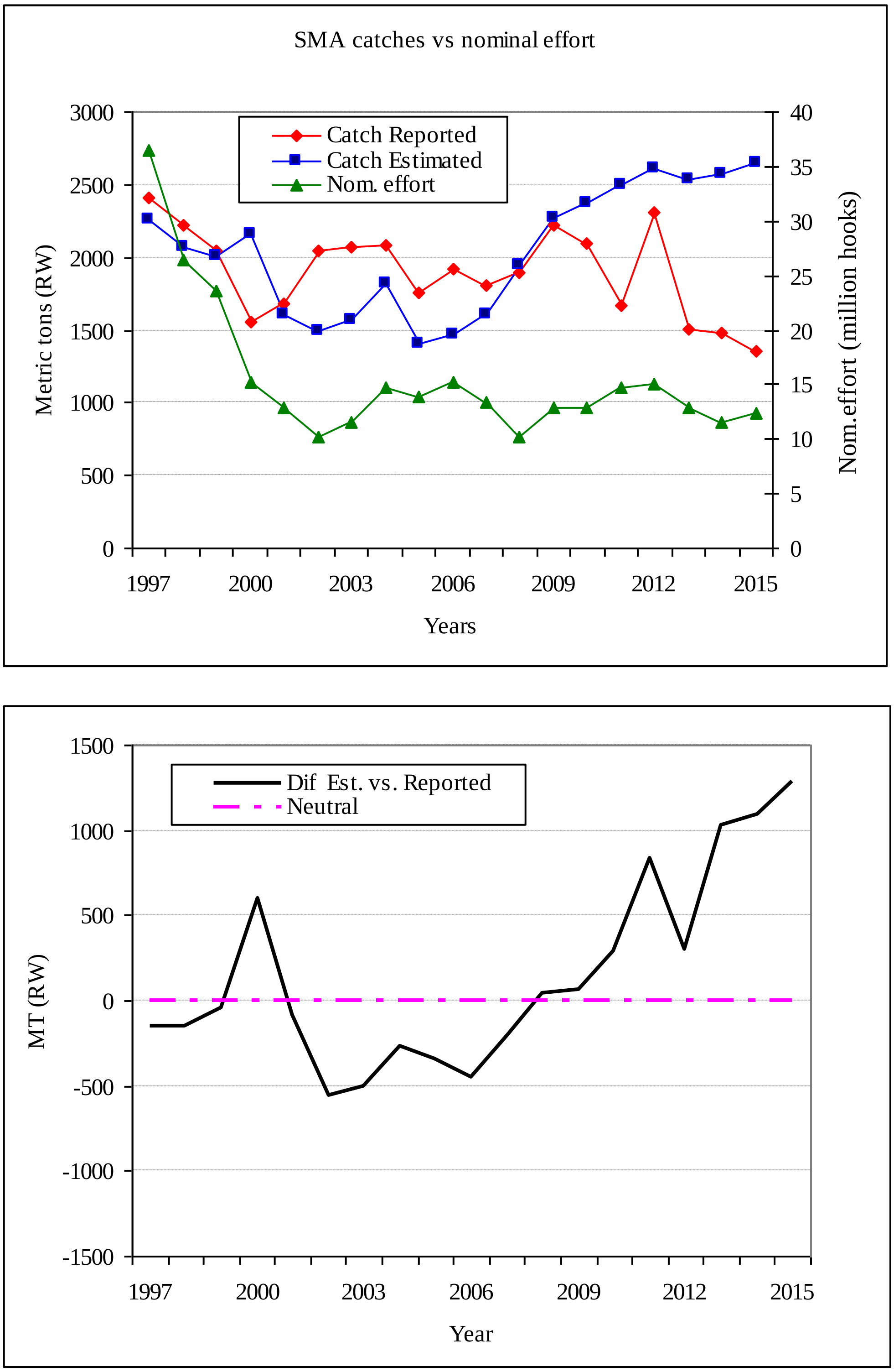

Figure 5. *Upper panel*: Comparison between the scientifically estimated catches (T1) of SMA for the EU-Spain for the period 1997-2015 (scenario C1) and the estimated catches based on ratio between species (Coelho and Rosa 2017) (scenario C2). Trend of the nominal effort in the EU-Spain fleet during that period (according to T2-ICCAT effort) is also plotted. *Lower panel*: Difference between the estimate of catches of scenario C2 (Coelho and Rosa 2017) and the scientifically estimated catches (T1) of SMA for EU-Spain during the period 1997-2015 (scenario C1).

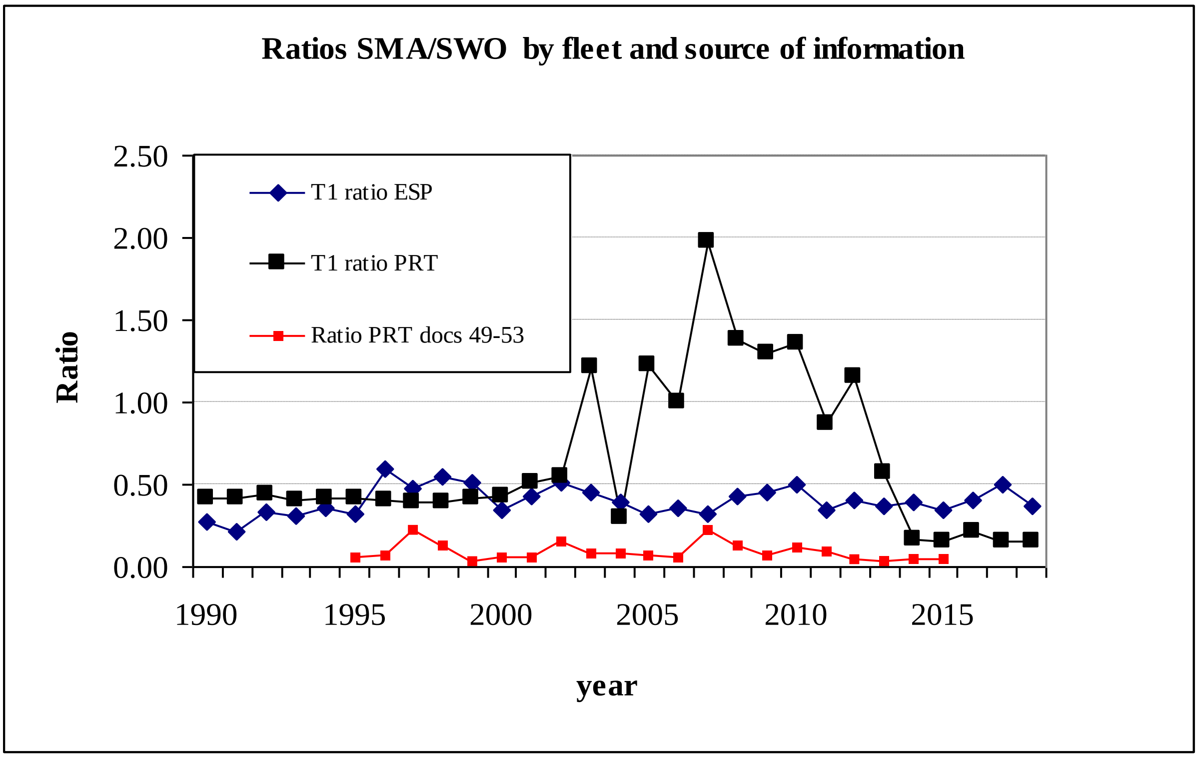

Figure 6. Comparison between three SMA/SWO ratios for the EU-Spain and EU-Portugal fleets fishing in the Northern stocks during the period 1990-2018 (or 1995-2015, depending on the series). *T1ratio ESP*: ratio SMA/SWO obtained from T1 of Spanish longline fleet (ICCAT T1 January 2020). *T1 ratio PRT*: ratio SMA/SWO obtained from the T1 of Portuguese longline fleet (ICCAT T1 January 2020). *Ratio PRT docs 49-53*: ratio SMA/SWO obtained from the SMA and SWO catch records of Portuguese longline for respective standardized CPUEs series (SCRS/2017/049 and SCRS/2017/053) using the same set of information and the same nominal effort observed in both data sets.

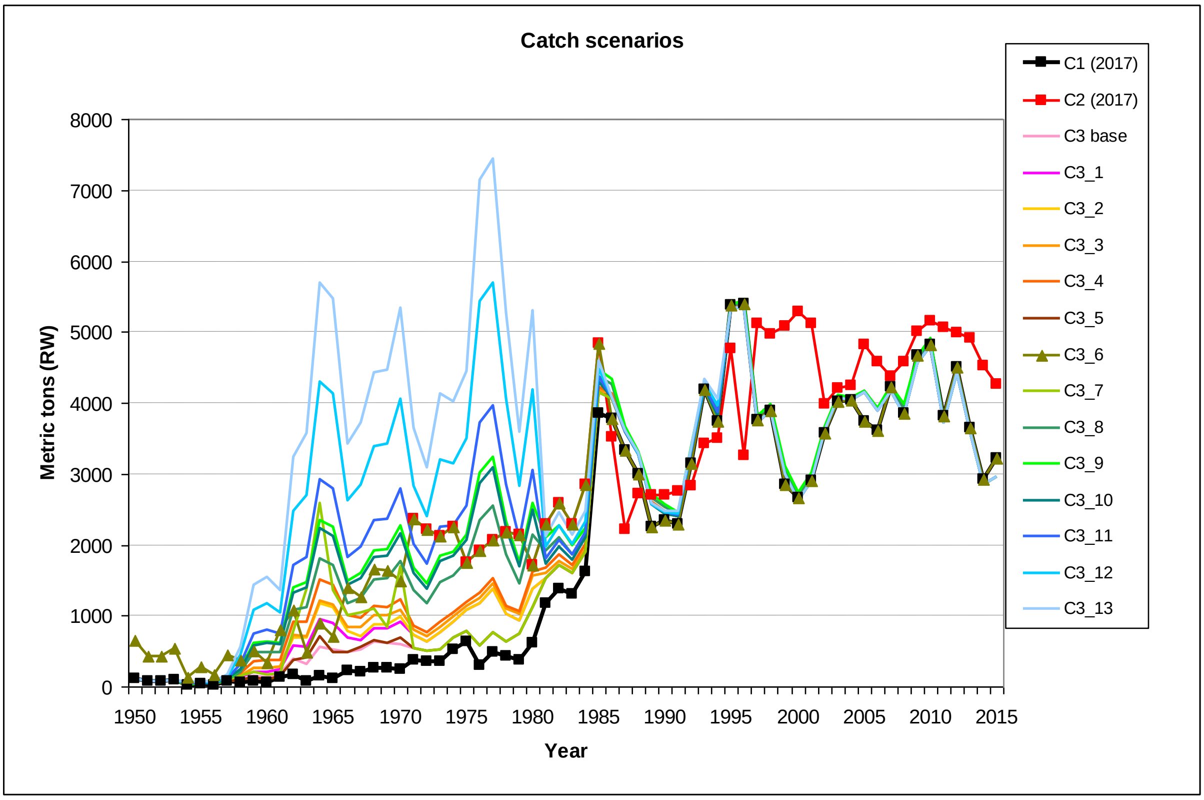

Figure 7. Some catch scenarios for the historical periods of the Northern Atlantic shortfin mako. Scenario C1: reported catches (Task 1) or estimated by national scientists 1950-2015 used as base case in the 2017 assessment. Scenario C2: hypothetical catch levels obtained applying ratios between catches of the target and the bycatch-SMA species for the period 1971-2015 (Coelho and Rosa 2017) used in sensitivity analyses of 2017 assessment. Scenarios C3: Several hypotheses based on the nominal effort by fleet and different assumptions of nominal CPUE for those fleet-years with nominal effort available or estimated, but catch not available/ reported. Some C3 scenarios are assuming different CPUE described in literature for some periods-fleets and in other cases CPUE levels were assumed from 0.75 to 2 fish per thousand hooks (50 kg mean round weight per fish). See details in discussion of charter 3.1. of the present paper.

Scenario	**Summary of the estimation**
C1 (2017):	Catch scenario C1 assumed in the 2017 base case (assessment 2017)
C2 (2017)	Catch scenario C2 assumed in the 2017 sensitivity analyses (assessment 2017)
C3 base	Mean reported nominal CPUEw assumed for those years with effort available but catch not available / reported:
C3_1	Nominal CPUEw/1000 hooks of 15 kg for fleets JPN & TWN…
C3_2	Nominal CPUEw/1000 hooks of 15 kg for JPN & TWN and 40 kg for USA & CAN
C3_3	Nominal CPUEw /1000 hooks of 15kg for JPN,TWN, KOR; 40 kg for USA & CAN, 15 kg for CUB
C3_4	Nominal CPUEw/1000 hooks of 25 kg, 15 kg for TWN & KOR respectively; 40 kg for USA & CAN, 15 kg for CUB
C3_5	Nominal CPUEw/1000 hooks as reported by Au (1995) for SMA
C3_6	Catch scenario (mix) assuming ratio C1/C2 of underreported catches 1950-1985 and full reporting 1986-2015
C3_7	Nominal CPUEw/1000 hooks as reported by Au (1995) for Isurus spp.
C3_8	Nominal CPUEw/1000 hooks 30 kg
C3_9	Nominal CPUEw/1000 hooks 40 kg
C3_10	Nominal CPUEn/1000 hooks of 0.75 fish (equivalent to 37.5 kg per 1000 hooks-mean weight 50 kg)
C3_11	Nominal CPUEn/1000 hooks of 1.0 fish (equivalent to 50.0 kg per 1000 hooks- mean weight 50 kg)
C3_12	Nominal CPUEn/1000 hooks of 1.5 fish (equivalent to 75 kg per 1000 hooks- mean weight 50 kg)
C3_13	Nominal CPUEn/1000 hooks of 2.0 fish (equivalent to 100 kg per 1000 hooks- mean weight 50 kg)

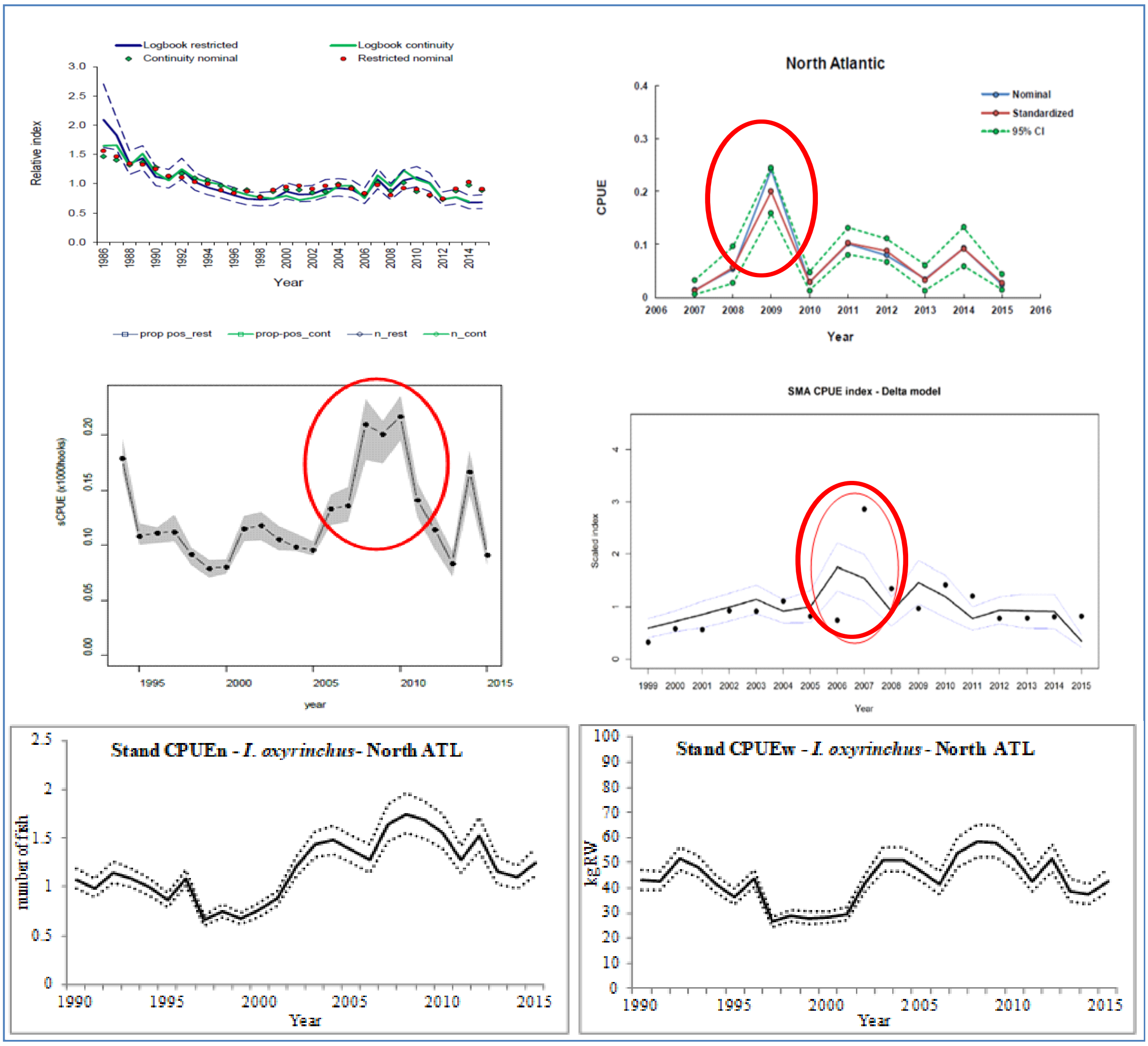

Figure 8. Main standardized CPUE series of longline fleets considered in North Atlantic SMA assessment models (Anon. 2017^b). Top left panel: USA Index 1986-2015 (number/1000 hooks) from logbook data (series 1). Top-right panel: Taipei Index 2007-2015 (number/1000 hooks) from observer data. Middle left panel: Japan Index 1994-2015 (number/1000 hooks) from logbooks + filtering processes. Middle right panel: UE-Portugal Index 1999-2015 (kg RW/1000 hooks) from various sources of information combined. Lower panel: EU-Spain index 1990-2015 (number and kg RW/1000 hooks) from scientific records of landings. USA: Cortés (2017). TAI: Tsai and Liu (2017). JPN: Semba *et al.* (2017). EU-POR: Coelho *et al.* (2017). UE-SPN: Fernández-Costa *et al.* (2017).

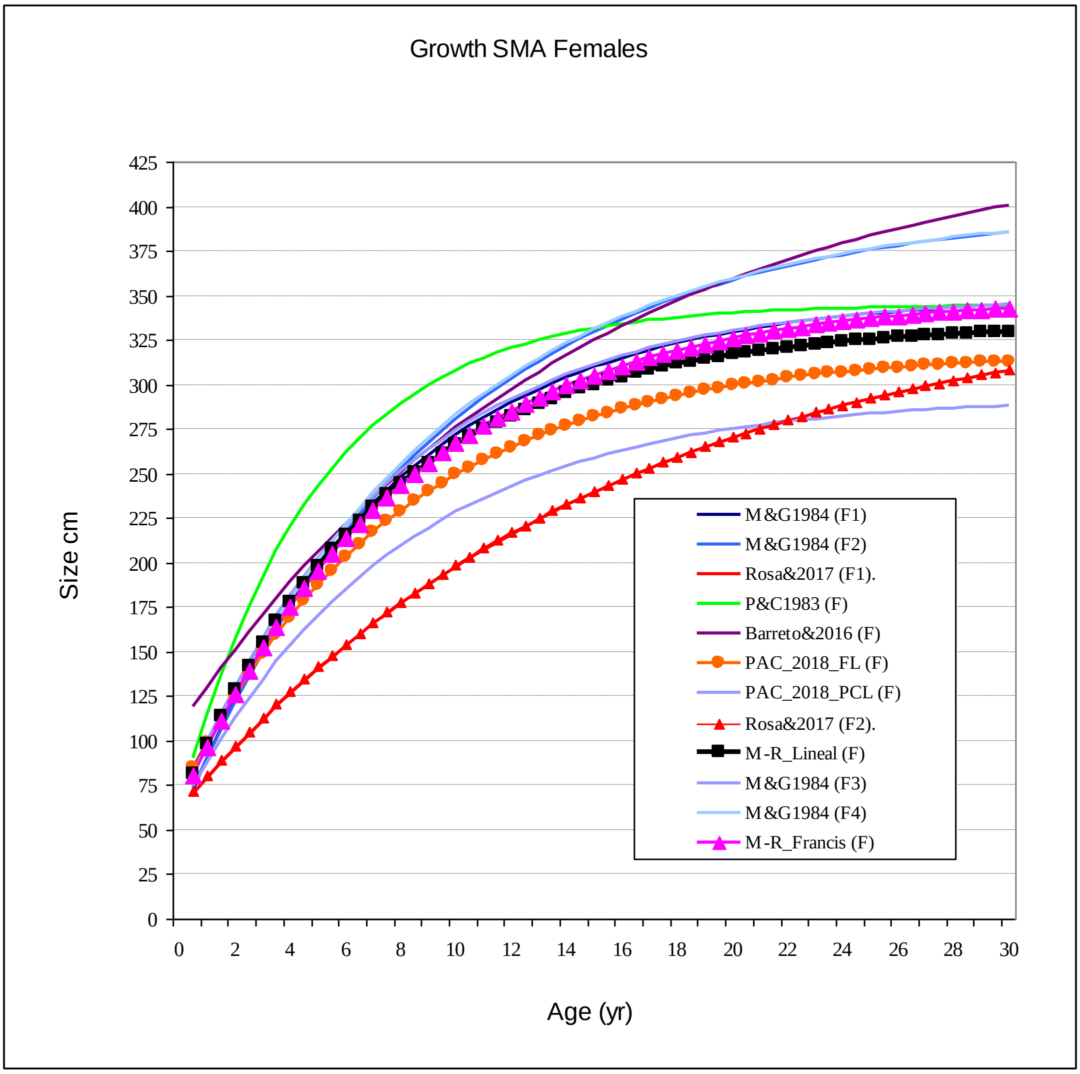

Figure 9. Comparison between predicted mean sizes at age by several growth models described for SMA females. Size is FLcm in all models except for PAC_2018_PCL (F) that it is also included in the original PCLcm unit. Note$_1$: Predictions of the size at age for some models are overlapped and differences are visually imperceptible between some of them.

M&G1984 (F1): Growth model of females in FL units estimated from length-frequency modes (Mejuto and Garcés 1984) assuming FL_{inf}= 350.3 cm (according to Rosa *et al*. 2017^b) and estimating the three VB growth parameters. *M&G1984 (F2)*: Growth model of females in FL units estimated from length-frequency modes (Mejuto and Garcés 1984) assuming FL_{inf} = 400 cm (Compagno 1984) and estimating the three VB growth parameters. *Rosa&2017 (F1)*: Growth model of females in FL units of Rosa *et al.* (2017)^b estimating t_o parameter. *P&C 1983 (F)*: Growth model of females in FL units estimated by Pratt and Casey (1983). *Barreto&2016 (F)*: Growth model of females estimated in FL units by Barreto *et al.* (2016). *PAC-2018_FL (F)*: Growth model of females implemented for the assessment of the North Pacific shortfin mako (Anon. 2018) and transformed into FL units using Mas *et al.* (2014). *PAC-2018_PCL (F)*: Growth model of females implemented for the assessment of the North Pacific shortfin mako in original PCLcm size units (Anon. 2018). *Rosa&2017 (F2)*: Growth model of females in FL units of Rosa *et al.* (2017)^b assuming FL_0=63 cm, used in the assessment of the North Atlantic shortfin mako. *M-R_L (F)*: Preliminary growth model of females in FL units obtained from tagging-recapture records of females obtained by our tagging-recapture program, assuming a linear fit and FL_0= 63 cm. *MG1984 (F3)*: Growth model of females estimated from FL length-frequency modes (Mejuto and Garcés 1984) assuming FL_{inf}= 350.3 (according to Rosa *et al.* 2017^b) and FL_0= 63 cm. *M&G1984 (F4)*: Growth model of females in FL units obtained from length-frequency modes (Mejuto and Garcés 1984) assuming FL_{inf}= 400 cm (Compagno 1984) and FL_0= 63 cm. *M-R _Francis(F)*= Preliminary growth model of females in FL units obtained from tagging-recapture records of females obtained in our tagging-recapture program, using maximum likelihood fit (Francis 1988) and FL_0= 63 cm. Note$_2$: In the case of PAC_2018, the conversion PCL-FL was based on the relationship Mas *et al.* (2014).

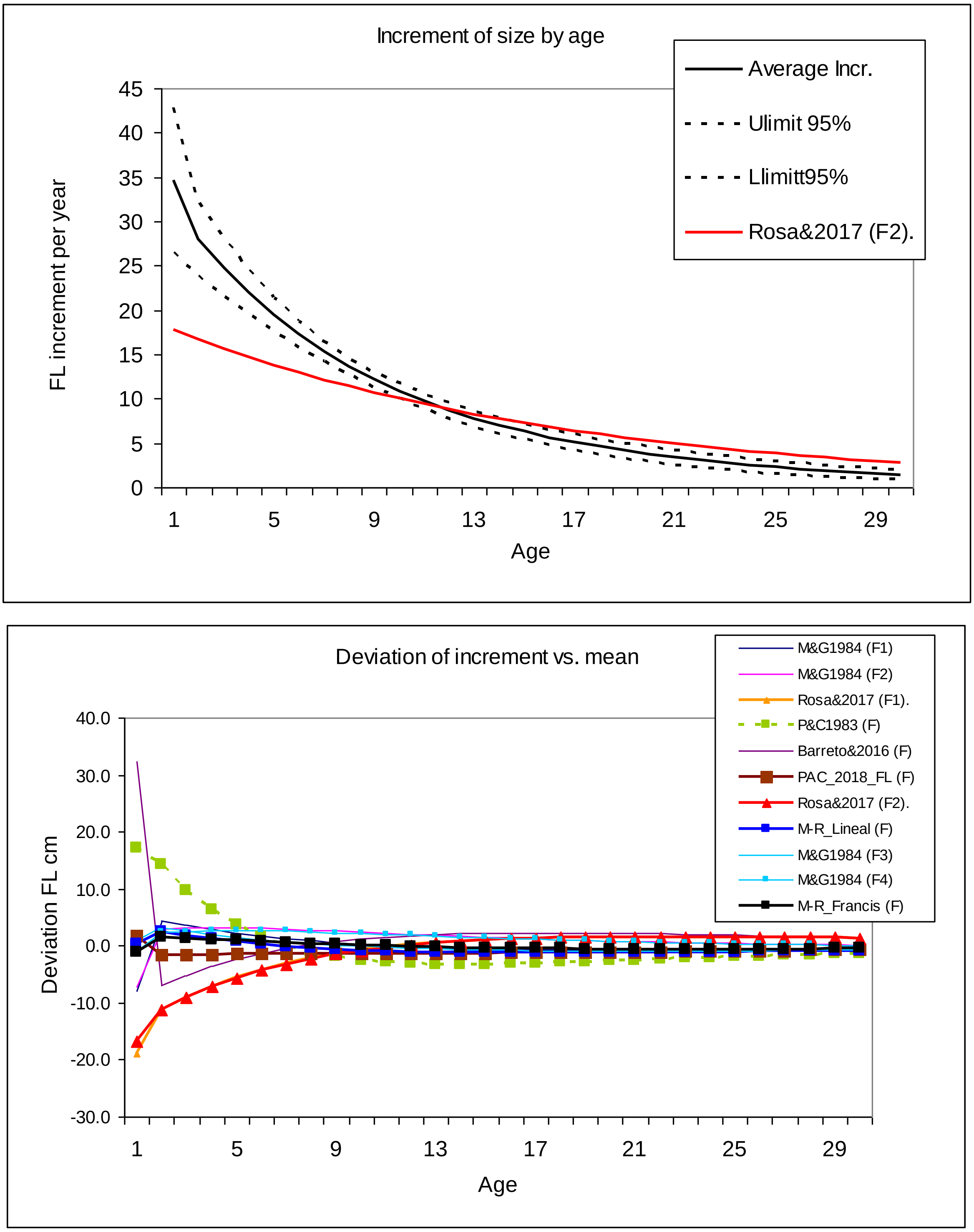

Figure 10. *Upper panel*: Mean increments and 95% confidence intervals of size (FL cm) during consecutive ages (y+1 *vs.* y) combining all growth models of females in FL units considered in the figure 9 (black lines) and mean increments predicted by the growth model used in the assessment of the Northern Atlantic SMA stock (red line). *Lower panel*: Deviation (FL cm) of the size increment by age predicted for each growth model of females in FL units vs. the mean increment by age of all models in FL units considered in figure 9.

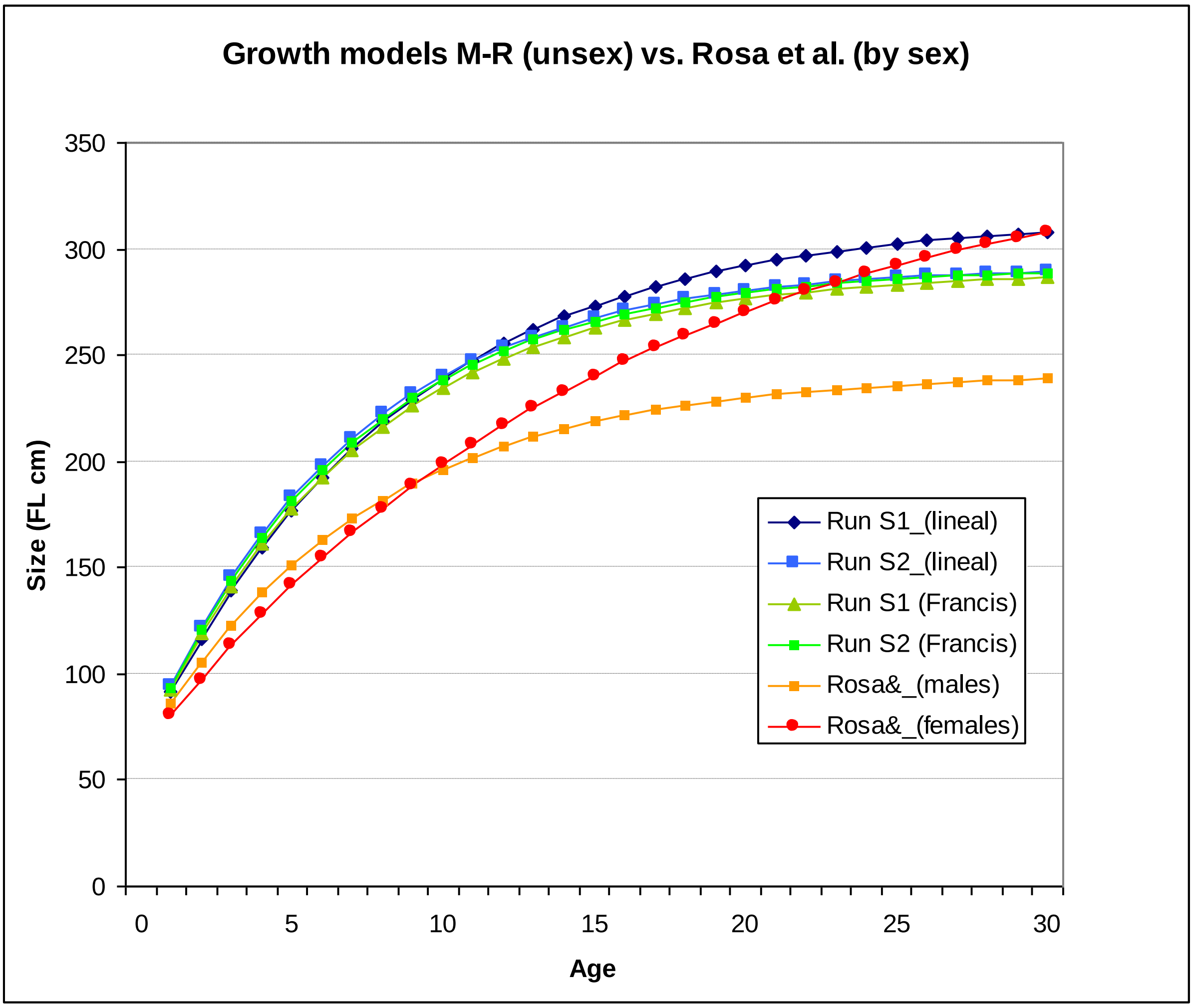

Figure 11. Predicted mean size (FL cm) at age (year) from the growth models fit from tagging-recapture ICCAT data set (data set available in Anon 2017[a]) for unidentified-sexes of SMA fishes at large during at least 3.5 years versus the predicted mean size at age (FL cm) from the growth model by sex (males or females) implemented in the assessment of the Northern stock in 2017 (Anon 2017[b]). Series of tagging-recapture data used: S1 or S2. Fit: simple lineal (Sparre and Venema 1998) or maximum likelihood (Francis 1988). See table 4 for details and growth parameters from tagging-recapture.

Annex 1

Summary of nominal fishing effort estimations: Nominal fishing effort data (hooks) assumed and reference used by fleet-period for areas of the North Atlantic SMA stock. Note that information is probably partial in some fleets for some periods-years.

Flag	Start activity	Period	Method	References
EU-España	1950	1950-1972	Nom. Eff. (catch SWO/CPUE SWO) estimated from SCRS/1985/61. Average CPUE for the 1973-1985	Historical Statistical Bulletin ICCAT Vol. 1; file {calculo.xls}
EU-España	1950	1973-1974	SCRS/1985/061	SCRS/1985/061
EU-España	1950	1975-2018	T2CE	ICCAT DB
Japan	1956	1956-2018	T2CE	Historical Statistical Bulletin ICCAT vol 1; "Fishery Management Plan, Regulatory Impact review, Initial Regulatory flexibility Analysis and final environmental impact statement for Atlantic Swordfish" February 1985; SCRS/1972/020; SCRS/1979/064; SCRS/1994/041
Chinese-Taipei	1962	1962-1966	Carry-over 1967	Historical Statistical Bulletin ICCAT Vol. 2; SCRS/1972/020
Chinese-Taipei	1962	1967-2018	T2CE	ICCAT DB
USA	1962	1962-1969	Carry-over 1979	Historical Statistical Bulletin ICCAT vol 2; "Fishery Management Plan, Regulatory Impact review, Initial Regulatory flexibility Analysis and final environmental impact statement for Atlantic Swordfish" February 1985; NMFS-F/SPO-29 Volumen V; SCRS/2013/116; SCRS/2017/137
USA	1962	1970-1978	Mercury restrictions	"Fishery Management Plan, Regulatory Impact review, Initial Regulatory flexibility Analysis and final environmental impact statement for Atlantic Swordfish" February 1985
USA	1962	1979-2016	Nominal effort estimated from SCRS papers	e.g. SCRS/92/028,SCRS/96/045,SCRS/2017/137
USA	1962	2017-2018	T2CE	ICCAT DB
Venezuela	1954	1954-1969; 1975-1980; 2001; 2018	Carry-over 1970; 1974; 2000; 2017	Historical Statistical Bulletin ICCAT Vol. 2; SCRS/1973/032; SCRS/1972/020
Venezuela	1954	1970-1974; 1981-2000; 2002-2017	T2CE	ICCAT DB
China	1994	1994-2018	T2CE	ICCAT DB
Canada	1962	1962	Carry-over 1963	Historical Statistical Bulletin ICCAT vol 2; "Fishery Management Plan, Regulatory Impact review, Initial Regulatory flexibility Analysis and final environmental impact statement for Atlantic Swordfish" February 1985; NMFS-F/SPO-29 Vol. V; SCRS/2013/059; SCRS/2013/116; SCRS/2017/137;
Canada	1962	1963-1970; 1979-2007	SCRS/2017/137	SCRS/2017/137
Canada	1962	1971-1978	Mercury restrictions	"Fishery Management Plan, Regulatory Impact review, Initial Regulatory flexibility Analysis and final environmental impact statement for Atlantic Swordfish" February 1985

Canada	1962	2008-2018	T2CE	ICCAT DB
Marroc	1961	1961-2003	¿?	Historical Statistical Bulletin ICCAT Vol. 2
Marroc	1961	2004-2015	T2CE	ICCAT DB
EU-Portugal	1979	1979-1989; 2018	Carry-over 1990; 2017	SCRS/2017/049; SCRS; Report for biennial period 1990-1991; NMFS-F/SPO-29 Volumen VI; SCRS/1994/109; SCRS/2017/049; SCRS/2017/053
EU-Portugal	1979	1990-1994	Assuming nominal CPUE of 30.9 kg/1000 hook	
EU-Portugal	1979	1995-2015	Nominal effort estimated from document SCRS/2017/053	SCRS/2017/053
EU-Portugal	1979	2016-2017	T2CE	ICCAT DB
Korea	1964	1964-1965; 1967-1973; 1998-2004; 2018	Carry-over 1966; 1974; 1997; 2017	Historical Statistical Bulletin ICCAT Vol. 2
Korea	1964	1966; 1974-1997; 2005-2017	T2CE	ICCAT DB
Cuba	1959	1959-1972; 1974; 1991-2001; 2003-2007	Carry-over 1973; 1975; 1990; 2002	Historical Statistical Bulletin ICCAT Vol. 1; T1NC último año con datos 2007
Cuba	1959	1973; 1975-1990; 2002;	T2CE	ICCAT DB
Panama	1970	1970-2005; 2010-2012; 2015-2018	¿?	Historical Statistical Bulletin ICCAT Vol. 3
Panama	1970	2006-2009; 2013-2014	T2CE	ICCAT DB
Belize	1954	1954-2006	¿?	Artisanal fleet activity on 1950s. Assuming that started the activity like Venezuela
Belize	1954	2007-2018	T2CE	ICCAT DB
Mexico	1954	1954-1993;	Carry-over 1994	Artisanal fleet activity on 1950s. Assuming that started the activity like Venezuela
Mexico	1954	1994-2018	T2CE	ICCAT DB
USSR	1965		¿?	Historical Statistical Bulletin ICCAT Vol. 2

Annex 2

Detailed review of CPUE series

3.2.1. USA-SCRS/2017/56: Stock status indicators of mako sharks in the western North Atlantic Ocean based on the U.S. pelagic longline logbook and observer programs (Cortés 2017[a]).

The document analyzed the USA longline fishery targeting different species over the years - swordfish and also tunas - that was developed in the NW Atlantic regions from the early sixties at longitudes > 45ºW and more intensely at longitudes > 60ºW. The paper analyzed two series of standardized CPUE (number of fish/1000 hooks). According to the data set used, the paper described trends from 1986 or 1992 to 2015. Fishing areas were expanded throughout this time period between the Grand Banks and 5º of latitude South along the Atlantic coast of North America. It describes the northern-temperate areas as those with the highest SMA catches reported (Areas 5, 7, 6 of those defined in the GLM). It also indicates the areas of space-time closure that have affected the temporal continuity of the analyzed data. It did not provide information on changes in the gear configuration (type if hooks, baits, type of brachlines-leaders) or fishing styles (swallow/mid water) (Goodyear in press-2021) despite the fact that the evolution of these factors over time in this fleet could have had some impact on standardized CPUEs and trends. Change of hook type progressively and voluntarily implemented since the early eighties was not considered. An increase of the catch rates of the target species and a reduction of catch rates of some shark species was pointed out for these new hooks (Wilson and Díaz 2012). The implementation of nylon in the leaders could perhaps have also affected the CPUE or facilitated the escape of largest SMA individuals. The document also provides a series of data on the trend in the average size of catches by sex throughout the period 1992-2015.

CPUE Series 1 used data by fishing set of mandatory logbooks of the commercial fleet during a period of 30 years (1986-2015), whose coverage is assumed in recent years close to 90-100% on the total activity of the analyzed fleet, according to the author's personal communication. However, this coverage was not always at that level, but gradually increased throughout the period analyzed since its mandatory implementation in 1986. It is estimated that the mean coverage of logbooks was around 69% for the entire analyzed period and the coverage for the initial period 1986-1992 was around 38% for some longline fleets in particular.

CPUE Series 2 used data per set of scientific observers over a 24-year period (1992-2015) with a mean coverage that the authors estimated at 5% -10% per year. This second set of data presents less quantitative coverage of observations and forced the author to restrict the analysis to only some of the areas considered in Series 1.

The document indicates that the positive sets in the mandatory logbooks data were between 12% -21% and the rest were reported sets with no capture, while in the observer data the positive sets were higher and, although not specified, it seems it would be around 20% on average (Fig. 6 of the cited document). The author points out that the percentage of positive sets in logbooks could probably be underestimated in recent years for detailed reasons (see below). The "area" factor was identified as the most important in both the positive CPUEs and the probability of being positive, for both data sets analyzed.

Reviewing the document (appendix tables of the cited document) it seems that the number of positive fishing sets was between 6.9% and 10.5% depending on the data set used or if the analysis was "total" or "restricted" (including/excluding area closures). It also indicates that observer coverage for the 1992-2015 period was around 6.1% on average and that positive sets were between 7-11%. This implies that, in the most favorable case, an average of about 1000 or 60 positive sets / year would be available to obtain the CPUEs from the logbook or observer data series, respectively.

The author points out that data on the genus Isurus spp. was modeled because there is no certainty of the registered species, assuming that approximately 90% -95% represent the SMA trends. Furthermore, the analysis of observer data (Series 2) should have been restricted to include only some of the defined areas due to the low representativeness of the observations within some of the areas considered in Series 1. This point may be of special interest since most of the positive catches occur in temperate areas of the North Atlantic where the fishing activity took place at the beginning of Series 1, compared to a later activity also targeting tunas, possibly in subtropical and intertropical areas with modifications in the gear configuration and changes in fishing areas and possibly the type of boats and gear-style involved.

The space-temporal closures effects were considered in the analysis, canceling for the entire series those data from those areas, thus reducing their possible effect over time. On the other hand, the document recognizes limitations in the data of Series 1: "*Changes in reporting practices as a result of the implementation of several logbook programs historically, and perhaps a tendency to under-report bycatch over time as fishers develop a growing perception that those reports resulted in increasingly restrictive management measures may have affected the logbook index to some extent*". This would perhaps explain the slightly decreasing trend of the CPUE of this fleet from 2012, an apparently common decrease for both this species and the swordfish. In this sense, the author already warns "*several issues that may affect the US. pelagic longline logbook dataset have been previously documented, notably species identification, misreporting, and changes in reporting practices.* "

However, other possible factors previously studied such as hook changes, brachline-leader or other changes implemented at domestic level that could have had a CPUE reduction effect of this species according to the suggested by some experiments (Driggers *et al.* 2011, Santos *et al.* 2017) were not described or considered. Not only has the reduced efficiency of monofilament leaders in retaining sharks been described in this fleet, but furthermore has been noted and taken advantage of by the commercial pelagic longline tuna and swordfish fleets to reduce unwanted shark bycatch. Based on that, specific data the comparison of shark catch rates using wire and monofilament are inappropriate (Driggers *et al*. 2011). Considering that monofilament was the type of leader most used from the 1980s onwards -with increases in the CPUE of tunas but decreases in the CPUE of sharks- it can not be ruled out that this factor had some effect on the reduction of SMA CPUE at least in the first years-period of Series 1 starting in 1986. Therefore, the possible change of hooks and leader that could have been used in this fleet between the eighties and nineties, together with the change of target species and the selection of new fishing areas, among other factors, could perhaps explain the change in trend in CPUE observed in the first years of Series 1, without ruling out that during the initial years of that series, logbook coverage was notably lower but possibly more reliable than those available in subsequent years due to being affected by underreporting in logbooks as the author points out and it can be seen when comparing with results of Series 2.

Regarding Series 2, the author pointed to an argument also postulated by other authors: "*sharp interannual changes in relative abundance, such as those displayed by the observer series in some years, seem inconsistent with the biology of most sharks, whose stock abundance would be expected to fluctuate relatively little from year to year"*. Abrupt changes of the overall abundance and in the indices considered representative should not be expected between consecutive years in this species and their inter-annual fluctuations should be biologically plausible (Ramos-Cartelle *et al.* 2011). This criterion had been suggested to qualitatively assess some indices in this type of species in which a close relationship is assumed between the size of the breeding stock, the volume of their litters and the levels of annual recruitment; so that the indices can be assessed as biologically plausible and representative of abundance, especially in the case of some fleets to which "credibility" and merit of the indices are assumed despite the fact that the trend or its interannual variability is biologically implausible in this species.

Despite the discussion and limitations indicated above, the conclusions of both data series were quite consistent and indicated that the U.S. index showed a stable trend since 1990: "*Overall, the logbook index did not show a substantial change in relative abundance since the late 1990s and the observer index showed a generally increasing tendency since the mid-1990s. The lack of strong trends in all series suggests that the status of the stock is stable, yet the declining trend since 2009-2011 should continue to be closely monitored. No discernible trends in size were detected [males, females or sex combined], suggesting that no specific segment of the population is being disproportionately affected* " [see figures 3 and 10 of the cited document].

The two series analyzed represented the only indices available for the areas of the ATL NW –Western of 45ºW-. They showed no evidence of depletion of the stock (or of the fractions considered) at least since 1990. They also did not show significant changes in the mean size of the catch over the years for either sex, suggesting no evidence of depletion or changes in its demography in all the ATL NW regions. The decreases in CPUE observed in the initial years could perhaps be due to changes in branchlines-leaders, changes in target species, logbook coverage, or the quality of reports in the years following the implementation of various regulations due to "*growing perception that those reports of bycatch species result in increasingly restrictive management measures*". These factors could have a substantial effect in the case of a shark species like SMA, which is a species of great interest in the sport fisheries of some CPC. The domestic regulatory measures implemented over the years, and more specifically since 2011 when the use of some types of hooks was apparently implemented in some of the areas, could have had an effect on lower fishing yields (real or in the logbook records) in most recent years of the series analyzed. As indicated by the author, Series 2 presented limitations of geographic coverage and number of observations, but while it did not suggest stock depletion, it helped confirm that Series 1 results are probably slightly underestimated for at least the most recent years due to the underreports in the mandatory logbooks, for which it is assumed that the Series 1 of observers is not affected.

The "weight" of the T1-USA of this fleet over the overall international catches (T1-international) reported to WG 2017 for this Northern stock between1990-2015 was on average 13.02% (including reported discards). However, due to a subsequent revisions of that data because of changes in conversion factors between DW-RW (Diaz-SCRS//2018/117[6]), the T1 value of this CPC could perhaps be revised and lower than values assumed in scenario C1 of Anon. (2017[b]) as well as for the comparison carried out with scenario C2 for this fleet.

Additionally, in order to assess the relative catchability between fleets, we should consider that, in the series of logbooks during the period analyzed, the mean nominal CPUEn was approximately 0.6 fish /1000 hooks with a constant average length of around 150 cm FL (average RW around 36 kg), which would represent an average CPUEw of about 22 kg RW/1000 hooks. In the case of Chine-Taipei -which is reviewed below- the average CPUE has been estimated at 0.06 fish/1000 hooks, with an average catch weight over 50 kg, which in that fleet would imply a CPUEw of 3.1 kg RW per 1000 hooks .

The WG Anon. (2017[a]) asked the very small sample size in the logbook data for 1986. It was suggested that the reason was uncertain, but that it could be, in part, the result of that year being the first year of mandatory collection of logbooks from the US longline fishery. Indeed, the review of information carried out in the present study shows that the mandatory implementation of the logbooks was not perfect from the beginning, but was initially very low and increased progressively from the beginning of that mandate. The group raised a further question about the decline indicated in 1986 in the restricted analysis and which had not been stated in the full analysis. Spatial-temporal closures did not appear to be the cause, since they were subsequently implemented. The trend after 1986 was quite similar across estimates, and therefore the authors

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[6] Document is not available in Collect. Vol. Sci. Pap. Document withdrawn

suggested that the effect for that year was small. However, it was recommended to use the standardized CPUE obtained from the full analysis in the assessment.

These two CPUE Series obtained for the same fleet from two different sources of information, *were considered useful by the WG* so as to be included in the North stock assessment models as indicators of abundance of the whole stock.

3.2.2. TWN-SCRS/2007/071: Standardized catch rates of the shortfin mako (Isurus oxyrinchus) caught by the Taiwanese longline fishery in the Atlantic Ocean (Tsai and Liu 2017).

The authors noted the poor accuracy of the SMA catch (T1) data historically reported for this fleet. Therefore, T1 data should not be considered for any purpose, neither to calculate standardized CPUEs from logbooks nor to be included in any of the assessment catch scenarios. The authors alternatively proposed a series of T1 catches based on the prevalence between species obtained from some observations noted during a brief period (2007-2015) (Table 5-bis of the cited document) and applied it retrospectively until 1981, that is, backdating data over a period of approximately 25 years.

This methodology for estimating retrospective catches seems to be inappropriate in the case of this fleet, considering the low coverage of observers during the brief period 2007-2015 analyzed, in addition to the fact that large changes have occurred in that fleet over the years in terms of their fishing areas, target species and gear style during the periods prior to 2007. Those important changes would not support a retrospective application of such an assumption based on constant and retrospective ratios between species for 25 years. As described by Su *et al.* (2019), this fleet was mainly targeted at *T. alalunga* (ALB) until 1990, then went on to prioritize *T. obesus* (BET), distinguishing several different periods of activity during 1968-2016 regarding fishing areas and gear configuration; therefore stating a very different prevalence between target-bycatch species according to each period. Studies suggest that the selected spatial variable, linked to the target species, was probably very important in determining the different catchability of the bycatch species in this long-distant longline fleets over the years, and a direct relationship between the catch cannot be established between the target species and the bycatch shark species.

Due to these limitations of logbooks for developing standardized CPUEs, the authors used data from 2007-2015 from scientific observers with an observed mean of 424.8 thousand hooks/year. That coverage is probably equivalent to observing a single trip per year between the 2007-2015 period. The document does not include information on the number of fish nor tons recorded by observers to estimate the positive CPUE data. Nor does it describe the configuration of the gear between areas and/or years that may be a relevant element in this fleet. However, it does provide information on the number of hooks and number of sets observed (Table 1 of that cited document) and other details that allow estimates to be made from the information provided (see **Table 2-** summary CPUEs of the present paper):

a) An average of 202 sets/year have been observed between 2007-2015 of which 89% would have been zero catch in the northern stock sets (Table 2 of the cited document). Therefore, an annual average of only 11% of the observed sets (about 22 sets) would have resulted in positive catches of SMA, and even less in the southern stock. This suggests that fishing practices or data differ substantially in relation to other fisheries described as the U.S. in particular to the 12-21% of sets which were positive according to logbook or observer data, respectively.

b) It is deduced from Table 5-Fig. 2 of the cited document that for GLM only 2 areas have been defined for the North stock (A: North of 20º and B: between 5º-20º North) compared to the vast fishing areas described for this fleet according to figure one of said document.

c) In three of the nine years analyzed, no observation with positive catches was obtained within Area "A" modeled in the GLM for the North stock (North of 20ºN), despite the fact that for the set of years the mean nominal CPUE in area A (Nom. CPUE Avg. = 8.56E-02) was over twice that obtained in area B (Nom. CPUE Avg. = 4.6E-02).

d) The annexes to the cited document indicate that some of the variables considered in the GLM - or the positive catch model itself - were not significant.

f) An especially limiting element of this study to be considered was the scarce information available of the data used to estimate standardized CPUEs (see table attached to document cited) and the difficulty of such data to be assumed as an indicator of abundance of a stock with such a wide distribution. Taking into account the observer coverage rates for the 2007-2015 period (Table 1 of cited document) and the reported T2-effort for that period, it could be estimated that the standardized CPUE series of the Northern Stock could probably be obtained from a catch average of about 80 fish/year (about 4 tons of catch/year) to represent the huge distribution of the Northern stock, resulting in an average of about 26 positive sets/year. The minimum number of positive observations would have been obtained in year 2007 with only 7 fish caught (0.3 t of observed in annual catch) in the set of all positive observations obtained for that year (**Table 3** of the present paper). The maximum number of observations would have occurred in year 2009 with 215 fish caught (about 11 t of annual catch) among all the positive observations for that year, most of them only within Area A.

g) The standardized CPUE obtained in year 2009 represented a change of approximately 300% over the value obtained in the immediately preceding and subsequent years, which is biologically implausible. This situation is probably due to the few observations available in 2009 within area A, which represented a nominal CPUE of approximately + 358% of the average nominal CPUE observed in the area A as a whole during the entire period 2007-2015. The standardized CPUE series followed the observed nominal CPUE, suggesting the ineffectiveness of the GLM insofar as removing the possible effect of the factors considered (some factors were not significant) or their little relevance as to explaining the variability of the CPUE in the few observations analyzed.

The revision of this document suggests that the study represents a scientific effort that should be duly acknowledged to the authors given that it outlines and informs upon the quality of the T1 data historically reported to ICCAT for this species and discusses the presence of SMA catches in a very small portion of the fleet and during very recent years (2007-2015). But it provided a very limited time context in relation to the high importance and long fishing history of this fleet in the North Atlantic from at least 1968. The data used for GLM contain important quantitative and qualitative limitations and small spatial-temporal coverage. These limitations, among others, probably would not allow this index to be assumed as an indicator of the abundance of the whole of the SMA stock of the North Atlantic, and even less to be incorporated in the assessment models as an indicator of abundance of a very widely distributed stock against other quantitatively and qualitatively much more robust and representative indicators.

It is also deduced from the document that for the short period analyzed, the average CPUE was around 0.06 fish / 1000 hooks, with an average weight of about 50 kg per fish, which would be equivalent to a very low average CPUEw of only about 3.1 kg RW/1000 hooks, an amount that is not comparable to the yields observed in most of the longline fleets analyzed or available in the literature.

The T1 of this fleet has been estimated indirectly by the authors at an average of about 32 t /yr during 2007-2014 period. Therefore, the "weight" of this T1 estimated on the total reported catches (T1-international) for the Northern stock between 1990-2015 have been on average only 0.58% (including discards).

Despite the elements included in the present revision, the WG Anon. (2017[a]) indicated that the proportion of zero catches in these data was very high compared to those of other fleets. However, the catch estimation method for the period 2007-2015 and 25 years prior to 2007 (no observer data available) was verified and the Group agreed that the T1 "*estimation method was robust*". Despite the limitations previously described in the present paper, this CPUE index was considered *useful to be used in the Northern stock* assessment models as an indicator of abundance (Anon 2017[b]) and it was diagnosed as "informative" in later implemented models (Courtney *et al.* 2019).

3.2.3. JPN-SCRS/2017/054: Revised standardized cpue of shortfin mako (Isurus oxyrinchus) caught by the Japanese tuna longline fishery in the North Atlantic Ocean between 1994 and 2015 (Semba *et al.* 2017)

The analysis used mandatory logbook data from the 1994-2015 period. A "filtering" method had to be applied to a breakdown by species which the catch records reported as "*combined sharks*". Discussion and methodological details for the breakdown applied are described in previous documents (Semba *et al.* 2012, Semba and Yokawa 2016).

The CPUE units used were in number of fish/1000 hooks. The document details that very substantial changes in the geographical distribution of this fleet occurred from the period 2005-2009 (Fig. 1 of cited document), which was mainly targeting ABFT during the initial period of the series (prior to 2005-2009) fishing in regions northern of 20ºN. Subsequently, there was a shift of the fleet towards lower latitudes (between 0º-20ºN) targeting ABFT and/or BET. This implied a substantial change in the gear configuration and hooks per basket (HPB) pattern that was considered as a factor in the GLM runs. The authors indicated that this change in fishing areas (with little activity in regions north of 20ºN from the 2005-2009 period), and of target species, caused the unrealistic decline of CPUE for the North Atlantic SMA in previous analysis. The authors tried to minimize this artificial drop by applying a slight modification in the definition of the areas modeled in GLM in relation to a previous analysis (see Figures 1 and 5 of the cited document). However, this limitation is probably not the substance of the problem of this index for it to be assumed as an indicator of abundance throughout the complete time series analyzed. Apart from other elements, the document describes the at least two very different periods: period-fleet directed to bluefin tuna in northern latitudes and period-fleet directed to tropical tunas in more southern latitudes.

The document tentatively defines 8 subareas for descriptive purposes, but the model used 3 large areas (fig. 5 of the cited document) basically defined according to a gradient of latitude, slightly modifying a previous definition (Semba and Yokawa 2016). Area 3 is probably defined from 0º N instead 5º N. The document describes in Figure 4 large differences in nominal CPUE between subareas. However, it is not possible to discern if these differences are real or due to the effect of the logbooks and /or because the "filtering" processes implemented for the breaking-down of catch by species from combined sharks. Analyzing each of the subareas over the years, it is observed that in some (for example areas: 1, 3 and 6) there are very important differences in nominal CPUE in number of fish between years - which biologically should not be interpreted as changes in abundance of SMA (see for example: subarea 2 year 1994, subarea 3 year 1994, subarea 6 between 2015-2010), which are more probably due to specific vessel fishing practices, type of gear used, and / or the effect of the quality of the logbooks and/or simply they are the result of the filtering processes. Those CPUE outliers and the data of some years should be deeply investigated before being incorporated into the GLM runs.

On the other hand, the subareas that consistently show the lowest CPUEs throughout the series analyzed were those between 0º-20ºN (subareas 7 and 8) in which the majority of the fishing activity of this fleet was developed from period 2005-2009 to the present with "type 3" HPB gear (deeper longline of more than 15 HPB, probably directed to BET with daytime sets) and that represent the majority of the observations available (see fig. appendix of the cited document). Therefore, the availability of SMA was probably much lower in recent period-areas than those occurred in more superficial fishing period-areas, as the electronic tagging studies carried out on this species have suggested. Likewise, studies carried out in other oceans also pointed out lower catch rates of SMA near the equator compared to temperate waters (Anon. 2018).

The document provides figures on the number of observations per subarea but lacks model diagnoses and survey data available for filtering processes. However, Fig-Appendix 1 of that document does provide interesting information on observations available for "every combination of covariates" from which it can be deduced:

(a) Starting in 2006, most -or almost all- of the observations of the most recent years come from Area 3 (between 0º-20ºN), while until 2006 the observations were much better balanced between the three Areas considered in the GLM while the areas of both North and South of 20ºN are better covered.

(b) The total number of observations available decreases substantially from 2010 to 2015 in relation to the previous period analyzed.

(c) As of 2006, almost all the observations become HPB type 3 and within Area 3, with few observations of other types of HPB.

(d) There is a huge imbalance between the available observations of the different levels of BPH/area/ year. The 45 thousand observations available at the HPB1 level mostly come from Area 1, while the approximately 100,000 observations at the HPB3 level come mostly from Area 3 (south of 20ºN with lower CPUE) and therefore for more recent year series.

The revision of the document suggests that, regardless of the qualitative limitations of the logbooks and the procedures used for the "filtering" of data in order to generate the observations finally analyzed, leaving aside methodological aspects and statistical diagnoses, the GLM would theoretically have some capacity -albeit limited - in order to remove the effect of some of the factors modeled in this highly unbalanced data scenario. However, some factors related to the configuration of gear in the different historical periods could have been omitted in the analysis, which could be very relevant in the case of SMA catch rates.

The data series 1994-2005 could perhaps mainly represent the standardized CPUE of this fleet –assumed as abundance- of the temperate areas of the North ATL where SMA seems to be distributed with higher prevalence. However, the increase in standardized CPUE of almost double between 2008-2010 compared to previous years is probably a artifice of the observations available or due to the filtering processes, especially in subarea 6 and also of the subarea 1 (being biologically unlikely that the abundance-biomass increase is almost double). In contrast, the period 2011-2015 would represent above all the fishing yields of subareas 7 and 8, which historically have shown nominal CPUE much lower than the other subareas analyzed, with very low and consistent values south of 20ºN throughout the period analyzed.

On the other hand, this relatively recent CPUE series does not provide information from periods prior to 1994 in which the fishing intensity of this fleet was very high within North Atlantic areas, for which SMA T1 data prior to 1971 are not available. Reported catches of this fleet represented on average 23% of the total reported catches of SMA of this northern stock during the period 1971-1993. During that initial T1 reporting period this fleet has probably been one of the main players with probable high SMA bycatches.

In short, the series for both periods analyzed should probably not be considered comparable. This index would probably show the effect on the fishing performance of this fleet as a consequence of changes in the fishing pattern over the years, in terms of changes in target species, fishing areas and gear configurations, but this complete series could hardly be interpreted as an indicator of the abundance of the stock as a whole throughout the complete period analyzed, especially from the year 2005 as the authors themselves have already suggested and supported in their discussion.

From the document it is also deduced that for the period 1994-2015 (22 years) the mean CPUE was 0.13 fish / 1000 hooks. Assuming an average catch weight of about 50 kg per individual -similar to that as obtained for the Taipei fleet- the average CPUEw for the recent period would be approximately very low and about 6.54 kg / 1000 hooks. However, such a low estimate should not be assumed for the periods prior to 1994 where activity in temperate areas with shallow longlines was very important and much higher CPUE values would be expected, likely similar to those observed in other surface longline fleets fishing in temperate water. Data provided in literature suggest much higher CPUEs during those historical periods.

The average T1 reported to ICCAT for the period 1990-2015 was 238.13 t per year. The "weight" of the T1 of this fleet over the total international catches reported for this stock between 1990 and 2015 (international T1) has been on average **6.35%** (including discards). However, this fleet was probably one of the main players in terms of SMA catches during periods prior to the CPUE series presented.

The WG Anon. (2017[a]) questioned the zero-catch ratio, which was 46% in the data from the logbooks before filtering processes. The method of estimating the specific catch was discussed and a possible approach was suggested using the effort data in 5x5 grids that are available in the ICCAT database. Based on a discussion upon the spatial pattern of operation and on the nominal CPUE of SMA, the definition of "fleet periods" was discussed. It was indicated that, based on a discussion of the observed differences (SCRS/2017/054, Appendix 1, lower left panel) the number of sets by gear type within the area, it might be important to address Japanese CPUE in the Atlantic north as "two separate fleets": one fleet in area 1, and a second fleet in area 2 and area 3 combined. Although the operating pattern is likely to differ depending on the areas in the Japanese fisheries, a spatial investigation of length frequency would not support differentiation in "various fleets", and it was reiterated by the WG that "*the Japanese fleet was to be treated as a fleet in Stock Synthesis analysis*." It was also noted that the filtering method was designed to reduce the overestimation and underestimation of CPUE standardization and that the filtering method is described in detail in previous SCRS documents.

3.2.4. PRT-SCRS/2017/049. Standardized CPUE and size distribution of the shortfin mako shark in the Portuguese pelagic longline fishery in the Atlantic (Coelho *et al.* 2017).

The document provides CPUE and size data for a surface longline fleet targeting swordfish. The CPUE was modeled from a combination of information (port sampling, self-sampling volunteer skippers-logbooks, and observer data). Data were analyzed by trip or sub-trip in units of kg round weight /1000 hooks. The document describes that the North Atlantic fishery started / starting in the late 1970s but mainly developed as from 1986.

The analysis had data from the period 1995-2015 with a total of 1615 observations from the North Atlantic stock, but instead used data from the period 1999-2015 (17 years) due to the low number of observations prior to 1999. The coverage of the data on total SMA catch represented between 1.2% and 9.3% (mean = 4.11% of annual coverage). Although the tentative analysis proposes a geographic stratification based on 11 areas between the North and South ATL, however only 3 areas in the North stock and 2 in the South stock however were those chosen to finally model upon by combining the tentative ones (see Fig. 1 of cited document). Most of the observations from the North came from areas 12+13 (merged into a single area) located between continental Portugal mainland and the Azores archipelago where most of the observed fishing effort was carried out. However, in those areas the highest fishing yields did not occur (Fig. 7 and 8 of the doc). There were only a few observations from the combined 9+10+11 areas further north which were analyzed and fewer observations within the 1+2 combined areas south of 30ºN. Therefore, the geographical representation of the observations used is very limited in quantity and geographic diversity, the observations being generally concentrated within temperate areas in the eastern Azores and to a lesser extent in some eastern tropical areas near the African continent. Based on the geographic stratification applied in the model, it is assumed that the representativeness of the observations has been scarce in some of the areas*quarters to be able to estimate the *lsmean* under a more ambitious area definition, so finally only 3 areas were used in GLM run for the Northern stock. Despite the level of aggregation of the data by trip, 24.7% of the analyzed observations recorded zero catch (range between 13.0-36.6% according to years), with high variability of zero catches between years, which differs from other similar fleets fishing in near areas targeting swordfish.

Data for 2007 showed a very high nominal and standardized CPUE that produces a vision of continued increase until that year and a subsequently decline until 2015. If 2007 were not considered in the analysis, the time series would probably have an almost flat trend. The available observations from 2007 and their possible relationship with over-reporting or under-reporting of this or other species should be investigated. In example of this Queiroz *et al.* (2017[7]) point out very high reports of shortfin mako that could have been of another species and that the SMA/SWO ratios of some of the sources consulted seem very unlikely (**Figure 6** of the present paper). On the other hand, it would be convenient to investigate if the availability of observations from the subareas located more towards the NW-central ATL, with generally very little observed effort but with higher CPUEs than in the other adjacent subareas (see Fig. 6 of that document), could explain the increase in nominal and standardized CPUE for 2007 (see Fig. 14 of the cited document) due to the observations from some of the westernmost subareas (see figures 7 and 8 of the cited document).

Regardless of the cause, the truth is that the nominal CPUE for 2007 presented a variation of +/- 200% over previous and subsequent years respectively, which seems biologically unlikely as a change in biomass in this stock in only one year. Although standardized CPUE somewhat softens that view, nonetheless the standardized series as a whole gives a "round-trip" picture that is probably a contrivance from the available data. As it was not possible to review the residuals by year, it was not possible to identify what had happened in the observations of the year 2007 in particular and adjacent years and with respect to the other years of that series.

The results provided in the document represent an advance in the study of the SMA CPUE in this fleet. It suggests the need to investigate the sources of uncertainty in the recorded catches and the interannual variability presented by this index. The coverage of data used in the GLM is on average around 5% of the total reported catches (T1) of this species from this fleet. Only some of the area-years have observations with sufficient representativeness. On the other hand, the areas covered by these data are incorporated in the analyses of other fleets with broader coverage and a longer time series. Therefore, this index should probably be investigated before being incorporated into assessment models or, failing that, applied in sensitivity tests after investigating the data used and specifically from year 2007.

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[7] Document is not available in Collect. Vol. Sci. Pap. Documents withdrawn or that not corresponds to ICCAT standard publication formats.

From the document it is deduced that for the period 1999-2015 (17 years) the average CPUEw was 30.90 kg round weight/1000 hooks. Assuming an average weight of approximately 30 kg RW per individual (according to fig. 4 of cited document) the mean CPUE would be approximately 1.03 fish/1000 hooks.

The average T1 of this fleet reported to ICCAT for the period 1990-2015 was 688.5 t/year. The "weight" of the T1 of this fleet for the overall international catches reported for this stock between 1990 and 2015 (T1-international) was on average **18.47%** (including discards).

As in this review, the WG Anon (2017[a]) pointed out the striking peak of the nominal CPUE for 2007 and that this peak only appeared for shortfin mako and not for other species. It was questioned whether that peak had been reported by a specific ship or for multiple ships. It was noted that those data had been re-coded for a specific area. Despite these limitations and uncertainties, Anon (2017[a]) *ruled that this CPUE series could be used in the 2017 SMA assessment of the North Atlantic stock.*

3.2.5. ESP-SCRS/2017/108. Updated standardized catch rates of shortfin mako (Isurus oxyrinchus) caught by the Spanish surface longline fishery targeting swordfish in the Atlantic ocean during the period 1990-2015 (Fernández-Costa *et al.* 2017).

The document updates CPUE data in number of fish and in biomass (kg RW) per 1000 hooks modeled from trip information scientifically collected during landings from 1990-2015 (over a 26-year period of scientific records). Data from the North fleet was obtained and analyzed by trip. In total, around 16 thousand of trips were analyzed from the northern stock, equivalent to 515.1 million hooks analyzed. The mean coverage of these observations represented around 71% of the total effort exerted by this fleet (T2-effort) during the period for North and South Atlantic stocks. The paper provides an update on analyzes performed for previous assessments. The authors proposed the same geographic stratification of the data in 5 areas in the North ATL (fig. 1 of the cited document), differentiating between areas 1 and 2 (separated by 30ºW) since the different CPUE existing between these two areas is known due to the seasonal behavior of the fleet and the seasonal occurrence of SWO and SMA during some periods which in some way also manifests itself in the analyzes carried out in other fleets.

As in previous studies, trips with positive catch were analyzed. These trips generally cover periods of 15-20 days of fishing within highly restricted areas. The data available confirm the very frequent presence and the relative medium prevalence of this species in most trips, with a very minor proportion and stable trend over time of zero catches per trip recorded (mean values of 2.8% for the North for trips longer than 9 fishing days analyzed). So, the analyzes of the positive catches were also based on positive trip data because the minimum sampling size considered reduced the probability of zero catches per observation modeled and other models tested had produced identical trends. The percentage of positive trips is different to those reported for CPUE analyses of the UE-Portuguese fleet.

The stability in the activity of this fleet over the years, the use of scientific data collected for this purpose and the consideration of the potentially most relevant factors -in addition to area and time- such as gear type, bait type and type of trip (target) provides a representative index in terms of the number of observations used and the representativeness of wide areas of the North ATL, covering Eastern areas of the ATL until reaching 45ºW. It is an index that provides a view of a very substantial part of the preferred areas of distribution of this stock and is geographically complemented by the Series 1 index provided by Cortés (2017[a]) for the ATL NW regions. Both fleets analyze significant volumes of information, albeit based on different sources of data. This CPUE index also represents a very broad view regarding the catch not only in number and weight, sizes and fishing effort covered but also in spatial-temporal coverage considering main areas where this stock is most likely to be distributed within the ATL-N. It provides data of a relatively stable epipelagic fishing gear over the years, which seems to have greater availability of this species according to the diel pattern described for this species in the electronic tagging studies (Sepulveda *et al.* 2004, Vetter *et al.* 2008, Stevens et al. 2010, Abascal *et al.* 2011). The two most important elements of change during the period analyzed (change of longline style and changes in the target) were considered in the GLM runs. Statistical diagnoses were satisfactory, and the use of alternative models did not change the perception of the trend of standardized CPUE (in number and weight) over the years. Likewise, it provided a stable long-term trend of the average weight of the catch, especially from the year 2000, as also suggested by the data on the average size of the U.S. and EU-Portugal fleets. In none of these three fleets were there significant changes in the mean size nor in the mean weight of the catch throughout the respective series analyzed.

The scientific estimate of the average T1 of this fleet reported to ICCAT for the period 1990-2015 was 1956 t/ year. The "weight" of the T1 of this fleet over the overall international catches **reported** for this stock between 1990 and 2015 (T1-international) was on average **55.12%**. The T1 series available at ICCAT has been retrospectively estimated up to 1950. However, the scientifically verified data that has led to the T1 records available at ICCAT for the period 1988-2015, with credible retrospective estimates up to 1983. The authors recommended caution in using T1 data prior to 1983 due to the assumptions implemented.

The WG (Anon. 2017[b]) again discussed the use in the GLM model of the variable "*type of trip*" defined according to the percentage of swordfish with respect to the combined catches of swordfish and blue shark. The group suggested the use of clusters in the analysis instead of the ratio in order to avoid redundancy in the model. Researchers from the EU-Portugal, whose fleet is assumed to be similar to the EU-Spain fleet, indicated that they had carried out cluster analysis on the data from their fleet and had obtained the same results when using clusters as when using ratios. Certainly, the authors of the CPUE series had also tested cluster analyzes and other approaches in the past with the same results, that is, by carrying out a previous categorization of the fishing strategy for each trip using different approaches and applying that categorization into the GLM runs. Based on those studies, the authors considered that applying the SWO/ BSH ratio is the best approximation in the case of this fleet in order to know the target criterion of skippers that has changed substantially over time. As a result, various simulations were also performed for testing proxies by the method working group of ICCAT (Anon. 2001). The cases identified for evaluation of this group were based on some fisheries in which systematic change in targeting had been described and among them just the scenario of swordfish (original target species) and blue shark (secondary target species) were specifically tested via these simulations. In that particular case, referring to the different proxy methods evaluated by the method working group, *the use of the ratio of catch of the target species to total catch performed best on average and remains the preferred proxy, although this method may not necessarily provide the best performance in all cases-fisheries* (Anon. 2001). The group also raised the question about the number of zero catches. The authors indicated that there were a low proportion of trips with zero catches (mean values of 2.8% and 4.3% for the North and South Atlantic stocks, respectively). Furthermore, trips with zero catch showed a stable trend over time. *The Group welcomed this update of the CPUE LL series north and south EU-Spain, and recommended that it be considered for assessment models.*