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CATCH ESTIMTES OF INDIAN OCEAN BLUE SHARK *(PRIONACE GLAUCA)*

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ABSTRACT

Catch histories form an important component of stock assessments and so having a reliable and believable catch series is a key part in gauging the level of stock depletion. In data-limited situations, reported nominal catches are often not considered reliable and so reconstruction of catch histories plays an important role. The first Indian Ocean stock assessment of blue shark took place in 2015, however, due to the amount of uncertainty in the assessments, the conclusion regarding stock status remained as uncertain. The historic catch series was considered to be one of the key sources of uncertainty and so the Working Party requested that participants develop new approaches to reconstructing historic catches to be used as alternate series for assessment. This paper uses the available nominal catch data currently held in the IOTC database and a generalized additive model (GAM) approach to reconstructing historic blue shark catches in the Indian Ocean. Additionally a ratio based method was used to estimate the unreported blue shark catches.

The methods described in this paper attempt to account for not reporting of blue shark catches. Based on the methodology used in 2017 GAM using target catches were used to predict the expected catches where there are zero reported catches. The resulting estimated catch series were very similar to the catches estimated in 2017 (same trend and scale) with catches increasing over the time period of the fishery, reaching approximately 50-66,000 t in recent years. With a drop in catches in the recent years that mimics the drop in reported catch. Similar to the work done in 2017 these estimates are prepared for used in the assessment model that has 8 fleets.

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

1 Introduction

Catch histories form an important component of stock assessments and so having a reliable and believable catch series is a key part in developing a good estimate of the level of stock depletion. In data-limited situations, reported nominal catches are often not considered reliable and so reconstruction of catch histories plays an important role. This is particularly important for bycatch species where data are often sparse and of varying quality. Nominal catches of blue sharks in the Indian Ocean held by the IOTC (IOTC 2021) are considered to be highly uncertain, and are likely to be 'severe underestimates' of the actual catches taken as concluded by the Working Party on Ecosystem and Bycatch in 2015, 2017 and again in 2021.

The first Indian Ocean stock assessment of blue shark took place in 2015, however, due to the amount of uncertainty in the assessments, the conclusion regarding stock status remained as uncertain (Rice and Sharma 2015). The historic catch series was considered to be one of the key sources of uncertainty and so the Working Party requested that participants develop new approaches to reconstructing historic catches to be used as alternate series for assessment. There a number of approaches that may be used to produce catch history reconstructions. One method that has been used previously for Indian Ocean blue shark was based on information obtained from the shark fin trade (Clarke 2015), providing estimates used in the 2015 assessment (Rice and Sharma 2015) that were approximately four times higher than the IOTC nominal catches (Clarke 2015). In 2017 an attempt at recreating the estimates based on the shark fin trade was undertaken, however this was unsuccessful due to changes in the fin trade, shifts major markets, and data availability. There was not sufficient data to estimate catch in recent years from the shark fin trade. Another method has been developed which is based on expert knowledge of Indian Ocean fisheries to determine catch rates of sharks to target species and separating out the different shark species using a proportioning method (Murua et al 2013). Yet another approach that has been applied for southern bluefin tuna in the southern Ocean involved the use of random forests to predict CPUE of non-members based on the reported CPUE of members (Chambers and Hoyle, 2015).

This paper uses the available nominal catch data currently held in the IOTC database and explores the use of a ratio based method and a GAM statistical approach to reconstructing historic blue shark catches in the Indian Ocean.

2 Methods

Data sources used: IOTC nominal catches

The best estimates of nominal catches of blue shark in the Indian Ocean are published annually on the IOTC website (IOTC 2021). These are based on catches reported directly to IOTC both contracting and non-contracting parties fishing for tunas in the Indian Ocean and include best estimates in some cases where data are particularly poor or lacking altogether.

This data is available by flag state, species (including IOTC species and bycatch), fishing gear and area (east or west Indian Ocean) in live weight equivalent. The data set extends back to the 1950s when industrial longlining began in the Indian Ocean. The data are generally considered representative (though the level of accuracy varies by year) of the nominal catch of the main IOTC target species, however, the reporting of sharks over the time period has been somewhat more inconsistent.

The nominal catch dataset for blue shark and the main amendments to reported catches that have been made have been fully described (IOTC Secretariat, 2016). The majority of nominal blue shark catches are taken by the Indonesian fleet (Figure 1) and catches are dominated by three major gear types: longline, gillnet and handline (Figure *2*). The Indonesian gillnet fleet is responsible for most of the historic catches of blue shark, followed by a transition to coastal longlines in the mid-1980s. In more recent years catches taken by the industrial longline fisheries have expanded, predominantly by the swordfish targeting longliners of EU-Spain and EU-Portugal, the deep-freezing longliners of Japan and Taiwan, China and the fresh longliners of Taiwan, China (

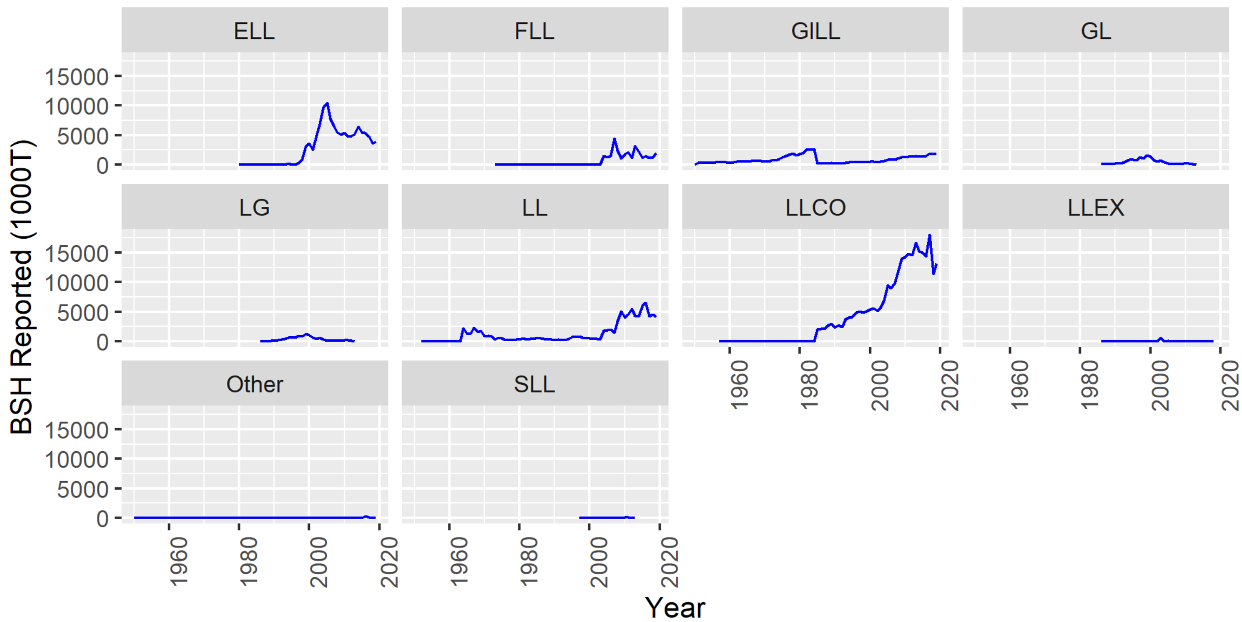

Figure 3).

A key issue with this dataset is the presence of the large *"Sharks various nei"* (SKH) category in the database which is assumed to include unidentified blue sharks. However, the extent to which these aggregates are composed of blue sharks relative to other shark species is unknown. Another major issue is the apparent many incidences of 'missing' catch. For example two fleets fishing in the same vicinity catching the same target species using the same gear type but only one reports any catch of (blue) sharks. This is likely a reporting issue. A third key issue is inaccurate reporting, e.g., a fleet catches substantial quantities of blue shark and only reports a small fraction of this. The method descried below aim to address these core problems with the dataset through predicting unreported catch based on historic reporting of blue shark catches.

GAM approach to estimate unreported blue shark catches

A statistical modelling approach based on generalized additive models (GAMs) was used to predict unreported catches. The estimate blue shark catches are based on the nominal catches in the IOTC database. The model was set up incorporating a number of explanatory variables thought to be influential in determining whether a fleet catches blue sharks, though in practice the number of variables related to the catch records is limited. The model was parameterised based on the records where reported blue shark and the selected covariates were available and the model was run on the remaining dataset where zero blue shark catches were reported, and where sufficient levels of the covariates were available for prediction.
Records with levels outside the model, and so for which prediction was not possible, were dropped.

The log transformed nominal blue shark catches were used as the response variable. Records were filtered to remove extremely high catch rates by selecting only those records where catches of blue shark were less than 80% of the total catches of non-shark species. This was performed to remove those high values where the fishery is likely to be targeting blue sharks and therefore more likely to be accurately reporting those sharks. Outliers were not well predicted by the model so the dataset on which to predict the unreported blue shark catches was also filtered to remove extreme values (records where target catches >80,000 t) which had a disproportionately large effect on the results. This resulted in the removal of 16 outliers which was 0.29% of the data set.

The explanatory variables year, target species catch, gear, area (E/W) and fishing ground (coastal, pelagic or all). Different classifications of non-blue shark species were also explored including separate covariates for temperate tuna species, tropical tunas, other shark species and all other species, added using splines. To avoid over-parameterisation, models were run sequentially starting from the simplest model and incorporating covariates and interactions, where they made sense theoretically (e.g. area-gear interactions) in an iterative manner. Models were evaluated based on AIC values and the amount of deviance explained.

Ratio method to estimate unreported blue shark catches

A second method based on the ratio of blue shark to target species was used in an attempt to estimate the unreported component of blue shark catches. Target species were defined as yellowfin tuna, bigeye tuna, skipjack tuna, albacore and swordfish. Nominal catches of these species are considered to be relatively accurate.

Starting from the nominal, records were separated out into four components where fleets were reporting:

1) Positive catches of target species and positive catches of blue shark where the target species catch is greater than the blue shark catch (used to calculate catch rate)
2) Positive catches of target species but zero blue shark catches (assumed to be non-reporting so were not included in the catch rate calculation)
3) Positive catches of blue shark but zero target species catches or positive catches of target species and positive catches of blue shark where the blue shark catch is greater than the target species catch (it is assumed here that blue sharks are actually the target species in this case and so the reporting is likely to be accurate, hence these records were excluded from the catch rate calculation)
4) Zero catches of both target species and blue sharks reported (these records were not used)

Blue shark catch rates were calculated, defined as the ratio of blue shark to the total target species catch where positive catches of target species and blue shark were caught and where the target species catches were greater than the blue shark catches. These catch rates were calculated by fleet, year and gear type (the finest scale gear classifications stored in the IOTC database). Catch rates were averaged across all fleets reporting blue shark catches for each gear-year combination (Figure *4*). Fleets reporting zero catches of blue sharks for a year-gear combination where other fleets were reporting positive blue shark catches were assumed to be false zeros and so were not used in calculating the average, while records where catches of blue shark were greater than the target species catches were also not used as in these cases, the blue shark was assumed to be the target species and should be more accurately reported. Unclassified gear types were removed to avoid meaningless predictions from unrelated gear types.

These ratios were then used to estimate the unreported blue shark catch component (defined as fleets reporting zero catches of blue sharks for a year-gear combination where other fleets were reporting positive blue shark catches). Fleets reporting zero blue shark catches were allocated catches by multiplying the average catch rate by the target catch for the fleet.

3 Results

Estimation of unreported blue shark catches based on target species ratios

The final results of the ratio estimate are comparable in scale to the nominal, which were used as a basis for that estimate (Figure 9). The estimated unreported catch component is shown in **Error! Reference source not found.** by aggregate gear group. The estimated unreported catches peak around 2008 and 2015 with a reduction in estimates for the years 2011-2012. This overall trend is unsurprising as it is similar to that of the target catches where numbers declined around the late 2000s due to the impact of piracy in offshore waters on catches of pelagic species. Unreported catch estimates are only available for those gear types that have been reporting catches of blue shark over time (gillnets, longlines and other lines). The estimates are dominated by the longline catches in early years, followed by other lines and gillnets in very recent years Estimated gillnet catches are very low until 2010, due to the low catch rates reported by gillnet fleets from around 1985 to 2005. Subsequent reported catch rates are much higher for the gillnet fleets.

The final estimates from the ratio method are presented in Figure *5*. The overall estimated quantities are higher in recent years. The peak in catches in 2010 that is present in the ratio based catch series is offset from the max reported catch in 2013. .

Estimation of unreported blue shark catches based on GAMs

A range of explanatory variables were explored through the GAM models: Year, Gear, Area, Fishing Ground, Target Catch (YFT+BET+SKJ+ALB+SWO), Tropical tunas (YFT+BET+SKJ), Temperate species (ALB and SWO), Other (not target or shark), Other sharks and BSH catch. Target catch is the sum of Tropical tuna and temperate catch. Given that the aim of the method was to predict the catches of countries that had not reported BSH catches, country was not used as an explanatory variable. The model was set up using only those records where blue shark was reported and the resultant coefficients were estimated. These were then used to estimate the unreported catch component by predicting the missing values based on the records where blue shark was not reported.

Stepwise model development resulted in the range of models shown in Figure 5 Multiple other models were also fit, however the resulting estimates of catch were often highly variable (with inter-annual fluctuations in the order of 10-20 thousand t), or estimated extremely high catch in the early part of the model when the exploitation was thought to be lightest. The following model was selected as the best based on AIC ranking:

gam(log(BSH_catch) ~ as.factor(Year) + s(TAR_catch) + Gear :Area)

The estimated catches based on this formula are similar to the previous estimates in annual scale and trend, though some differences exist (Figure 6). The residual diagnostics are shown in **Error! Reference source not found.**.

The results of the GAM modelling provide final estimates that are very similar to the ratio based estimates, however there are greater estimated catches in the early years resulting in a slightly flatter overall trend (Figure *5*). Estimated catches in the early years are primarily attributed to the Japanese longline with a small amount estimated for the Taiwanese longline and the gillnet fleets. In later years, the relative distribution of catches across fleets remains fairly consistent, however, the scale is greater and total catches are estimated to reach approximately 60,000 t (Figure).

4 Discussion

The methods described in this paper attempt to account for two key sources of error in reported catches: (i) not reporting to species, and (ii) not reporting at all. The procedure used to disaggregate reports of 'sharks NEI' has been used to address the limited reporting to species level, while ratio and GAM based models using target catches can be used to predict the expected catches where there are zero reported catches. The accuracy of all of these methods is entirely dependent on the quality of the original data on which they are based.

The ratio and GAM based methods both provide different approaches to the estimation of the 'missing' blue shark catches. Both methods used the nominal catches as a base and estimated the unreported catch. A key assumption of both of these methods is that all zero reported catches, where there are reported catches of target species present, are false. This might present an overestimation bias in the results by estimating catches where there were actually zero catches. Nevertheless, the data used were based on aggregated annual values and so, given this time period of aggregation, the assumption that reported zero catches are false seems reasonable. These methods also make the assumption that target catches are reported accurately. If target catches are in fact also under-reported, then this may result in an underestimation bias in the results. Nevertheless, as only the five species for which data are deemed to be of reliable quality are used, this should also be a reasonable assumption.

A further assumption these methods make is that those fleets that are reporting positive blue shark catches are doing so accurately. Due to issues with the reporting of processed weight rather than round weights and retained catches rather than total catches, this may also lead to an underestimation bias in the results. Estimated catches will be greatest for gear types for which there are a large number of zero reporters (with substantial target catches) and a high average catch rate by the reporting fleets. If there are few zero reporters but many under-reporters, this will result in under-inflated catch rates and underestimates for the final catches. A filtering approach was used here to remove fleets which were deemed to be targeting sharks to avoid over-inflated catch rates, however, establishing lower thresholds was more problematic with the data available.

The GAM method uses a statistical approach to fill in the gaps where data are lacking and so provides advantages over the ratio method where simple average catch rates are used. The GAM method also uses a greater number of predictor variables to account for items such as spatial differences in catch rates where the sparse and patchy nature of the data means that this is not appropriate for the ratio method.

Any type of catch reconstruction that is attempted will include some level of error, so in practice it is common to include multiple alternative catch time series in assessments for data limited stocks such as these and to explore the outcomes based on the different sensitivity runs. This paper outlines the methods and results for two new alternative catch series that may be used in the assessment model; a series based on ratio approach to estimation and a GAM estimation method. If a preferred catch series is to be used as an alternative series for the assessment, then it is recommended that the GAM estimated catch is used.

5 References

Chambers, M. and Hoyle, S. 2015. Proposed approach to estimate non-member catch of SBT using ransom forests to model CPUE. CCSBT/CPUE2015/04

Clarke, S., 2015. Historical Catch Estimate Reconstruction for the Indian Ocean based on Shark Fin Trade Data. IOTC–2015–WPEB11–24

IOTC Secretariat, 2021. IOTC-2021-WPEB17(DP)-DATA03 Nominal catches by fleet, year, gear, IOTC area and species. https://iotc.org/meetings/17th-working-party-ecosystems-and-bycatch-wpeb17dp-data-preparatory-meeting

IOTC Secretariat, 2015. Report of the 11th Session of the IOTC Working Party on Ecosystems and Bycatch. Olhão, Portugal, 7-11 September 2015.

IOTC Secretariat, 2016. Blue Shark catches reported to the IOTC Secretariat and a review of current estimation procedures. IOTC-2016-WPEB12-INF04

Marra, G., and S. N. Wood. 2011. Practical variable selection for generalized additive models. Comput. Stat. Data Anal. 55: 2372–2387. doi:10.1016/j.csda.2011.02.004

Murua H., Santos, M.N., Chavance, P., Amande, J., Seret, B., Poisson, F., Ariz, J., Abascal, F.J., Bach, P., Coelho, R., Korta, M. 2013b. EU project for the Provision of Scientific Advice for the Purpose of the implementation of the EUPOA sharks: a brief overview of the results for Indian Ocean. 9th Working Party on Ecosystems and Bycatch, 12-16 September, La Reunion, French Overseas Territories. (IOTC Doc: IOTC–2013–WPEB09–19).

Rice J and Sharma R., 2015. Stock assessment blue shark (Prionace glauca) in the Indian Ocean using Stock Synthesis. IOTC-2015-WPEB11-28 Rev_1.

6 Tables

Table 1. A sample of the fleet / gear / area / region / type of operation configuration mappings used by the Nominal Catch definition of fishing region

Country	Rep. country	Gear	Area	Region	Type of operation
…	…	…	…	…	…
ESP	ESP	LLEX	IREASIO	EASIO	IND
ESP	ESP	LLEX	IRWESIO	WESIO	IND
ESP	ESP	PS	IREASIO	EASIO	IND
ESP	ESP	ELL	IREASIO	SWEIO	IND
ESP	ESP	LL	IREASIO	SWEIO	IND
ESP	ESP	ELL	IRWESIO	SWEIO	IND
ESP	ESP	LL	IRWESIO	SWEIO	IND
ESP	ESP	BB	IRWESIO	WESIO	IND
ESP	ESP	PS	IRWESIO	WESIO	IND
ESP	ESP	SUPP	IRWESIO	WESIO	IND
FRA	FRA	HAND	IRWESIO	MOZCH	ART
FRA	FRA	TROL	IRWESIO	MOZCH	ART
FRA	**FRA**	**ELL**	**IRWESIO**	**SWEIO**	**IND**
FRA	FRA	PS	IREASIO	EASIO	IND
FRA	FRA	PS	IRWESIO	WESIO	IND
FRA	REU	LLCO	IRWESIO	SWEIO	ART
FRA	REU	HAND	IRWESIO	SWEIO	ART
FRA	REU	HATR	IRWESIO	SWEIO	ART
FRA	REU	TROL	IRWESIO	SWEIO	ART
FRA	REU	ELL	IRWESIO	SWEIO	IND
FRAT	FRA	PS	IREASIO	EASIO	IND
FRAT	FRA	HAND	IRWESIO	MOZCH	ART
FRAT	FRA	HATR	IRWESIO	MOZCH	ART
FRAT	FRA	TROL	IRWESIO	MOZCH	ART
FRAT	FRA	ELL	IRWESIO	SWEIO	IND
FRAT	FRA	PS	IRWESIO	WESIO	IND
…	…	…	…	…	…

Table 2. IOTC nominal catches and catch estimates

Year	Nominal Catch	Ratio Based Estimate	GAM Estimate
1950	47	470	131
1951	269	723	755
1952	293	736	1709
1953	297	805	1974
1954	367	883	3933
1955	367	893	4394
1956	389	900	4052
1957	372	1332	4952
1958	371	978	4791
1959	372	994	5024
1960	367	1092	4587
1961	394	1126	4509
1962	488	1517	4944
1963	497	1927	5860
1964	2679	4729	6522
1965	1859	3876	4480
1966	2048	5040	5473
1967	2906	6296	8939
1968	2217	6389	8622
1969	2452	8406	9031
1970	1470	5337	4841
1971	1506	4947	5164
1972	1536	6346	5124
1973	1158	5432	3385
1974	1532	7448	5005
1975	1851	7614	5401
1976	1653	7936	4636
1977	1888	9248	5048
1978	2122	12412	6253
1979	1936	14247	7963
1980	2080	11713	7532
1981	2464	14693	10300
1982	2919	15051	9447
1983	2981	11017	10958
1984	3111	11026	11314
1985	2893	6621	7029
1986	2974	7974	9808
1987	2910	6941	9068
1988	3363	8338	10414
1989	3767	10471	13167
1990	3013	8072	8256
1991	3733	10700	10487

1992	3567	10583	10729
1993	5168	12834	13088
1994	6498	12814	17067
1995	6842	17595	17571
1996	7420	18707	18369
1997	8846	19146	24457
1998	8876	19163	16861
1999	12121	25092	22341
2000	12403	30727	28946
2001	10485	26102	21183
2002	11858	22690	26016
2003	15355	30225	33361
2004	21398	34767	40935
2005	24394	38501	43858
2006	21452	34049	40590
2007	23291	34296	38638
2008	24147	41258	42523
2009	26562	37688	48429
2010	27416	41641	46506
2011	28033	37195	48862
2012	27827	39578	52250
2013	31021	40838	56496
2014	29616	34103	54758
2015	29077	32199	50793
2016	29467	38832	55308
2017	30388	40923	57530
2018	22624	31017	37032
2019	24914	32195	43240

Table 3. AIC and model information for the various GAM models used. The bolded model (Model 5) is the model chosen for the stock assessment.

Model Number	Model	Resid. Df	Resid. Dev	Df	Deviance	AIC_vec
1	log(BSH)~ Year	660.00	2986.1			3241.98
2	+Target Catch	651.35	1968.1	8.6526	1017.9766	2954.95
3	+Gear	638.33	1184.4	13.0213	783.7126	2610.26
4	+Area	631.26	960.2	7.0696	224.1300	2471.26
5	**Gear:Area**	**622.23**	**865.7**	**9.0286**	**94.5503**	**2413.65**
6	Gear*Area	622.23	865.7	0.0000	0.0000	2413.65
7	'+Fgrounds	622.23	865.7	0.0000	0.0000	2413.65

7 Figures

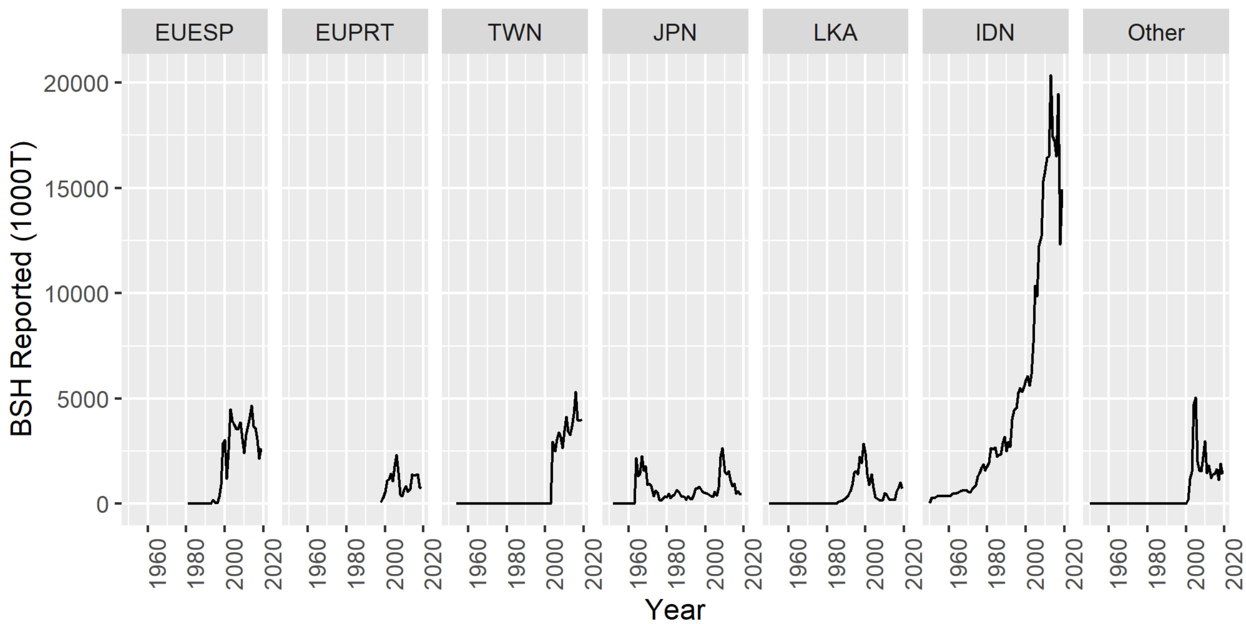

Figure 1. Catches of blue sharks in the IOTC area of competence by CPC (Nominal catches, IOTC database, 2021)

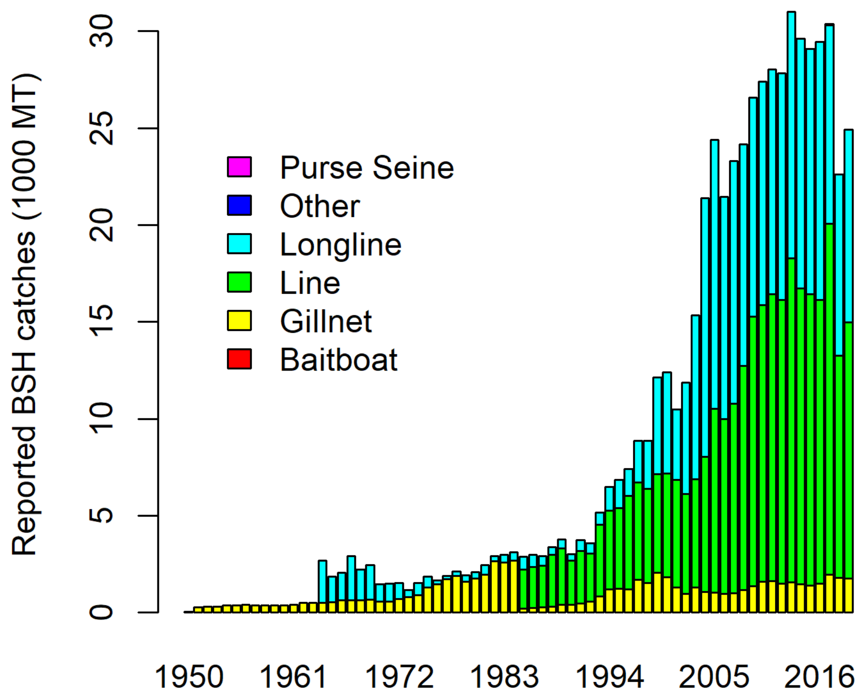

Figure 2. Nominal catches (t) of Indian Ocean blue sharks by gear (IOTC database, 2021)

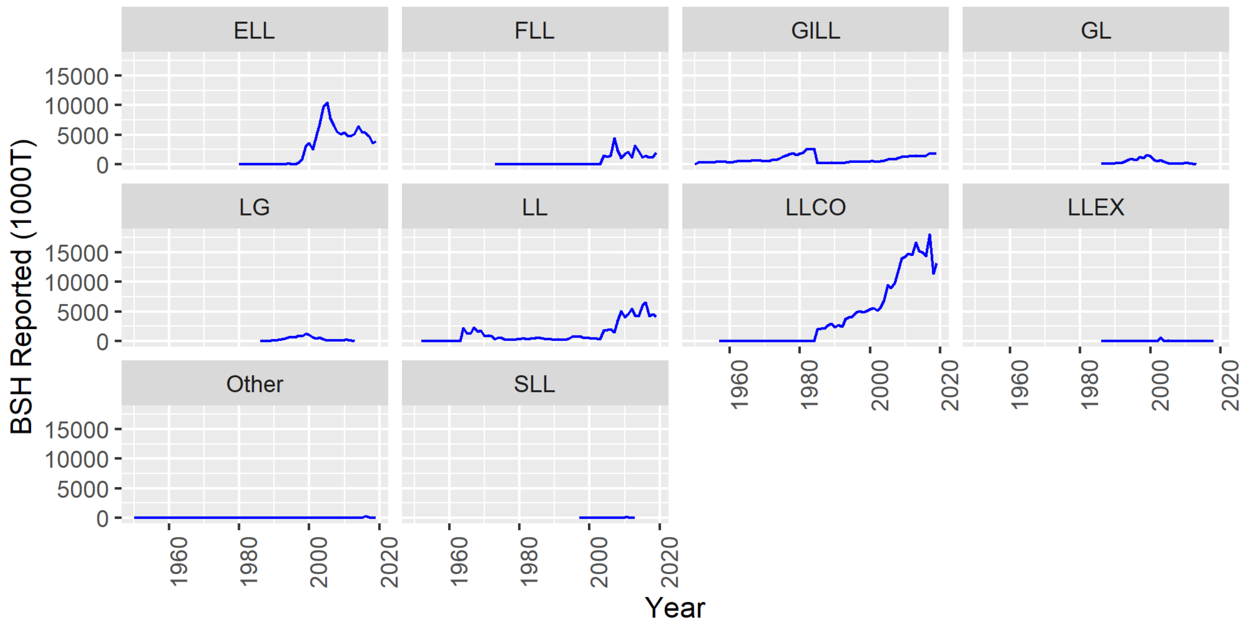

Figure 3. Nominal catches of Indian Ocean blue sharks by gear, top 9 gears with the other gears aggregated to 'Other'. (IOTC database, 2021)

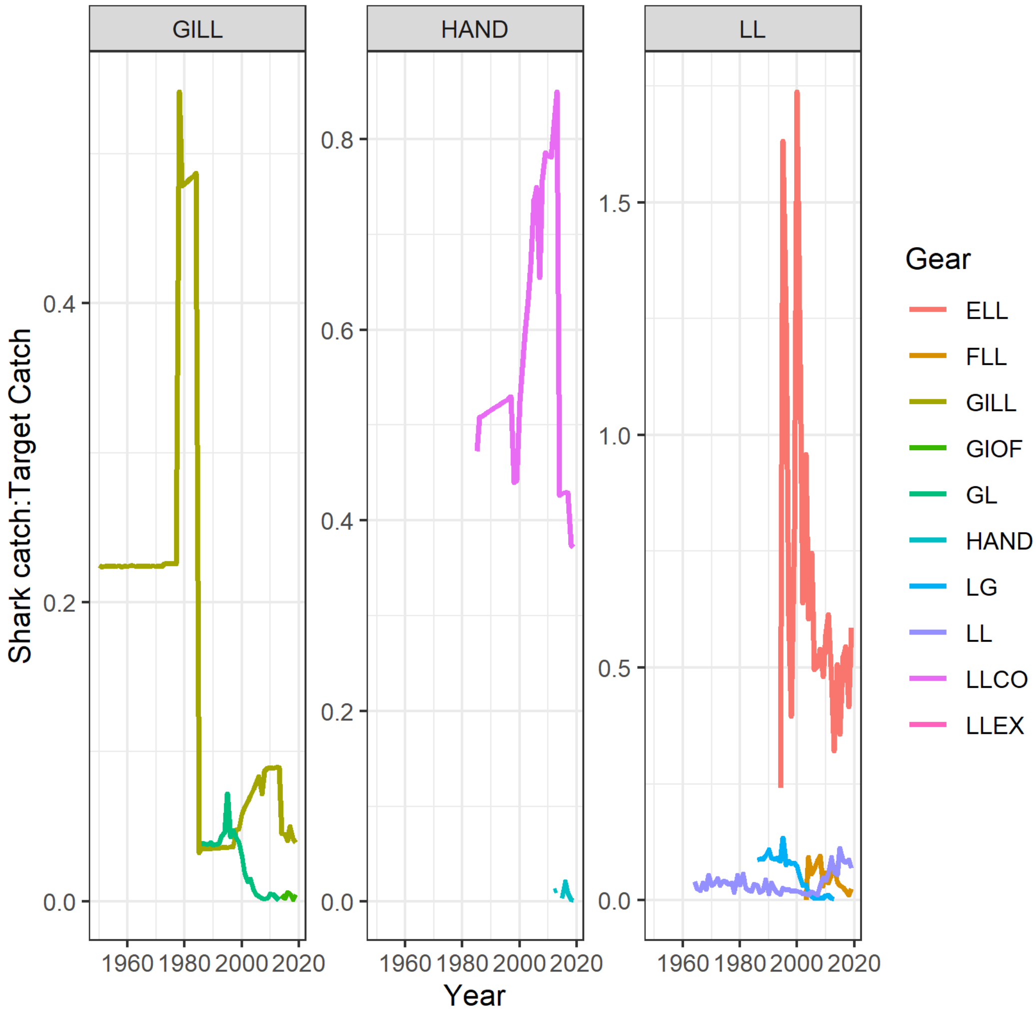

Figure 4. Ratio of reported blue shark catch to target catch by gear over time for gillnet, handline and longline fisheries.

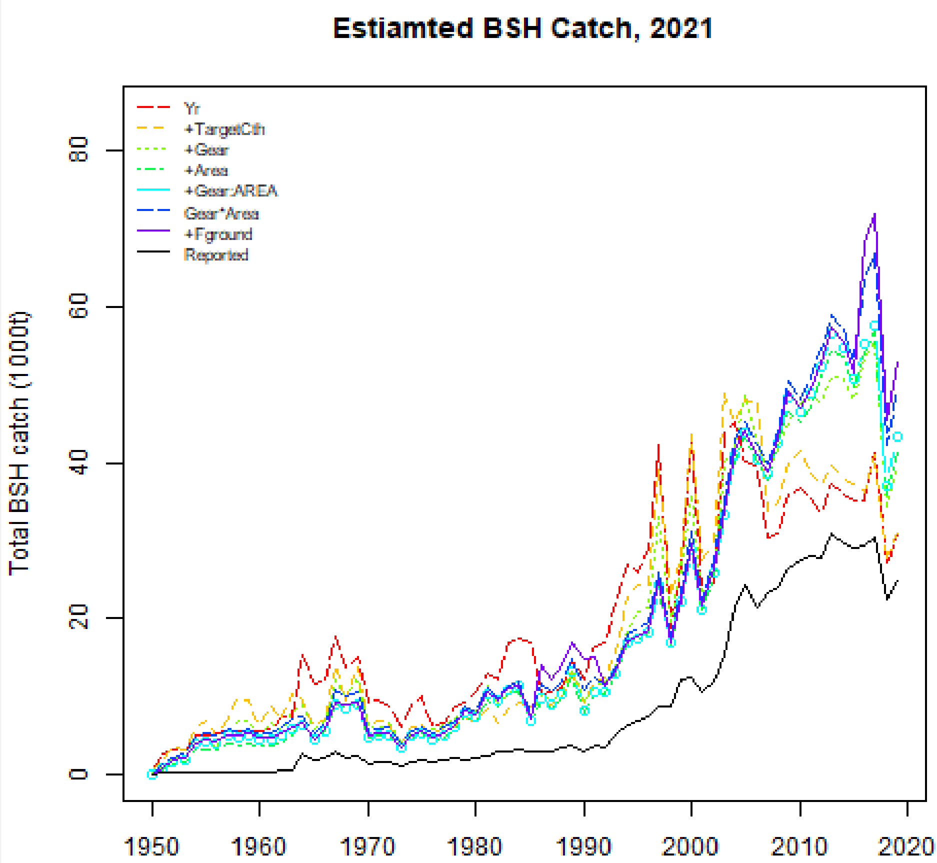

Figure 5 Stepwise results of predicted catch via GAM on the nominal catch data set (selected model = teal line, the +Gear:Area).

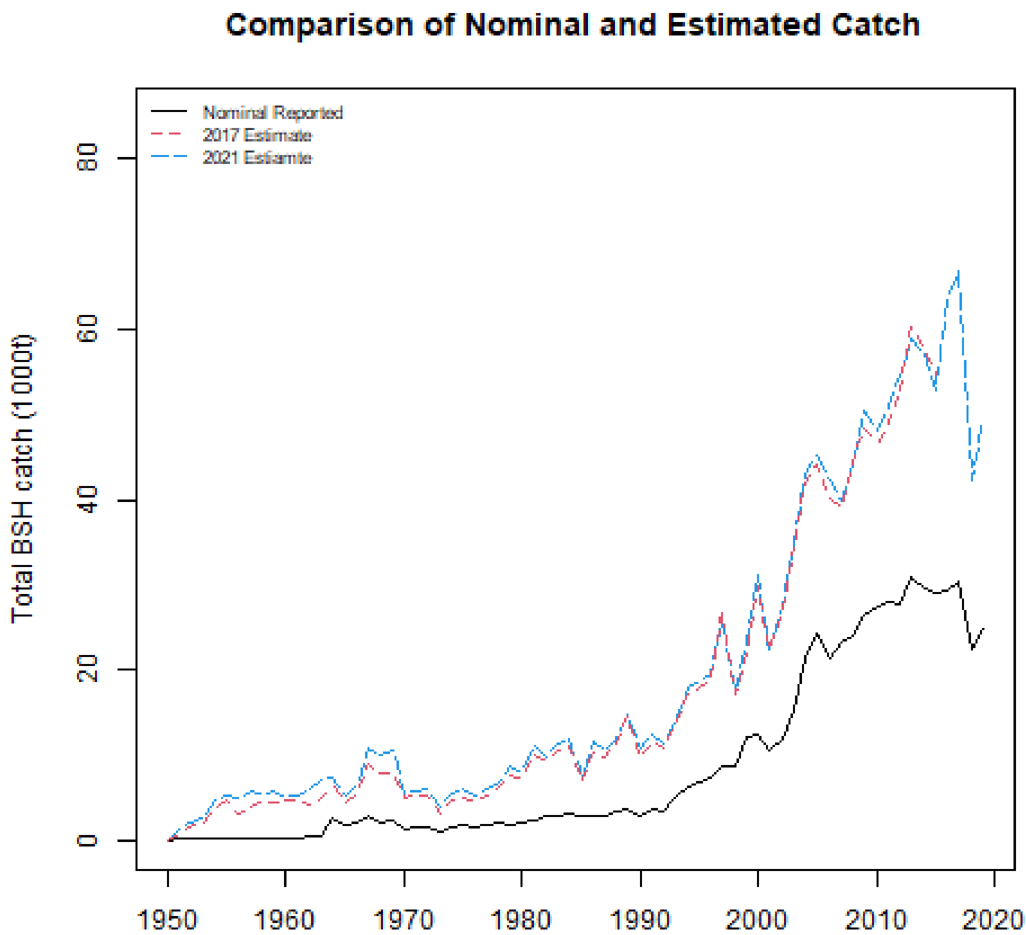

Figure 5. Comparison of Nominal (black line) 2017 estimated catch (red line) and 2021 estimated catch.

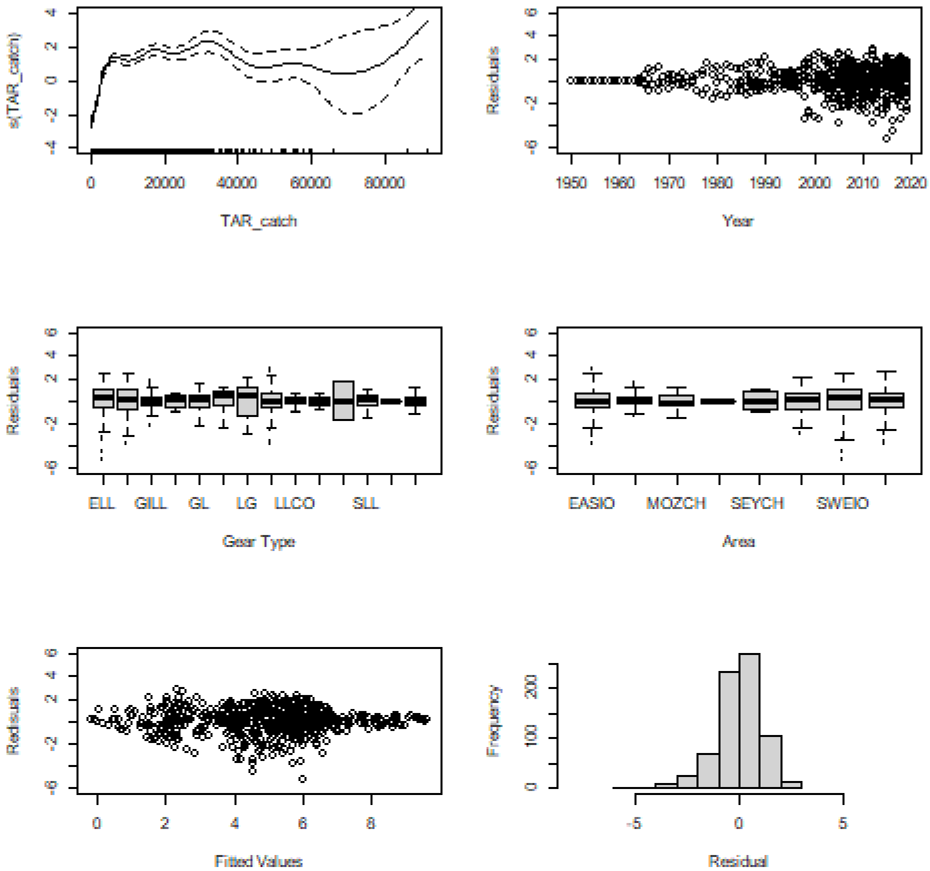

Figure 7. Residual plots of final GAM model

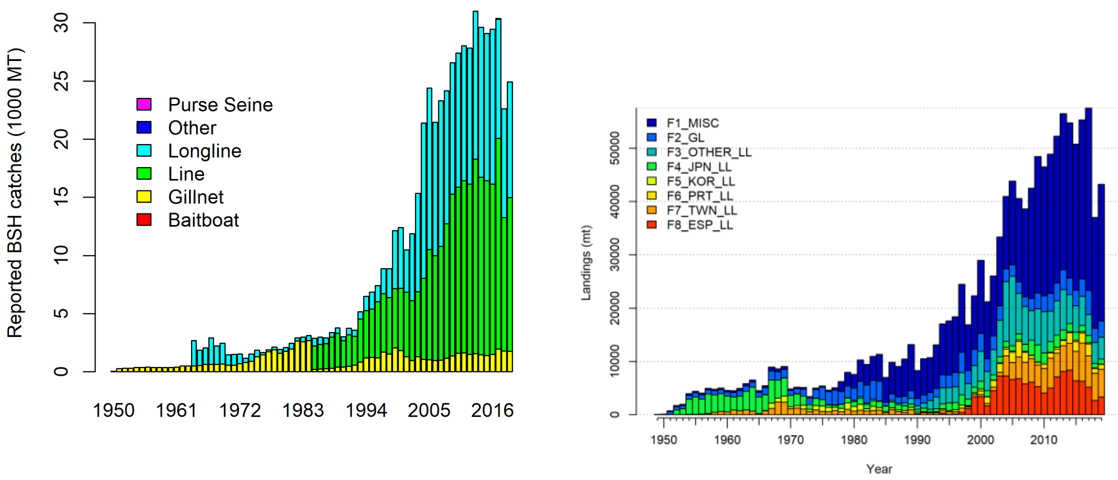

Figure 8. Nominal catch by fleet (left panel) and estimated catch by fleet based on the GAM model (right panel). Note the difference in scale of the y axis.

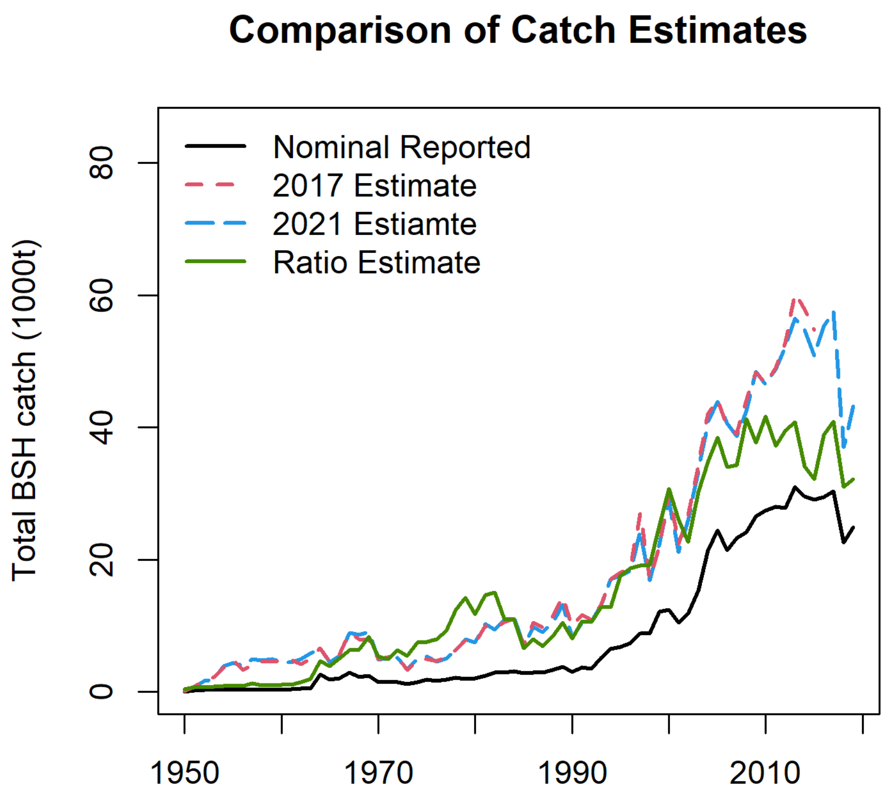

Figure 9. Comparisons of nominal reported catch, 2017 GAM catch estimates, 2021 GAM catch estimates and the 2021 ratio based estimate.

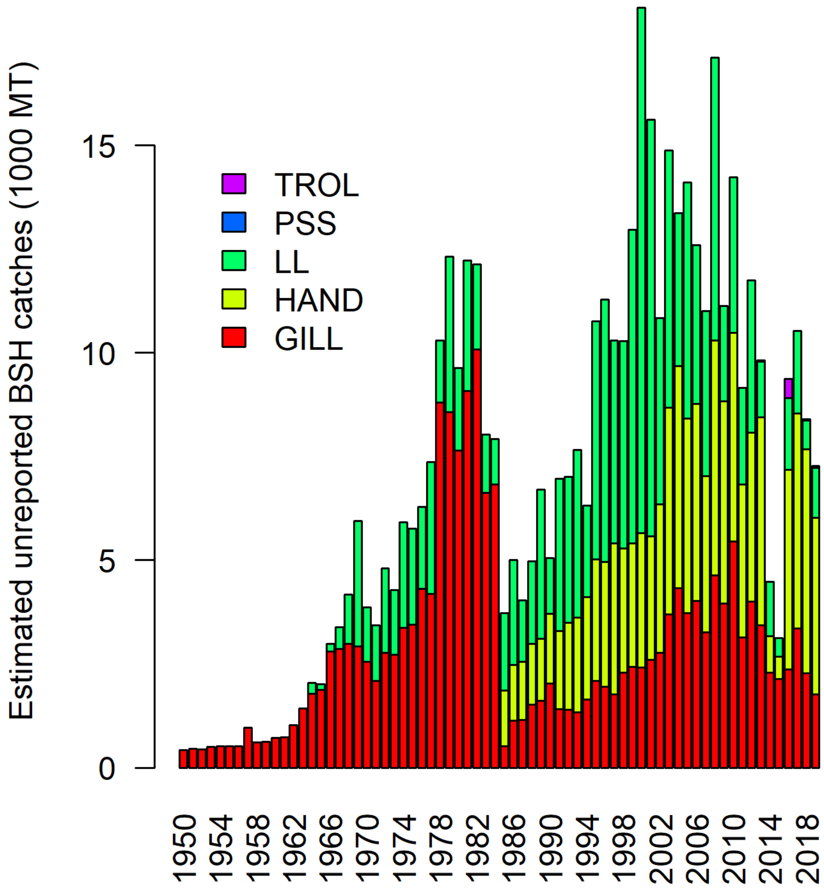

Figure 10. Estimated unreported catch component by gear type from the ratio based estimate.