Draft review of size data from Indian Ocean longline fleets, and its utility for stock assessment.

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Executive summary

This is an incomplete draft report on a project to review the procedures used to collect and process longline size data for use in IOTC stock assessments. Further work will be carried out after the WPTT data preparation meeting and the report updated for presentation at the WPTT stock assessment meeting. This draft report is provided to help inform discussion about data preparation for the 2021 yellowfin stock assessment. All conclusions and recommendations expressed herein should be regarded as preliminary.

Introduction

Each year the IOTC Secretariat prepares input tables for the assessments of IOTC stocks, including catches in number and weight for tropical tunas, albacore and swordfish, by fishery, species, length class, year, quarter and fishing area, as defined by the IOTC working parties. Total numbers of tunas and billfish are derived from the available nominal catch, catch-and-effort and size frequency datasets, as provided by IOTC CPCs1 or other Parties.

For a number of years, the IOTC Scientific Committee has expressed concern about the poor coverage of length frequency samples for several of the major longline fleets, such as those from Japan, Indonesia, and India, and the potential negative impact on stock assessments.

In addition, there have been difficulties reconciling the catch-and-effort and size frequency datasets available for the Taiwanese longline fleets, in which average weights derived from catch-and-effort and size data for the same area and time-period are highly conflicting.

In light of the above, and additional information presented at the previous meetings of the IOTC Working Party for Tropical Tunas (WPTT), in 2013 the Scientific Committee recommended “joint work on the documentation of procedures for the collection, processing and reporting of size frequency data” (SC15.78) for the main longline fleets, given the potential impact on stock assessments.

Also, given that the data collection and processing systems used for distant-water longline fisheries tend to apply to all oceans, the WPTT agreed on the value of informing other tuna-RFMO Secretariats on the issues identified for longline fisheries and facilitate their participation in a review of the datasets reported by longline fleets.

Review of longline size data and processing systems

Review the procedures used for the collection and processing of size data from large-scale tuna longline fisheries in the Indian Ocean, for selected years, in particular:

- Types of size data collected, data sources, and data validation and processing (e.g. stratification, procedures used to convert sizes into fork length, etc., where required).
- Other uses of size frequency data, where applicable (e.g. estimation of catches in weight from numbers recorded in logbooks, or contribution of size data to the estimation of nominal catches for the fishery).
- Address concerns raised by the IOTC Working Parties and Scientific Committee concerning the quality of size data available for Japanese, Korean, Taiwanese, and Seychellois longline fleets.
- Compare length frequency data from different sources (e.g. scientific observers, fishers, training and research boats) and the effect on the assessments of IOTC species – specifically

tropical tunas (as well as albacore tuna, swordfish and marlins depending on the time/resources available).

- For fleets, such as the Taiwanese fleet, that have been collecting both length and weight measurements for the same species, compare measured lengths and lengths derived from weight measurements in order to validate the reliability of datasets.
- Explore the reasons for discrepancies in average weights derived from the catch and effort and size frequency datasets, and the reasons behind the sudden changes in the shape of length frequency distributions recorded for the Taiwanese longline fleet since the early-2000s; in particular the marked decrease in the amount of small fish in the samples recorded for the last decade.
- In coordination with the IOTC Stock Assessment Expert, assess the effect of changes in sampling coverage and contribution of length frequency data from longline fleets have on the assessments of IOTC species, in particular tropical tunas, albacore, swordfish and marlins.
- Liaise with other tuna-RMFOs and inform them of the main findings of the size data review.
- Identify areas for future work (e.g., inclusion of other species or gears, where appropriate; the extent of historical time series under consideration, in addition to future collaboration with other tRFMOs in the case of overlapping data issues) and propose a road-map for these activities to be carried out, for the consideration and endorsement by the IOTC Scientific Committee.
- The incumbent will be responsible for preparing the following information and final report for dissemination at the IOTC Working Party on Data Collection and Statistics (WPDCS), Working Party on Tropical Tunas (WPTT), and Scientific Committee in 2019. The report will cover the following:
- Documentation of procedures for the collection and reporting of size frequency data used by Japanese Korean, Taiwanese, Seychellois and other important longline fisheries, including:
- Full description of the type of sampling platforms used (e.g., commercial boats, research boats, training boats, etc.), and data collection source (e.g., fishermen, researchers, scientific observers, etc.)
- Full description of the sampling protocols used (e.g. full enumeration of every set, every other set, first 30 fish from each set sampled for size, etc.), by type of sampling platform and data collection source.
- Type of measurements collected (e.g. gilled-and-gutted weight, fork length, etc.) and measurement tools used (caliper, measuring board, measuring tape, scale, etc.) by type of sampling platform, data collection source, and species.
- Type of time-area stratification used for each species (e.g. quarter and defined area) and procedures used for the estimation of sampled weights in each stratum, including all equations used for the conversion of non-standard measurements into standard measurements, by species (e.g. deterministic conversion using a single length weight equation for all areas and time periods, etc.).
- Description of any other procedures which involve the use of length frequency data (e.g. estimation of weights from the numbers reported in logbooks and substitution scheme in the case that lengths are not available in areas where there are catches and effort recorded, etc.).
- Appraisal of any apparent discrepancies in the longline size frequency data, implications for the stock assessment of IOTC species, and suggested remedial actions (if appropriate). Investigate the spatial and temporal trend of size distribution by fleet using linear or generalised linear modelling approach; identify and quantify effects that corroborate with CPUE indices or other fishery indicators in explaining spatial and temporal variations of the population.

- Where necessary, recommend changes to the data collection and/or processing systems for longline fleets, and propose a roadmap for the implementation of the activities recommended by the institutions concerned.
- Report the results and provide guidance to the IOTC Working Parties and Scientific Committee on the best use of the available length frequency data for the assessments of IOTC species, including the type of fisheries to be considered and the procedures that are recommended for the preparation of the different datasets.
- Ensure other Tuna-RMFOs are fully informed on the issues discussed by the report findings.

This report is an incomplete draft report on the size data project. Further work will be carried out after the WPTT data preparation meeting and the report updated for presentation at the WPTT stock assessment meeting. This draft report is provided to help inform discussion about data preparation for the 2021 yellowfin stock assessment. All conclusions and recommendations expressed herein should be regarded as preliminary.

Part A: Review of Sampling Procedures

1. Sampling

1.1. Japanese data

Japanese data are currently/recently sampled from the following platforms: 'voluntary' measurements by the fleet on commercial vessels, measurements by observers on commercial vessels, and measurements on research and training vessels. In earlier periods there was also port sampling.

Measurement by the fleet

Voluntary measurements by the fleet have been undertaken since 1980 on commercial vessels. However, there is currently little or no voluntary measurement. Fishermen still weigh fish for their own purposes, but don't like to measure. They have only done so because of the scientific requirement.

The protocol is to measure the first 50 fish per set. Tuna lengths are measured as fork length, billfish as eye fork length.

Measurement resolution in logbooks has always been 1 cm for all species. In early years this was rounded to 2cm or 5cm to save computer storage space. Some sources state that tunas were measured to the next-highest 2-cm interval , and billfishes to the next-highest 5-m interval (Miyabe and Bayliff, 1987; Nakano and Bayliff, 1992), but this appears to be based on the rounded values.

Bigeye and yellowfin tunas are weighed by the crew after processing to a semi-dressed state (gilled and gutted, gg).

The sequence for processing by the crew during the commercial longline haul for each captured bigeye or yellowfin is as follows: land the fish, kill / iki, measure length, bleed, cut off tail, gill and gut, measure weight. Intentional bleeding began in the 1980s.

Albacore are weighed without being gilled and gutted. However, the tail is removed, and the fish is bled. The assumed processed weight ratio is 1.1 for ALB.

Billfish heads are usually removed. Large swordfish are filleted, and small swordfish are dressed.

The voluntary system distributed 180cm poles for measuring length.

Port sampling

Before 1980, fish were landed at the market and placed in a row, where scientists from the National Research Institute for Far Seas Fisheries (NRIFSF) (now Fisheries Resources Institute, FRI, since 20/7/2020) could measure them.

In 1980 the Japanese market system changed. Buyer companies developed which would buy the entire catch from a vessel and determine the price. As a result, the fish no longer went to the market, and there was no time to measure the fish after landing.

"In the case of measurement at unloading site, month is generally determined to the month when catch is the largest in the cruise, and position is determined with an appropriate resolution (1°x1°, 5°x5°, 5°x10° or 10°x20° block in latitude x longitude) so that most of catch is contained in the one particular size of unit area" (Uosaki, 2007).

Observers

Observer coverage varies among fisheries. For the southern bluefin tuna fishery (based on CCSBT regulations) the target is 10% coverage of the effort or catch. Selection of vessels involves identifying 3-4 areas in which fishing will occur and selecting vessels at random for 10% of the probable effort in each area. To allocate observers to vessels there is a lottery.

In the rest of the Indian Ocean (non-CCSBT) there is a target of 5% coverage. Coverage is generally taken as the percentage of hooks but it's not a requirement – coverage is not defined.

Observers are meant to be on shift for 8 hours. They take a break of about 20 mins for a meal.

Discards mainly occur when fish are damaged by sharks or whales. Observers are meant to measure these fish. The damage rate is generally less than 5%.

Observers measure lengths as follows (Matsumoto et al., 2005). This information is for the Atlantic, but observers follow the same approaches in all oceans. "Length by 1cm interval (round up) and clasper length of sharks by 0.1cm interval, body weight (in principle to the nearest 1 kg, and partly to the nearest 0.1kg), gonad weight (for tunas and billfishes, mainly for female, to the nearest 5 to 100g) and product weight (to the nearest 1 kg) were measured as many as possible. When there was substantial numbers of catch, priority was given to tunas and billfishes, but in principle the number of individuals was counted for all catch. Different length measurements were taken: fork length for tunas (for some individuals pre-dorsal length was also measured), eye-fork length for billfishes, precaudal or fork length for sharks, disk length for rays, and total or fork length for other fish. Lengths were measured with a caliper, a scale or a tape measure."

Research sampling

Special research projects have periodically measured samples of some species. For example, the Research project on Japanese bluefin tuna (RJB) collected catch totals and size data for Pacific bluefin from 1994 until at least 2016 (Sakai et al., 2015).

Representativeness

Does trans-shipment occur? This is unclear. During the early period there was a system involving motherships and small boats.

For port sampling, the sampler interviews the fishing master to identify which fish came from where. This port sampling was during an early period when trips durations were shorter. Port sampling may have collected both length and weight.

Ratios of processed weight to whole weight have been provided for all species.

Equipment

Port samplers use wooden callipers.

Other sources

Kume and Joseph (1966) obtained EPO data from 1555 days of fishing May 1958-March 1964 by NRIFSF research and training vessels. The form only had provision for reporting individuals 82-184 cm. Fish outside this range were sometimes noted but the notes were sometimes questionable. Of bigeye tuna, 1.6% were over 184 cm. Collection methods were described by Suda and Schaefer (1965).

"Records of the size-composition of long-line catches made by the experimental fishing boats were obtained in the following manner: The fork lengths of all yellowfin caught by individual long-line sets were measured by slide callipers and recorded by centimetres, a fractional centimetre being rounded to the next higher whole centimetre. Sex was determined the examination of gonads. Length frequencies were tabulated for each long-line set by sex and by length classes of 2 cm. The reporting form provided by NRFRL to the fishing vessels has provision for entries only for the length range from 83 cm (class 82 cm to 84 cm) to 183 cm (182 to 184 cm). Fish having lengths outside this range were sometimes recorded by individual lengths, but, in other cases, only the number fish less than 82 cm and the number greater than 184 cm were recorded. Therefore in this analysis we have eliminated the data respecting fish less than 82 cm and greater than 184 cm".

Suda and Schaefer (1965) note that "more than 50% of the catch is butchered aboard the vessels and processed into fillets. the larger fish tending to be filleted and the smaller fish landed whole, or with only gills and viscera removed. Thus, the size-composition of the unfilleted fish unloaded at the fish markets in Japan by the commercial boats is not representative of the original catch on the fishing grounds."

1.2. Korean data

Korean size data are collected on commercial fishing vessels by fishers and scientific observers. The main species sampled by scientific observers are yellowfin, bigeye, albacore, and southern bluefin tunas along with some samples for billfish, and observers sample as many fish as possible.

The IOTC database includes size data from the (commercial) longline for 1991-2017; for LL observer 2010, 2012-2017. Some observer data that are non-tunas and tuna like species have been submitted by Korea as trip reports, from which the size data are not straightforward to extract.

Recently the Korean scientific observer programs in the Indian Ocean start at the beginning of the southern bluefin tuna fishing season, in April, and continue until they achieve the observer coverage required by the IOTC. Vessel selection is random. Selection of fishing areas and target species depend on captains' fishing strategies.

For vessel data collected by fishers, Korea follows the IOTC guidance in recommending that fishermen measure one specimen per ton of catch by species. They recommend that observers measure 70% of individuals caught per set.

Measurement occurs during the set and on deck beside the place where fishermen process fish.

Observers measure discards except in cases where fish have been predated. Fishermen don't measure discards but report them on their logbooks. If there is size-dependent discarding, this may affect observed sizes.

Korea recommends that fishermen and observers measure both length and weight. Tunas and tuna-like species are measured in fork length. Weights are whole or processed weight depending on the operating conditions. If catches are too large for observers to measure all the fish, they take length and processed weight, head length (optional), and body height (optional). A variety of equipment is used, including T-shaped rulers, tape, and scales.

All fish are measured fresh. Resolution are 1cm for length, 1 kg for weight. Measurements are rounded down.

Forms used for data collection.

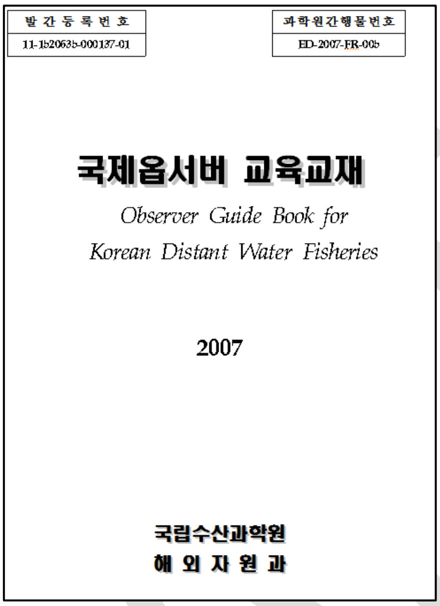
표 3. 옵서버 승선 과학조사시 어획물의 어획 상태, 어획 후 취급상태, 피식 손상상태 및 어체크기

낚시걸린 부위 (M:입, TH:목, B: 몸통, F: 지느러미, U: 미확인) / 성숙도 (1:미숙, 2:중숙, 3:완, X: 알수없음, U: 미확인)

어획시 상태 (A:생존, D:사망, U: 미확인) / 취급상태 (K:보관, A:생존방류, D:사망방류, U:미확인) / 손상상태 (CC:Cookie손상, SQ: 오징어피식, SB:상어피식, FG: 어구에 손상 NO: 손상없음,WH: 고래피식, X: 알수없음, U: 미확인)

No	No. Set	No. catch	No. buoy	No. hook	Part caught	Species	Status at caught	retained or discarded	Damage status	Sex	Maturity	FL	HL	BH	EF	CK	DW	DL	TL	whole weight	Processed weight	stomach contens	Remarks	No. photo
1																								
2																								
3																								

Sampling procedure manuals



발 간 등 록 번 호	과학원간행물번호
11-1520635-000137-01	ED-2007-FR-005

국제옵서버 교육교재

Observer Guide Book for Korean Distant Water Fisheries

2007

국립수산과학원
해 외 자 원 과

Overall observer coverage is currently 5%, but coverage in space and time depends on captains' fishing strategies.

Since 2010 about 10 Korean longline vessels have operated in the IOTC convention area, most of which have SBT quota. During the SBT fishing season they target only SBT, and then move to other areas to fish for BET, YFT and sometimes ALB. These patterns affect the spatio temporal distribution of the catch by species and possibly also the sizes.

1.3. Taiwanese data

The following processes are used for data collection in 3 oceans.

Fishing crews collect most data via logbook forms. The protocol has always been for the crew to measure the first 30 fish.

Observers also collect length data. Observers work for 8 hours per day in two periods of 4 hours each. They start to measure when the vessel starts hauling, taking 1-2 hours rest. Observers started in 2003, initially sampling 30 fish per set. From 2004-2009 they were instructed to sample 60 fish per set. From 2009 they sampled all fish.

Length data are also collected at the port, though the main target of port sampling is small-scale longliners inside EEZs. Only domestic vessels are sampled in the Taiwanese EEZ.

Both crew and observers are instructed to sample whatever is caught. However, the proportions of measured fish can be quite different from the catch, indicating selection by the fishermen.

Measurements

Tunas and tuna-like species are measured to upper jaw fork length, billfish to lower-jaw FL, and sharks to total length.

Since 2009, crew members have been asked to record the processed weight of individual catches.

Weight resolution is 1 kg, lengths 1 cm.

Observers also collect sex.

Scales are often spring balances, belonging to the vessel.

Sometimes fishermen use measuring sticks, sometimes tape, or callipers. There is no standard equipment. With tape we’re not sure if they use curved or straight FL.

Observers use callipers.

Observers

The Indian Ocean coverage rate is > 5% for large scale longliners. For small scale longliners coverage is 5%. For SBT coverage is about 10%.

Observers increased a lot in 2017. > 2 trips for each observer. For small scale, 4 or 5.

Observer trip selection is according to design by the government. All companies negotiate. For large scale longliners, given the piracy issues in the north, observers were deployed in the southern hemisphere. FA have a list of vessels and when they will go out. The observer coordinator will visit the company to negotiate. If company agrees then they randomly select an observer. Companies used to refuse, but this is uncommon now. They now have a duty to accept. Refusal occurred on occasion because operations are mostly outside Taiwanese waters, and vessels must visit a port to pick up an observer.

Freezer temperature ~ -20C. In Phuket landing some fresh, but in Mauritius frozen. In Sri Lanka mostly fresh, landing in Colombo.

When an observer is on board, the observer will measure fish first. Then a crew member probably records the number from the observer.

As a rule, there are no checks based on comparisons between data from individual observers and vessels.

Sorting of the catch does not occur in the case of observers. Fishermen however can separate their fish into groups, and it’s not possible to control the approach for measurement. Different vessels operate in different ways, and some vessels sort fish before measuring.

Discards – fishermen measure the first 30 fish retained. Observers should measure all fish that are landed, even if discarded later. Fish may be discarded if damaged (e.g. bitten by a shark or whale).

Like most fleets flying other flags, small fish size is speculated to be a reason for discarding, particularly for species with quotas. Reasons for discards are recorded and these could be analysed.

Most large-scale vessels report lengths, but only about 20% of small-scale vessels do so.

There is a logbook manual on how to measure fish by species.

There was a major change in the fishery in 2003 with many fishermen retiring, and new fishermen may be less reliable for measurements.

Observer length measurement requirement involve forms for observers and fishermen. Different forms were used in 2002-3, 2004-8, and then in 2009.

Observer data are stored in Kaohsiung. Digital files are held in Taipei but not hard copies. Observers do their own data entry, and OFDC have entered the data for commercial vessels. Commercial vessel data are now provided electronically.

For sharks, observers must measure fin weight and carcase weight as well as length. New forms were introduced in 2009 and 2014.

Port sampling: Staff measure each fish unloaded on a sampling date. Most fish are measured fresh. Coverage rate is 20-30% of the catch.

Measurement of weights. For SWO the conversion factor is 1.54. It would be possible to analyse average weights and infer diversity of catches.

1.4. Seychellois data

All size data from Seychelles deep-water longliners are collected at sea onboard the commercial vessels without any selection of the vessels.

According to a representative of the Seychelles industrial longliners, the “duty to measure the fish is mostly performed by the crew on rotation/random basis under supervision. A minority are performed by the captain and or/ first officer or freezer officer.”

Data have been collected since June 2007. From 2016 to date, the data have been collected but are still being captured in the database.

The main species sampled are Yellowfin, bigeye, swordfish, striped marlin, black marlin, blue marlin, albacore, blue shark, black-tip shark, oceanic white-tip shark, and shortfin mako shark.

The sampling protocol was established by SFA in collaboration with Taiwanese Deep-Sea Fisheries in June 2007. The sampling is carried out on Seychelles-flagged vessel by crew members. They measure the first 30 fish per each set and record the data on a sampling form which is submitted to SFA by email on a weekly basis. Before June 2017, 20 fish per set were measured. However, “the number of fish measured can be smaller than 20 since about 20% of the fishing sets reported during 2007-2015 included less than 20 fish caught on the longline.” (Chassot et al., 2016).

The data recorded are: Vessel details, Date, Position, and the measurement for the first 30 fish by species. The measurement type varies by species:

For Tuna species the dorsal fork length (DFL) is taken. For swordfish, the lower maxillary fork length (LMFL) is recorded. For sharks, the total length is recorded.

The same protocol is expected to be applied to all fishing sets. Since all sets are expected to be sampled, the sampling should be fully representative of the fishery.

Sizes are measured on the deck just after the fish has been hauled so it should be close to the forward part of the fishing deck. Note that the EMS pilot project onboard 3 Seychelles industrial longliners planned to start between August and October 2019 will provide accurate information on where and how the fish are measured.

Catch dates and locations are reported on the sampling form by position in degree-minute, to the nearest minute.

There is not believed to be any sorting of the catch prior to sampling.

Discards: Although the current version of the Seychelles industrial longline logbook includes fields to indicate discards of target species, the vessels do not report any discards. The form includes the fields 'Released alive' and 'Discarded dead' for all shark species as well as for marine mammals, sea birds, marine turtles and other fish. According to the company representative, there is no discard of target species (tuna and billfish) in the fishery.

There is no sampling from transhipment vessels, or from catch after other fish have been transhipped.

Only length data are available.

A survey made by the representative of the companies through email in September 2017 indicated that all size measurements for tuna were made in fork length and only one case was reported whereby the head and tail were removed before measurement. A preliminary analysis of the size data presented at IOTC in 2015 however showed some inconsistencies in some of the data that should be further explored, including possible measurements not taken in fork length (IOTC-2016-WPDCS12-17_rev1).

According to a survey made by the representative in September 2017, most vessels use tape measures (83%) and measuring boards (12%) while a small minority would use callipers or flexible tape measures (5%).

Fish are measured fresh when they are hauled on the deck.

There is no standard protocol for measuring with mouth open or closed. The representative of the fleet considers that the mouth might be open after taking the hook out of the mouth. This might however result in a very small difference in the length of the fish and might be close to the uncertainty in size measurement. Again, information on size measurement method will be collected through the EMS pilot project for the 3 vessels selected.

Fish are measured to the nearest centimetre. The current version of the protocol does not include the type of rounding used and it will be corrected to include this and also provide clarification about the size resolution. It is assumed that the measurements are rounded "normally", i.e. rounds digits 1,2,3, and 4 down, and digits 5,6,7,8, and 9 up.

The only known change to the sampling protocol has been to increase the number of fish measured from 20 to 30 fish in June 2017.

Examples of forms have been provided.

Preliminary analysis of the size data suggested inconsistencies in some measurements when compared with mean weights derived from catch data (Chassot et al., 2016). For instance, some samples only include bigeye less than 45 cm fork length when the average weight derived from the logbook indicated bigeye of 30-50 kg. Comparison between length measurements and weight measurements for Seychelles data showed that "size frequency data collected at sea by fishermen are consistent with logbook information in several vessels while some data available from some vessels are spurious" (Chassot et al., 2016). Further analysis of the data is required to identify the potential, multiple issues.

2. Data storage and management

2.1. Japanese data

Data are stored in a series of independent MS Access databases, one for each year and data type (observer, training and research, port sampling). R code is then used to generate a flat file of size data.

In early years data were binned to 2cm or 5cm in order to shrink the dataset, due to computer capacity limitations. Thus, there may be hard copies of data at higher resolutions.

There may be some early period data stored at the Fisheries Resources Institute (FRI) that has not been included in the common pool, such as bigeye length data for the period before 1960.

Data entry is carried out by both FRI staff and others. Entry can occur up to 1 year after the data are provided. In July 2019 observer data had been entered up to 2018.

Validation during data entry is based on size ranges and distances from previous sets. The observer data are cross-checked with other data.

2.2. Korean data

Since 2018 data have been stored in a SQL Server database.

Data are entered by researchers based at the National Institute of Fisheries Science (NIFS), generally after one- or two-month delay. Size data are currently up to date, but further data may be added later. In the past, some vessels have reported their data after their trips (one or two years later).

Range-checking and other data-checking procedures are applied to the data.

Datasets include fishing date, location (latitude and longitude), vessel name, length (FL, HL, BH, etc.), weight (RW and PW), and sex.

Conversion factors for length and weight measurements are those provided by the tuna RFMOs.

2.3. Taiwanese data

Data are stored in a SQL Server database. Before 2015 data were entered by OFDC staff after receiving paper logbooks. From 2016 vessels have provided data daily via an electronic logbook system, including small-scale vessels. The e-logbook system has been developed since 2005. There was a transition period of about 2 years from 2014, with duplicate systems.

Observer data stored in SQL server. Record daily data at sea using a laptop.

Data validation was focused on range checking prior to 2009, and an additional check on weight and length relationship by species has been applied to data after 2009.

2.4. Seychellois data

Logbook data are stored in a MySQL database (FINSS) which will soon be migrated to a new version of the IRD software ObServe (PostgreSQL/PostGIS).

Sampling data are currently stored in a dedicated MS Access database linked to FINSS. The sampling data will also be migrated into the ObServe database.

Tests of version 8.0 of ObServe are currently ongoing and the work should be completed by January 2020.

Data are received in PDF format and stored on a server.

They are entered into the database by SFA technicians.

In 2019, data were still being captured for year 2016 and thereafter due to recruitment issues.

Currently available data cover June 2007 to 2015. Data for 2016, 2017 and 2018 have been partially captured.

The fish length by species are checked against minimum and maximum values as follows:

ref_Spcs_Size			
SpcsID	**Spcs_Acode**	**Min_Size**	**Max_Size**
12	BXQ	64	290
13	SWO	50	260
14	YFT	31	190
15	BET	48	186
21	ALB	20	165
23	SKH	51	352
30	THR	30	290
120	BSH	67	333
124	OCS	69	168
161	CCL	21	290

Each sample is compared with logbook entries for dates and positions. Codes are used to flag inconsistent samples or size measurements, etc. (see Metadata). The codes used are:

1 No logbook Received
2 No Fishing
3 Cruising
4 In port on logbook
5 Logbook null for given date
7 Fish length not recorded on form
9 Position significantly different to Logbook
10 Fish size

An example of description of the checking and control procedure is given in the document "sys_ll_dw_fishery.html" (Appendix 2). It shows the numbers of samples and fish identified by type of inconsistency between the samples and the logbooks. It also gives the numbers of fish with measurements outside the size bounds provided above.

The database contains two main data tables and various reference tables (see Metadata). The main data table is the A1_smplSample containing the following list: Sample ID, Vessel ID, Vessel Name, TripHistory ID, Logbook ID, Position.

The second data table is the A"_SmplSampleData containing the fields: Sample ID (FK_ A1_smplSample), Fish Number, Species, Fish length, Length un it, Measurement type.

The length frequency data are not processed but reported as collected by fishermen and provided to SFA.

Conversion factors for length and weight measurements (e.g. from gilled and gutted to whole weight, including all conversion factors and stratification) are not used.

Numbers are not converted to weight as part of the data curation process. Conversions based on IOTC morphometric relationships are only performed for data analysis.

3. Issues identified

3.1. Japanese size data

Japanese data were provided with the rules reported in Appendix 1.

The rules added 0.5 to the absolute value of each cell, with the expressed aim of defining the middle of each cell. This works when vessels report at 1x1 resolution, but doesn't allow for the fact that the data are also reported at other stratifications: (1 = 10°×20°, 2 = 5°×10°, 3 = 5°×5°, 4 = 1°×1°).

Sufficient information was available in the dataset to correct this error, but the IOTC data should be checked to ensure that they are not affected by this problem.

3.2. Taiwanese size data

There has been concern about the reliability of Taiwanese length frequency data, given inconsistencies in size composition through time and with other fleets (Geehan and Hoyle, 2013). Data before 2002 include a lot of small fish, which are largely absent after this period. Earlier data are also much more variable.

Since 2009 fishermen have been required to report both length and weight (from spring balances) in logbooks. The Taiwanese government has provided this to IOTC. The weight data are reliable, but length data are not considered reliable.

Since 2009, observer data have been collected. OFDC have compared observer data with logbook data and found a very large number of differences.

It may be advisable to use only the post-2009 observer data, although logbook weight data may also be usable.

OFDC suggest the need for a change to CMM 11/04 because it only describes the need to submit trip reports, rather than the data required for science. Changing the CMM to require submission of the relevant scientific data would make it easier for OFDC to provide this information.

4. Recommendations

Taiwanese length frequency data collected before 2002 should be further explored before they are considered in stock assessments, so they will not be used in stock assessments at this time.

Taiwanese length frequency data collected by fishermen since 2002 will not be used in stock assessments.

Taiwanese weight data are likely to be usable, once they have been thoroughly explored and compared with other datasets to determine whether they can be used in stock assessments.

There is no evidence of problems in Taiwanese observer length frequency data and they should be used in stock assessments.

An amendment to CMM 11/04 should be considered to require observer size data (and other data) to be reported to the IOTC Secretariat in an appropriate database format, in addition to the trip report.

Seychelles length frequency data collected by fishermen on some longline vessels are likely affected by similar problems to the Taiwanese length frequency data collected by fishermen. Analyses to date suggest similar types of inconsistencies within the dataset, with some consistent and some inconsistent data. The Seychelles data should be thoroughly checked. Until this issue is resolved the length frequency data collected by fishermen on Seychelles longline vessels should not be used in IOTC stock assessments.

Part B: Data exploration

Data coverage

The data provided by each fleet have differing characteristics, which in many cases change through time. In some cases, there are differences between data held by the CPC and the data provided to IOTC. Attributes that vary include the proportion of the catch sampled, the areas sampled, the spatial and temporal resolution of samples, and the measurement type (length / whole weight, processed weight). There is also variation in the coverage of the size sampling when the temporal and spatial distributions of size and catch data are compared.

Variation in data characteristics can affect the ability to use data in stock assessments, and the way the data must be prepared before including them in the assessment.

Here we summarise the characteristics of available data, to identify issues that should be considered when preparing data for stock assessments, or that may require clarification or revision by the agency providing the data. Characteristics are summarised for all bigeye and yellowfin size data held by the IOTC, with a particular focus on the Japanese, Korean, Taiwanese and Seychelles fleets. In addition, we compare the data held by the IOTC with the data provided by the Japanese, Korean, Seychelles and Taiwanese fishing agencies. We explore size data coverage by comparing the time-area distributions of the size data and the catch.

Spatial stratification

The spatial stratification of size data has several effects. Within a stock assessment, stratification affects the way regions are defined, because the problems of using samples that do not come entirely from within a region constrain regional boundaries to match the spatial strata. This can be limiting when data are collected at a coarse resolution like 10 x 20, with 5 x 5 or finer resolution preferred. Spatial stratification can also affect understanding of the stock, because sampling at coarser resolution is more likely to include areas with fish of different average sizes. This makes it harder to identify environmental factors affecting size distributions, and harder to adjust for size variation by standardizing the size data (Maunder et al., 2020).

The IOTC holds tropical tuna longline data in three main spatial resolutions: 1 x 1, 5 x 5, and 10 x 20 (Table 1, Table 2). All 10 x 20 data are Japanese and cover the period from the start of the time series until 2008. From 2009 the Japanese fleet starts to be represented in 5 x 5 data, and this continues until the present.

Japan-held size data have almost all been collected at finer resolutions than those provided to analysts by IOTC (Table 4). Rather than 10 x 20, data are available at 5 x 10 starting in 1952, with the dominant resolution changing to 1 x 1 in 1967. Some data are held at 10 x 20 between 1965 and 1989, but these are always a small subset of the data collected.

The Korean data provided to analysts by IOTC are either at 1 x 1 resolution (2001, 2002 (bigeye only), 2006-2007, 2009-2010, 2012-present) or in very coarse Indian Ocean quadrant resolution (1991-2000, 2003-2005) which cannot be used for stock assessment. Sample sizes have increased in recent years. The resolution of the Korean data provided to this size data project was also 1 x 1 (Table 5).

Seychelles data provided to analysts by IOTC are at 1 x 1 resolution from 2007 to the present. For the period 1996 to 2002 some hundreds of samples per species per year are provided at 10 x 10 resolution - the only fleet provided at this resolution. The size data currently held by Seychelles (Table 6) are all at 1 x 1 resolution, with usable numbers starting in 2007.

In the IOTC data provided to analysts, the Taiwanese fleet is presented entirely by 5 x 5 data. It provides the most data at this resolution in all years from 1980 until the end of the time series. The Taiwanese hold vessel-sourced length data from 1980 up to the present, but only provided to this study data for 1980-2002 (Table 7). These data are all at 5 x 5 resolution. Observer data and vessel-sourced weight data were provided to this study for the years 1999 – 2018, and all these data were at 1 x 1 resolution.

Temporal stratification

As for spatial data, the temporal resolution of data limits the ways it can be used. Most IOTC stock assessments use quarterly resolution, which is sufficient for most purposes. Some assessments operate annually. Modeling at finer temporal resolutions such as monthly may be useful for short-lived species such as skipjack tuna or for tracking cohorts of young fish, although this is more likely to be applied to size data from purse seine, bait boat, or troll fleets than to the longline data considered here.

Most stock assessment software including Stock Synthesis (Methot and Wetzel, 2013) require all data to have the same time resolution. Given the resolution of the available Japanese data, this limits IOTC stock assessments to quarterly or larger time steps. However, MULTIFAN-CL (Fournier et al., 1998) can vary time resolution at the fishery level, such as when using monthly time strata for the New Zealand albacore troll fishery to estimate the rapid growth of young fish in the South Pacific albacore stock assessment (Hoyle et al., 2012).

IOTC-held data for Japan are all at quarterly resolution from 1952-2008 (Table 9), switching entirely to 1-month resolution in 2009. This contrasts with Japanese-held data which are at 1-month resolution throughout the time series from 1952.

IOTC-held versions of the Korean, Seychelles and Taiwanese datasets are all provided to analysts at 1-month resolution, whereas each of the respective datasets provided to this project were reported at daily time intervals.

It would be useful to explore the available longline size data at monthly resolution to see if there are datasets and locations where sampling is good enough to identify and follow cohorts. It would also be useful if Japan would grant access to size data at monthly resolution, which would allow analysts to explore running models at monthly scale.

Measurement type and conversion

Currently, data are used in IOTC tuna assessments only as length data. They are provided to analysts after conversion to fork length using the equations in Appendix 2. There are some disadvantages to converting between data formats, which will introduce bias when conversion factors are not accurate. In addition, applying the same conversion factors to all fish of the same species will cause bias if the true conversion ratios vary with other factors.

The conversion factors used for bigeye and yellowfin tuna are based on relatively few fish, small areas, few fisheries, and short time series. For example, the weight (gg) to length conversion factors come from the Penang Sampling Programme 1992-93, with 2361 and 316 fish for YFT and BET respectively. Other conversion factors are based on data from the Atlantic, and from sampling (6752 fish for length-weight relationship) at the Seychelles canneries (Marsac et al., 2006).

To be accurate, conversion factors should adjust for factors that affect the relationship between the two measurements. Length-weight relationships essentially measure fish condition, which is affected by spatial and seasonal factors, environmental conditions, and may vary through time due to densitydependent factors. Length-weight relationships will vary between sexes to some degree. They will also change as fish grow, which is reflected in the fact that different length-weight relationships are used for purse seiners and longliners.

Similarly, fish preparation (gilling and gutting) will vary to some extent between fleets and fisheries, which will also affect the length-weight relationship.

Reflecting these effects, various studies have obtained different length-weight relationships (see Marsac et al. (2006)).

To verify the existence of variability in length-weight relationships, and to check our understanding of factors that may affect it, we used generalized additive models to analyse bigeye tuna data (n = 7363) from Korean longline vessels sampled 1999-2018. We used log(weight) as the response variable, fitted a smoother to the effect of log(length), and used quarterly surfaces to estimate the effect of location.

We found statistically and biologically significant spatial and seasonal variation in log(length)-log(weight) relationships (Figure 41), and the relationship was not linear but varied with length (Figure 42). The quarterly model fitted better than a model that assumed the same pattern throughout the year. An interannual effect was not supported for this dataset.

To better support conversion of weights to lengths, broad-based length-weight conversion models should be developed that cover as many fisheries, fleets, locations, seasons, and years as possible. We recommend the development of a shared database that IOTC members can contribute to. These data should then be modelled using modern statistical techniques to develop length weight relationship that can more reliably convert weights into lengths.

Through time, Japanese data have been collected and/or stored in several different formats. Tropical tunas were either weighed gilled and gutted or measured to fork length (Table 8), with the proportions changing through time. The IOTC data

Measurement resolution

All IOTC tuna data are reported to analysts in 2 cm length bins, which is the resolution used in stock assessment.

As described earlier, all Japanese length data were initially measured and recorded at 1 cm intervals, but in early years were rounded to either 2 cm or 5 cm due to data storage capacity limits. The direction of rounding changed in 1970 from rounding up to rounding down. Since the current practice is to round up, rounding practices must have changed again after 1988 (Hoyle et al., 2017a). These changes in rounding direction have been adjusted for in the analyses of Japanese data in this report. However, they have not been adjusted for in the IOTC data provided to analysts. This issue should be explored with Japanese data providers so as to improve the quality of the data used in the assessments.

Korean, Taiwanese and Seychellois data are stored at 1 cm resolution.

Data sources

The source of the data can be an indicator of its quality. Data sources are reported to analysts in the data provided by IOTC.

Coverage and available data

Part C: Recommendations for use in stock assessments

How does size data affect stock assessments?

Tuna stock assessments are very dependent on size data, which have been collected in many fisheries and for long time series. Given the models' reliance on these data, it is important to understand the impact of data quality on assessment outcomes.

Size data informs the estimation of selectivity. Selectivity affects how catch is extracted from the modelled population. It also affects how the model fits to the observed CPUE. In IOTC tropical tuna assessments, the selectivity of longline fisheries linked to CPUE indices has always been constrained to be constant through time. However, the current version of Stock Synthesis can also estimate time-varying selectivity. It should be noted that longline sizes can vary significantly within regions of the Indian Ocean (Figure 7 to Figure 12) (Hoyle et al., 2017b).

Size data provide information about the relative strengths of recruitments. This is particularly true for size data from fisheries that take small fish, such as purse seiners, and is less the case for longline fisheries which mostly take large fish.

Size data also inform the model about the average size of the fish being caught. The average size of fish caught is affected both by the size structure of fish in the population (or the sub-population within the region), and by selectivity. When selectivity is assumed to be constant through time (rather than time-varying), the model interprets trends in observed fish sizes as changes in the population. These changes can have a large impact on assessment results. If the average size of observed fish decreases through time, the model will tend to explain this trend as due to an increase in fishing mortality, which will reduce the proportion of old and large fish in the population. The essence of fishing mortality is catch / abundance. Since catch is known and fixed, the model cannot change it, but it can adjust the abundance trend by changing the recruitment trend, or to some extent by changing the overall population scaling.

Poor quality size data can substantially affect stock assessment results by introducing bias through the mechanisms described above. There are different ways that size data can be of poor quality for the purposes of stock assessment. Moderately unrepresentative sampling that has the same features through time will result in worse fit to the size data but may not seriously bias the results. The most serious problems are caused by highly unrepresentative sampling, and changes through time in the quality of sampling.

A number of different factors can affect the sizes of fish caught, including location, year, time of year, the type of fishing gear used and the way it is deployed, and random chance, reinforced by the fact that tunas tend to associate with conspecifics of similar sizes. Location is particularly important for tunas, since there can be significant spatial size variation (see Figures 7-12 for yellowfin tuna, and Figures 23-28 for bigeye tuna). Seasonality is important since tuna distributions are affected by environmental conditions. Estimating different distributions by quarter considerably improves the AIC of gams of size distribution for both yellowfin and bigeye (Figures 14 and 31).

It should be noted that the population selectivity (the realised selectivity of a fishery) is defined differently from contact selectivity. Population selectivity defines the relationship between the size distributions of the catch taken by the fishery and the population potentially vulnerable to the fishery, so it must allow for the effects of spatial distribution of fishing relative to spatial size variation within the vulnerable population. Contact selectivity defines probability of capture at size for individual fish (Sampson, 2014).

The current fishery definitions for tunas include within individual fisheries areas with different size distributions, which vary seasonally. Since tuna longline fishery effort distribution varies through time, the realised selectivities of these fisheries also vary through time and by season.

What information in size data is reliable?

Sampling is usually designed to be representative of the catch, and this is achieved for different datasets with varying degrees of success. Here we list the various data sources, note potential concerns, and make recommendations for how they should be used in stock assessments, in the short and the long term.

To explore this issue we applied a simple standardization model to size data by location and year-quarter, with the formula: size ~ year-quarter + location, implemented as follows using the R package mgcv (Wood, 2011).

```
mod <- gam(len ~ yrqtr + te(lon, lat, k = c(10,10)), data=dat, weights = dat$nfish)
```

Models to explore quarterly size distribution changes included an additional term.

```
mod_qtr <- gam(len ~ yrqtr + te(lon, lat, qtr, k = c(10,10,4)), data=dat, weights=dat$nfish)
```

Results of these models (maps of relative sizes in space, and time series of relative sizes) are provided in Figures 7 to 22 for yellowfin tuna, and Figures 23 to 40 for bigeye tuna.

These models indicate for yellowfin tuna that spatial size patterns are similar between IOTC-held Japanese data (Figure 7), Japanese-held data at finer spatial scales (Figure 9, as expected since this is mostly the same data), and Korean-held data despite relatively small sample sizes. IOTC-held Taiwanese length data have very large sample sizes and might be expected to show a similar pattern, but in fact the spatial pattern is somewhat different with less spatial variation (Figure 8). IOTC-held Seychelles length data also have quite large sample sizes and a different spatial size distribution from other datasets (Figure 10). IOTC-held Chinese length data (Figure 11), and length datasets from other fleets (Figure 12), are too sparsely sampled to estimate spatial size distributions.

Time series of predicted sizes from the IOTC-held data and the national datasets show some distinct differentiation among fleets. The Japanese yellowfin data indicate a decline in expected size from 1952 until about 1965, and stable thereafter, with more variability when data become sparse in the early 2000s (Figure 15). Standardizing the IOTC-held Japanese 5 x 5 size data indicates similar stability (Figure 16). Standardizing the Japanese 5 x 10 and 1 x 1 length data provided by Japan at 5 x 10 resolution gave a similar time series to the 10 x 20 size data held by IOTC, though extending through to 2018 with the inclusion of small amounts of 1 x 1 data.

Time series from the IOTC-held Seychelles (Figure 18) and Taiwanese (Figure 19) size data, show more time-series variation. The Taiwanese time series in particular is very variable from 1980 until 1992, when the expected size suddenly drops to over 20cm less than the start of the time series, and then from 2000 steadily increases to reach an average of almost 10 cm more than the start of the time series. The IOTC-held Chinese dataset is still relatively sparse which may explain its high variability (Figure 20). The predicted length time series was relatively stable for data from fleets submitting 5 x 5 data other than the Japanese and Taiwanese (Figure 21). Most of these data came from India and Sri Lanka, with smaller amounts from Portugal, Maldives, Mozambique, Mauritius, and the European Union. Length data provided by Korea also showed relatively stable time series despite low sample sizes (Figure 22).

For bigeye tuna, models indicate that spatial size patterns are similar between IOTC-held Japanese data (Figure 23), Japanese-held length data and weight data at finer spatial scales (Figure 24 and Figure 25), and even for Korean-held data with relatively small sample sizes (Figure 26). Size maps based on Taiwanese-held observer data (Figure 27) and vessel-sourced weight data (Figure 28) show patterns that are somewhat similar, with differences that may be due to small sample sizes and differences in the period covered. Maps based on IOTC-held Taiwanese length data with very large sample sizes show a similar spatial pattern with to other datasets the largest fish in the northwest (Figure 29). IOTC-held Seychelles length data also have quite large sample sizes and but the spatial pattern is less distinct than most of the other fleets (Figure 30).

Differentiation among fleets for predicted sizes of bigeye tuna was similar to the results for yellowfin tuna. The Japanese data started in 1965, so any decline as seen in the yellowfin until about 1965 would not have been apparent. Expected sizes were relatively stable thereafter, with more variability when data become sparse in the early 2000s (Figure 32). Standardizing the Japanese 5 x 10 and 1 x 1 length data provided by Japan at 5 x 10 resolution gave a similar time series to the 10 x 20 size data held by IOTC, though extending through to 2018 with the inclusion of small amounts of 1 x 1 data (Figure 33). Standardizing the Japanese-held weight data also showed relatively stable size trends through time (Figure 34).

Time series from the IOTC-held Seychelles (Figure 35) and Taiwanese (Figure 36) size data, show more time-series variation and are similar to one another. The Seychelles bigeye time series has a remarkably similar pattern to yellowfin, with low points in early 2011 and high points in late 2015. The Taiwanese time series also shows very similar patterns in both bigeye and yellowfin, dipping from local highs in 1996 to lows in 2000, after which sizes steadily increase. Sizes for both species dip in 2010 and then increase again to reach high points near the end of the time series.

Predictions for the Taiwanese bigeye tuna observer data (Figure 37) and weight data (Figure 38) are much less variable than the 5 x 5 IOTC-held data, and both suggest a trend of slightly increasing size between the 2009-2013 period and 2014-2018.

In contrast, the predicted length time series suggested slightly decreasing size over the same period for fleets submitting 5 x 5 data other than the Japanese and Taiwanese (Figure 39), although the estimates are uncertain. Most of these data came from India and Sri Lanka, with smaller amounts from Portugal, Maldives, Mozambique, Mauritius, and the European Union. Length data provided by Korea predicted relatively stable time series with some decline in the 2014- 2018 period compared to 2005-2010 period (Figure 40), but these trends are also relatively uncertain.

These analyses support the understanding that there is consistent spatial variation in bigeye and yellowfin tuna sizes, both within and between the current region definitions.

Summaries and recommendations by fleet

Japanese data for yellowfin show a large and steady decline in average size before 1965. This change may represent a real decline in fish sizes, which warrants further analysis. However, sampling practices changed during this early period and is there is doubt about their consistency. Past assessments have been unable to fit these data with the same selectivity, and a plausible reason for this is that average selectivity changed as large fish were removed from the population. Given the uncertainty about what happened, the large influence of these data on results, and the fact that neither of the proposed explanations could be accommodated by the assessment, we should not include these data. We therefore recommend omitting these pre-1965 data from the assessment. After 1965 the Japanese data are reasonably consistent and show coherent spatial patterns, so may be included pending further investigation of some parts of the time series.

Taiwanese and Seychelles length-sampled logbook data held by IOTC show evidence of changing size sampling behaviour through time, with patterns that are similar across species, inconsistent with data from other fleets, but similar between these two fleets. Spatial patterns for Seychelles bigeye and yellowfin and for Taiwanese yellowfin are dissimilar from other fleets. Given these inconsistencies and the strong influence of these data on the assessment, we recommend omitting all Taiwanese and Seychelles logbook length data until the problems can be addressed. We understand this includes all Taiwanese length data currently held by IOTC. As discussed earlier, measuring fish for length is not a standard part of vessel work practices on most longline vessels, whereas fishermen weigh the fish for their own purposes.

In contrast, Taiwanese weight-sampled logbook data and Taiwanese observer data show temporal patterns that are consistent with one another, and spatial patterns that are consistent with one another and with other fleets. They do not show signs of sampling problems and may be included in the assessment. This conclusion is based on the Taiwanese observer and logbook weight data for bigeye tuna since we did not have access to the yellowfin data. We therefore recommend checking the yellowfin data before including it in the model.

Size data for the Korean fleet and for other fleets providing 5 x 5 data appear to have spatial and temporal patterns without major anomalies and are not inconsistent with the Japanese data. We therefore do not currently recommend removing these data, pending further investigation and comparisons among fleets.

How should analysts configure assessments, given size data quality?

After sampling, further data preparation should depend on the assumptions of the stock assessment model. Traditionally, all available size data have been included in the model, apart from samples known to be biased. Each longline fishery has been assumed to have the same selectivity throughout the time series, and that selectivity has often been shared across all longline fisheries. The same selectivity has been used for extracting catch and for fitting to the index of abundance. These have been the approaches used in recent stock assessments for Indian Ocean yellowfin tuna (Fu et al., 2018; Langley, 2015).

However, alternatives to these approaches have been developed which should be considered for Indian Ocean tuna assessments. These new approaches differentiate between the selectivity used to extract catch and the selectivity applied to longline CPUE indices (Maunder et al., 2020). Catch selectivity is defined as time-varying, and the size data are structured to be representative of the catch. The longline CPUE indices are included in separate fisheries, and index selectivity is defined as constant through time. The size data associated with the index fisheries are structured to be representative of the population, so that the variation in fishing location does not affect the size data. This is achieved by standardizing the size and CPUE data together and predicting standardized size distributions (Thorson and Haltuch, 2019). This approach has been applied in both IATTC and WCPFC stock assessments (Ducharme-Barth et al., 2020; Minte-Vera et al., 2020; Vincent et al., 2020; Xu et al., 2020).

Longline selectivities should not be shared among regions, but estimated independently (Hoyle and Langley, 2020).

There is unlikely to be time to develop an index fishery approach for the 2021 yellowfin assessment, so the assessment will require an approach that is robust to temporal changes in population selectivity.

The stock assessment currently assumes constant selectivity though time. Estimating this selectivity only requires a relatively short size data time series. Longer time series that include periods with different population selectivity (which the model does not address) only result in data conflict, which the model tries to resolve by changing the population scale, and fitting poorly to other datasets such as the CPUE index. This conflict can be reduced in various ways: a) improve the fit to the size data by developing fishery definitions that better reflect size variation in space and time, b) reduce the bias caused by poorly fitting size data by reducing effective sample sizes, generally well below the recommendations of methods such as McAllister and Ianelli (1997), c) improve the size data by fixing anomalies such as inaccurate weight conversions, d) where there is evidence of changing selectivity within a fishery time series, remove the size data except for periods that best represent the selectivity.

We recommend a combination of the above approaches, with an initial focus on step d: removing or severely downweighting any conflicting parts of the longline size data time series. Including conflicting data in a stock assessment leads only to unreliable results. When constant selectivity is assumed for a fishery, selectivity changes will cause changes in observed sizes that the model cannot fit. This has no local effect on the sizes of fish removed from the population. There is therefore no benefit for removals from including these conflicting size data.

An SS assessment model does not need a full time series of longline size data to estimate stock status. There is information about population scaling in tagging data, information about population trends in CPUE time series, and information about recruitment in the size data from purse-seine fisheries. Two areas potentially affected by reducing data conflict in this way are information about the movements of large fish, and information about spatial recruitment distributions. Movement rates are constrained to be constant through time, and in many current model scenarios are estimated to be unrealistically high. Current models also estimate strong spatial trends through time in recruitment distribution. Reducing data conflict may help to improve estimates of these parameters.

5. Tables

YFT

Table 1: Number of length measurements in data held by IOTC for yellowfin tuna by spatial resolution, flag, and year.

10x10

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
1996	0	0	0	0	0	0	0	0	0	0	0	0	485	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	256	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	229	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	207	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	111	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	409	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	157	0	0

10x20

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
1952	0	0	0	0	0	0	2903	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	8195	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	17238	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	88499	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	70220	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	68746	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	55250	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	61602	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	74271	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	39437	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	58072	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	20915	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	68093	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	74321	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	62999	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	40244	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	62470	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	44304	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	37065	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	49929	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	39765	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	20249	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	19873	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	22939	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	26204	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	26717	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	21479	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	19020	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	13527	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	16684	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	26160	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	30829	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	56765	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	66140	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	56580	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	22162	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	28183	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	25051	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	31081	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	13888	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	10876	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	11204	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	6418	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	9501	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	7456	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	6985	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	17620	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	11297	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	9034	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	5577	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	1449	0	0	0	0	0	0	0	0

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
2003	0	0	0	0	0	0	920	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	1039	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	2970	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	1403	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	1760	0	0	0	0	0	0	0	0

1x1

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
2001	0	0	0	0	0	0	0	267	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	299	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	687	0	0	0	0	11677	0	82
2008	0	0	0	0	0	0	0	0	0	0	0	0	7219	0	106
2009	406	0	0	0	0	0	0	470	0	0	0	0	3708	0	122
2010	647	0	0	0	0	0	0	139	0	0	0	0	714	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	6763	0	0
2012	1310	0	0	0	0	0	0	46	0	0	0	0	7345	0	0
2013	1419	0	0	0	0	0	0	198	0	0	0	0	10398	0	0
2014	20	0	0	0	0	0	0	522	0	0	0	0	14726	0	0
2015	28	0	0	0	0	0	0	799	0	0	0	0	1013	0	0
2016	1432	0	0	0	139	0	0	765	0	0	0	0	1925	0	0
2017	1928	63	11	0	124	0	0	4057	0	0	0	0	4820	0	0
2018	3007	0	0	0	104	0	0	3237	0	0	0	0	2561	0	4210
2019	0	0	0	0	184	0	0	1582	0	0	0	0	8760	0	0

5x5

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	7251	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	20502	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	24730	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	32298	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	31445	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	35820	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	61600	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	38925	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	30428	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	8872	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	20118	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	3500	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	2792	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	75072	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	34114	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	39099	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	95575	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	77225	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	53235	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	38503	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	41678	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	52602	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	95511	584
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	166706	483
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	230602	1071
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	635930	114
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	350435	212
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	232499	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	112575	0
2009	0	0	0	0	0	0	313	0	0	0	0	0	0	80998	0
2010	0	0	0	0	0	0	192	0	0	0	0	0	0	78135	241
2011	0	0	0	30	0	0	363	0	0	0	0	0	0	80158	0
2012	0	0	0	20	0	0	1778	0	0	0	0	0	0	77799	0
2013	0	0	0	36	0	0	2807	0	0	0	0	0	0	70578	0

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
2014	0	0	0	25	0	10182	718	0	0	163	0	0	0	70656	0
2015	0	0	0	29	0	14622	2063	0	0	189	138	0	0	40145	0
2016	0	0	0	43	0	9549	1903	0	4864	38	153	0	0	53553	0
2017	0	0	0	62	0	5017	4234	0	6680	99	0	233	0	39389	0
2018	0	0	0	56	0	5594	5212	0	8716	0	0	604	0	67591	0
2019	0	0	0	81	357	2408	5659	0	10940	0	0	0	0	47686	0

BET

Table 2: Number of length measurements in data held by IOTC for bigeye tuna by spatial resolution, flag, and year.

10x10

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	PHL	SYC	TWN	ZAF
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	49	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	603	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	181	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	295	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	253	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	204	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	87	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	64	0	0

10x20

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	PHL	SYC	TWN	ZAF
1965	0	0	0	0	0	0	58466	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	42635	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	38134	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	39015	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	43847	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	35320	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	38832	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	19816	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	14285	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	17209	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	14866	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	11831	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	14374	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	24674	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	38035	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	33436	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	33098	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	45542	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	61349	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	74645	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	95433	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	91036	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	45043	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	47141	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	38046	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	25508	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	20778	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	15902	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	7019	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	4897	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	7848	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	3306	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	7868	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	13126	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	3191	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	4271	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	2848	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	2118	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	1039	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	1512	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	2195	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	2865	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	2381	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	570	0	0	0	0	0	0	0	0	0

1x1

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	PHL	SYC	TWN	ZAF
2001	0	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	152	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	382	0	0	0	0	0	29753	0	22
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	48660	0	316
2009	2873	0	0	0	0	0	0	179	0	0	0	0	0	35951	0	245
2010	3800	0	0	0	0	0	0	79	0	0	0	0	0	9030	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	42321	0	0
2012	2805	0	0	0	0	0	0	383	0	0	0	0	0	77612	0	0
2013	5606	0	0	0	0	0	0	839	0	0	0	0	0	61792	0	0
2014	128	0	0	0	0	0	0	192	0	0	0	0	0	44460	0	0
2015	128	0	0	0	0	0	0	288	0	0	0	0	0	5362	0	0
2016	1853	0	0	0	300	0	0	327	0	0	0	0	0	2402	0	0
2017	810	40	38	0	166	0	0	1312	0	0	0	0	0	7857	0	2624
2018	2762	0	0	0	132	0	0	981	0	0	0	0	0	3934	0	0
2019	0	0	0	0	114	0	0	414	0	0	0	0	0	2952	0	0

5x5

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	PHL	SYC	TWN	ZAF
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21775	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38632	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62901	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61660	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54440	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58176	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60608	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35012	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23025	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12388	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17645	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7673	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8171	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10809	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33930	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34828	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117609	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107517	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107912	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100623	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	104275	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110749	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	221538	1234
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	546294	746
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	531335	511
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	621246	298
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	522237	554
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	491508	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	306218	0
2009	0	0	0	0	0	0	1098	0	0	0	0	0	0	0	405095	0
2010	0	0	0	0	0	0	2674	0	0	0	0	0	0	0	243280	295
2011	0	0	0	1955	0	0	2834	0	0	0	0	0	0	0	241444	0
2012	0	0	0	185	0	0	4081	0	0	0	0	0	1500	0	354009	0
2013	0	0	0	74	0	0	3665	0	0	0	0	0	907	0	202821	0
2014	0	0	0	36	0	21492	9254	0	0	911	0	0	634	0	145955	0
2015	0	0	0	341	0	26207	8540	0	0	305	140	0	0	0	81819	0
2016	0	0	0	99	0	23115	11966	0	1017	42	92	0	0	0	86788	0
2017	0	0	0	85	0	18312	12546	0	1733	0	0	195	0	0	82485	0
2018	0	0	0	50	0	10150	3304	0	0	0	0	263	0	0	79728	0
2019	0	0	0	61	180	2261	8002	0	2877	0	0	0	0	0	89796	0

Table 3: Number of yellowfin tuna size measurements in data held by IOTC by flag and gear type.

	ELL	ELLOB	FLL	LL	LLOB
CHN	0	0	0	6503	3694
EUFRA	0	63	0	0	0
EUGBR	0	0	0	0	11
EUPRT	0	0	0	0	382
EUREU	357	551	0	0	0
IDN	0	0	2408	44964	0
JPN	0	0	0	1694182	24891
KOR	0	0	0	9162	3906
LKA	0	0	31200	0	0
MDV	0	0	0	489	0
MOZ	291	0	0	0	0
MUS	837	0	0	0	0
SYC	1854	0	0	81629	0
TWN	0	0	52000	3270546	33784
ZAF	3015	0	0	4210	0

Table 4: Number of yellowfin tuna size measurements attributed to Japan in data held by Japan and the IOTC by spatial stratification and year.

	Japan 10x20	Japan 1x1	Japan 5x10	IOTC 10x20	IOTC 5x5	Japan Total	IOTC Total
1952	0	0	13279	2903	0	13279	2903
1953	0	0	17035	8194	0	17035	8194
1954	0	0	22469	17238	0	22469	17238
1955	0	0	96059	88499	0	96059	88499
1956	0	0	70961	70219	0	70961	70219
1957	0	0	43929	68745	0	43929	68745
1958	0	0	46800	55249	0	46800	55249
1959	0	0	50382	61602	0	50382	61602
1960	0	0	69384	74271	0	69384	74271
1961	0	0	30053	39436	0	30053	39436
1962	0	0	56301	58071	0	56301	58071
1963	0	0	22461	20914	0	22461	20914
1964	0	0	47254	68093	0	47254	68093
1965	11483	0	45581	74320	0	57064	74320
1966	9807	0	48800	62999	0	58607	62999
1967	6526	14322	8603	40244	0	29451	40244
1968	12045	22855	15316	62469	0	50216	62469
1969	3025	27873	7877	44304	0	38775	44304
1970	1580	28557	6113	37064	0	36250	37064
1971	3210	35560	6969	49928	0	45739	49928
1972	1194	34839	3275	39764	0	39308	39764
1973	971	20882	1977	20248	0	23830	20248
1974	1146	17799	2854	19872	0	21799	19872
1975	1245	21161	2136	22938	0	24542	22938
1976	0	26772	217	26203	0	26989	26203
1977	254	25931	1054	26716	0	27239	26716
1978	0	19352	1583	21478	0	20935	21478
1979	0	17718	1342	19019	0	19060	19019
1980	0	12621	455	13526	0	13076	13526
1981	232	14778	721	16683	0	15731	16683
1982	145	16373	4749	26160	0	21267	26160
1983	924	19139	5031	30828	0	25094	30828
1984	1052	20878	16892	56765	0	38822	56765
1985	372	17550	24054	66139	0	41976	66139
1986	862	27202	6434	56579	0	34498	56579
1987	0	15521	519	22161	0	16040	22161
1988	0	16698	1540	28183	0	18238	28183
1989	170	14237	2194	25051	0	16601	25051
1990	0	19949	408	31080	0	20357	31080
1991	0	9445	510	13887	0	9955	13887
1992	0	6274	0	10875	0	6274	10875
1993	0	7483	30	11203	0	7513	11203
1994	0	5269	0	6418	0	5269	6418
1995	0	7848	0	9501	0	7848	9501
1996	0	5679	0	7456	0	5679	7456
1997	0	7003	0	6985	0	7003	6985
1998	0	14241	0	17619	0	14241	17619
1999	0	12261	0	11297	0	12261	11297
2000	0	9812	0	9033	0	9812	9033
2001	0	5500	0	5576	0	5500	5576
2002	0	1451	0	1449	0	1451	1449
2003	0	889	0	920	0	889	920
2004	0	1691	0	255	0	1691	255
2005	0	2226	0	1039	0	2226	1039
2006	0	2971	0	2970	0	2971	2970
2007	0	1403	0	1403	0	1403	1403
2008	0	1752	0	1760	0	1752	1760
2009	0	313	0	0	313	313	313
2010	0	194	0	0	192	194	192
2011	0	363	0	0	363	363	363
2012	0	1778	0	0	1778	1778	1778
2013	0	2807	0	0	2807	2807	2807
2014	0	718	0	0	718	718	718
2015	0	2063	0	0	2063	2063	2063
2016	0	1903	0	0	1903	1903	1903
2017	0	4234	0	0	4234	4234	4234
2018	0	2250	0	0	5212	2250	5212

Table 5: Korean yellowfin tuna size samples by measurement type, source, and year. For all data the spatial resolution is 1 x 1.

yr	wt_observer	wt_vessel	len_observer	len_vessel
1999	0	18	0	18
2000	0	380	0	380
2001	0	288	0	288
2002	0	12	0	12
2003	0	525	0	525
2004	0	849	0	849
2005	0	622	0	622
2006	0	568	0	568
2007	0	251	0	251
2008	0	63	0	63
2009	0	587	0	587
2010	61	78	61	78
2012	23	0	24	0
2013	3	104	3	104
2014	19	78	19	78
2015	1169	851	1225	851
2016	1403	779	1464	779
2017	1004	2104	993	2104
2018	0	1926	0	1926

Table 6: Seychelles yellowfin tuna size samples by year. For all data the spatial resolution is 1 x 1, measurement type is length, and the source is the vessel.

yr	len_vessel
2005	0
2006	3
2007	12252
2008	7657
2009	3936
2010	746
2011	7379
2012	7996
2013	12135
2014	17256
2015	15035
2016	12147
2017	25601
2018	6929

Table 7: Taiwanese bigeye tuna size samples by measurement type, source, spatial stratification, and year.

yr	len_vessel_5x5	wt_vessel_1x1	len_observer_1x1	wt_observer_1x1
1980	21775	0	0	0
1981	38631	0	0	0
1982	62876	0	0	0
1983	61660	0	0	0
1984	54440	0	0	0
1985	58176	0	0	0
1986	60627	0	0	0
1987	35012	0	0	0
1988	23025	0	0	0
1989	12388	0	0	0
1990	17645	0	0	0
1991	7673	0	0	0
1992	8171	0	0	0
1993	10841	0	0	0
1994	33902	0	0	0
1995	34828	0	0	0
1996	117610	0	0	0
1997	107517	0	0	0
1998	107912	0	0	0
1999	100623	0	0	0
2000	104275	0	0	0
2001	110749	0	0	0
2002	221301	0	0	0
2009	0	2896	8568	8568
2010	0	17992	8455	8455
2011	0	9354	4593	4593
2012	0	2932	3271	3271
2013	0	18013	4015	4015
2014	0	12185	3376	3376
2015	0	9950	2542	2542
2016	0	23758	2321	2321
2017	0	40719	2136	2136
2018	0	35402	2642	2642
2019	0	0	127	127

Table 8: Number of yellowfin tuna size measurements in data held by Japan for by measurement type, spatial stratification, and year.

	len 10x20	len 1x1	len 5x10	wt 10x20	wt 1x1	wt 5x10	len Total	wt Total
1952	0	0	13279	0	0	0	13279	0
1953	0	0	15522	0	0	1513	15522	1513
1954	0	0	22469	0	0	0	22469	0
1955	0	0	96059	0	0	0	96059	0
1956	0	0	60244	0	0	10717	60244	10717
1957	0	0	10825	0	0	33104	10825	33104
1958	0	0	23563	0	0	23237	23563	23237
1959	0	0	27579	0	0	22803	27579	22803
1960	0	0	47491	0	0	21893	47491	21893
1961	0	0	18604	0	0	11449	18604	11449
1962	0	0	26263	0	0	30038	26263	30038
1963	0	0	8623	0	0	13838	8623	13838
1964	0	0	13859	0	0	33395	13859	33395
1965	1423	0	28281	10060	0	17300	29704	27360
1966	2841	0	28669	6966	0	20131	31510	27097
1967	376	14322	0	6150	0	8603	14698	14753
1968	467	22855	1196	11578	0	14120	24518	25698
1969	0	27873	0	3025	0	7877	27873	10902
1970	0	28557	0	1580	0	6113	28557	7693
1971	0	35560	0	3210	0	6969	35560	10179
1972	0	34839	0	1194	0	3275	34839	4469
1973	0	20882	0	971	0	1977	20882	2948
1974	0	17799	0	1146	0	2854	17799	4000
1975	0	21161	0	1245	0	2136	21161	3381
1976	0	26634	0	0	138	217	26634	355
1977	0	25931	0	254	0	1054	25931	1308
1978	0	19352	0	0	0	1583	19352	1583
1979	0	17718	0	0	0	1342	17718	1342
1980	0	12621	0	0	0	455	12621	455
1981	0	14778	0	232	0	721	14778	953
1982	0	16373	0	145	0	4749	16373	4894
1983	0	19139	0	924	0	5031	19139	5955
1984	0	20878	0	1052	0	16892	20878	17944
1985	0	17550	0	372	0	24054	17550	24426
1986	0	12415	0	862	14787	6434	12415	22083
1987	0	9918	0	0	5603	519	9918	6122
1988	0	7754	0	0	8944	1540	7754	10484
1989	0	8150	0	170	6087	2194	8150	8451
1990	0	9633	0	0	10316	408	9633	10724
1991	0	5002	0	0	4443	510	5002	4953

	len 10x20	len 1x1	len 5x10	wt 10x20	wt 1x1	wt 5x10	len Total	wt Total
1992	0	1661	0	0	4613	0	1661	4613
1993	0	3822	0	0	3661	30	3822	3691
1994	0	4120	0	0	1149	0	4120	1149
1995	0	6163	0	0	1685	0	6163	1685
1996	0	3895	0	0	1784	0	3895	1784
1997	0	6999	0	0	4	0	6999	4
1998	0	10844	0	0	3397	0	10844	3397
1999	0	12260	0	0	1	0	12260	1
2000	0	9783	0	0	29	0	9783	29
2001	0	5409	0	0	91	0	5409	91
2002	0	1451	0	0	0	0	1451	0
2003	0	887	0	0	2	0	887	2
2004	0	1672	0	0	19	0	1672	19
2005	0	2211	0	0	15	0	2211	15
2006	0	2971	0	0	0	0	2971	0
2007	0	1403	0	0	0	0	1403	0
2008	0	1752	0	0	0	0	1752	0
2009	0	313	0	0	0	0	313	0
2010	0	191	0	0	3	0	191	3
2011	0	363	0	0	0	0	363	0
2012	0	1778	0	0	0	0	1778	0
2013	0	2807	0	0	0	0	2807	0
2014	0	718	0	0	0	0	718	0
2015	0	2063	0	0	0	0	2063	0
2016	0	1903	0	0	0	0	1903	0
2017	0	4234	0	0	0	0	4234	0
2018	0	2250	0	0	0	0	2250	0

Time stratification: YFT

Table 9: Number of length measurements in data held by IOTC for yellowfin tuna by temporal resolution, flag, and year.

1 month

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	7251	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	20502	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	24730	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	32298	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	31445	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	35820	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	61600	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	38925	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	30428	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	8872	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	20118	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	3500	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	2792	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	75072	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	34114	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	39099	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	485	95575	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	256	77225	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	229	53235	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	207	38503	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	111	41678	0
2001	0	0	0	0	0	0	0	267	0	0	0	0	409	52602	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	157	95511	584
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	166706	483
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	230602	1071
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	635930	114
2006	0	0	0	0	0	0	0	299	0	0	0	0	0	350435	212
2007	0	0	0	0	0	0	0	687	0	0	0	0	11677	232499	82
2008	0	0	0	0	0	0	0	0	0	0	0	0	7219	112575	106
2009	406	0	0	0	0	0	313	470	0	0	0	0	3708	80998	122
2010	647	0	0	0	0	0	192	139	0	0	0	0	714	78135	241
2011	0	0	0	30	0	0	363	0	0	0	0	0	6763	80158	0
2012	1310	0	0	20	0	0	1778	46	0	0	0	0	7345	77799	0
2013	1419	0	0	36	0	0	2807	198	0	0	0	0	10398	70578	0
2014	20	0	0	25	0	10182	718	522	0	163	0	0	14726	70656	0
2015	28	0	0	29	0	14622	2063	799	0	189	138	0	1013	40145	0
2016	943	0	0	43	139	9549	1903	765	4864	38	153	0	1925	53553	0
2017	1928	63	11	62	124	5017	4234	4057	6680	99	0	233	4820	39389	0
2018	3007	0	0	56	104	5594	5212	3237	8716	0	0	604	2561	67591	4210
2019	0	0	0	81	541	2408	5659	1582	10940	0	0	0	8760	47686	0

3 months

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
1952	0	0	0	0	0	0	2903	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	8195	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	17238	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	88499	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	70220	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	68746	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	55250	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	61602	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	74271	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	39437	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	58072	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	20915	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	68093	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	74321	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	62999	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	40244	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	62470	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	44304	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	37065	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	49929	0	0	0	0	0	0	0	0

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
1972	0	0	0	0	0	0	39765	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	20249	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	19873	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	22939	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	26204	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	26717	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	21479	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	19020	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	13527	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	16684	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	26160	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	30829	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	56765	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	66140	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	56580	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	22162	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	28183	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	25051	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	31081	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	13888	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	10876	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	11204	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	6418	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	9501	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	7456	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	6985	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	17620	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	11297	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	9034	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	5577	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	1449	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	920	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	1039	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	2970	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	1403	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	1760	0	0	0	0	0	0	0	0

7 months

	CHN	EUFRA	EUGBR	EUPRT	EUREU	IDN	JPN	KOR	LKA	MDV	MOZ	MUS	SYC	TWN	ZAF
2016	489	0	0	0	0	0	0	0	0	0	0	0	0	0	0

6. Figures

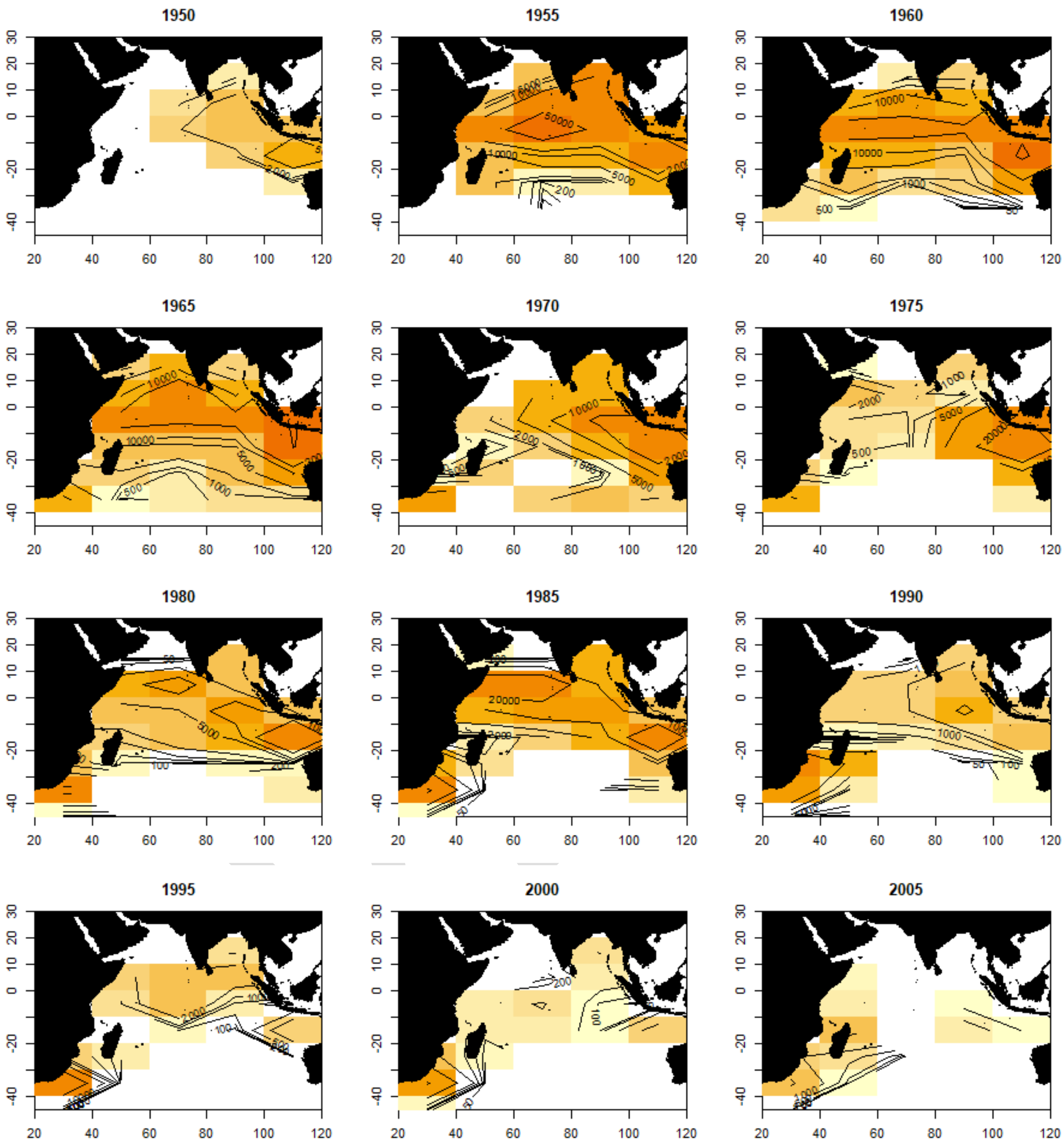


Figure 1: Sampling locations of Japanese 10 x 20 yellowfin size data in IOTC dataset.

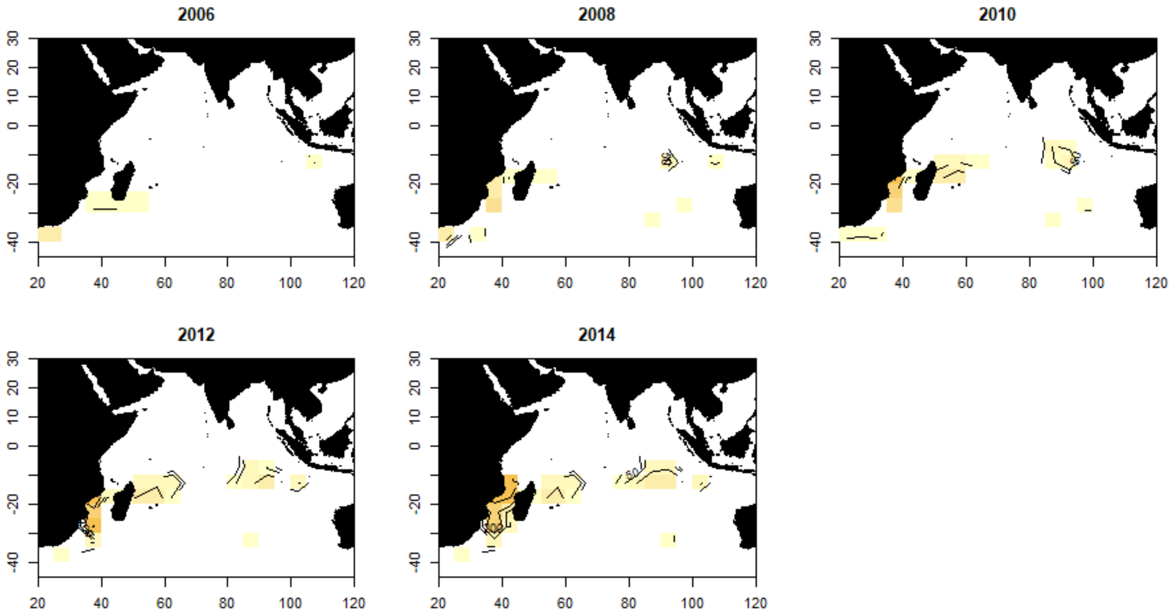


Figure 2: Sampling locations of Japanese 5 x 5 yellowfin size data in IOTC dataset.

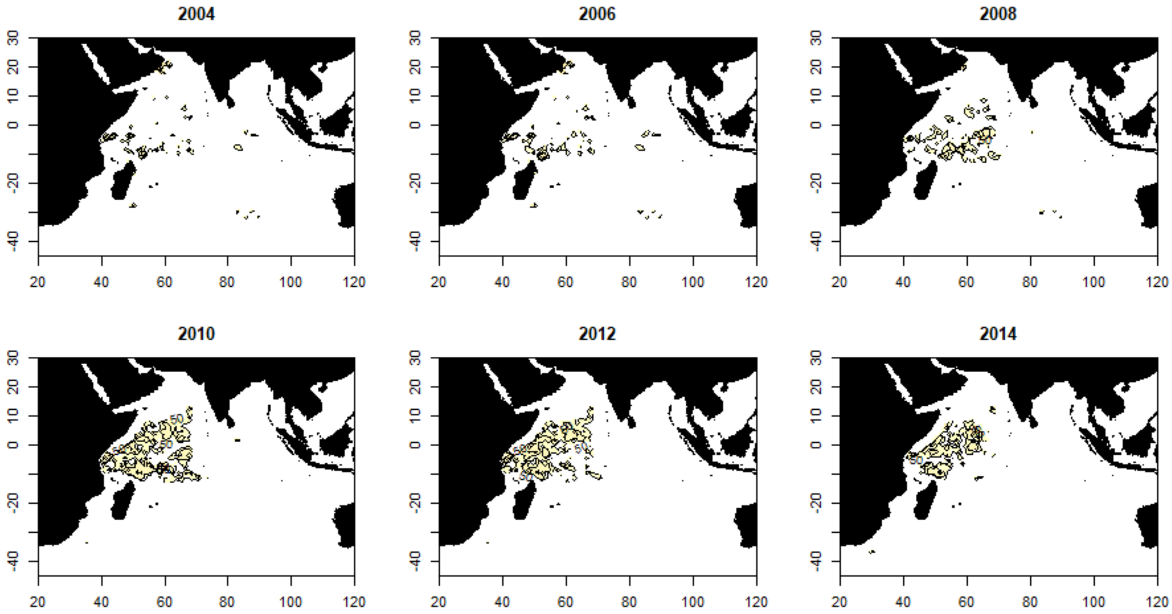


Figure 3: Sampling locations of Seychelles 1 x 1 yellowfin size data in IOTC dataset.

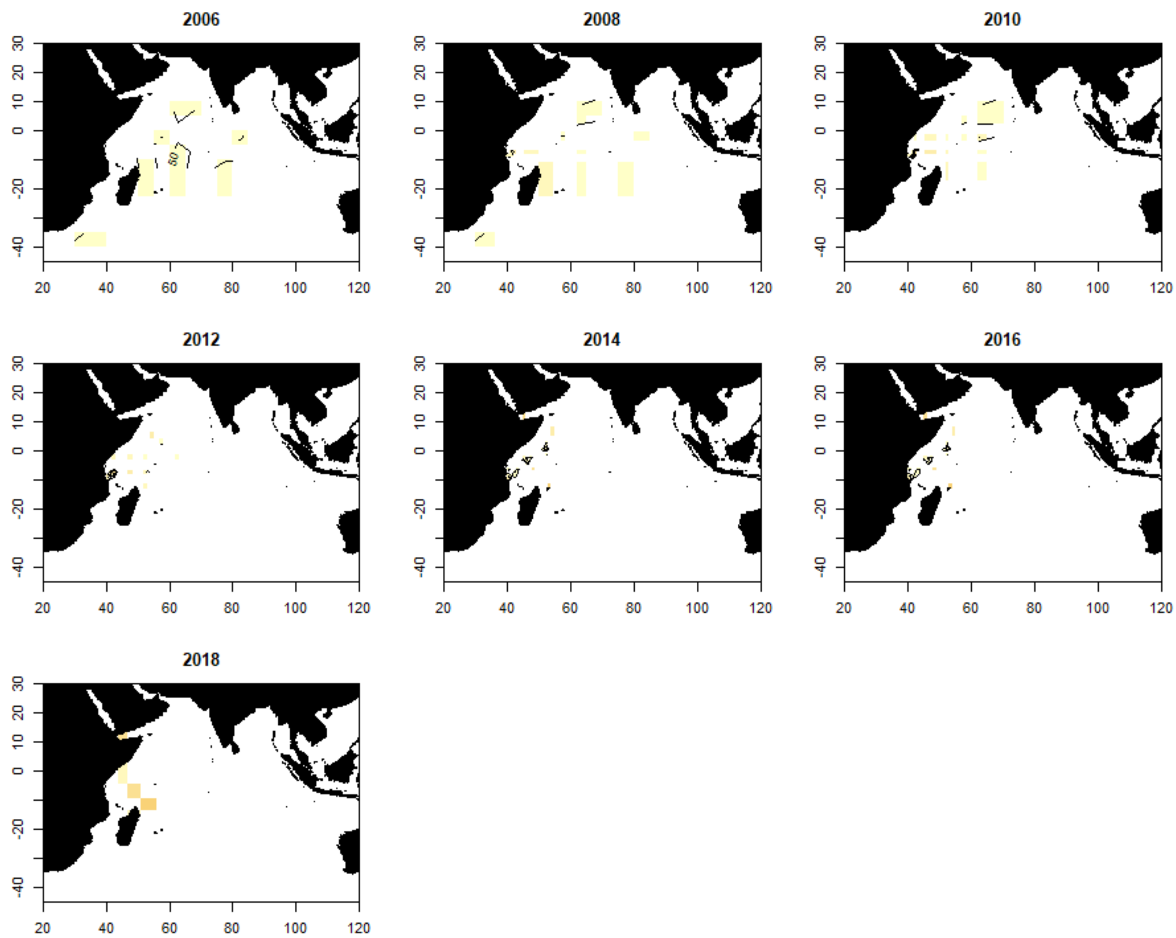


Figure 4: Sampling locations of Chinese 1 x 1 yellowfin size data in IOTC dataset.

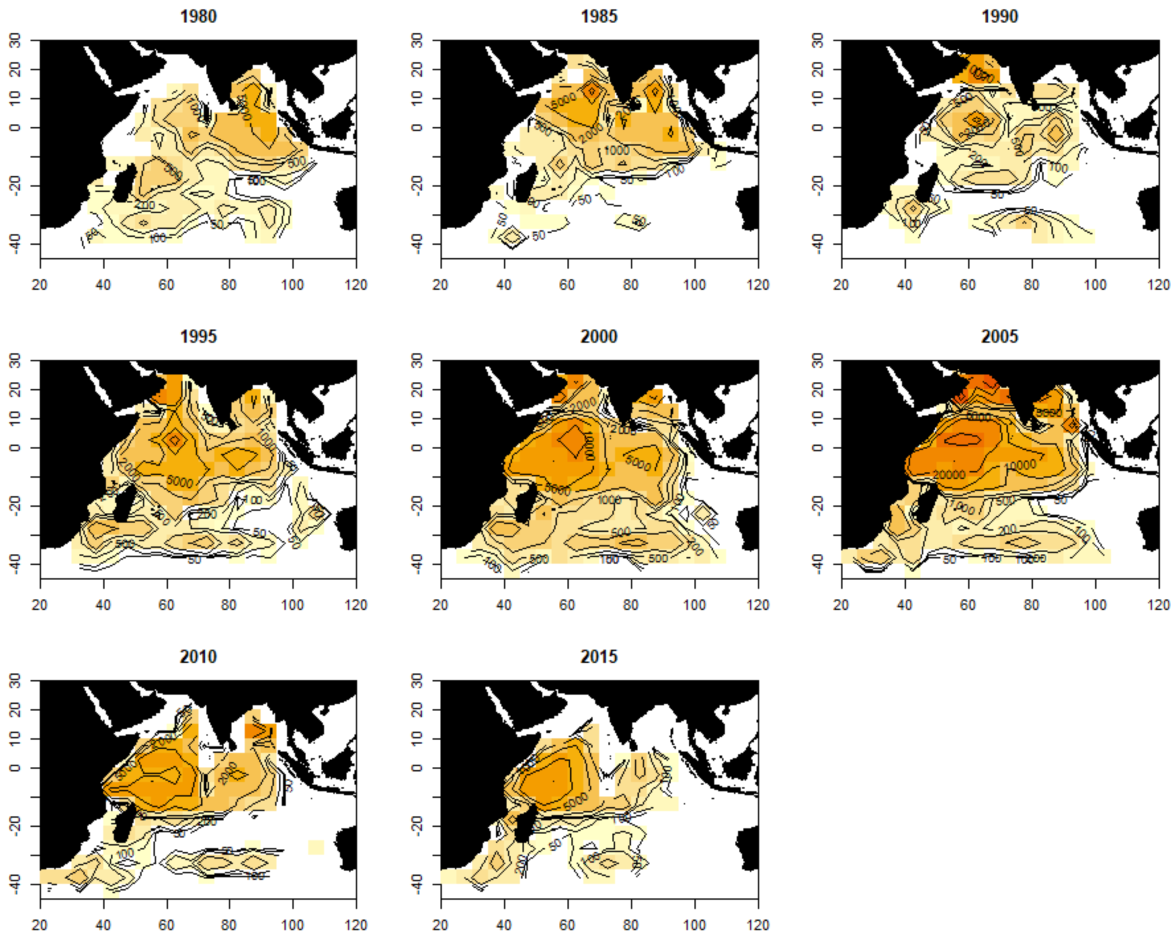


Figure 5: Sampling locations of Taiwanese 5 x 5 yellowfin size data in IOTC dataset.

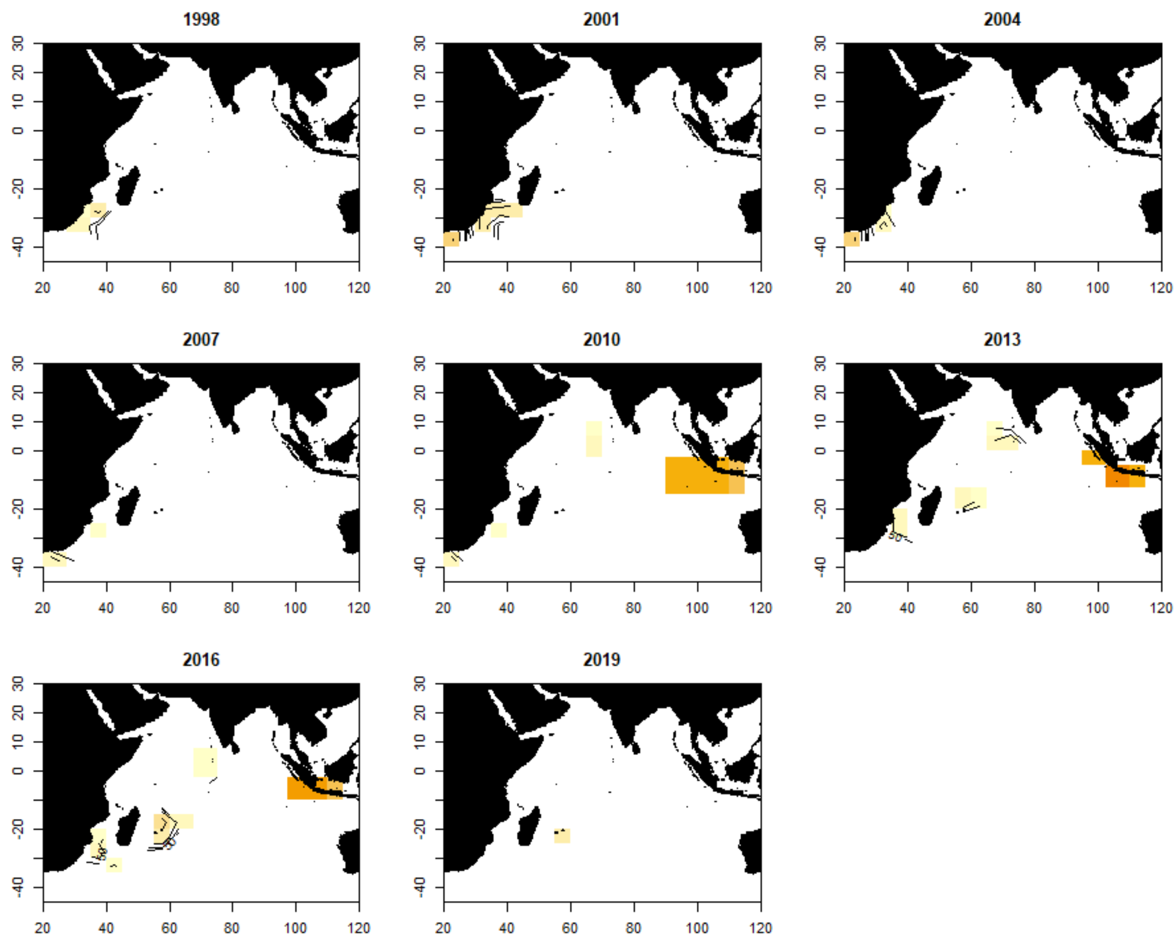


Figure 6: Sampling locations of other fleets 5 x 5 yellowfin size data in IOTC dataset.

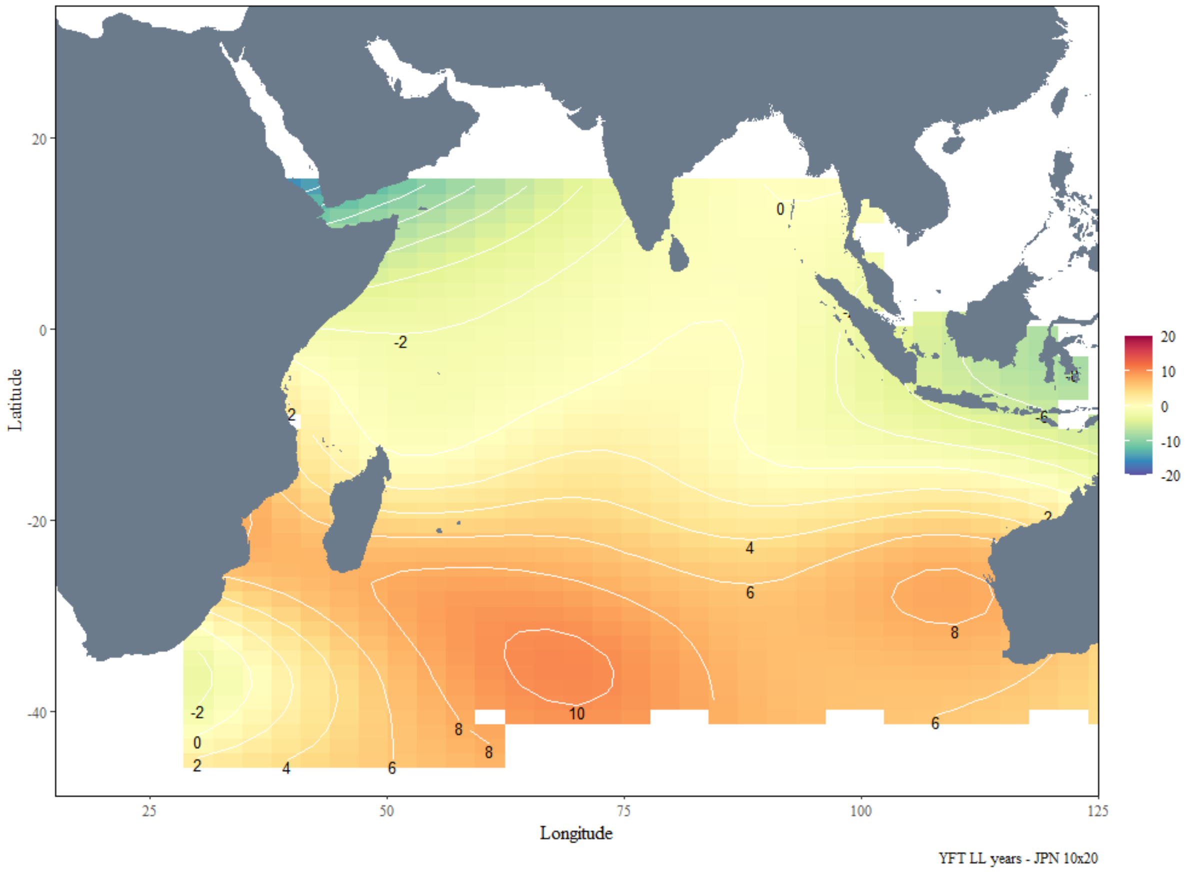


Figure 7: Map of predicted relative lengths from gam model of Japanese 10 x 20 size (lengths and converted weights) data for yellowfin tuna held by IOTC.

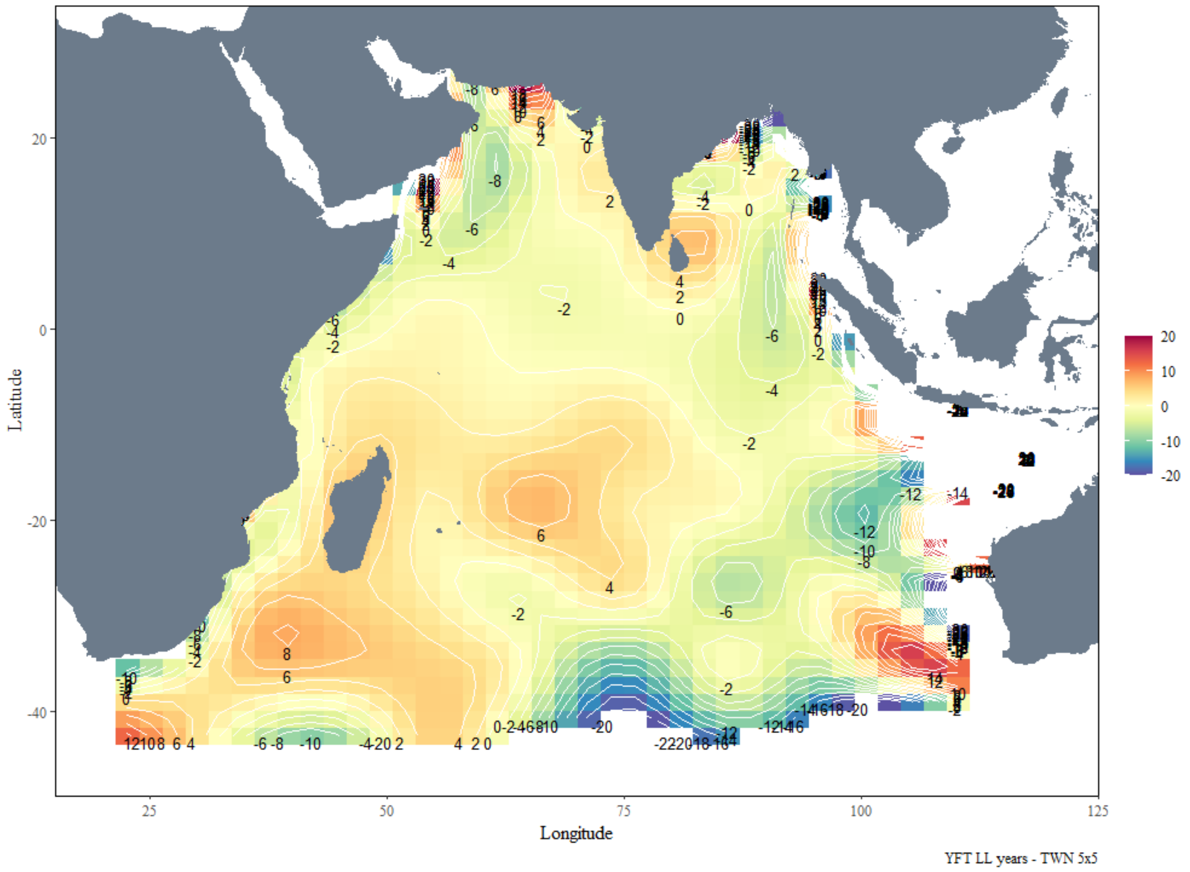


Figure 8: Map of predicted relative lengths from gam model of Taiwanese 5 x 5 length data for yellowfin tuna held by IOTC.

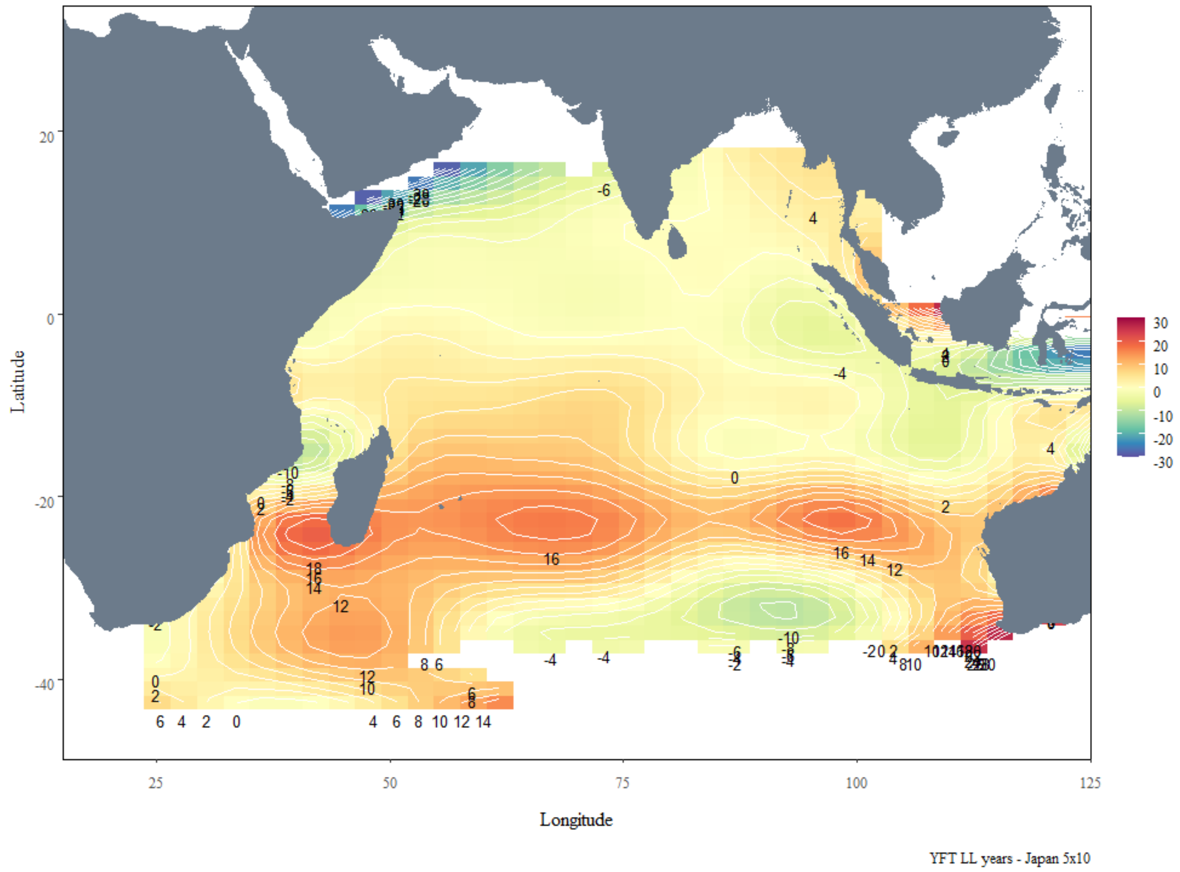


Figure 9: Map of predicted relative lengths from gam model at 5 x 10 resolution of Japanese 5 x 10 and 1 x 1 length data for yellowfin tuna held by Japan.

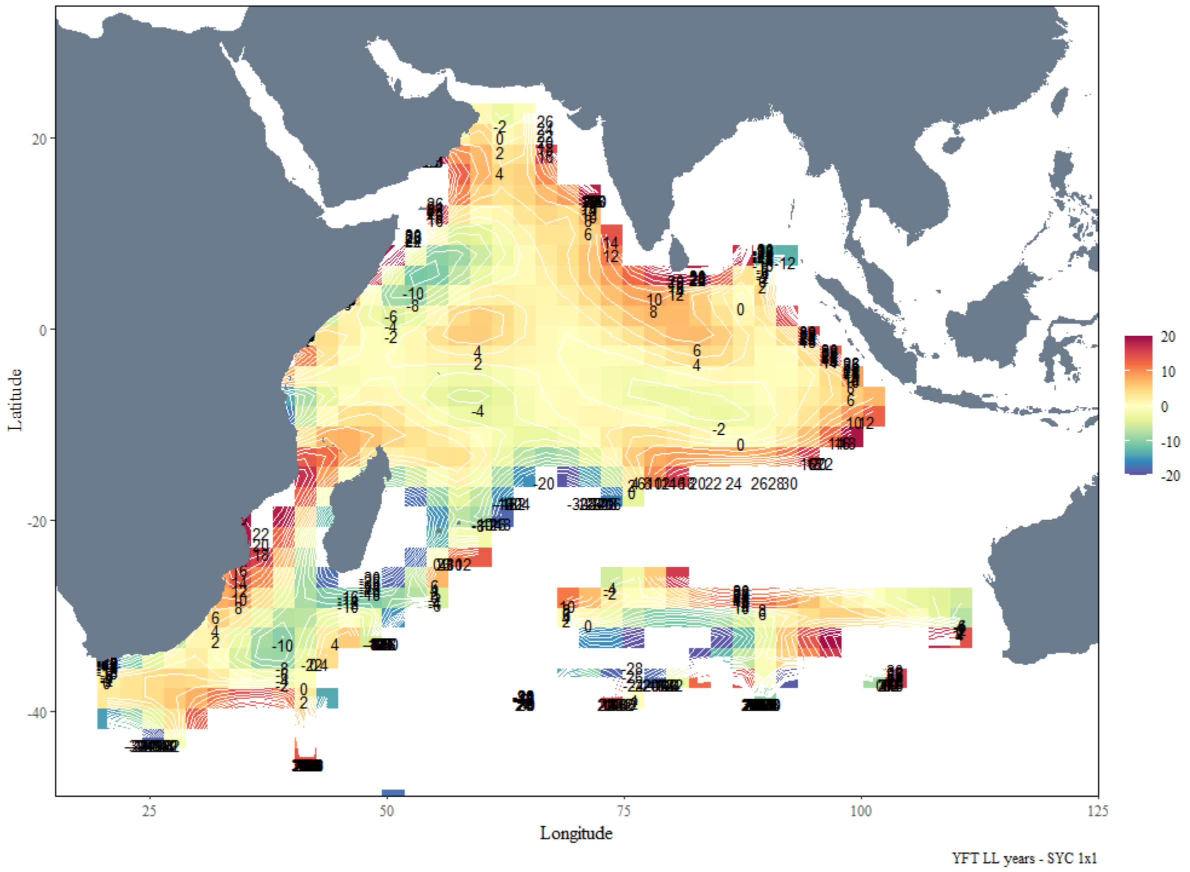


Figure 10: Map of predicted relative lengths from gam model of Seychelles 1 x 1 length data for yellowfin tuna held by IOTC.

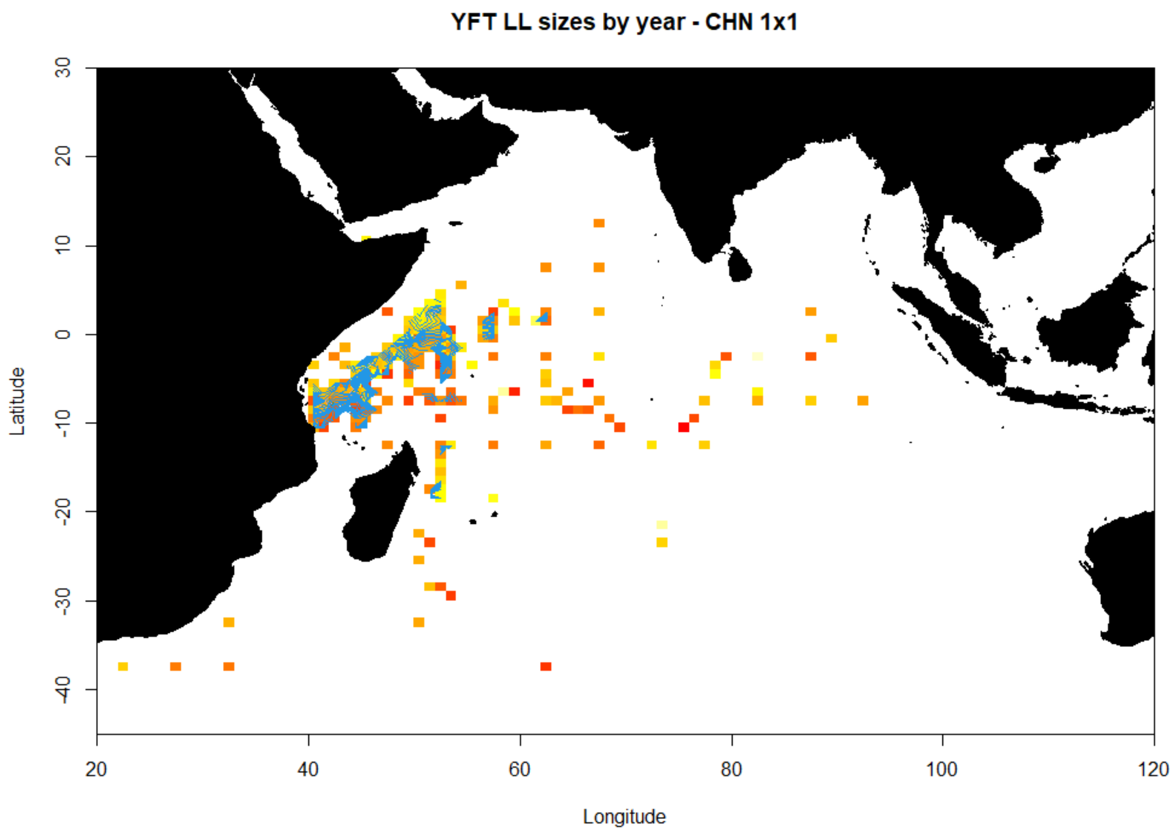


Figure 11: Map of predicted relative lengths from glm model of Chinese 1 x 1 length data for yellowfin tuna held by IOTC.

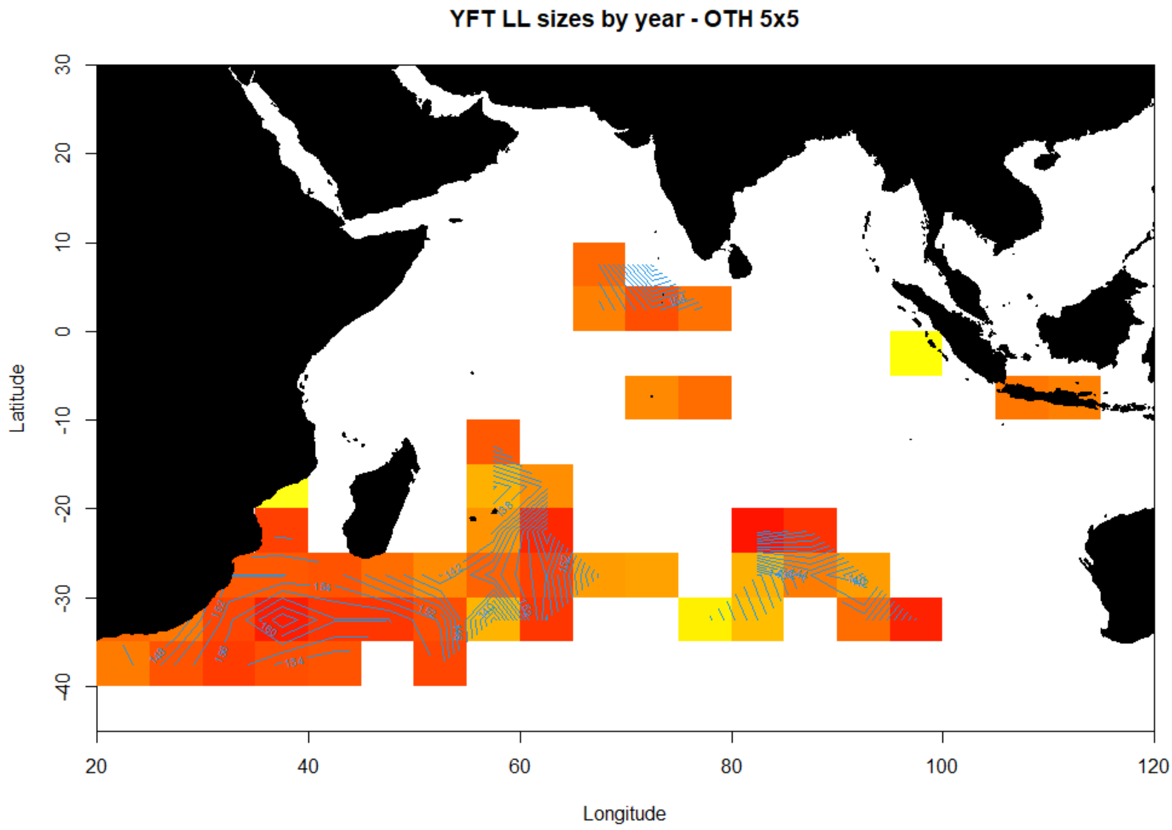


Figure 12: Map of predicted lengths from glm model of other flags 5 x 5 size data (lengths and converted weights) for yellowfin tuna held by IOTC.

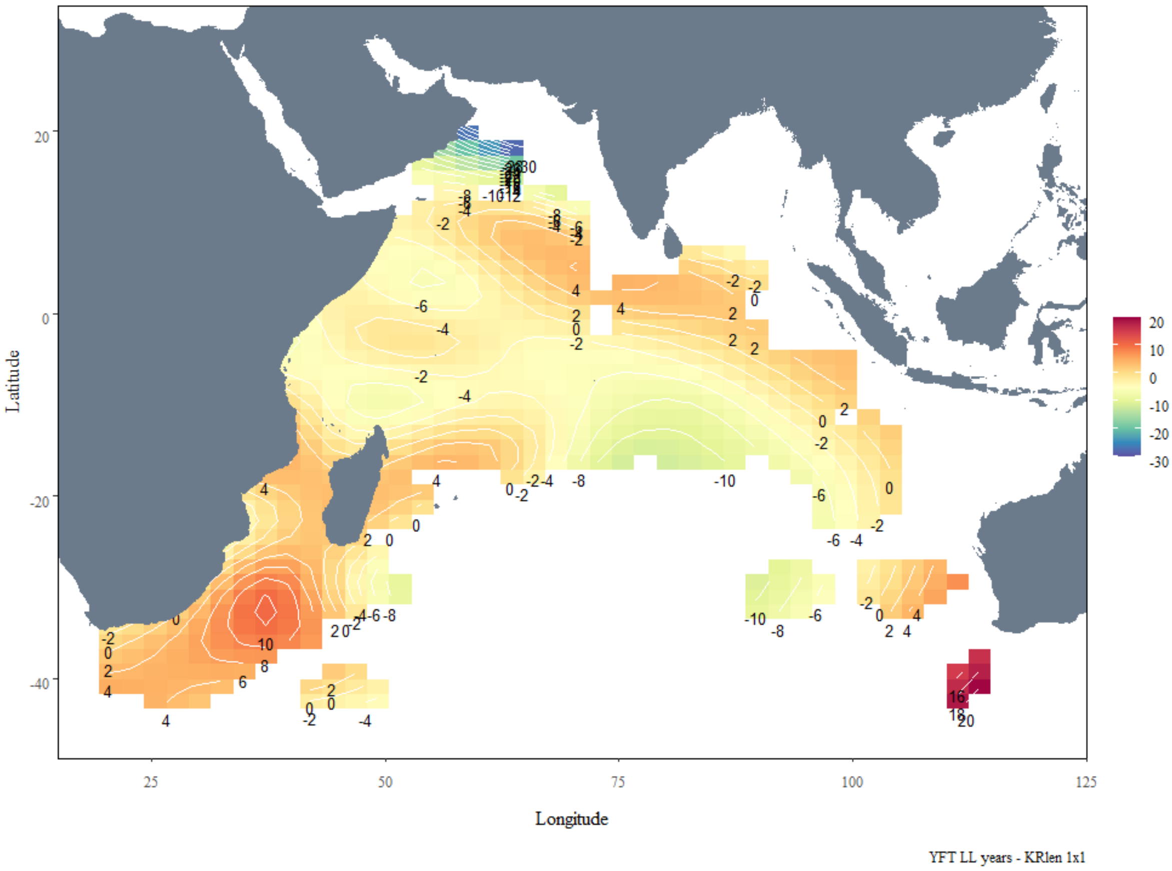


Figure 13: Map of predicted lengths from gam model of Korean 1 x 1 length data for yellowfin tuna held by the Korean government.

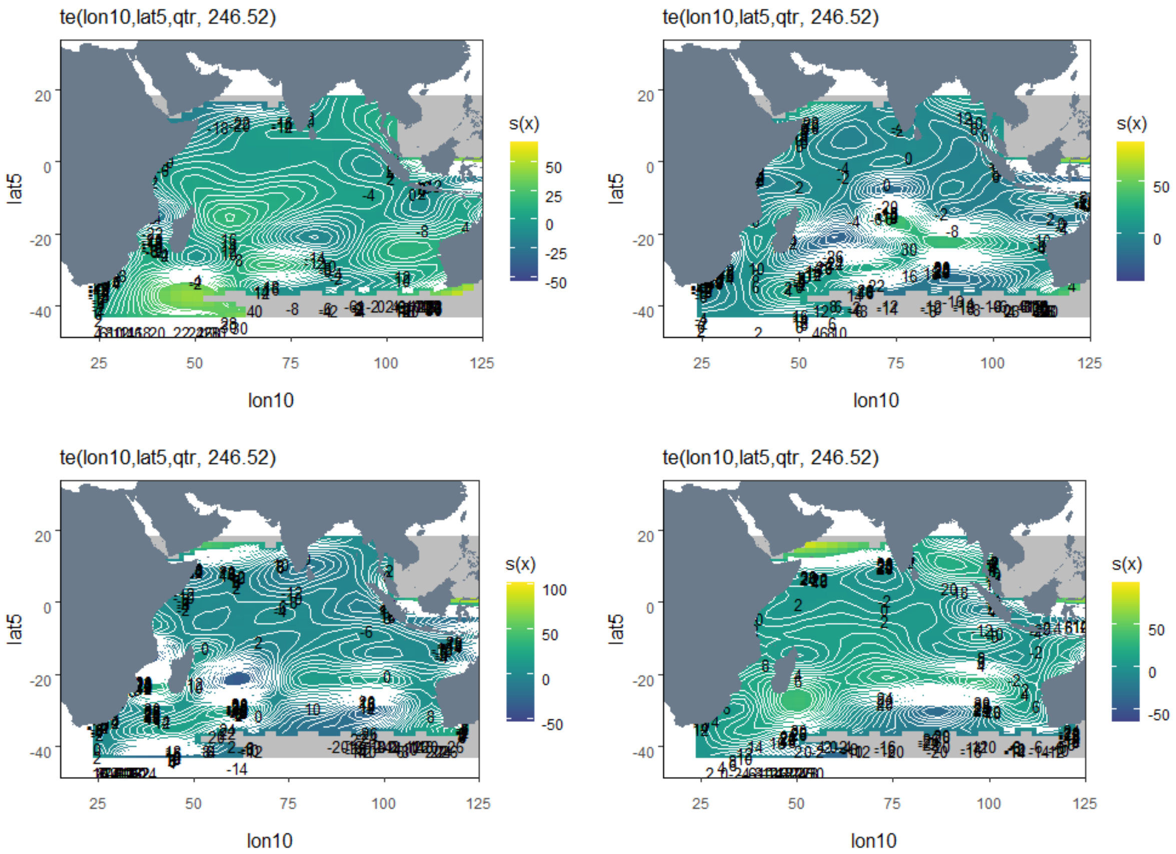


Figure 14: Quarterly maps of predicted relative lengths from gam model at 5 x 10 resolution of Japanese 5 x 10 and 1 x 1 length data for yellowfin tuna held by Japan.

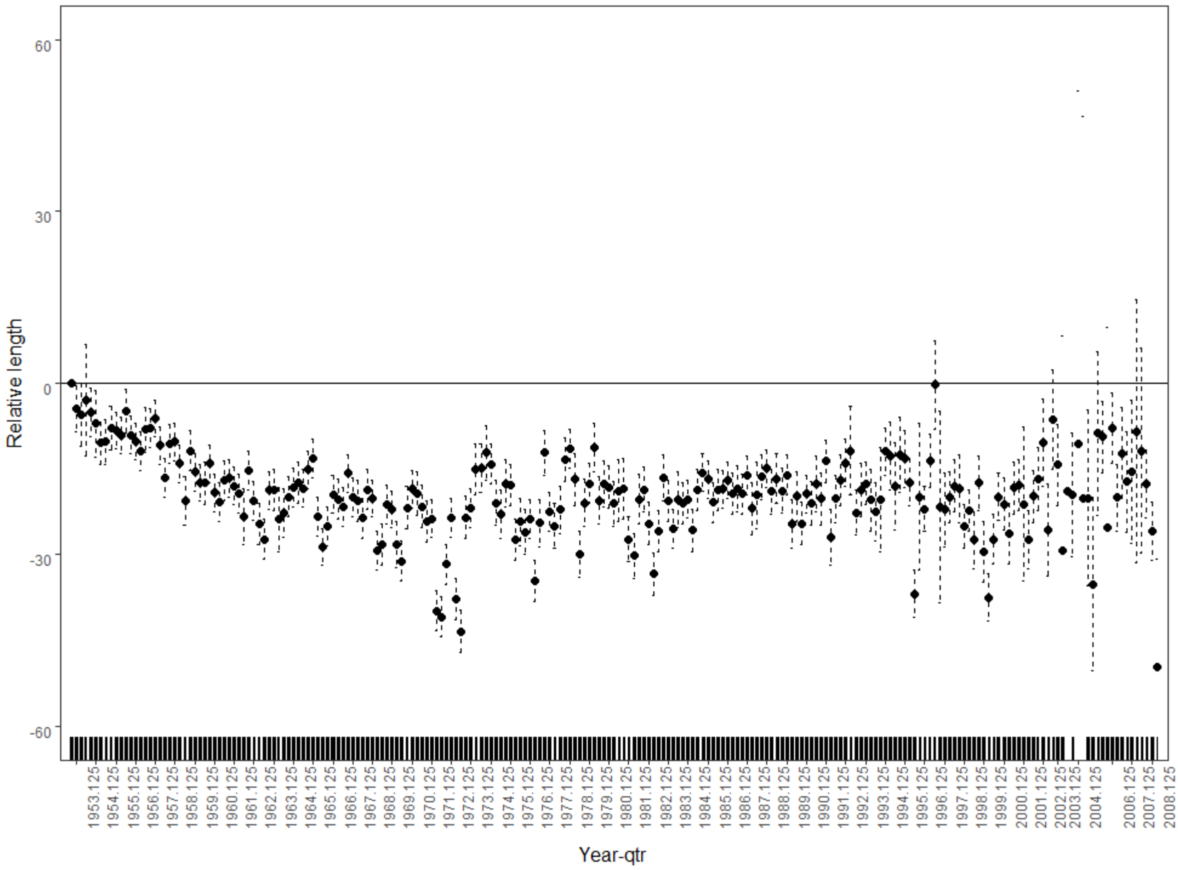


Figure 15: Plot of predicted relative lengths by year-quarter from gam model of Japanese 10 x 20 yellowfin tuna size data (lengths and converted weights) held by IOTC.

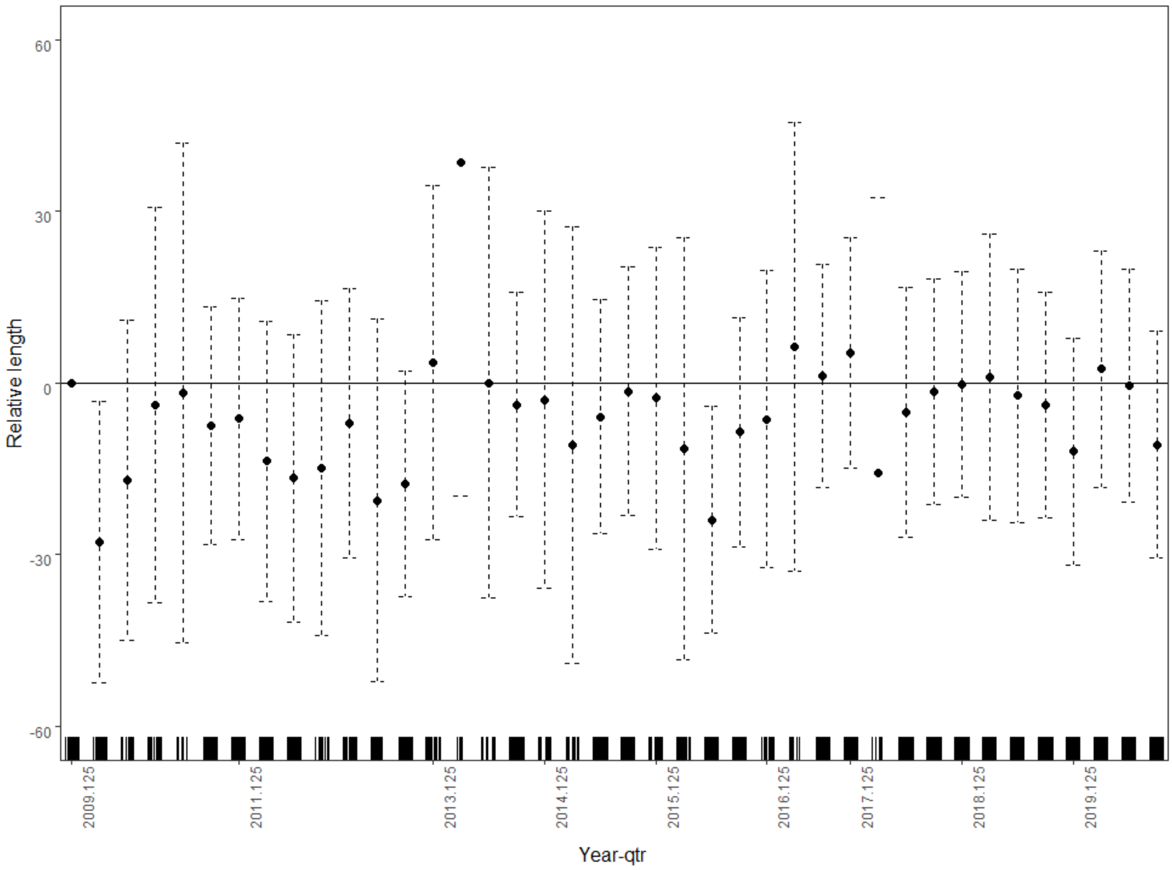


Figure 16: Plot of predicted relative lengths by year-quarter from gam model of Japanese 5 x 5 yellowfin tuna size data (lengths and converted weights) held by IOTC.

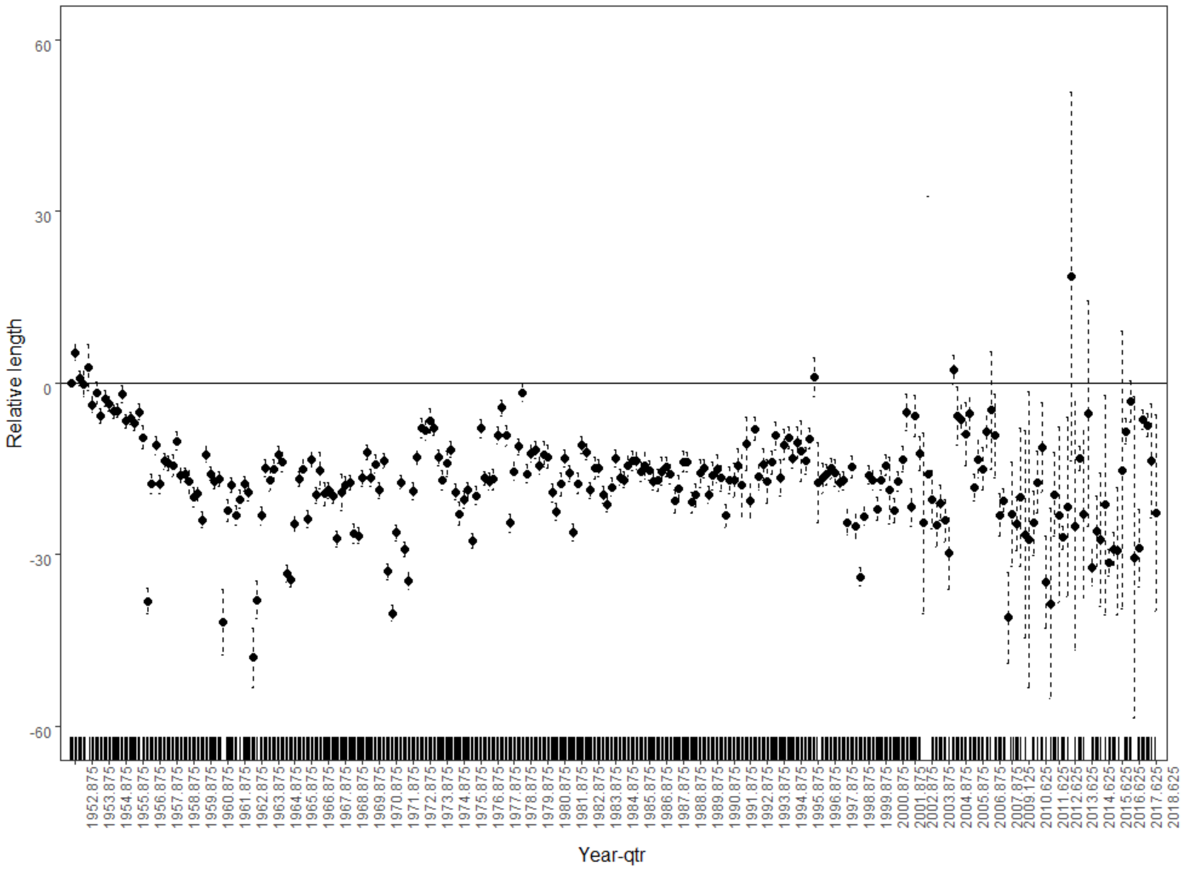


Figure 17: Plot of predicted relative lengths by year-quarter from gam model at 5 x 10 resolution of Japanese 5 x 10 and 1 x 1 yellowfin tuna length data held by Japan.

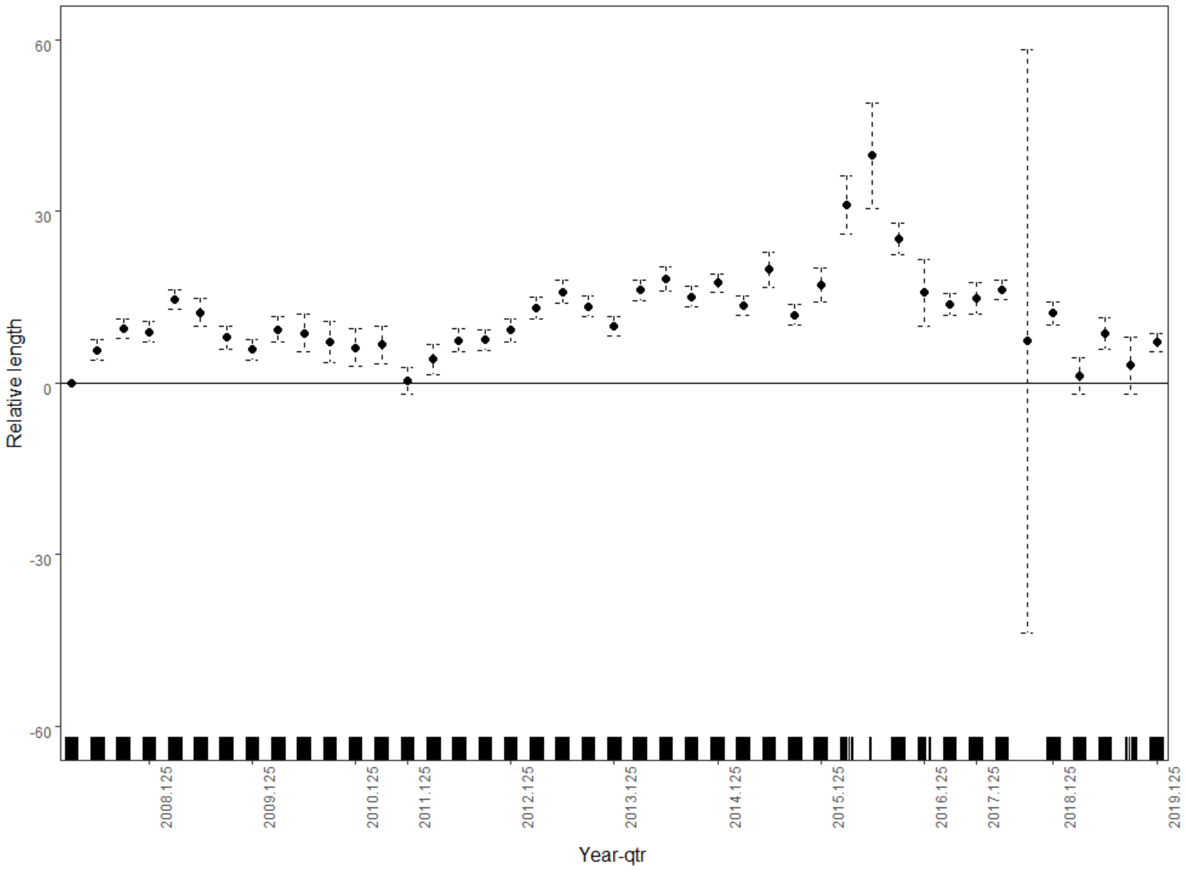


Figure 18: Plot of predicted relative lengths by year-quarter from gam model of Seychelles 1 x 1 yellowfin tuna length data held by IOTC.

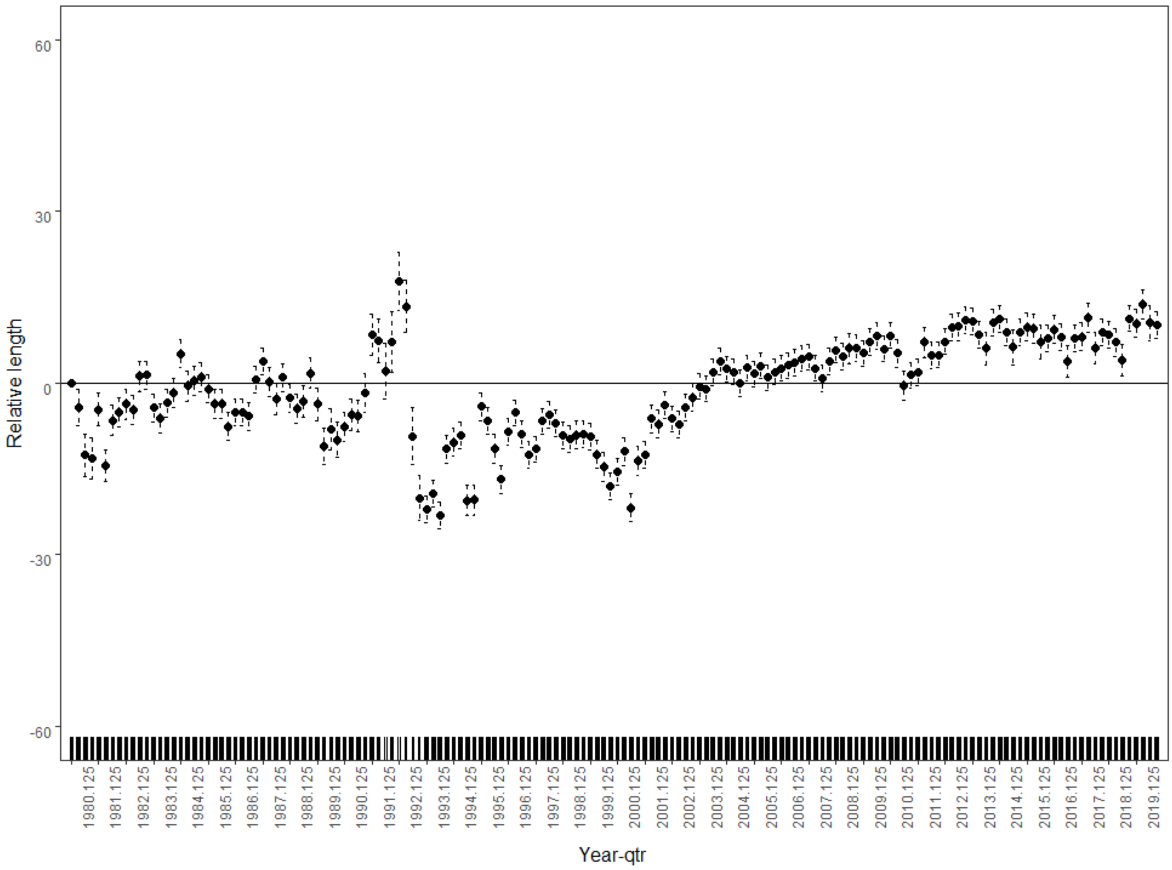


Figure 19: Plot of predicted relative lengths by year-quarter from gam model of Taiwanese 5 x 5 yellowfin tuna length data held by IOTC.

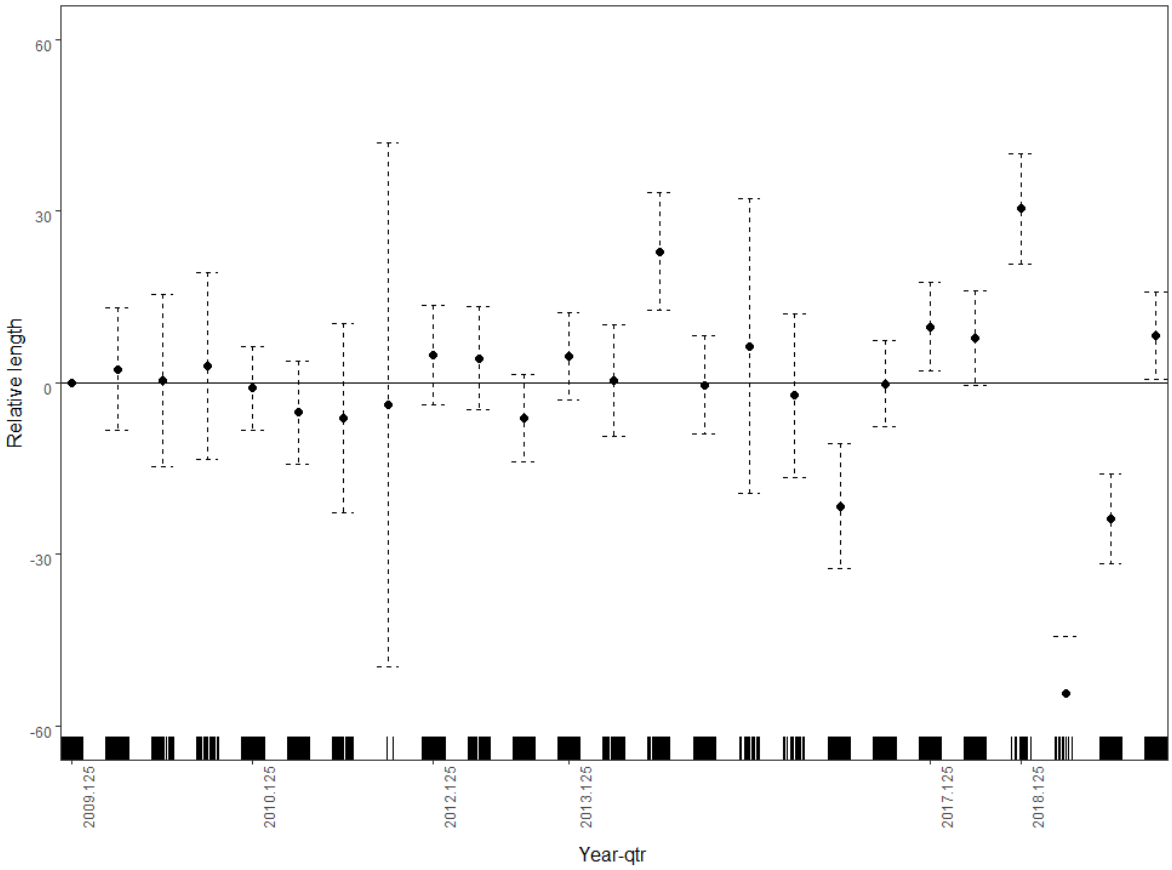


Figure 20: Plot of predicted relative lengths by year-quarter from gam model of Chinese 1 x 1 yellowfin tuna length data held by IOTC.

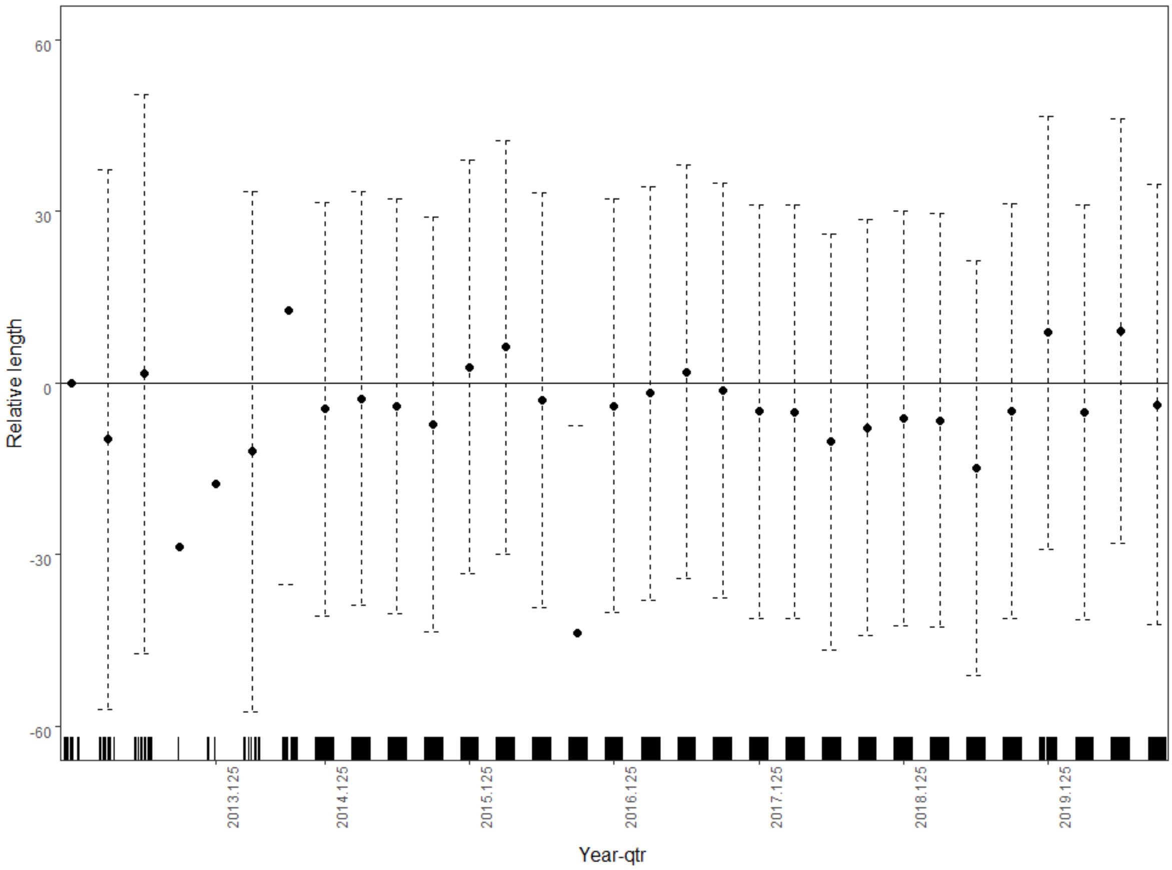


Figure 21: Plot of predicted relative lengths by year-quarter from gam model of other fleets 5 x 5 yellowfin tuna length data held by IOTC.

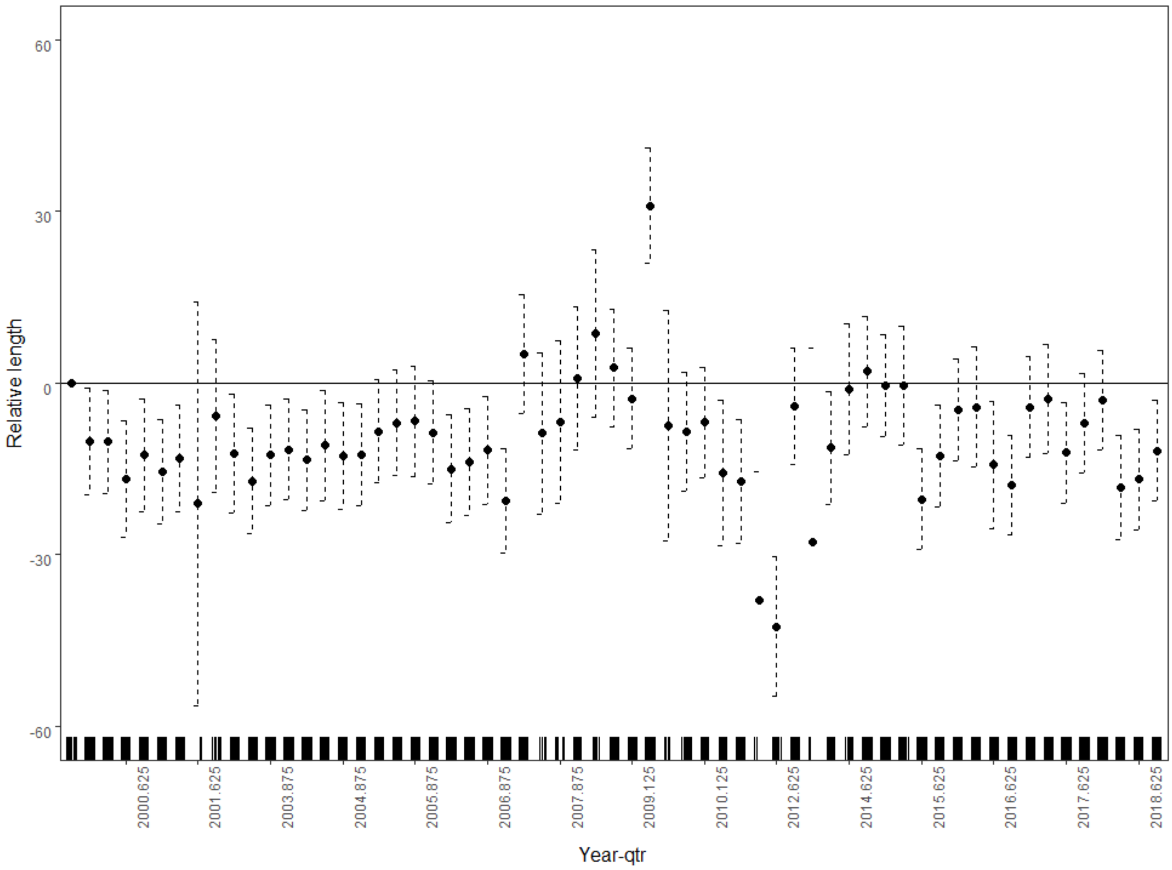


Figure 22: Plot of predicted relative lengths by year-quarter from gam model of Korean 1 x 1 yellowfin tuna length data provided by the Korean government.

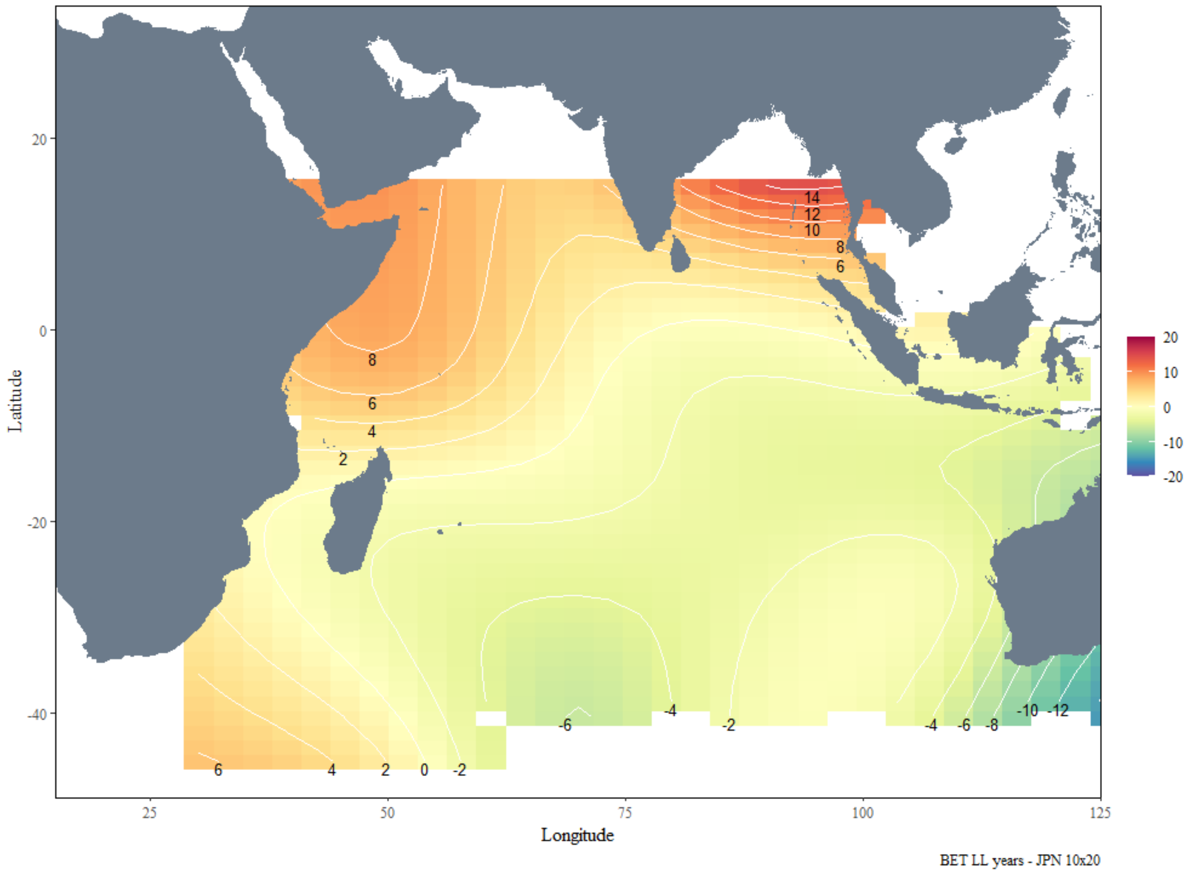


Figure 23: Map of predicted relative lengths from gam model of Japanese 10 x 20 size (lengths and converted weights) data for bigeye tuna held by IOTC.

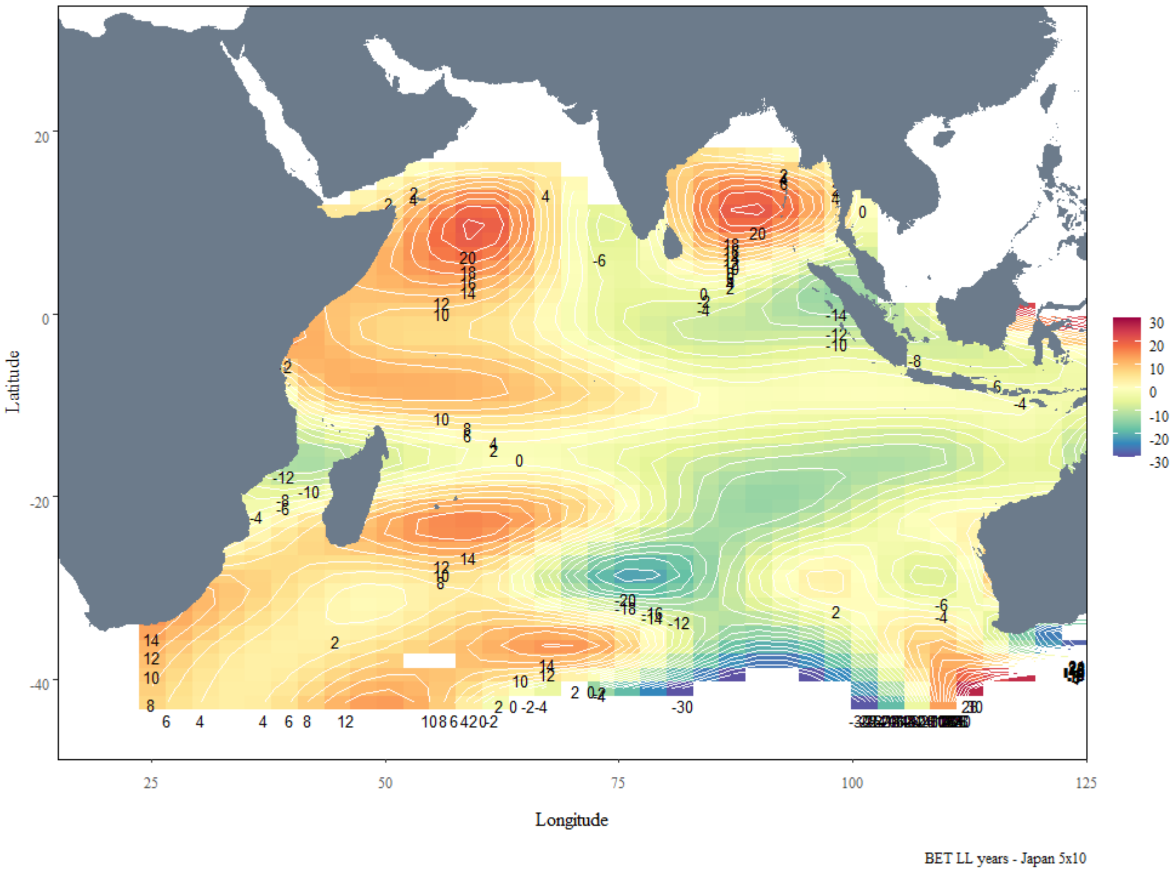


Figure 24: Map of predicted relative lengths from gam model at 5 x 10 resolution of Japanese 5 x 10 and 1 x 1 length data for bigeye tuna held by Japan.

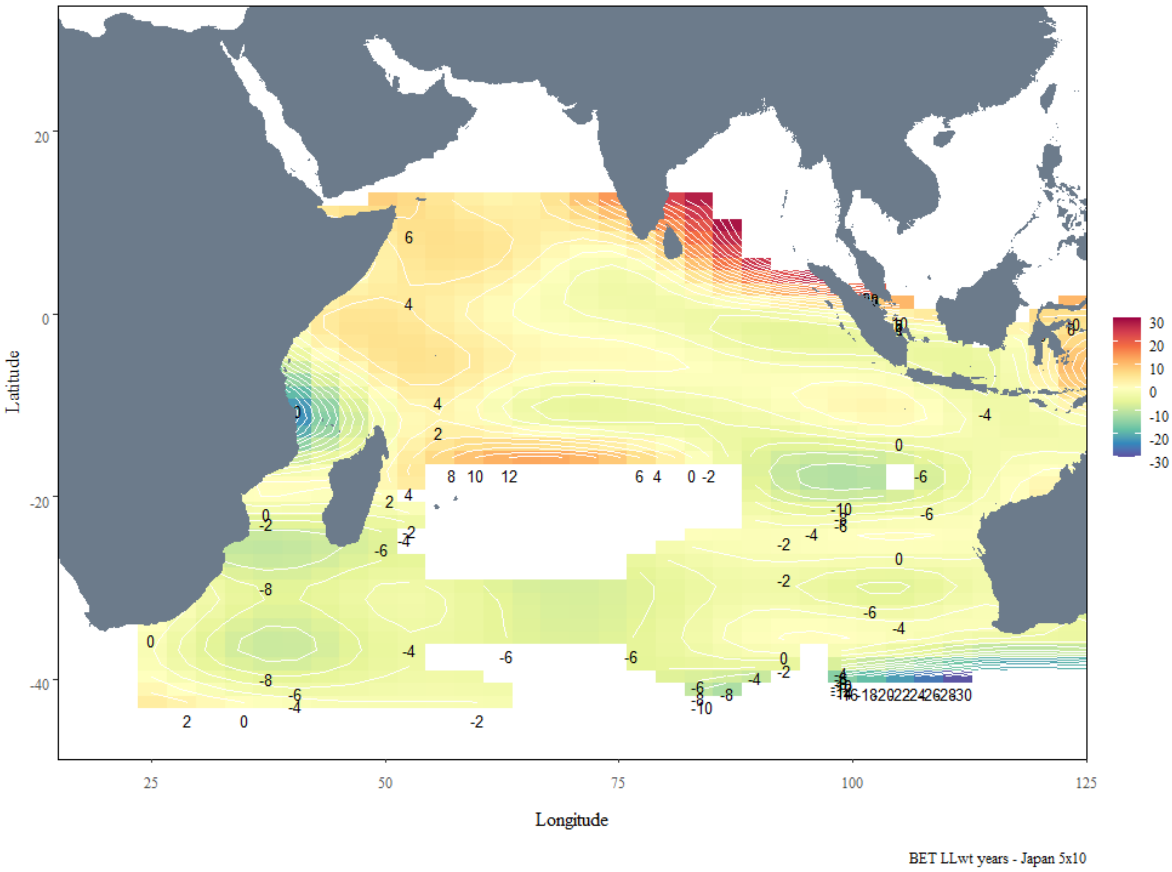


Figure 25: Map of predicted relative weights from gam model at 5 x 10 resolution of Japanese 5 x 10 and 1 x 1 weight data for bigeye tuna held by Japan.

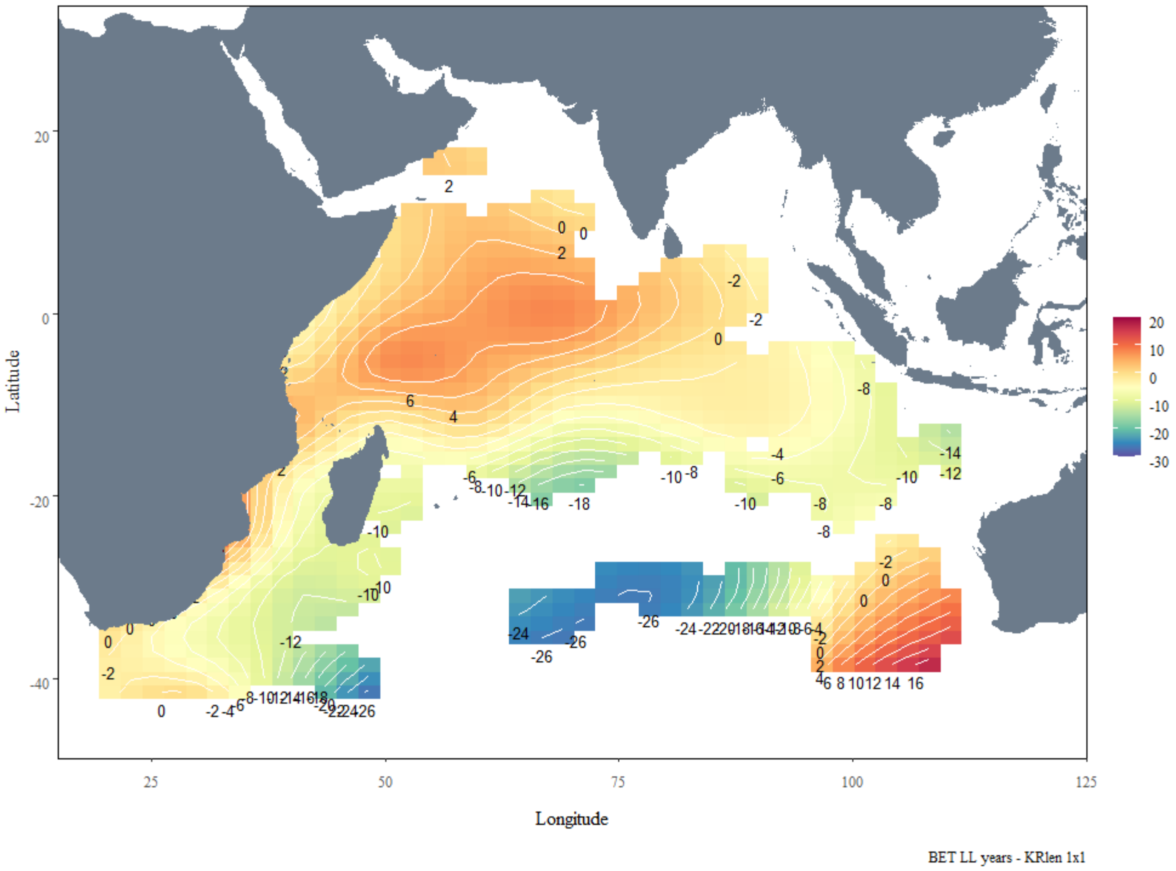


Figure 26: Map of predicted relative lengths from gam model of Korean 1 x 1 observer length data for bigeye tuna held by the Korean government.

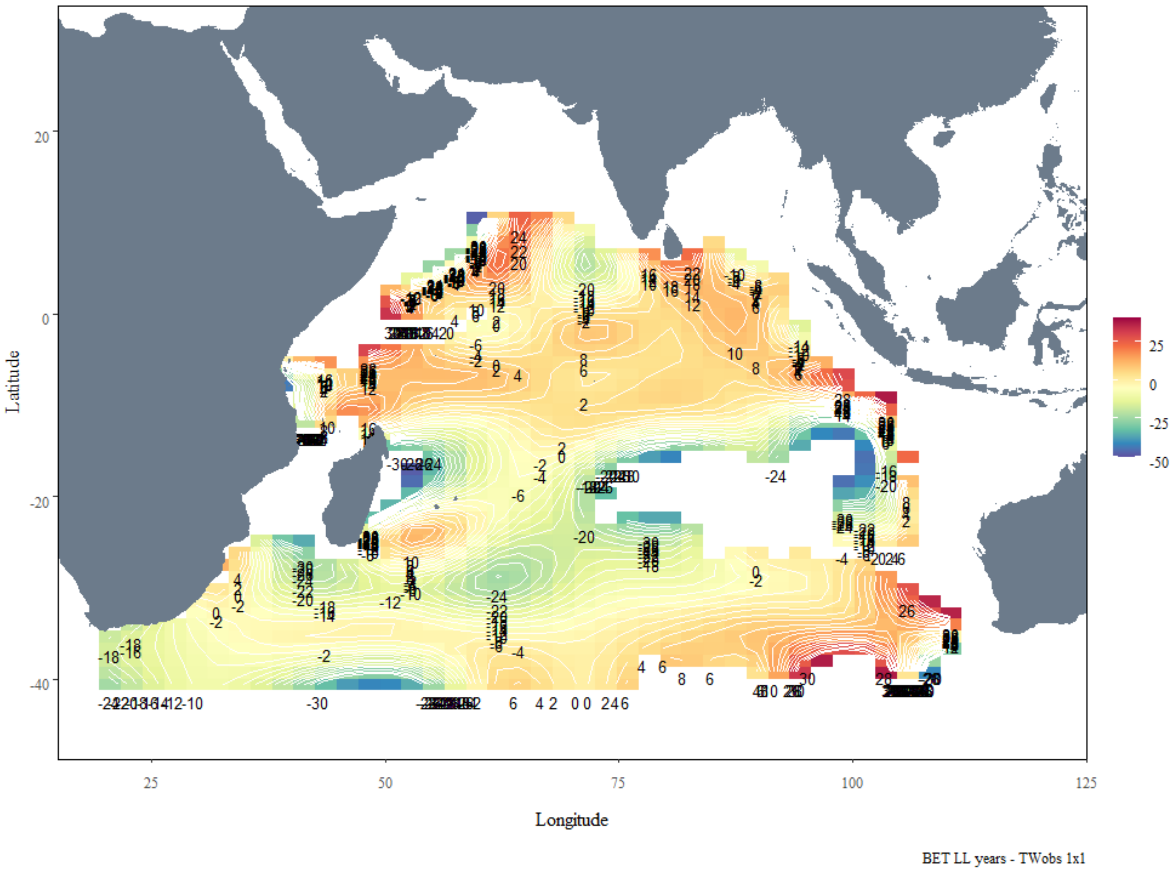


Figure 27: Map of predicted relative lengths from gam model of Taiwanese 1 x 1 observer length data for bigeye tuna held by the Taiwanese government.

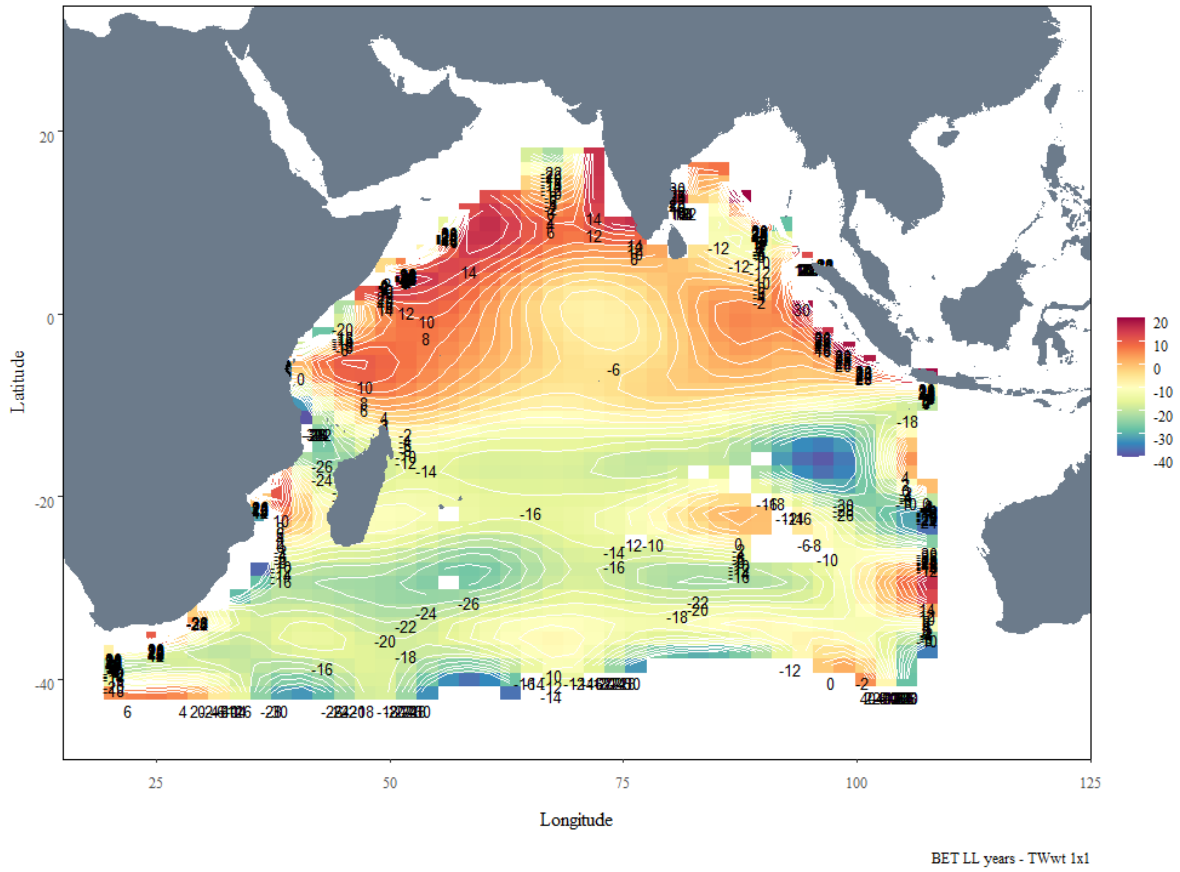


Figure 28: Map of predicted relative weights from gam model of Taiwanese 1 x 1 weight data for bigeye tuna held by the Taiwanese government.

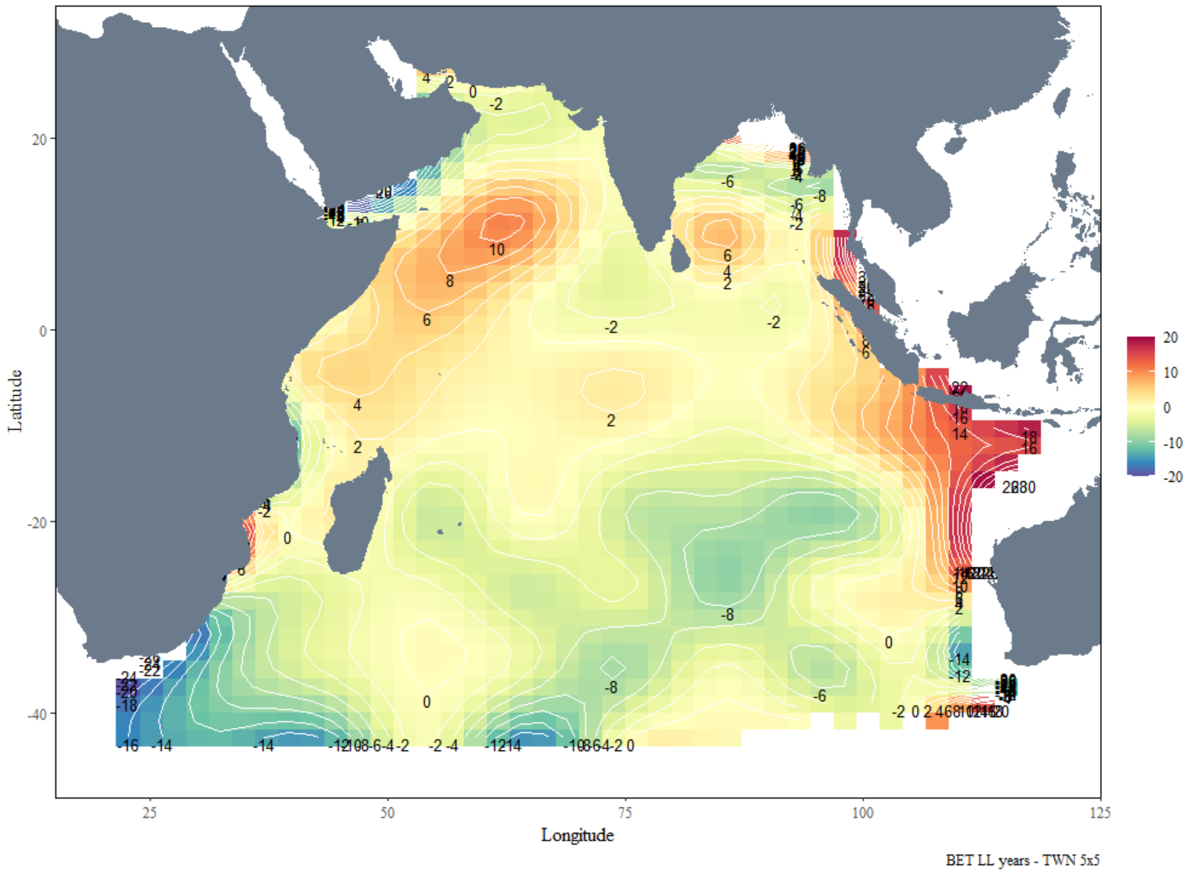


Figure 29: Map of predicted relative lengths from gam model of Taiwanese 5 x 5 length data for bigeye tuna held by the IOTC.

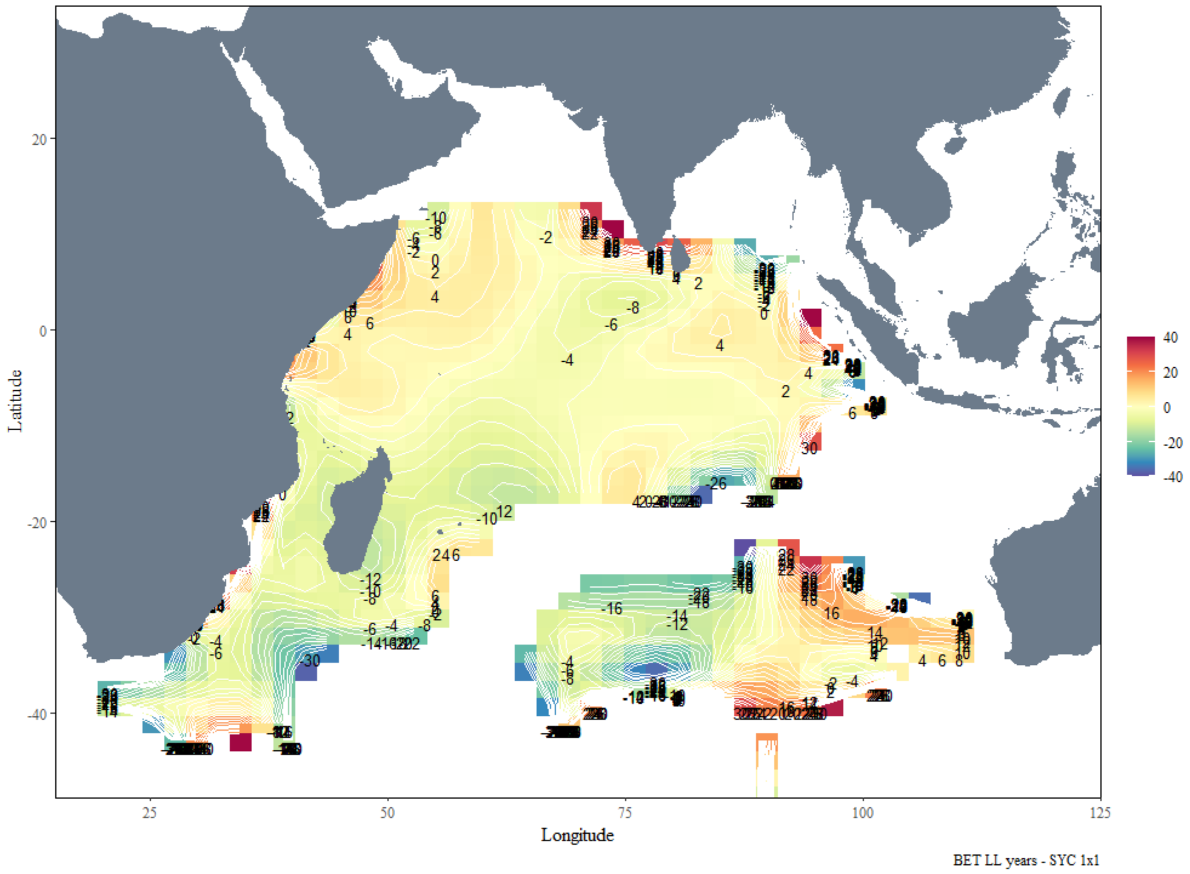


Figure 30: Map of predicted relative lengths from gam model of Seychelles 1 x 1 length data for bigeye tuna held by the IOTC.

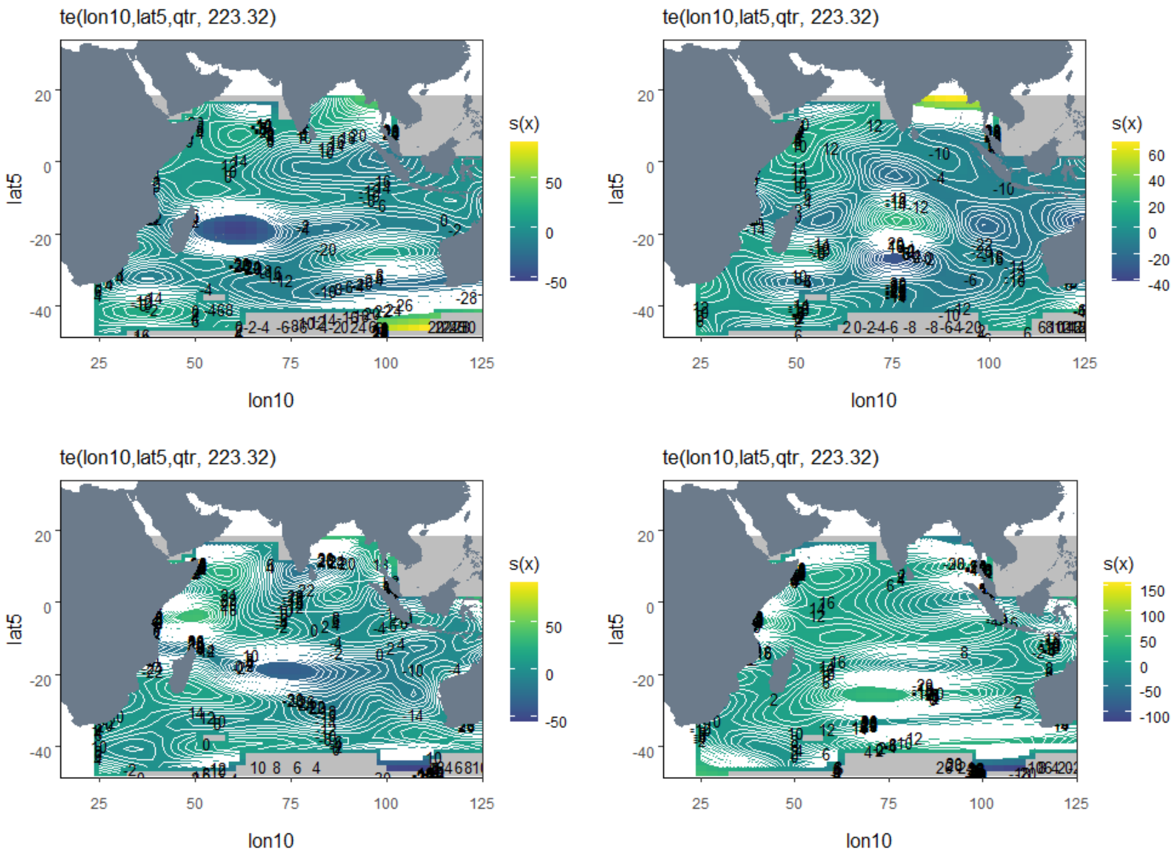


Figure 31: Quarterly maps of predicted relative lengths from gam model at 5 x 10 resolution of Japanese 5 x 10 and 1 x 1 length data for bigeye tuna held by Japan.

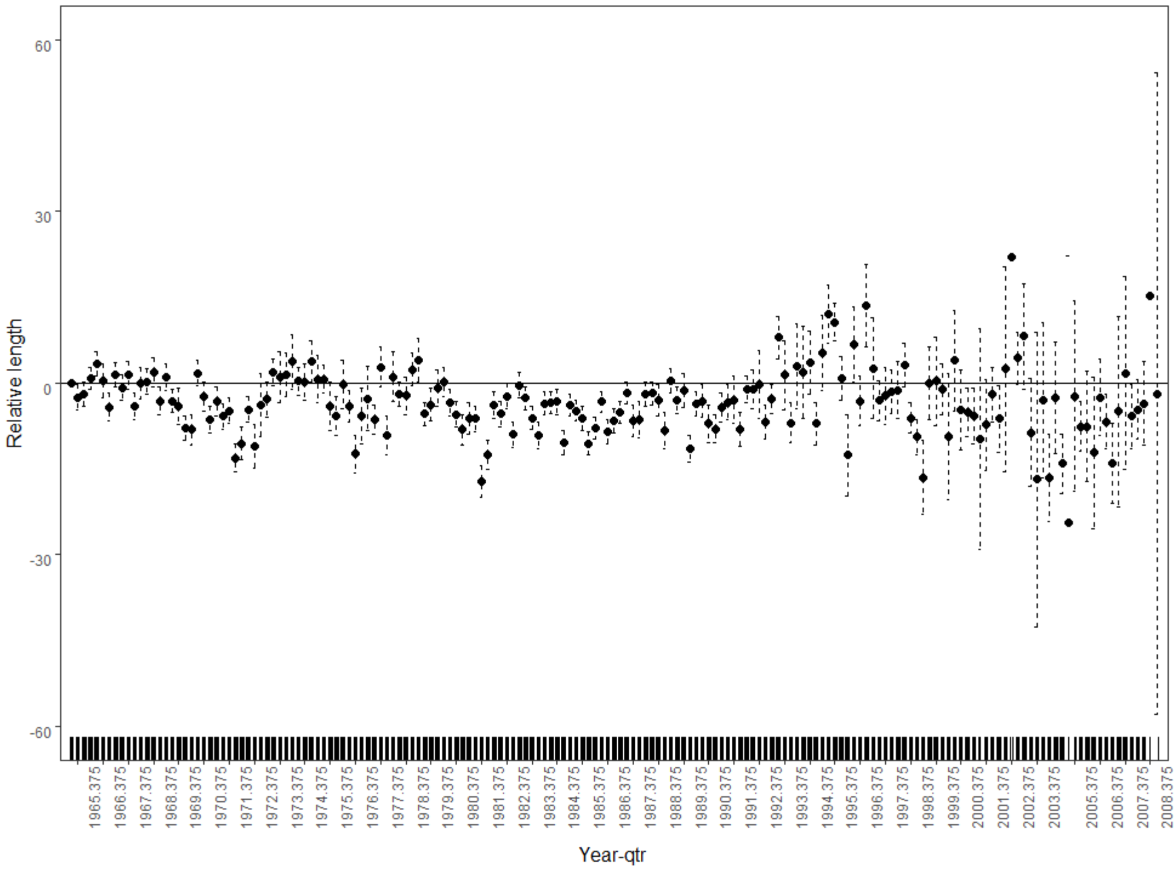


Figure 32: Plot of predicted relative lengths by year-quarter from gam model at 5 x 10 resolution of Japanese 10 x 20 bigeye tuna length and converted weight data held by IOTC.

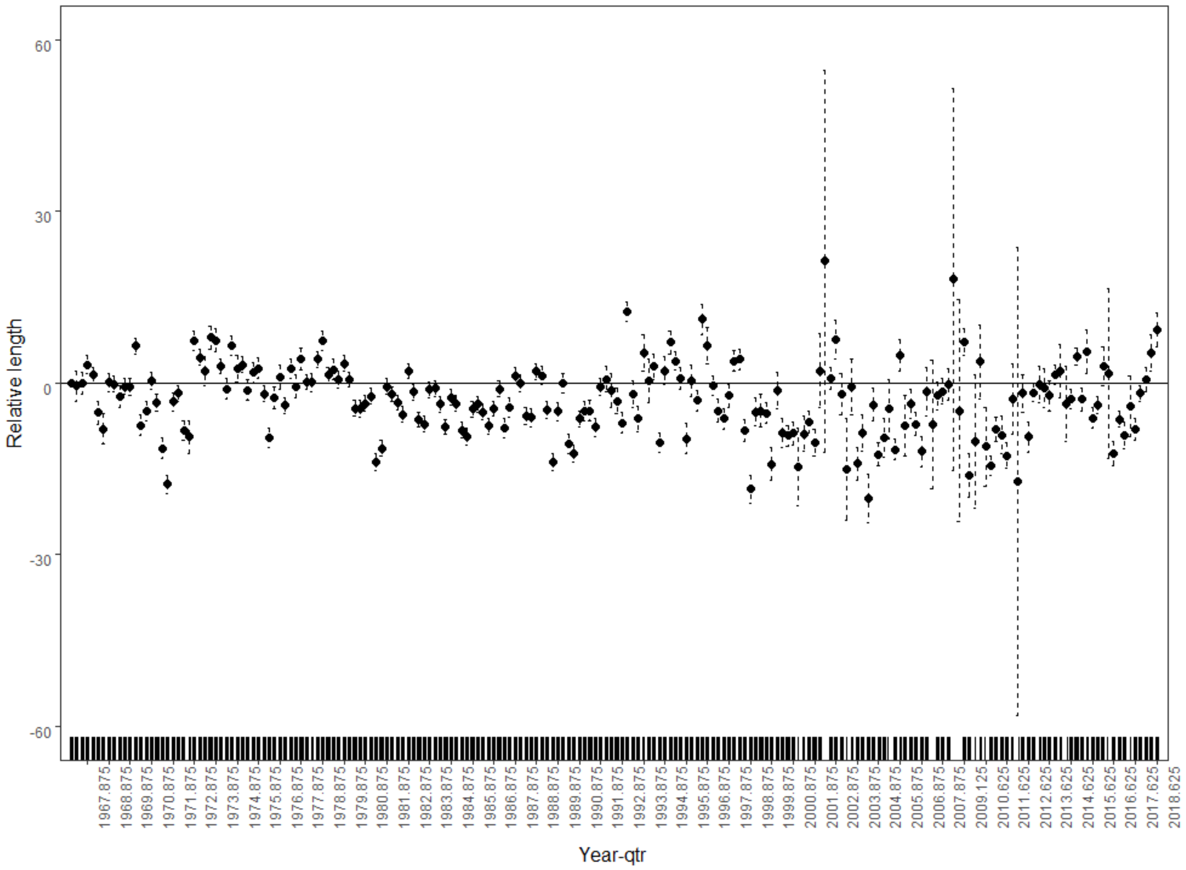


Figure 33: Plot of predicted relative lengths by year-quarter from gam model at 5 x 10 resolution of Japanese 5 x 10 and 1 x 1 bigeye tuna length data held by Japan.

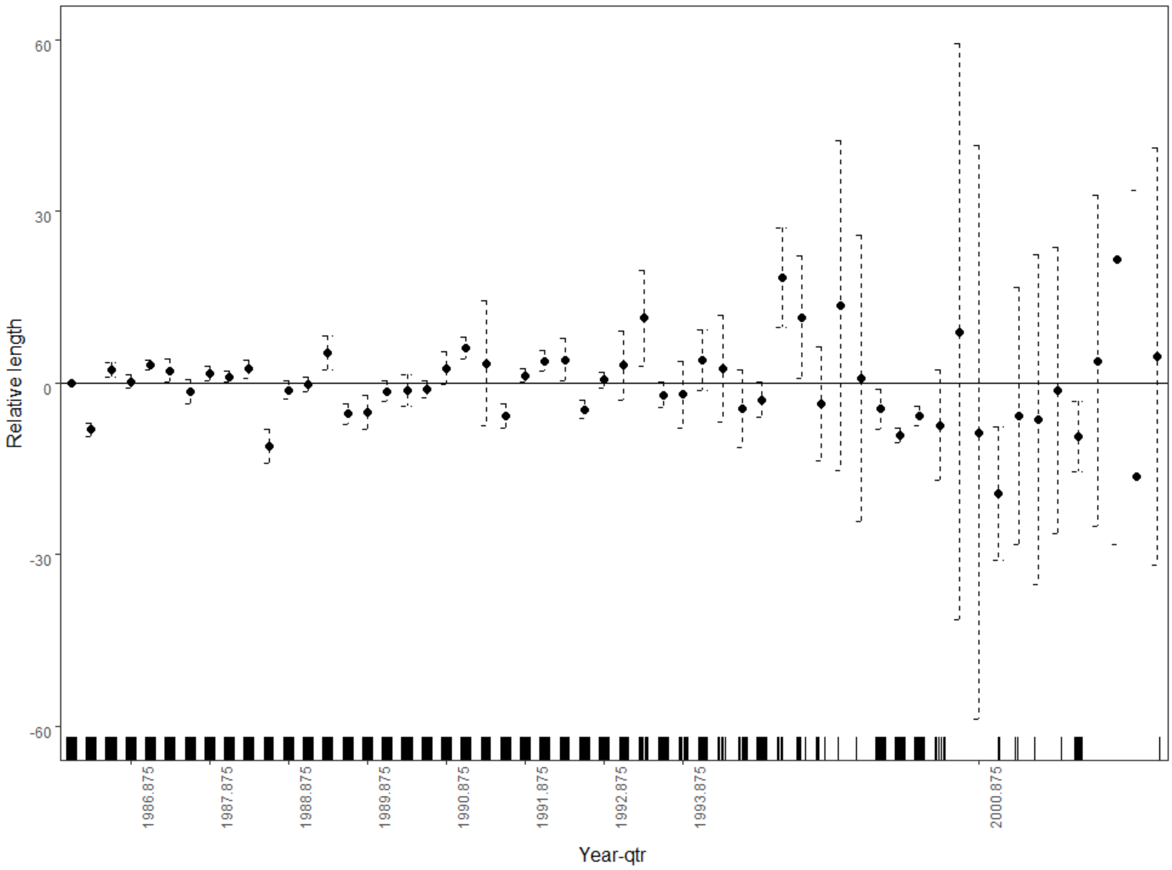


Figure 34: Plot of predicted relative weights by year-quarter from gam model at 5 x 10 resolution of Japanese 5 x 10 and 1 x 1 bigeye tuna weight data held by Japan.

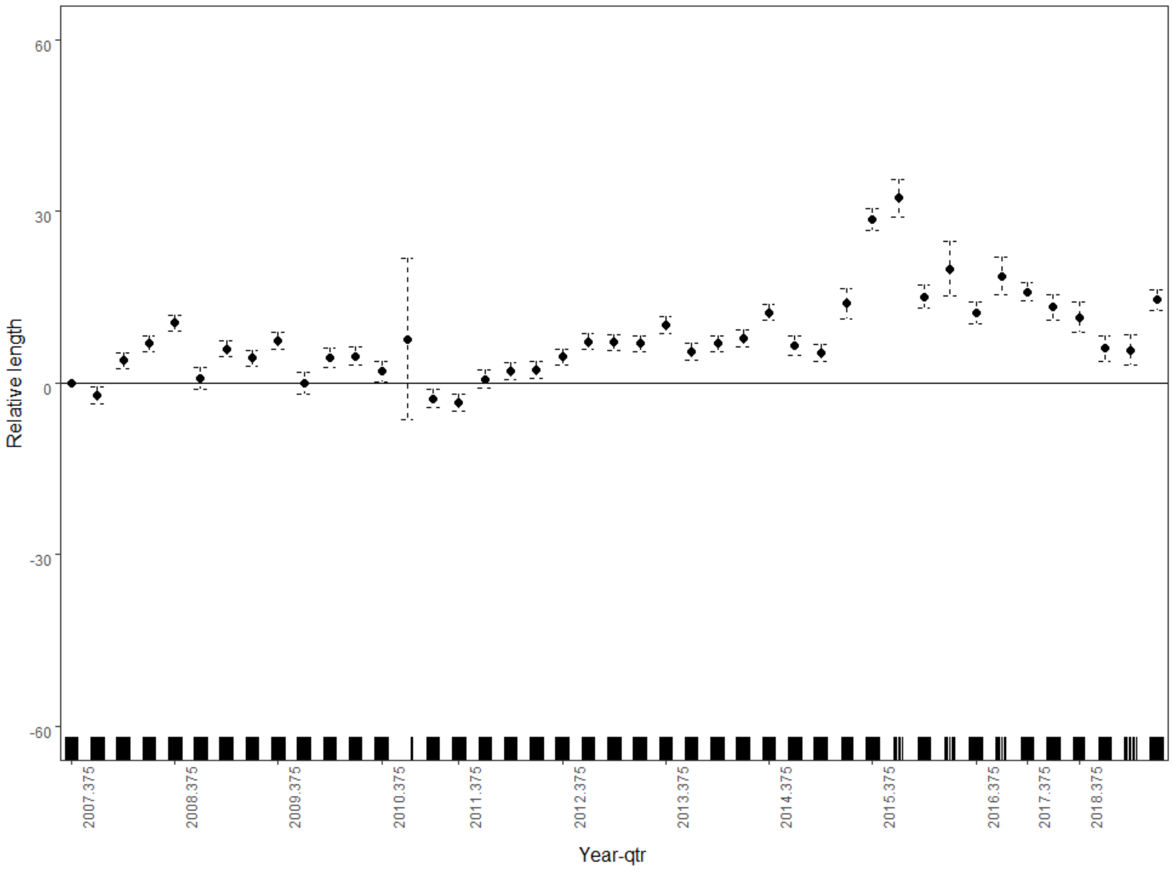


Figure 35: Plot of predicted relative lengths by year-quarter from gam model of Seychelles 1 x 1 bigeye tuna length data held by IOTC.

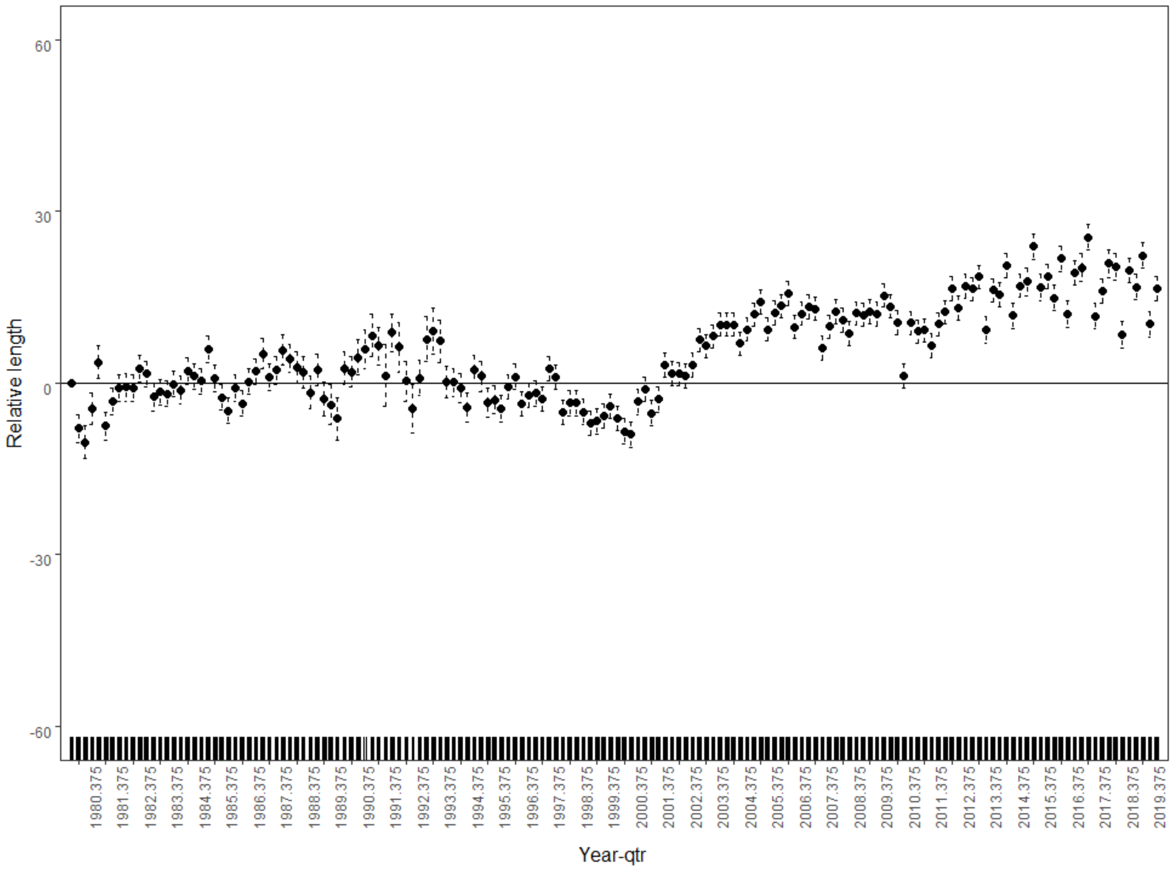


Figure 36: Plot of predicted relative lengths by year-quarter from gam model of Taiwanese 5 x 5 bigeye tuna length data held by IOTC.

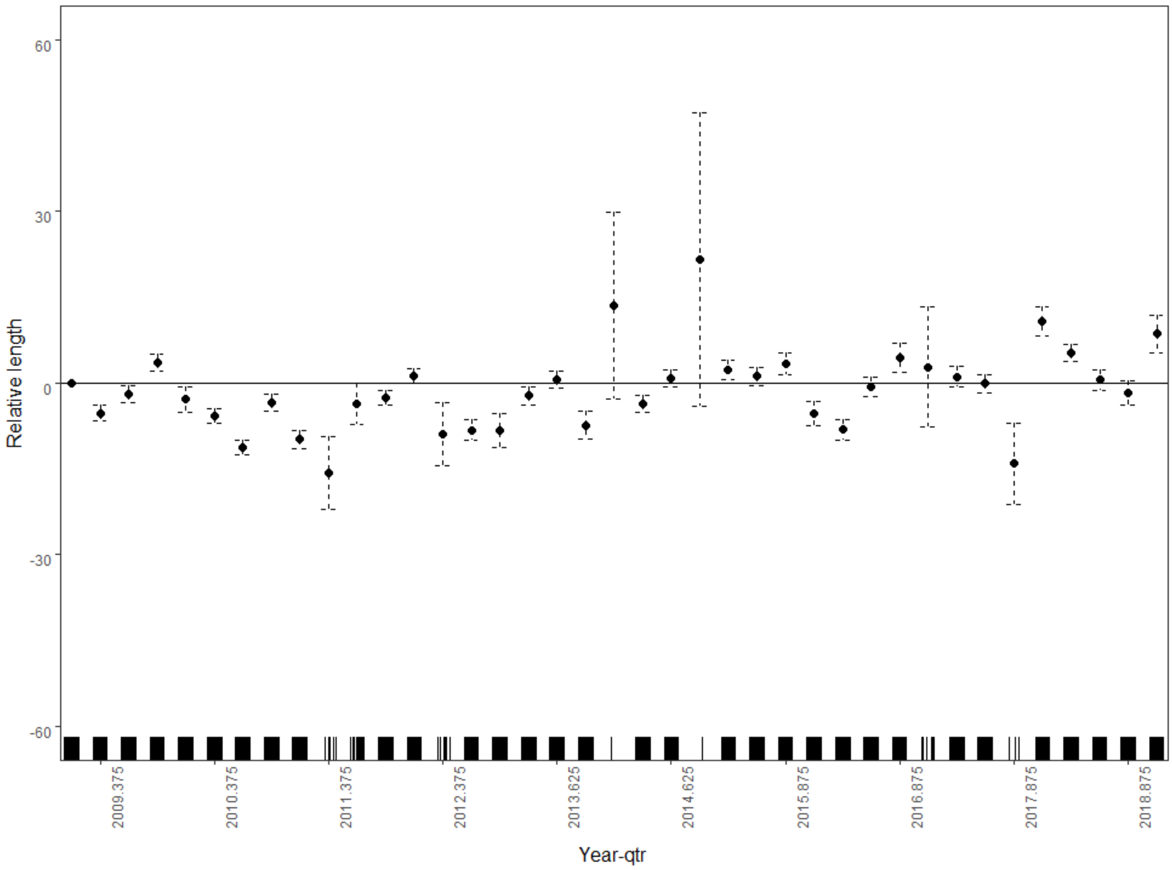


Figure 37: Plot of predicted relative lengths by year-quarter from gam model of Taiwanese observer 1 x 1 bigeye tuna length data held by the Taiwanese government.

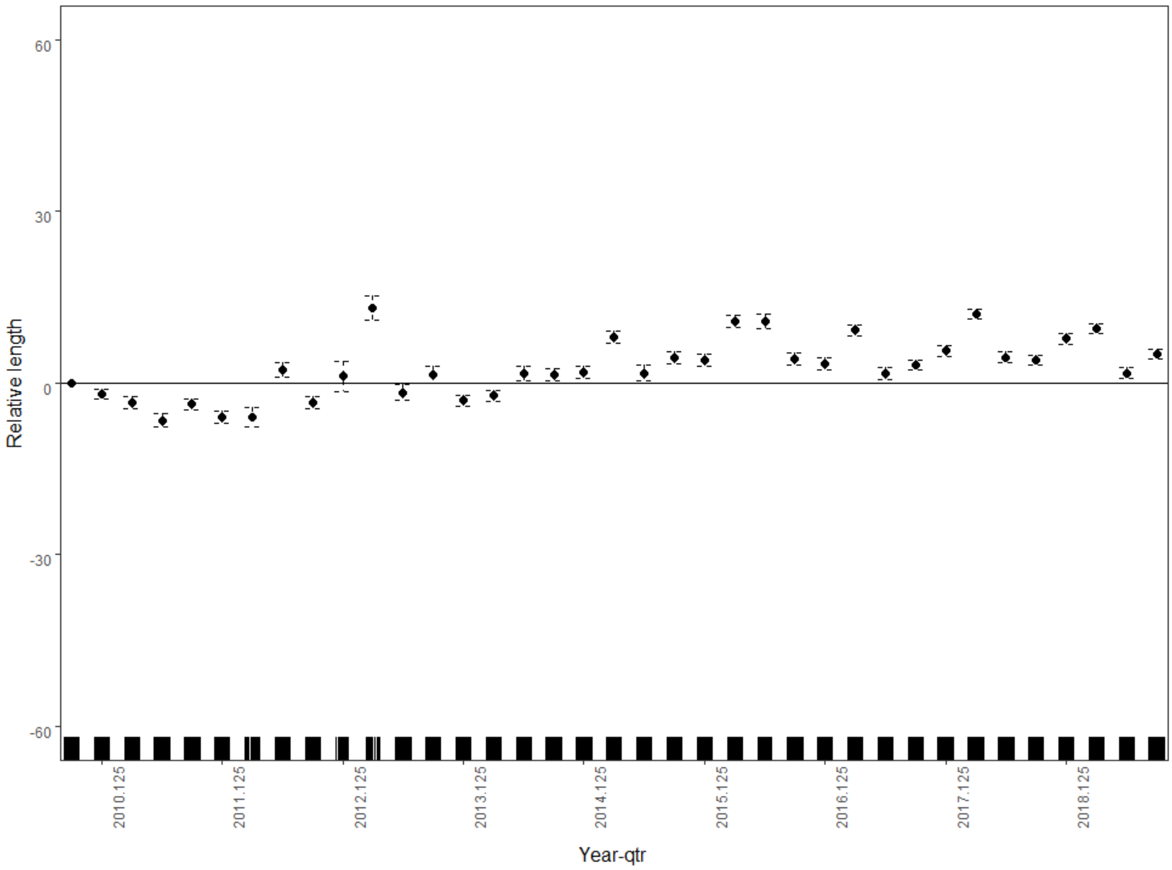


Figure 38: Plot of predicted relative weights by year-quarter from gam model of Taiwanese 1 x 1 bigeye tuna weight data held by the Taiwanese government.

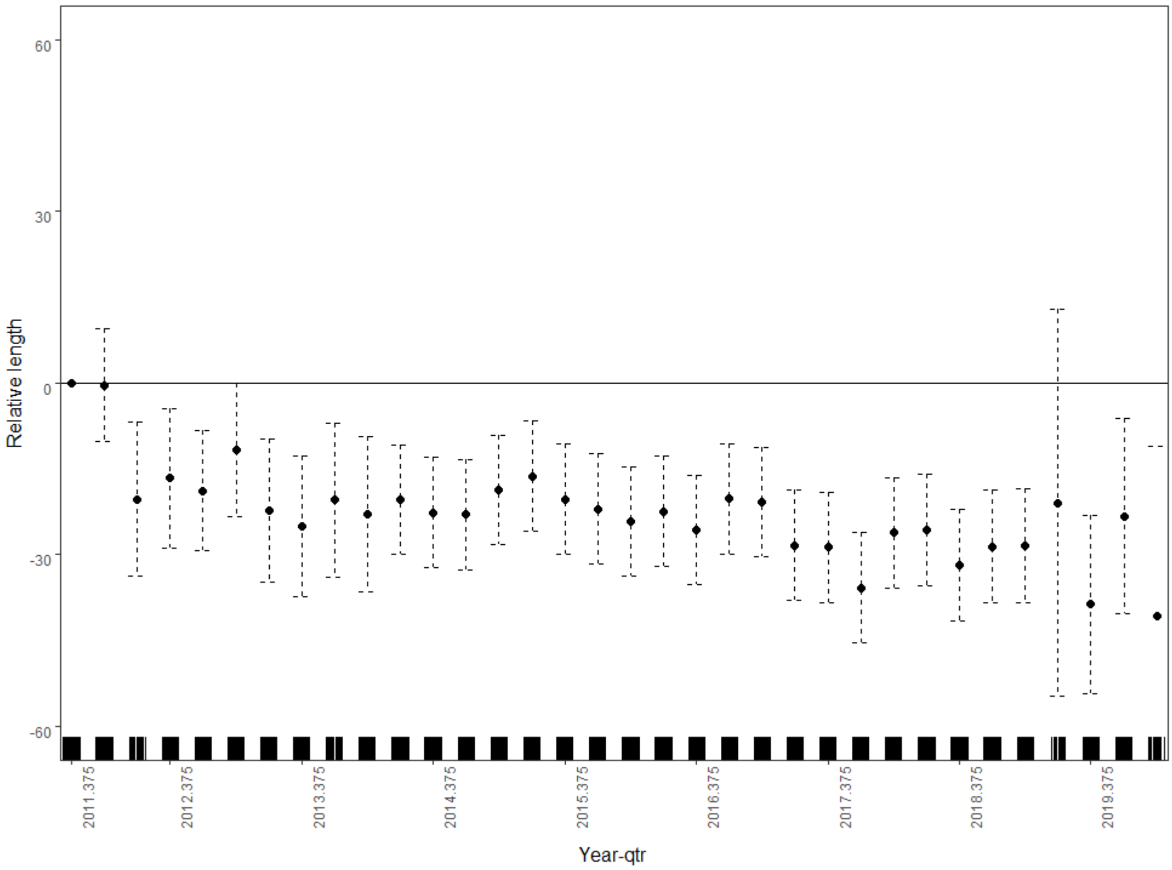


Figure 39: Plot of predicted relative lengths by year-quarter from gam model of other fleets 5 x 5 bigeye tuna length data held by the IOTC.

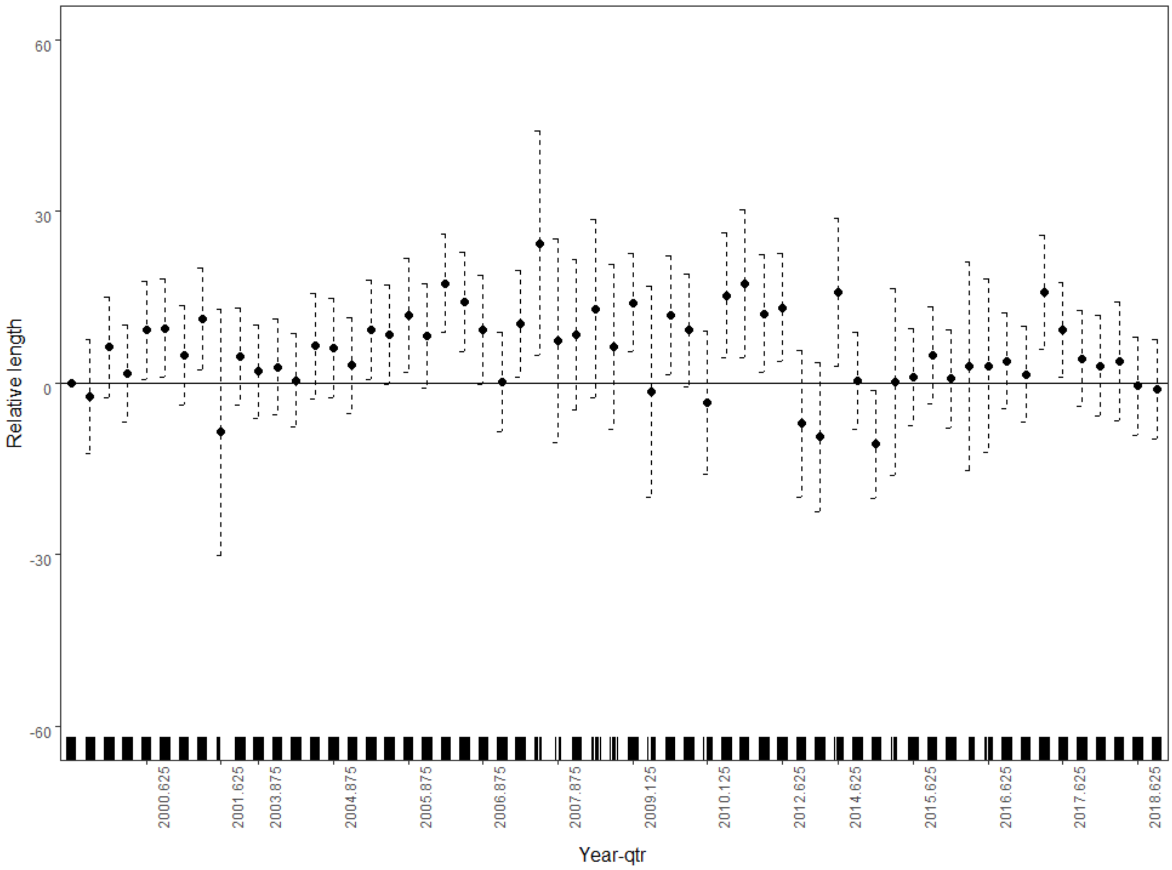


Figure 40: Plot of predicted relative lengths by year-quarter from gam model of Korean 1 x 1 bigeye tuna length data provided by the Korean government.

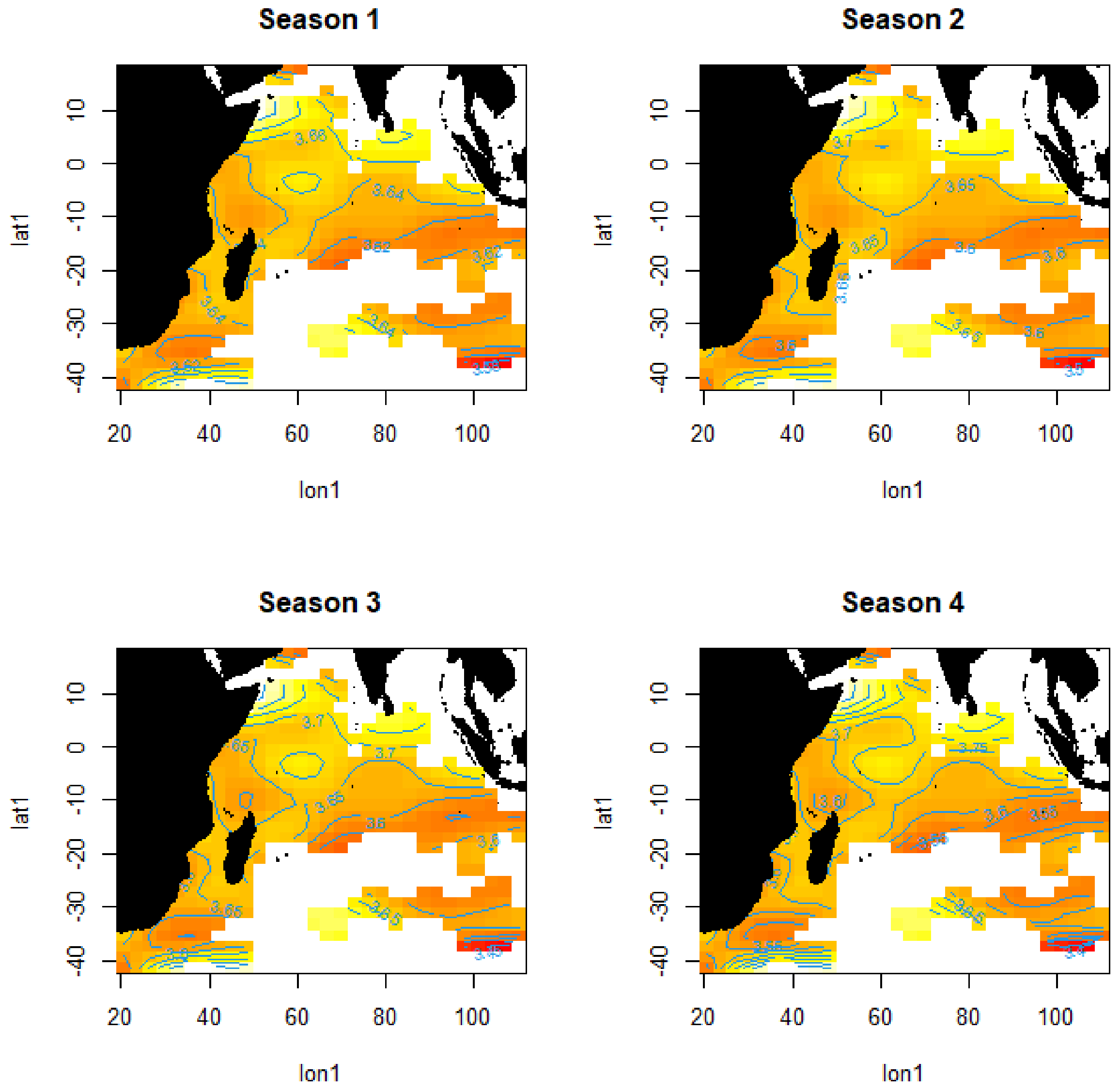


Figure 41: Seasonal and spatial variation in length-weight relationship of bigeye tuna, based on data from the Korean longline fishery.

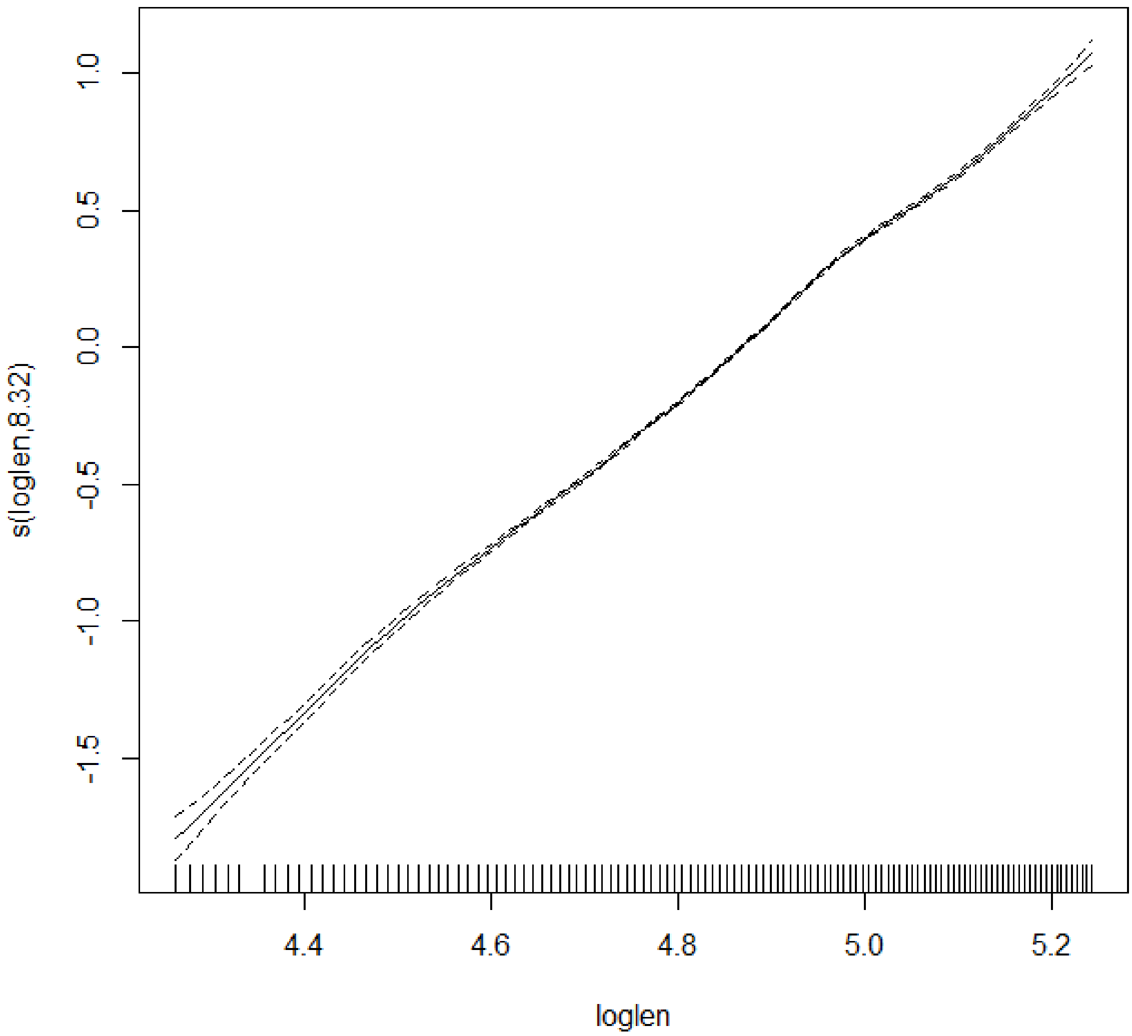


Figure 42: Relative log(weight) at log(length) for bigeye tuna in the Indian Ocean, based on data from the Korean longline fishery.

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Appendix 1: Format of JPN LL size data for 2019 IOTC collaborative analysis

Keisuke Satoh and Takayuki Matsumoto (NRIFSF)

August 15, 2019

Data format (csv format)

- “-9999” in any data fields means that the data is not available.
- Species; 4; bigeye, 5; yellowfin
- YY; Catch year
- MM; Catch month
- level; Spatial resolution (1; 10°×20°, 2; 5°×10°, 3; 5°×5°, 4; 1°×1°)
- Position (latitude and longitude); The position is transformed using following rules. If in the northern hemisphere, Y = (latitude+0.5). If in the southern hemisphere, Y = -1*(latitude+0.5). If in the east longitude area, X = (longitude+0.5). If in the west longitude area, X = 360-(longitude+0.5). Thus, the position Y (latitude) -1.5 means the vessel operates at >= 1S and < 2S. The position X (longitude) 135.5 means the vessel operates at >=135E and <136E, while the position 182.5 means the at >=177W and <178W).
- M_unit; Size unit (3; weight 1 kg, 6; length 1 cm, 7; length 2 cm, 8; length 5 cm)
- NGYO; Vessel type (1; commercial vessel, 2; training vessel)
- Sex; (1; female, 2; male, -9999: not available).
- CLS; Size
- Num; Number of fish
- ioc; ocean code -> only Indian Ocean (2) is available
- place; location for measurement. (1: On board (fisherman), 2 - 12, >=14: Port sampling, 13; On board (observer))
- ocean; basically equivalent to “ioc”

Delete abnormal data and/or outline

- If YY =. then delete, if YY <=1950 then delete, if YY >=2020 then delete, if DD >=32 then delete. Abnormal date is also deleted including 31th in April, June, September and November, and Feb. 29 when it is not a leap year.
- If longitude=. then delete, if longitude=180 then delete, if longc=. then delete, if longc=0 then delete, if longc>=3 then delete, if latitude=. then delete, if latc=. then delete, if latc=0 then delete.
- If CLS=. then delete, if CLS=0 then delete.
- If Num=. then delete, if Num=0 then delete.

Notes

- Several gear codes in the IOTC size database are missing from the SFRef reference file
- "BBOF","LIFT", "HLOF", "TROLM"

Appendix 2: Estimation of catches at size for IOTC species

Copied from the document 'Equations.doc' (https://www.iotc.org/documents/length-frequency-equations-used-estimate-standard-lengths-and-weight).

Equations used to convert from non-standard measurement to fork length (Table 1) and from fork length to round weight (Table 2)

Table 1: Regression equations used to convert from non-standard measurements into standard lengths (tunas: tip of the snout to fork length; swordfish: lower-jaw to fork length) per species

Species: Yellowfin tuna	***Standard length: Tip of snout to fork of tail***

Type Measurement	*Equation*	*Parameters*	*Sample size*	*Size*	*Variance*	*Covariance ab*	*Mean Residual*	*Gradient*
Weight gilled and gutted[A]	a*W^b	a= 44.28699 b= 0.3008591	2,361	Min:14 Max:71	a=0.00752476509 b=2.86244E-07	-4.626246E-05	4.095958	a=3.033852 b=495.6385
Length to the base of the 1st dorsal fin[B]	a*L^ b	a=2.0759 b=1.1513	7,036	Min: 29 Max: 164				

Species: Bigeye tuna	***Standard length: Tip of snout to fork of tail***

Type Measurement	*Equation*	*Parameters*	*Sample size*	*Size*	*Variance*	*Covariance ab*	*Mean Residual*	*Gradient*
Weight gilled and gutted[A]	a*W^ b	a= 42.2186 b= 0.3012349	316	Min:12 Max:107	a=0.0321755341 b=1.299934E-06	-0.0002034041	3.98137	a=3.03806 b=473.1455
Length to the base of the 1st dorsal fin[C]	$\frac{(L+a)^2}{(b)^2}$	a=21.45108 b=5.28756	2,858	Min:13 Max:48				

A: Data from Penang Sampling Programme (1992-93)

B: Data from the Indian Ocean (Marsac, F. et al in IOTC-2006-WPTT-09)

C: Data from the Atlantic Ocean, Champagnat et Pianet (1974) (ibid. B)

Table 2: Equations used to convert from standard length into round weight, per species

Species	*Gear Type/s*	*From type measurement – To type measurement*	*Equation*	*Parameters*	*Sample size*	*Length*
Yellowfin tuna	Purse seine Pole and Line Gillnet	Fork length – Round Weight(kg)[A]	RND=a*L^b	a= 0.00001886 b= 3.0195	6,752	Min: 29 Max: 164
	Longline Line Other Gears	Fork length(cm) – Gilled and gutted weight(kg)[B] Gilled and gutted weight(kg) - Round Weight(kg)[C]	GGT=a*L^b RND=GGT*1.13	a= 0.0000094007 b= 3.126843987	15,133	Min:72 Max:177
Bigeye tuna	Purse seine Pole and Line Gillnet	Fork length(cm) – Round Weight(kg)[D]	RND=a*L^b	a= 0.000027000 b= 2.95100	n/a	n/a
	Longline Line Other Gears	Fork length(cm) – Gilled and gutted weight(kg)[B] Gilled and gutted weight(kg) - Round Weight(kg)[C]	GGT=a*L^b RND=GGT*1.13	a= 0.0000159207 b= 3.0415414023	12,047	Min:70 Max:187

A: Data from the Indian Ocean (Marsac, F. et al in IOTC-2006-WPTT-09)

B: Multilateral catch monitoring Benoa (2002-04)

C: ICCAT Field Manual (Appendix 4: Population parameters for key ICCAT species. Product Conversion Factors)

D: Cort (1986)