CATCH RECONSTRUCTION FOR THE INDIAN OCEAN BLUE SHARK: AN ALTERNATIVE HYPOTHESIS BASED ON RATIOS

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SUMMARY

The reconstruction of shark catch time series is particularly important for stock assessments, as the nominal catch data on sharks is usually very limited and a major source of uncertainty. This document provides an alternative hypothesis for the reconstruction of shark catches in the Indian Ocean (IOTC fisheries) based on a method developed for the EUPOA-Sharks (EU Plan of Action for Sharks). The estimation method is based on ratios of sharks:main species catches, obtained from observer programs, literature revision and/or personnel communications. In this paper we present the average estimations by fleet/métier for the Indian Ocean (2000-2015) as well as time series for 1971-2015. These time series (stock level) can be considered for use as alternative catch histories in the 2017 IOTC BSH stock assessment, both for production models (stock level estimations) and integrated models (fleet specific estimations).

KEYWORDS: Catch reconstruction, catch history, data-limited stocks, nominal catches, blue shark, stock assessment.

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1. Introduction

The main purpose of the European Union Plan Of Action on Sharks (EUPOA-Sharks) is to contribute to the general objectives outlined in the FAO IPOA Sharks by ensuring the management of shark stocks fished by the EU fleet. The Plan of Action covers all fishery activities in relation to sharks, such as directed commercial, by-catch commercial, directed recreational, and by-catch recreational fishing. It covers fisheries within EU waters, and also fisheries by the EU fleet operating outside EU waters in the high seas managed by tuna-RFMOs. Thus, from a scientific point of view, the operational objectives of the EUPOA-Sharks aims to efficiently monitor and assess shark stocks on a species-specific level and develop harvesting strategies in accordance with the principles of biological sustainability and rational long term economic use.

In this context, the European Commission promoted an initial project with the main objective of obtaining scientific advice for implementing the EUPOA-Sharks (Murua et al., 2013a, final report available online[1]). In 2016, the EU Commission (EASME - *Executive Agency for Small and Medium-sized Enterprises*, and DG-MARE - *Directorate-General for Maritime Affairs and Fisheries*) commissioned a new consortium of EU laboratories to continue research on the current status of development and provide advice to further advance the EUPOA-Sharks implementation (Coelho et al., 2017). One particular task of this new project (task 1) aims to update the state of knowledge and data compilation of the original EUPOA-Sharks study, including historical catch and effort, discards, length frequencies, biological information and fishery indicators.

The reconstruction of catch histories is particularly important for the stock assessments of data limited stocks, as most by-catch species (including sharks). In 2015, a preliminary blue shark (BSH) stock assessment was carried out for the IOTC convention area, but the stock status remained uncertain (IOTC, 2015). One of the main causes of uncertainty identified in the assessment was the time series of the catch history. The IOTC-WPEB (*Working Party on Ecosystems and Bycatch*) considered critical the proper reporting of shark nominal catches, and recommended conducting further analysis to obtain reliable estimates of shark catches by species for the entire time series (IOTC, 2015). Several approaches are possible to use for reconstructing catch histories, including the use of a ratio of shark catch to tuna catch and the use of shark fin trade information (IOTC, 2015).

Due to the uncertainty in the estimates of the historic catches of sharks, particularly severe in the IOTC convention area, there is an urgent need to further progress research and hypothesis for obtaining alternative catch histories that can then be used as alternative scenarios in stock assessments. Considering that the IOTC WPEB is carrying out a stock assessment of BSH in 2017, the main goal of this paper is to provide alternative time series of catch histories both at a stock level and also fleet-specific level that can be considered in the stock assessment models.

2. Materials and methods

A revision on the available catch and effort data for oceanic sharks and rays was carried out, as defined in the scope of the EUPOA-Sharks study in the various tuna-RFMOs and from other relevant sources: Overall, this revision included the Atlantic, Indian and Pacific Oceans, as well as the Mediterranean Sea (see Murua et al., 2013a, 2013b for general methodological aspects).

For updating the EUPOA-Sharks study results, the data was processed in a 3 step approach:

1) Data gaps: summaries on what countries report data to the tuna-RFMO on shark catches (i.e., summary information presenting if the data is available or not by country);

2) tuna-RFMO official catch data for major fleets and countries catching sharks based on current data available in the tuna-RFMOs: this includes the catches of sharks and/or the target species, which may be indicative of global shark catch;

3) Estimation of "possible" catch shark by major fleets and countries which are estimated to be catching sharks based on the ratio of shark catch/by-catch over the main target species. The ratios were estimated through observer programmes data, literature revision and/or personal communications (as applied in Murua et al., 2013a).

The 2 first steps of the process are revisions based on the currently available information. For the estimation of the potential catches that is presented in the 3rd step, the datasets available in the tuna-RFMOs were analyzed in order to identify fleets/métiers susceptible to generate catches of sharks.

[1] https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/scientific-advice-sharks_en.pdf

As reported by Murua et al. (2013a, 2013b) the basic assumption of the method is that the target species quantities declared by flag/fleet to the tuna-RFMOs are correct, and that it is reliable to use these estimates to compute the potential shark catches knowing each fleet specific métier (target species and gear characteristics) and the corresponding catch ratio (shark:target species). With this information and assumptions, the biomass of sharks caught by each fleet/métier can then be estimated.

Based on the original nominal catch databases from the tuna-RFMOs, which typically include tuna and shark catch information by year, species, area, gear, country, flag and fleet, we then estimated the “potential” shark catches by major fleets involved in fisheries capturing sharks. For the global averages the data used are the reported nominal catches by species for the period 2000-2015, while specific data by year was used for the time series.

The final tables and estimations are the result of the following steps:

1 - Ratio references by métier: preparation of reference ratios of shark by-catch/catch over target species catch by métier. This information is based on literature available, expert knowledge and unpublished observer data (see Murua et al., 2013a).

1.1 - A list of métiers (combination of gear and target species group) is identified and for each of these métier the following is defined:

1.1.1 - A ratio of shark (all species combined) catch to target species group (in weight);

1.1.2- Shark species composition in proportion (sum = 1): For this specific sub-task the original EUPOA project focused on 18 major pelagic sharks species or groups of species

2 - Preparation of data.

2.1 - Data task I (total nominal catches by flag and year) from each tuna-RFMO was compiled by fishery, i.e., a combination of flag, fleet and gear for the period 2000-2015 (16 years),

2.2 - Mean nominal catches were calculated for target species groups (main shark species, major tuna including billfishes but excluding swordfish, other sharks, other species, small tunas, swordfish). Two types of means were then calculated:

2.2.1 - Simple mean using all 16 years including zeros (0s). This means that if a country makes no declaration one year, this will be used as a 0 catch to calculate the mean. With this scenario it is assumed that each 0 or blank (no declaration) in the data corresponds to a year without catch (real zero). This method provides the update of the "Low Estimate" scenario as was done in the EUPOA study;

2.2.2 - For positive years only, in this case assuming that most zero declarations do not correspond to zero catches, but to missing data (e.g., lack of data submission). In this scenario, the mean is estimated by considering only years with positive shark catches. This method provides the update of the "High estimate" scenario, as was done in the EUPOA study;

2.2.3. The number of positive years is compiled and compared to analyze the effect of these two different assumptions in the final results.

3 Estimation of "potential" shark catches by métier.

3.1 - Based on the ratio by métier (step 1) and target species average nominal catch declared (step 2), the potential catch of the sharks by species are then estimated:

3.1.1 - Shark species catch = Target species * $\text{Ratio}_{\text{shark species/target species}}$

3.2. The results are summarized and ranked by:

3.2.1 - Shark species mostly impacted;

3.2.2 - Métiers with most impact in shark catches (overall);

3.2.3 - Métiers with most impact in shark catches (species-specific).

Additionally to the overall averages over the last 16 years (2000-2015), time series were also created for some species complexes, species or stocks. In this paper we provide the results specific to the BSH for the Indian Ocean, to be considered as sensitivity scenarios in the 2017 IOTC BSH stock assessment.

3. Results and Discussion

3.1. Estimates of overall shark catches in the Indian Ocean

Given the continued lack of sufficient quantitative information for stock assessment purposes, there is still an interest in using alternative methods for reconstructing alternative catch histories, especially for the main shark species. The original outputs of the EUPOA-Shark project were presented to the IOTC in the 2013 WPEB (Murua et al., 2013b), showing the overall estimated shark species catches for the period 2000-2010. However, at that time it was not possible to estimate the potential shark catches by year, and therefore the results could not be used in the stock assessments. Now, based on the same method but adding the stratification by year, it was possible to further develop the method and provide results in terms of time series that can be considered in future stock assessments.

Based on the information provided in the IOTC nominal catches, the major fisheries (country/fleet/gear) targeting tunas, swordfish and sharks in the Indian Ocean were identified. According to the aggregated total catch available in the IOTC database for the Indian Ocean during the last 16 years (2000-2015), the largest shark catches (all species combined) have been declared by Indonesia, followed by Pakistan, Yemen, Iran and Sri Lanka. The list of flags that account for 90% of the catches are shown in **Table 1**. **Figure 1** presents the total sharks reported landing (major sharks and other species) for the aggregate period 2000-2015.

The estimated “potential” shark catches vary between around 120,000 to 140,000 t, depending on considering the High and Low estimation scenarios (see methods for the description on those estimates). This contrasts to the currently reported shark catches of around 80,000 t presently declared to IOTC for the Indian Ocean, but noting that a substantial proportion (around 50%) is still currently declared as sharks not identified (*sharks nei*) (**Figure 2** and **Figure 3**). Among the different métiers identified, gillnets and gillnets combined with longlines are the most impacting with the majority of the total estimated shark species catches (**Figure 4** and **Figure 5**). This is followed by the "other" fishing categories, and then by longlines.

In terms of species, the shark with more estimated catches is blue shark, with the majority of the catches, followed by silky shark. Other species as threshers, shortfin mako, oceanic whitetip and hammerheads are also estimated to have some significant catches. The blue shark is mainly impacted by longlines, gillnets associated with longlines and other gears. Species like the silky shark, threshers, and hammerheads are mainly impacted by gillnets associated with longlines (**Figure 6** and **Figure 7**).

In terms of fleets and métiers, in the Indian Ocean the impact on pelagic sharks is highly concentrated in just a few fisheries (**Figure 8** and **Figure 9**). The main fleets responsible for the shark catches in the Indian Ocean are Sri Lanka and Iran gillnets associated with longlines, Indonesia and Taiwan longlines (**Figures 8** and **Figure 9**).

One important note on these results is that these fleets/métiers were identified on the basis of tuna and tuna like reported catches to IOTC. Such data is based on the national reports from the national fisheries agencies, and can have significant limitations due to data collection, reporting efficiency and problems related with species identification. As such, the presented estimates are affected by possible under- or non-reporting of the main targeted tuna and tuna like species by each country.

In terms of time series, and as an extension to the EUPOA-Sharks project method, it was now possible to carry out an estimate of the time series of overall catches. The estimates start in 1971, as that is the starting year of many stock assessment models for sharks, before the expansion of oceanic fisheries in the 1970's. The time series for the EUPOA shark species and for all sharks is shown in **Figure 10**.

3.2. Times series for blue shark catches

With the extension of the estimation method, it is now also possible to reconstruct alternative catches for specific species delimited by stock, which can be directly included in the stock assessment models. **Figure 11** and **Table 2** provide the alternative reconstructed catches for blue shark in the Indian Ocean using the EUPOA-Sharks method.

At a stock level, there are differences of blue shark reported *versus* estimated catches along the entire time series (**Figure 11**). In both series there is a relatively rapid increase until the early 2000's. In the reported time series the catches continue to increase until 2015, while in the estimated catches there are oscillations between 2005 and 2015 but no longer an overall increase (**Figure 11**). Fleet specific estimation using the fleet definitions as used in the 2015 IOTC BSH assessment (SS3 models) are shown in **Figure 12**.

Both those time series is of particular interest, as the blue shark is currently being assessed by the IOCT Working Party on Ecosystems and Bycatch (assessment taking place in September 2017), and this reconstructed series can be used as a sensitivity scenario to the nominal catches reported to IOTC.

4. Acknowledgments

The research conducted for this paper was funded by the EU Commission through two studies. The current work with updated information and estimations of time series is funded by Project "*SAFEWATERS-2 SC01: Improving scientific advice for the conservation and management of oceanic sharks and rays*", Ref: EASME/EMFF/2016/008-SC01 (managed by the Executive Agency for Small and Medium-sized Enterprises - EASME). The original methods and analysis were funded through Project "*EUPOA-Sharks: Provision of scientific advice for the purpose of the implementation of the EUPOA sharks*" Ref. MARE/2010/11 (managed by the Directorate-General for Maritime Affairs and Fisheries – DG MARE). The authors thank all the scientific collaborations from various observer programs that contributed with data/information for the ratios used in the catch reconstructions. Rui Coelho is supported by an Investigador-FCT contract from the Portuguese Foundation for Science and Technology (FCT, *Fundação para a Ciência e Tecnologia*) supported by the EU European Social Fund and the Programa Operacional Potencial Humano (Ref: IF/00253/2014).

5. References

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Tables

Table 1. Sharks (all species) total reported catches by fleet from 2000 to 2015. Only fleets until cumulative catches of 90% are shown (source: IOTC nominal catches database).

Flag	Total catch (t)	%	Cum %
Indonesia	299,040.8	18.5	18.5
Pakistan	197,164.0	12.2	30.7
Yemen	162,617.0	10.1	40.8
Iran Islamic Rep.	159,573.4	9.9	50.6
Sri Lanka	146,402.6	9.1	59.7
Oman	92,310.7	5.7	65.4
Madagascar	91,000.3	5.6	71.0
Taiwan,China	66,421.5	4.1	75.1
EU.Spain	63,791.0	3.9	79.1
Maldivas	61,611.3	3.8	82.9
Tanzania	41,770.4	2.6	85.5
India	36,172.7	2.2	87.7
Un. Arab Emirates	29,298.5	1.8	89.5

Table 2. Reported *vs.* estimated blue shark (BSH) catches, between 1971 and 2015, for the Indian Ocean (IOTC).

Year	BSH Reported	BSH Estimated
1971	1505.6	9645.2
1972	1535.6	10856.5
1973	1158.0	12120.3
1974	1531.4	14933.4
1975	1851.4	14733.4
1976	1653.7	16281.5
1977	1887.5	19792.1
1978	2122.4	17400.4
1979	1935.9	15363.8
1980	2079.9	16646.6
1981	2464.3	14806.8
1982	2919.0	17899.1
1983	2981.2	16531.9
1984	3111.4	15760.6
1985	2892.4	16696.4
1986	2972.9	20156.7
1987	2910.7	23131.7
1988	3362.8	25609.3
1989	3768.3	28223.6
1990	3013.3	29853.5
1991	3732.8	29796.6
1992	3567.1	37390.2
1993	5169.0	47125.1
1994	6498.6	43572.1
1995	6841.4	41952.3
1996	7420.5	47683.8
1997	8846.5	50267.5
1998	8875.5	51921.4
1999	12122.6	54801.8
2000	12403.7	51132.4
2001	10484.0	52192.5
2002	11853.9	54029.0
2003	15353.9	56568.1
2004	21398.7	71887.3
2005	24392.9	72090.3
2006	21791.5	65363.6
2007	23293.0	62539.0
2008	24144.6	55791.4
2009	26562.8	54520.9
2010	27414.3	56465.7
2011	28033.5	61068.7
2012	28158.9	71469.3
2013	32302.5	70589.4
2014	29127.7	70455.9
2015	30053.9	67086.8

Figures

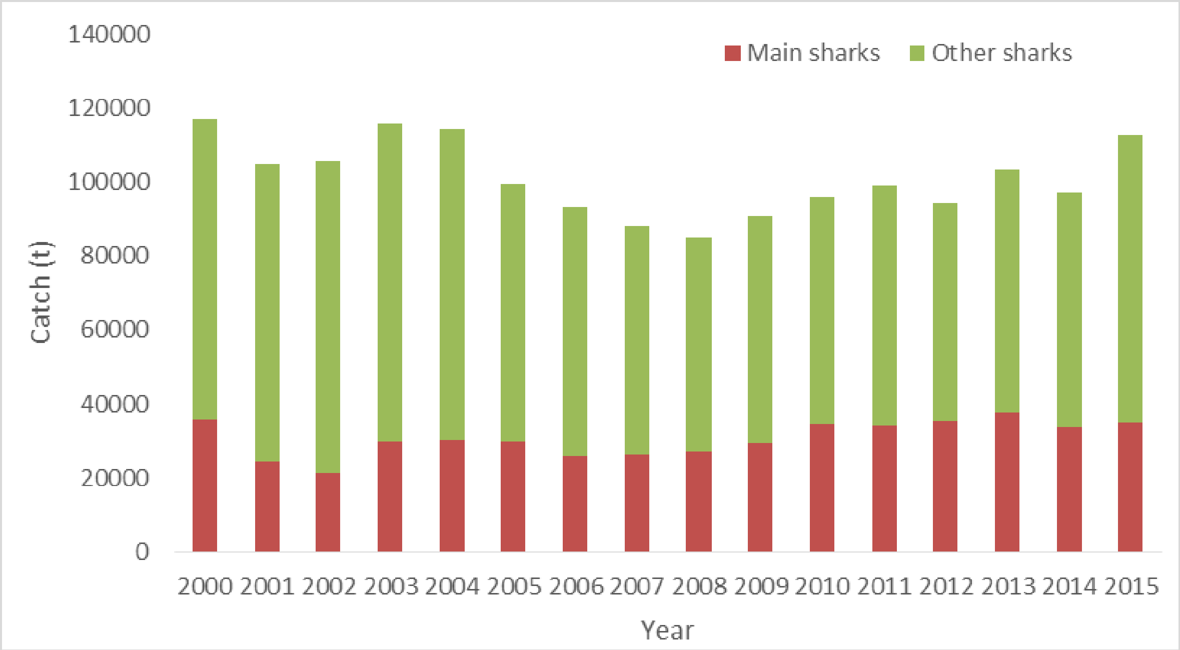

Figure 1. Reported landings of sharks (t) between 2000 and 2015 in the Indian Ocean (IOTC) for main sharks (BSH, SMA, FAL, OCS, BTH, PTH, SPL) and other shark species.

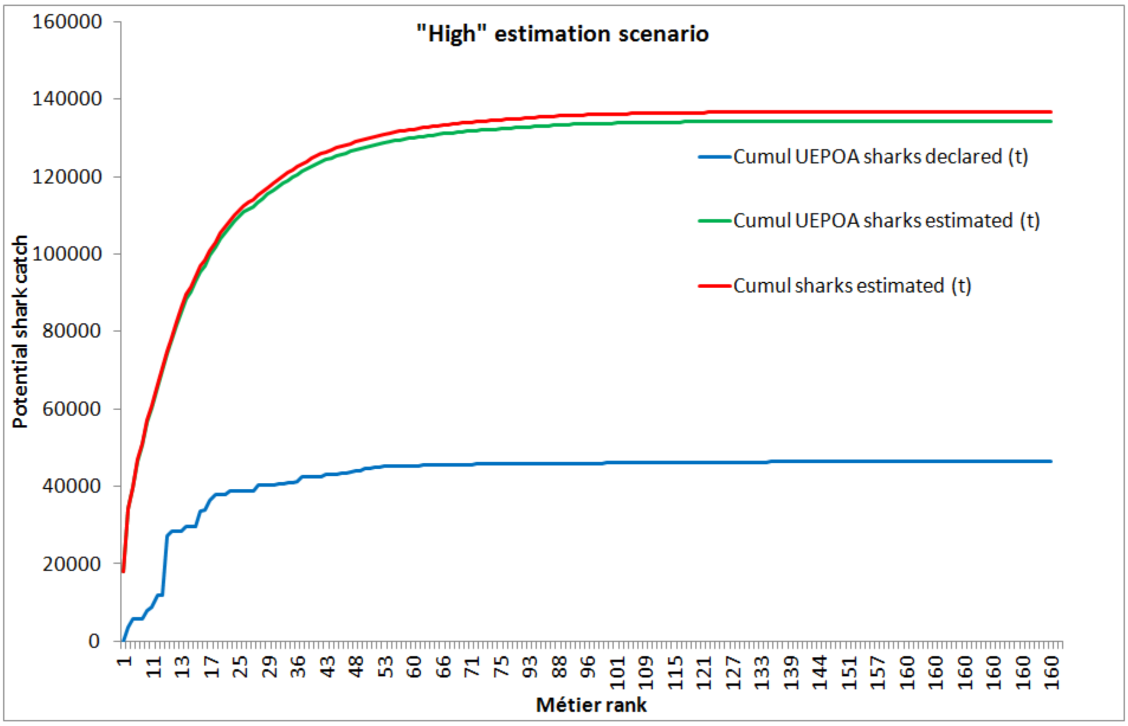

Figure 2. Cumulative catches (t) of reported catches and estimated "potential" reconstructed catches for the "High" estimation scenario, ranked by métier. "Cumul UEPOA sharks" refer to the 18 species originally in the EUPOA project and "Cumul sharks" refer to all shark species combined.

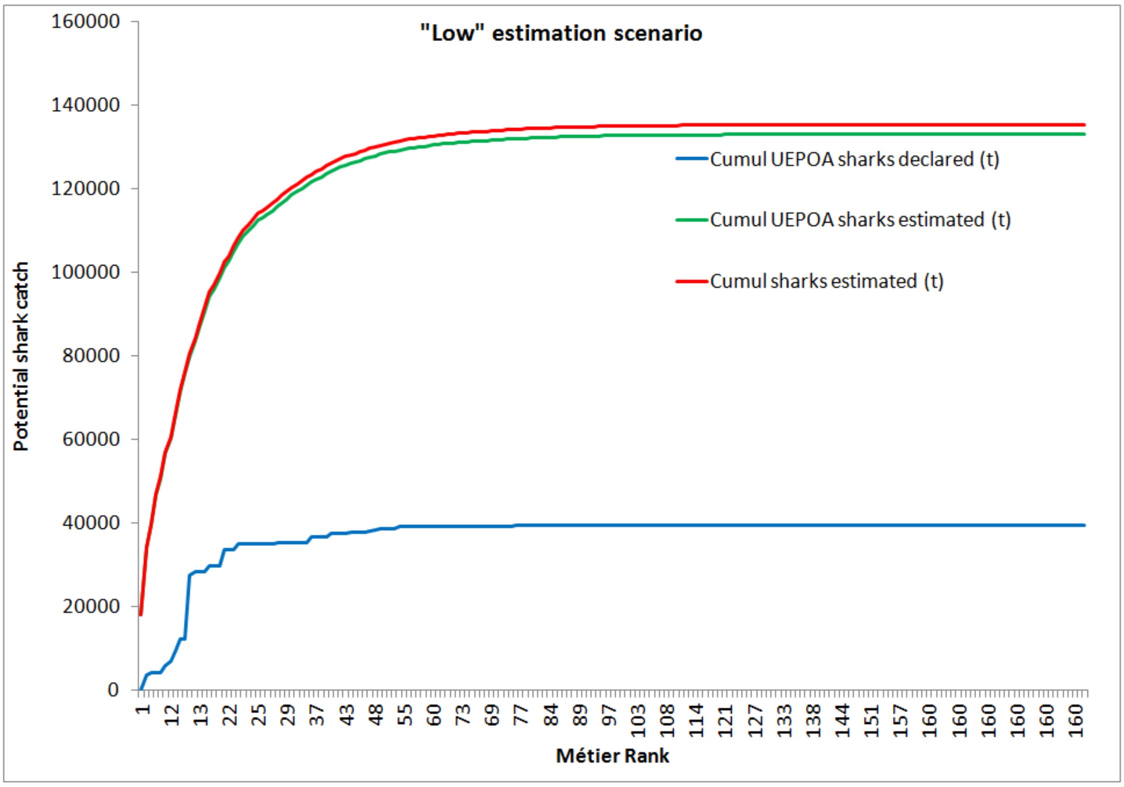

Figure 3. Cumulative catches (t) of reported catches and estimated "potential" reconstructed catches for the "Low" estimation scenario, ranked by métier. "Cumul UEPOA sharks" refer to the 18 species originally in the EUPOA project and "Cumul sharks" refer to all shark species combined.

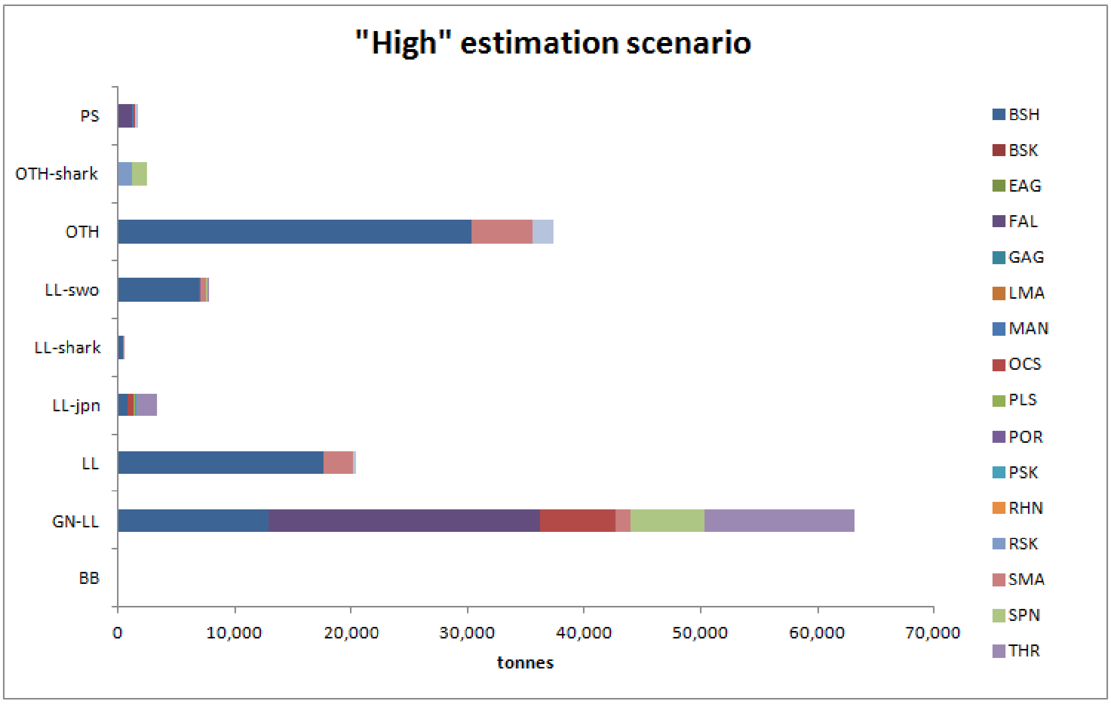

Figure 4. Estimated Catch (tonnes) by métier and by species in the Indian Ocean, for the "High" scenario estimation.

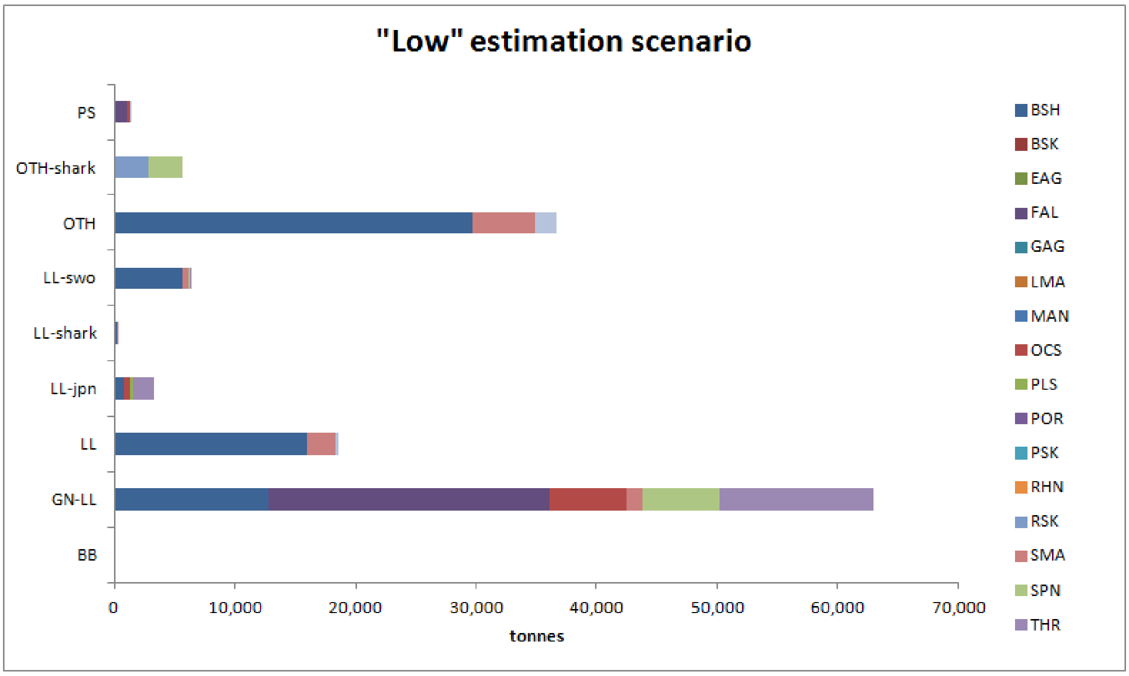

Figure 5. Estimated Catch (tonnes) by métier and by species in the Indian Ocean, for the "Low" scenario estimation.

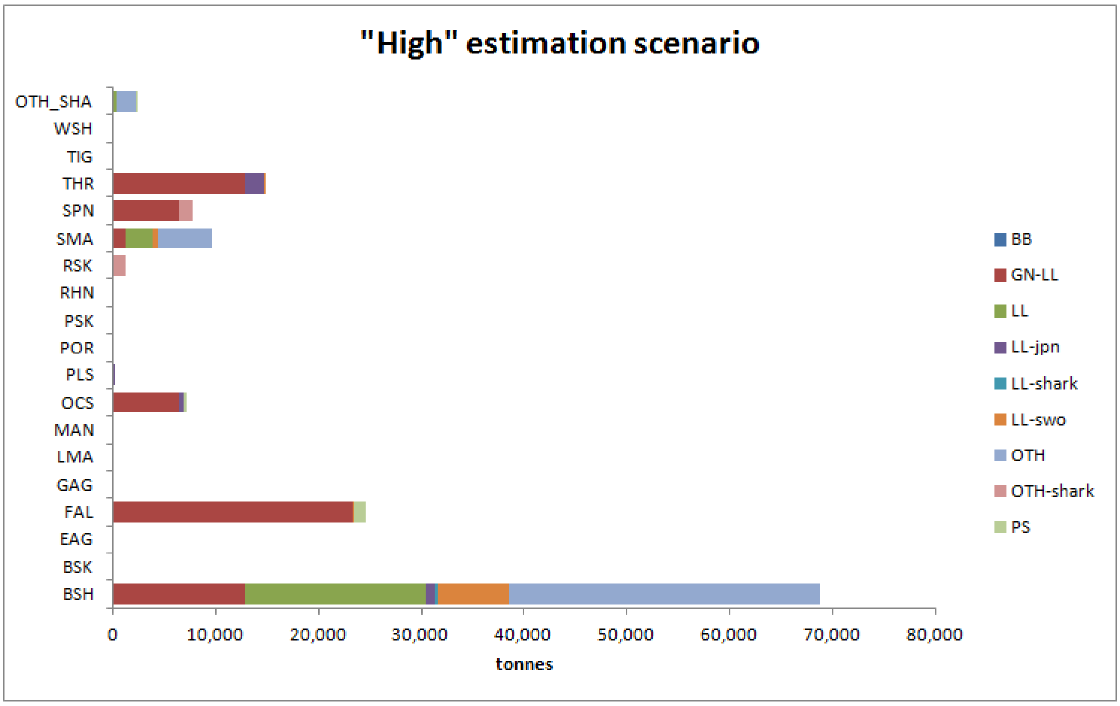

Figure 6. Estimated catch (tonnes) of the EUPOA shark species by métier in the Indian Ocean, for the "high" estimation scenario.

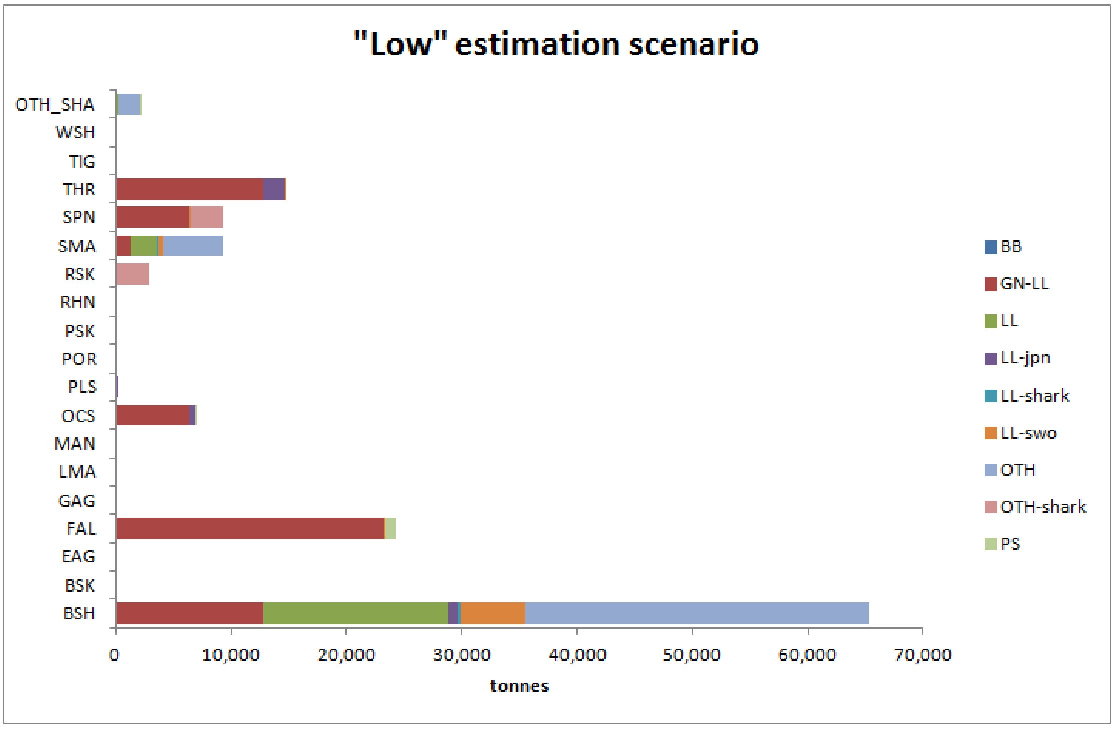

Figure 7. Estimated catch (tonnes) of the EUPOA shark species by métier in the Indian Ocean, for the "low" estimation scenario.

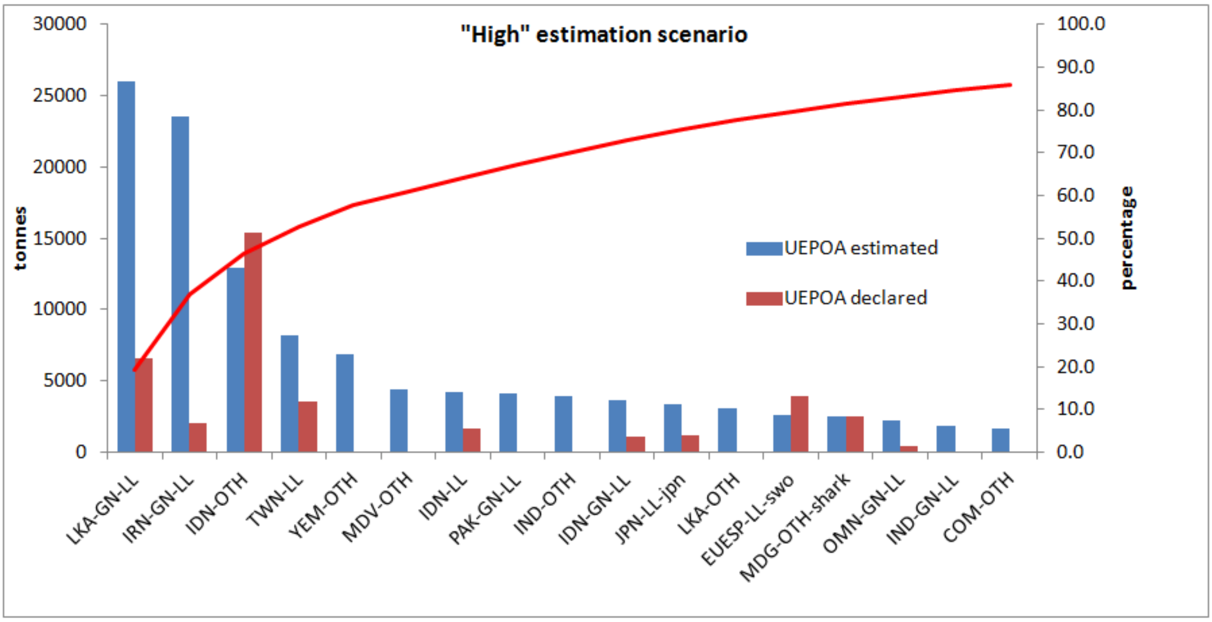

Figure 8.Main fisheries (flag and métier) responsible for catching pelagic sharks species in the Indian Ocean (EUPOA shark species), under the "high" estimation scenario.

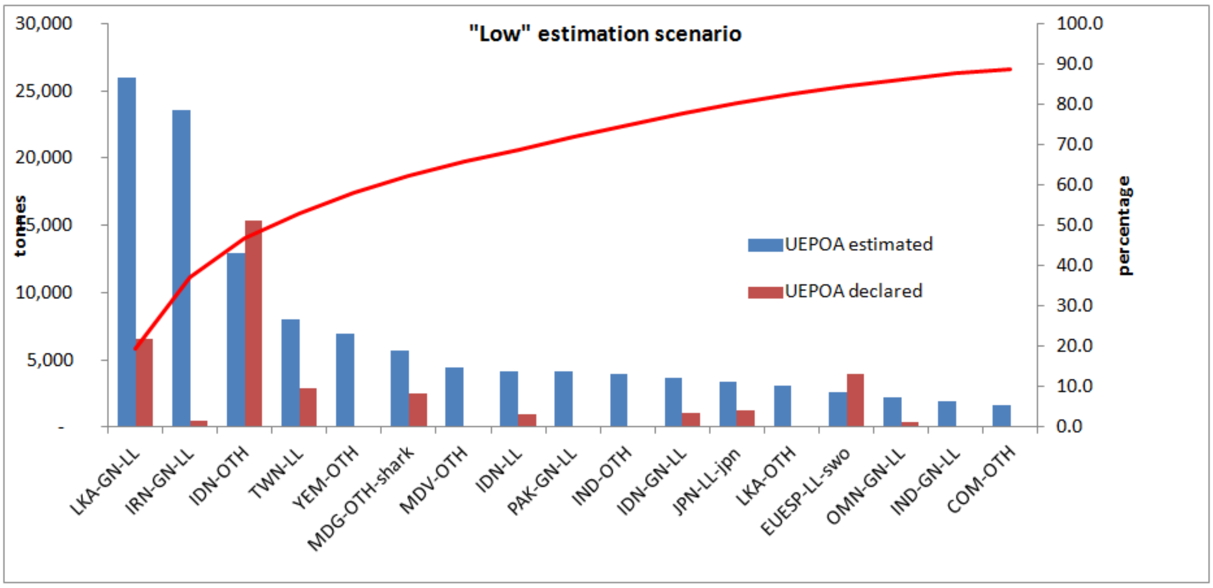

Figure 9. Main fisheries (flag and métier) responsible for catching pelagic sharks species in the Indian Ocean (EUPOA shark species), under the "low" estimation scenario.

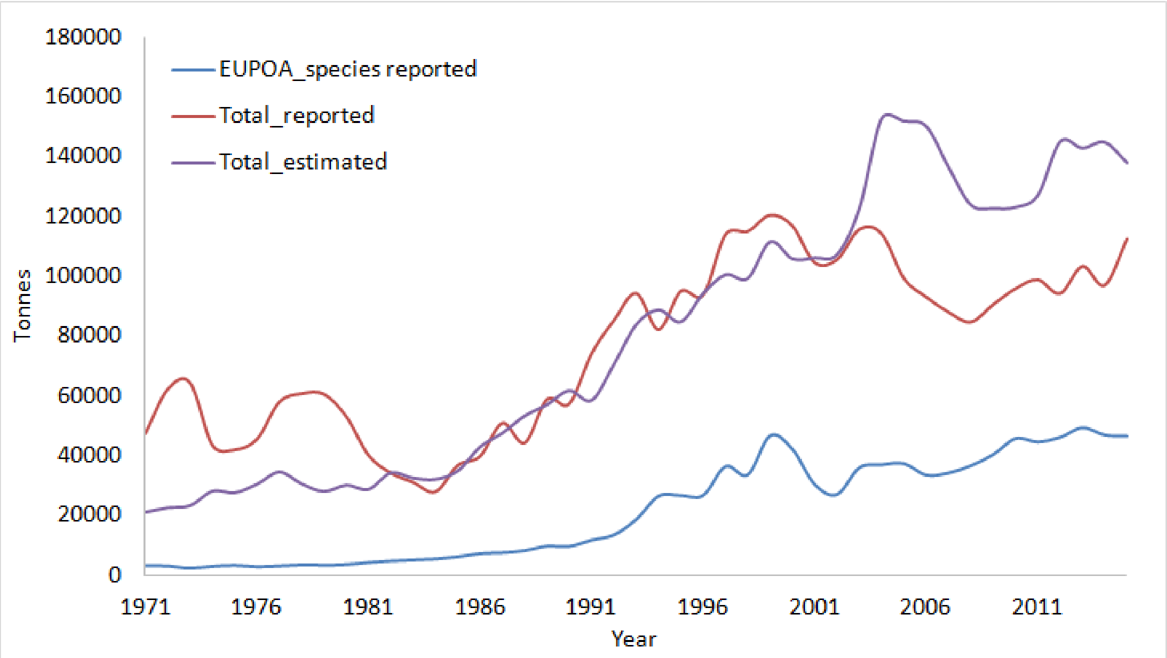

Figure 10. Time series of declared and estimated shark catches, between 1971 and 2015, for the Indian Ocean.

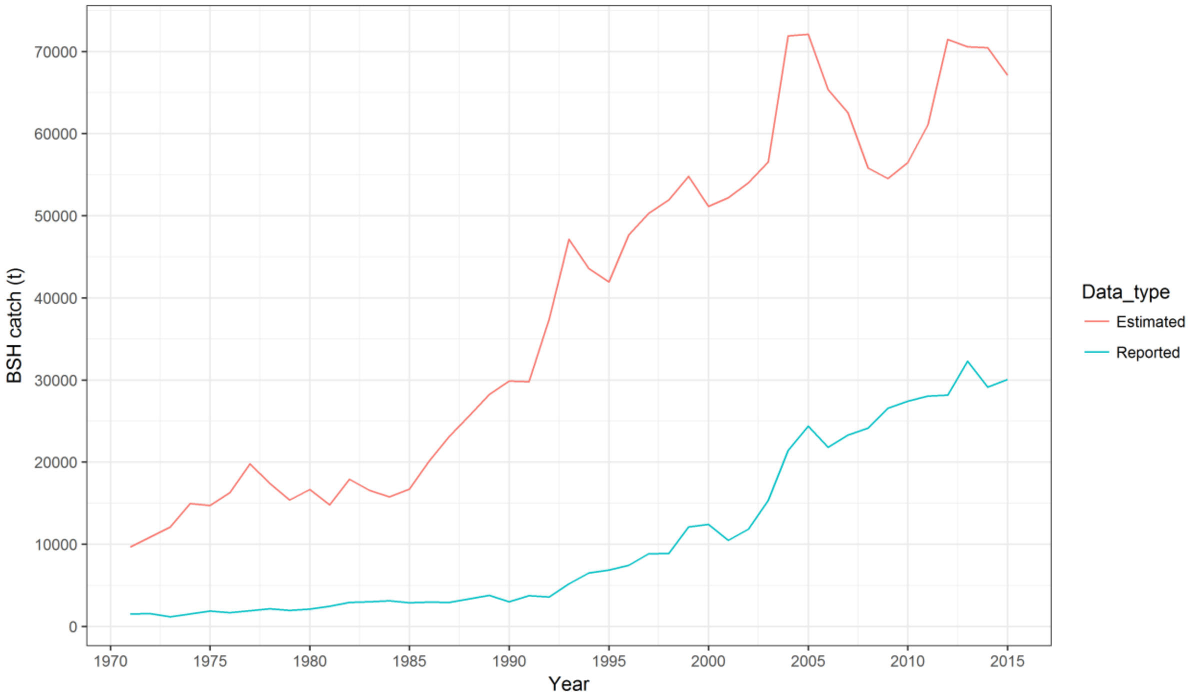

Figure 11. Time series of reported and estimated blue shark (BSH) catches, between 1971 and 2015, for the Indian Ocean.

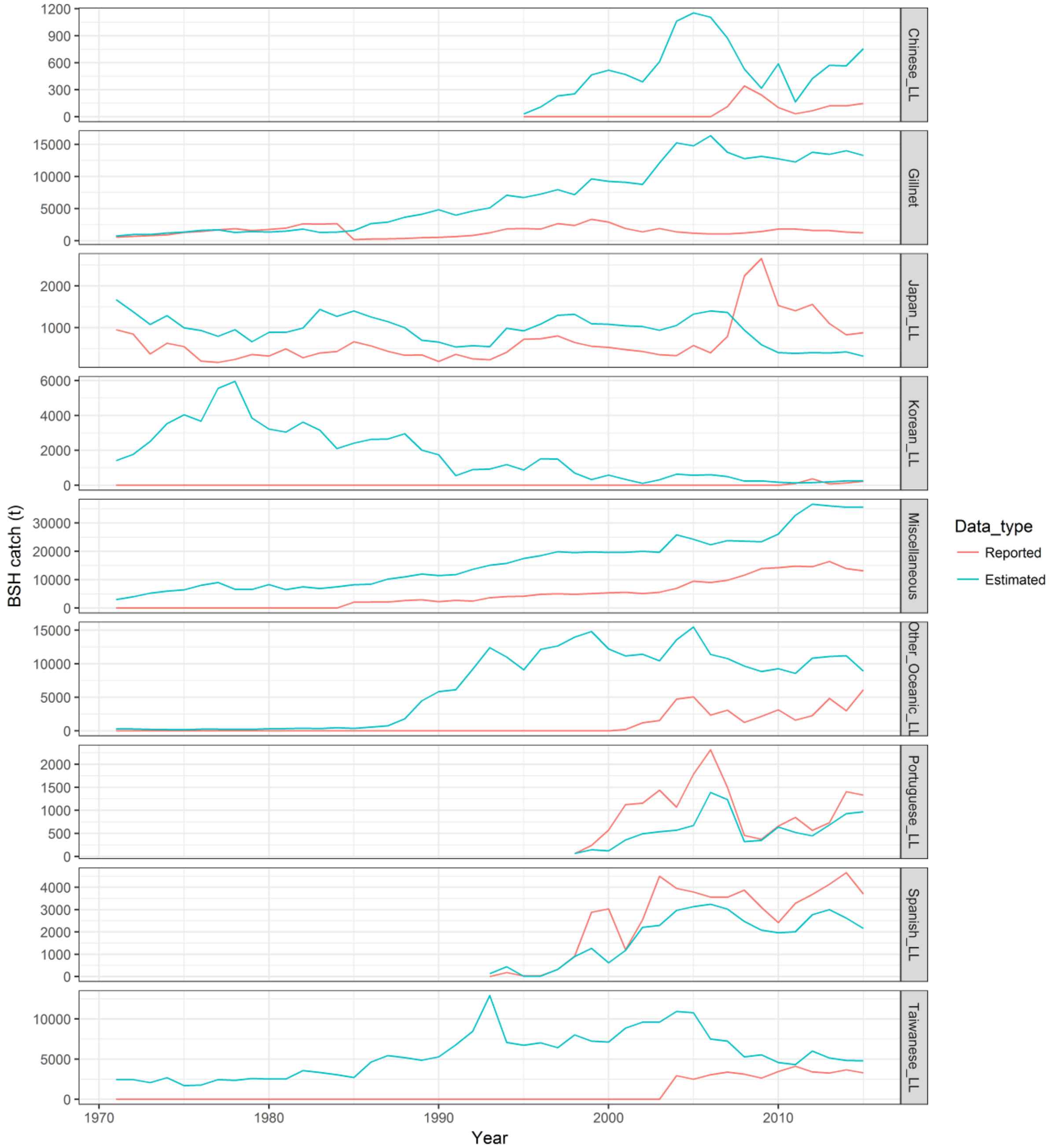

Figure 12. Time series of reported and estimated blue shark (BSH) catches, between 1971 and 2015, for indicator fleets capturing BSH in the Indian Ocean (fleets as defined in the BSH SS3 model of 2015).