REVIEW OF LENGTH FREQUENCY DATA OF THE TAIWANESE DISTANT WATER LONGLINE FLEET

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The following paper was drafted by the IOTC Secretariat, in consultation with the Overseas Fisheries Development Council of Taiwan,China (OFDC) who provided comments on an earlier draft of the report. The paper was first presented at the Working Party on Tropical Tunas 2013 (WPTT-15), and provides an update following comments received by OFDC in November 2013.

PURPOSE

To provide participants at the Working Party on Data Collection and Statistics (WPDCS09) with an overview of recent changes in the size frequencies of bigeye (*Thunnus obesus,* BET), yellowfin (*Thunnus albacares,* YFT), and albacore (*Thunnus alalunga,* ALB) recorded by the Taiwanese distant water longline fleet (DWLL).

BACKGROUND

Taiwan,China has collected one of the longest and most extensive sets of size frequency data of longline fleets operating in the Indian Ocean. According to the Overseas Fisheries Development Council of Taiwan,China (OFDC), since 1980 over 10.6 million tuna specimens have been recorded for lengths by the Taiwanese distant water longline fleet; between 2003 and 2005 alone, size data were collected for over 3.2 million samples. For almost 20 years the fleet has accounted for between 80%-100% of size frequency samples of BET, YFT and ALB from longline fleets published by the IOTC Secretariat. The size data reported by Taiwan,China are also one of the main inputs to the stock assessments of tuna species in the Indian Ocean, in an area where longliners have contributed over 75% of the total catch of BET, 85% of ALB, and 35% of YFT since the 1950s. Ensuring that the size data are of the highest quality, and understanding the implications of any changes to the collection and processing of the data, are of critical importance.

DISCUSSION

Unusual attributes have been noted in the frequency distributions of BET, YFT, and ALB sampled for lengths by Taiwanese longline vessels over the last decade. Between 2000 and 2006, the average weight of samples increased by

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as much as 50-60% (e.g., around 20kg for BET, and 13kg for YFT). The distributions of lengths during the years of highest sampling are remarkably uniform compared to earlier years; smaller sized fish less than 100cm in length virtually disappear from samples; while differences between the average weights from sampled lengths and catch-and-effort data recorded by logbooks diverge during the years of some of the highest levels of sampling coverage.

The analyses presented in the paper indicate that the changes from around 2003 in the size frequencies of BET, YTF, and ALB samples recorded by Taiwan,China are likely to result from a change in the sampling protocols or processing and management of the data. Alternative explanations (changes in the population structure or changes in fishery selectivity) are unlikely given the nature of the changes and the fact that similar changes are observed for all three species.

RECOMMENDATIONS

In view of the concerns over the reliability of recent increases in lengths of samples recorded by Taiwan,China, the WPDCS may wish to **CONSIDER** recommending the following:

- excluding from stock assessments the size data for BET, YFT and ALB from the Taiwanese DWLL fleet after the early-2000s, until the cause of changes in the size frequency data have been determined by the WPDCS;
- OFDC and the related Fishing Agencies of Taiwan,China to collaborate with the IOTC Secretariat to conduct a full and comprehensive assessment of the data quality of the size data *for all years* for the Taiwanese DWLL fleet, providing details of the sampling areas, procedures for sampling lengths and the processing steps of the size frequency and catch-and-effort datasets;
- that as part of the review of the Taiwanese DWLL fleet size data, to assess the reasons for discrepancies identified by the IOTC Secretariat, provide a comparison of length frequency samples collected from commercial and scientific observers, in accordance with the recommendation of the Scientific Committee (SC15.78), which states:

> SC15.78 (para.141) "*NOTING that there were discrepancies in catch, effort and notably size data (low sampling rate, uneven distribution of sampling in regard to the spatial extent of the fishery) in the Japanese and Taiwan,China tropical tuna data sets, the SC RECOMMENDED they review the data to assess reasons for discrepancies identified by the IOTC Secretariat and to report results at the next meeting of the WPTT, including a comparison of length frequency data samples collected from commercial, research and training vessels*."

- to endorse the recommendations of the WPTT (WPTT15.05, para.74) proposing an inter-sessional meeting attached to the WPDCS and WPM on *data collection and processing systems from the main longline fleets in the Indian Ocean*, to be carried out in early 2014, and encourage the attendance of Taiwan,China, Japan, Indonesia and other parties having important longline fisheries in the Indian Ocean, as well as other tuna-RFMO Secretariats, noting that some of the issues identified for longline fisheries may also affect other oceans.

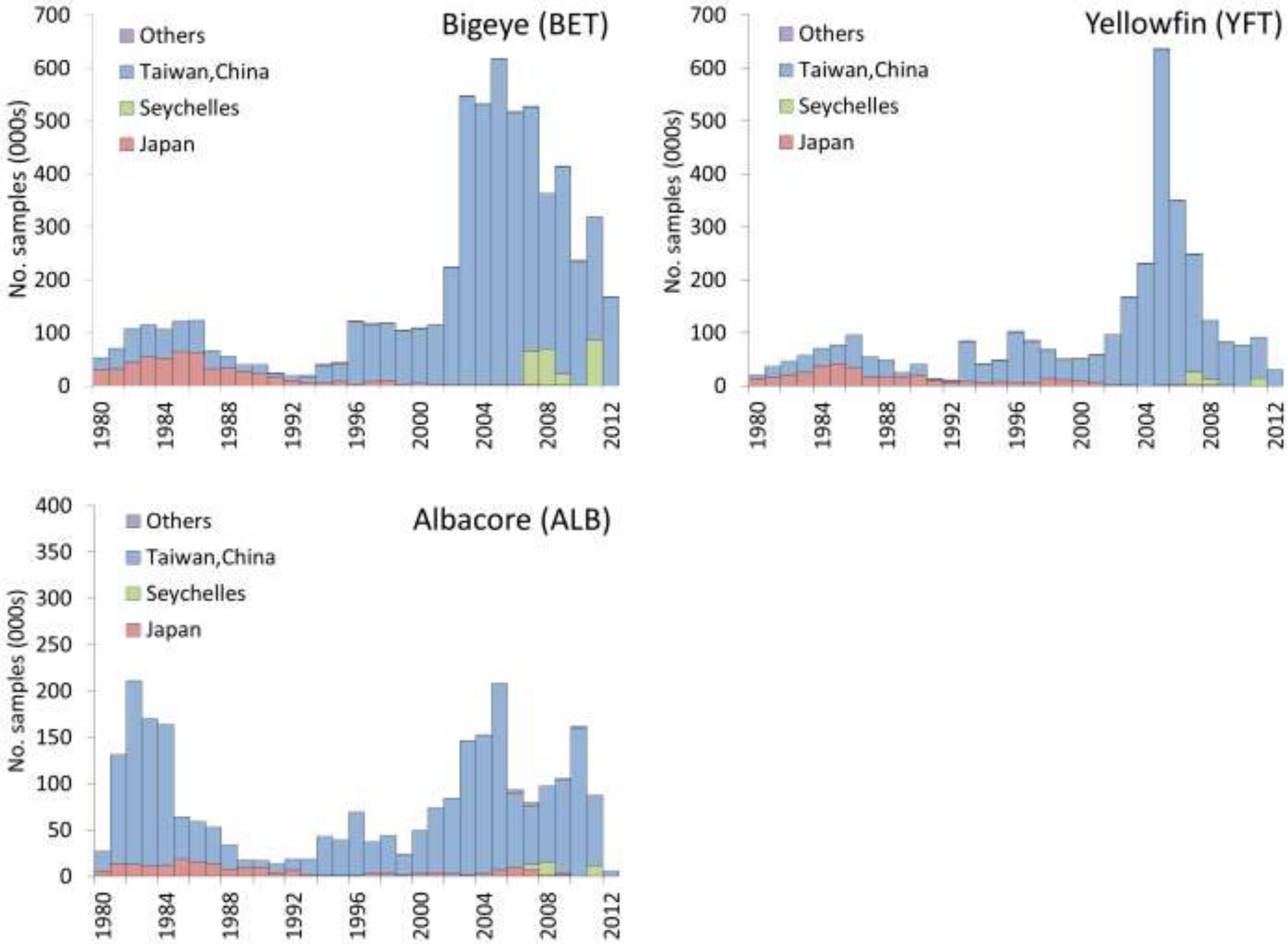
1.1 Introduction

The Taiwanese distant-water longline fishery (DWLL) has exploited the Indian Ocean's tuna resources for over 50 years and represents one of the most important fleets in terms of total catch of tuna and tuna-like species in the Indian Ocean. Yellowfin (Thunnus albacares, YFT), Bigeye (Thunnus obesus, BET)and albacore (Thunnus alalunga, ALB) are the main species caught by the fishery; between 1990-2012, Taiwan,China accounted for around 30% of total longline catches of YFT, 40% of BET longline catches, and over 50% of ALB longline catches in the Indian Ocean.

The Taiwanese fleet has also collected one of the largest sets of length measurements of longline fleets operating in the area. Since 1980 over 10.6 million BET, YFT and ALB specimens have been measured for lengths by the Taiwanese fleet; mostly collected on-board vessels by crew and recorded in logbooks. The number of samples collected by Taiwan,China has increased dramatically in the last ten years. According to the Overseas Fisheries Development Council of Taiwan, China (OFDC), during the years of highest sampling between 2003 and 2005, size data was collected for over 3.2 million BET, YFT and ALB specimens.

Taiwan,China also accounts for the majority of samples collected from longline vessels operating in the Indian Ocean: from the early 1990s over 80% of longline samples of BET/YFT/ALB have been collected by the Taiwanese fleet, and from 2000 as high 95%-100% of samples (Fig. 1). This is partly as the availability of size data from longline fleets collected by the IOTC Secretariat is only partially complete and does not include data from a number of important fleets operating in the area (e.g., Indonesia, Sri Lanka, and Republic of Korea); secondly, since the early 1990s Taiwan,China has replaced Japan as the main source of size data for longline fleets. Japan has historically collected significant numbers of length measurements of BET/YFT/ALB prior to 1990s (around 50,000 to 100,000 samples per year), but in 1991 the number of specimens sampled onboard longline vessels fell and has since remained low. Since 2008 less than 4,000 samples per year have been reported by Japan.

Fig. 1. *Total number of size frequency samples recorded by longline fleets available to the IOTC Secretariat, for selected species.*



1.2 Importance of length compositions for stock assessment

Size data for longline fisheries are dominated by samples collected by the Taiwanese fleet, and length measurements available from Taiwan,China are used to indicate size patterns in the catches of the overall longline fleet. More importantly the data are used to make inferences about the population dynamics of the total catch of the Indian Ocean, in an area where longliners account for up to 85% of the total catch of Tropical and Temperate tuna species[2]. The data represent one of the few longline fleets, in addition to Japan, that has collected samples of length measurements in sufficient numbers and over a long enough period, to be of use for the purposes of stock assessment.

Yearly length distributions provide information about year class strength in the underlying population and are also affected by total mortality, and the selectivity of the longline gear categories that encounter the fish.

[2] Between 2009-11, longliners accounted for 85% of the total catch for albacore in the Indian Ocean, 56% of the catch of bigeye, and between 19% of the catch of yellowfin.

Implicitly, the quality of the size data affects the quality of the stock assessment and related management advice. Size frequencies are one of the main sources of information about the size selectivities of fisheries. Issues with the reliability of length composition data – e.g., insufficient sampling coverage in time and space, or poor implementation of sampling protocols resulting in samples not including the whole range of sizes in the catch – can lead to biased estimates of selectivity, and more importantly can bias estimates of total mortality or available spawning biomass through time. These problems then affect the estimates in other parts of the model. Thus, inaccurate data will provide an inaccurate picture of the stock strength both in current and historic terms, as well as inaccurate estimates of fishing mortality.

Without reliable and consistent data collection of length measurements – and the age structure it implies – it may be difficult to estimate recruitment strength over time, leaving analysts reliant of the index of abundance data for capturing time specific dynamics. Integrated analysis models such as Stock synthesis and MULTIFAN-CL work by combining information from several data sources, and in this context the length frequency data should be compatible with the index of abundance. Inconsistencies between the datasets imply that there are either problems with the index of abundance or with the length composition data.

2.1 Objectives and scope

The remainder of the paper discusses changes in the size frequencies of BET, YFT and ALB recorded by the Taiwanese longline fleet, focusing on the last ten years during the period in which the number of samples increased substantially (refer to Fig. 1). Given the importance of Taiwan,China samples in terms of the overall length composition of longline fleets in the Indian Ocean, and also as one of the primary data inputs of stock assessments, it is critical to ensure data is of the highest quality and that significant changes in fish sizes are thoroughly explored.

The discussion focuses primarily on inconsistencies in sizes recorded for BET and YFT – given the number of samples available for these two species – in addition to ALB which appears to show similar changes in the length composition as the other two species, albeit to a lesser extent.

2.2 Data sources and definitions

The Taiwanese distant water longline fishery (DWLL) is composed of two types of vessels: regular or fresh-tuna longline fishery that target ALB, and deep-freezing longline fishery that target BET and YFT tuna (Lee et al. 1996). As the majority of size measurements have been sampled from deep-freezing longline vessels, references to the Taiwanese DWLL in this paper are used interchangeably with the deep-freezing longline fishery.

Data used in the analysis are the size frequency data and catch-and-effort data provided to the IOTC Secretariat by the OFDC of Taiwan,China according to the standards set out in IOTC Resolution 10/02 Mandatory statistical requirements for IOTC members and cooperating non-contracting parties[3]. Almost all analyses of the size frequency data have been carried out on the original data, rather than the catch-at-size dataset (raised to the total catch), for the

[3] Size frequency data are recorded by Species, Fleet, Year, Gear, Fishing Mode, Time Interval (month or quarter or year usually) and area (5° square area longitude and latitude, or 10° latitude by 20° longitude) for longline fisheries.

purposes of transparency[4]. It should be noted however that during the initial analysis comparisons were made using the original size frequency data and catch-at-size data, and which reported only relatively minor differences in terms of the average lengths or weights calculated from both datasets. Size data were provided in 2cm size intervals; the mid-point of each class interval was then calculated and used in the analysis of overall length and weight distributions.

Lastly, the conversion of lengths to weights in Section 4 was carried out using the standard formulae of lengths to round weights recommended by the IOTC Secretariat, detailed in Annex 1 and available on the IOTC website.

2.3 Data collection of size frequency data

Size frequency data are collected from the Taiwanese deep-freezing longline fleet from on-board sampling by crew members and entered in logbooks submitted mandatorily to the port authorities (although the data are not validated). Length measurements are recorded from each vessel for the first 30 retained fish in each set, with no sorting or selection of samples. Since 2005, the logbook data collection has been used to record the catch-and-effort data and size measuring data. The logbooks are split into two parts: one is the basic data of a vessel, including vessel name, tonnage, company, captain's name, total fishing days, etc., and the other is the data of fishing records including fishing time, fishing area, water temperature, fishing effort, baits used, catch species in number and weight, and the measure of the initial 30 fish (Lee et al. 1996).

The format of logbooks has undergone a number of revisions over the last decade in order that the statistical and data processing systems of OFDC and Fisheries Agencies of Taiwan,China are close to capturing near real-time fisheries information that meets the requirements of Regional Fisheries Management Organizations. Changes to the data collection include the addition of species recorded by logbooks (e.g., marlins and sharks), establishing more frequent and periodical catch data reporting, and the implementation of an electronic 'e-Logbook' and Statistical Documents for vessels targeting bigeye. The introduction of the e-logbooks is of particular importance – while the format of e-logbooks is consistent with paper-based logbooks, vessels are required to report catches by satellite transmission on a daily basis, enabling greater control and monitoring of near real-time catch amounts of bigeye tuna. In addition, since 2009, processed weights have also been recorded in logbooks for specimens sampled for lengths (OFDC, 2013).

From 2002 onwards, national scientific observers have also been dispatched to Taiwanese fishing vessels to observe fishing operations and collect biological data, including length measurements which are used to verify the accuracy of logbook data – although data collected by observers have not been provided to the IOTC Secretariat at the time of writing.

3. Distribution of lengths: main trends

Figs. 2a. and 2b. show the length distribution of samples recorded by Taiwanese longline vessels since 1980. The sampling coverage is also shown alongside each year, expressed as number of fish per tonne of catch (denoted by the size of the green proportional circle; the larger the circle the higher the sampling coverage).

[4] The processing of catch-at-size data involve raising the original size samples to the total catch, and can lead to adjustments in the length composition through the substitution of lengths in strata in which catches are recorded but samples do not exist or are available in sufficient numbers. For further details, refer to Herrera et al (2011).

***Fig. 2a.** Distribution of lengths and sampling coverage of BET and YFT size data available from Taiwanese DWLL vessels. Red cross-hairs indicate the mean length in each year; the proportional circles the sampling coverage (number fish sampled per tonne of catch).*

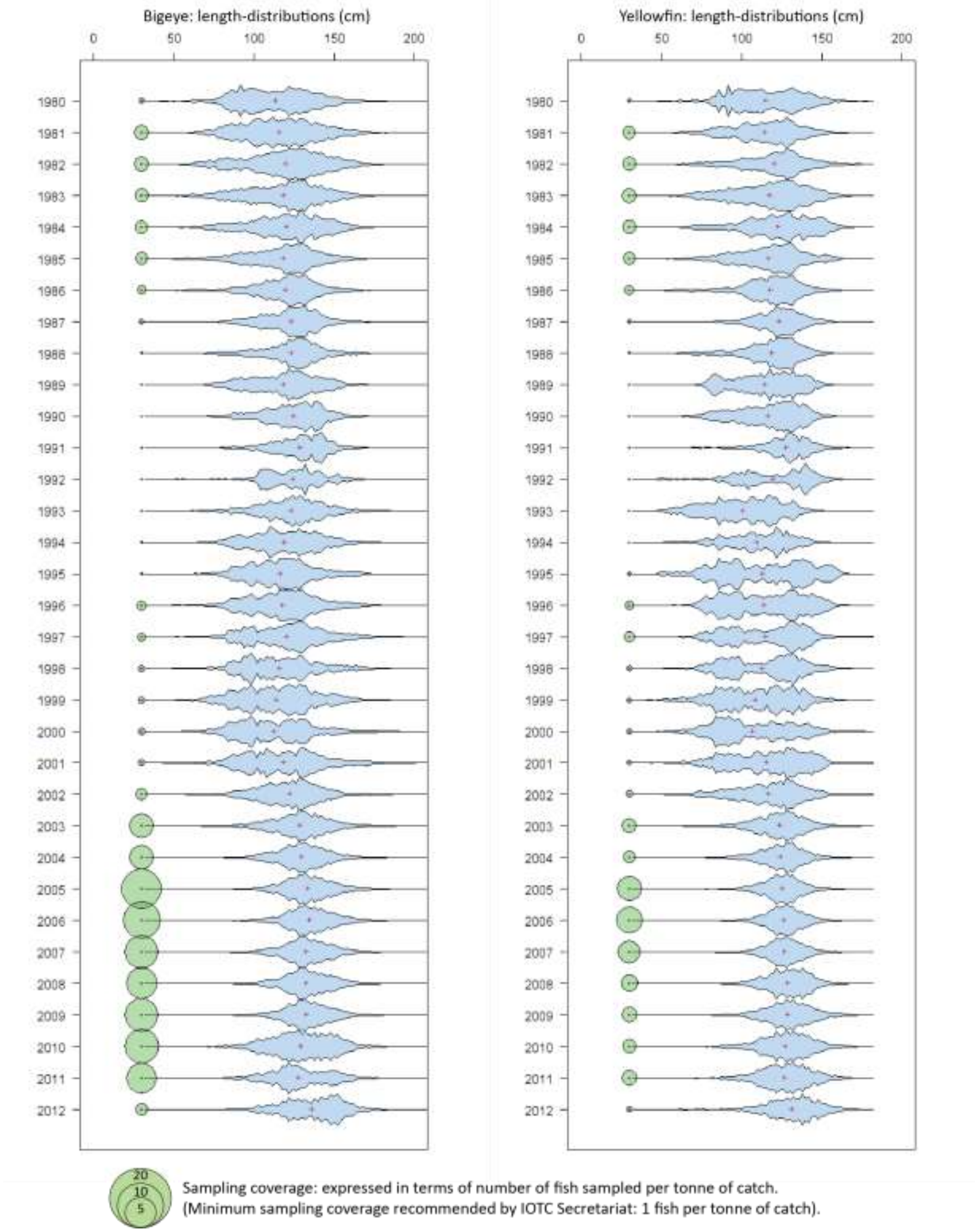
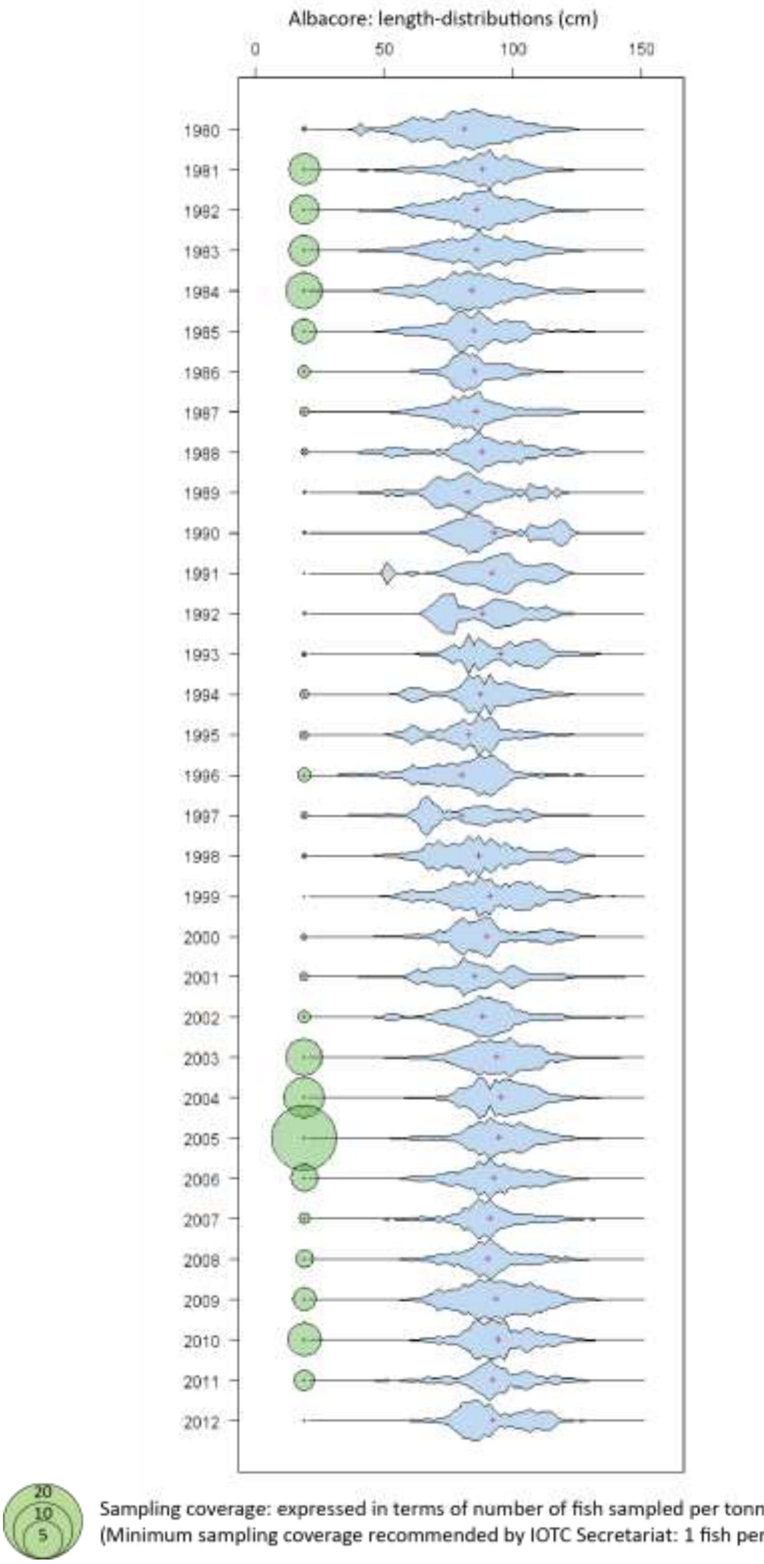


Fig. 2b. *Distribution of lengths and sampling coverage of ALB size data available from Tawianese. Red cross-hairs indicate the mean length in each year; the proportional circles the sampling coverage (number fish sampled per tonne of catch).*



Sampling coverage: expressed in terms of number of fish sampled per tonne of catch.
(Minimum sampling coverage recommended by IOTC Secretariat: 1 fish per tonne of catch).

There is a close correlation between the size data for BET and YFT, in terms of years of highest sampling coverage as well as trends in the distribution of lengths:

i. Aside from years of low sampling coverage during the late-1980s and early 1990s, there appears to be three separate periods in which the distribution of lengths are similar for each species BET and YFT, coinciding with the periods 1980-1990, 1991-2002, and 2003 onwards.

ii. Changes in the length distributions from 2003 compared to previous years are particularly distinctive. Average lengths after 2002 increase markedly and are generally sustained in following years, which see average lengths of BET increase from around 120cm to 130-135cm, and YFT from 115cm to around 130cm.

iii. From 2003 the distribution of BET and YFT lengths also appear unusually narrow and uniform between years, coinciding with the period in which some of the highest numbers of samples were recorded. The proportion of smaller sized fish sampled declines dramatically and there appears a systematic shift of samples composed of larger sized fish for both species. Fish under 100cm virtually disappear from samples – accounting for less than 5% of samples of BET and YFT after 2002 (compared to between 20%-50% of samples in earlier years) (Fig. 3).

The similarities between BET and YFT should not be wholly surprising, as the two species are often caught together and share common fishing grounds. What is unusual is the extent to which changes in the distribution of lengths are so closely mirrored and over exactly the same period – highly unlikely in the populations, but suggest a possible bias is the sampling or an artefact of the processing of the data.

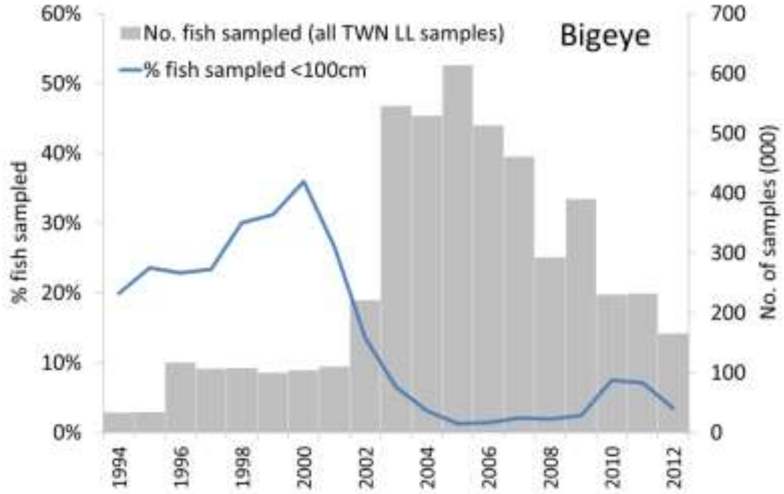
There is evidence of similar changes in the distribution of lengths reported for ALB, albeit of a smaller magnitude, as the sizes of ALB specimens are smaller than the other two species:

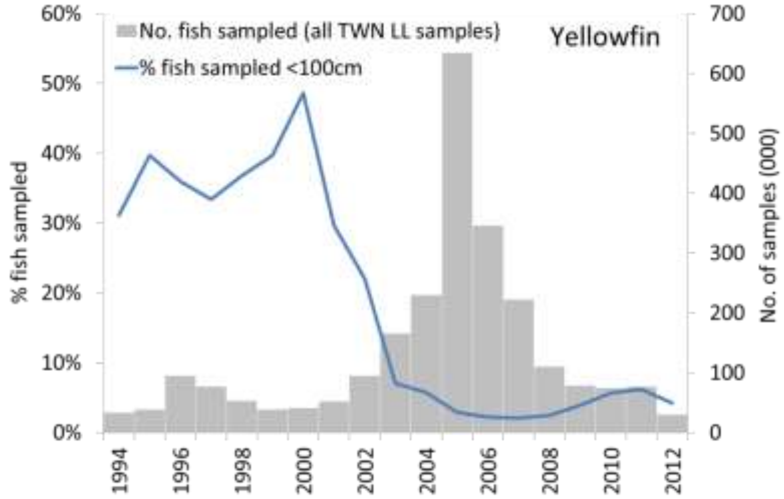
i. While there is greater consistency in the distribution of lengths over time there is some evidence of three separate groups of length compositions with similar change dates to BET and YFT (Fig. 2b).

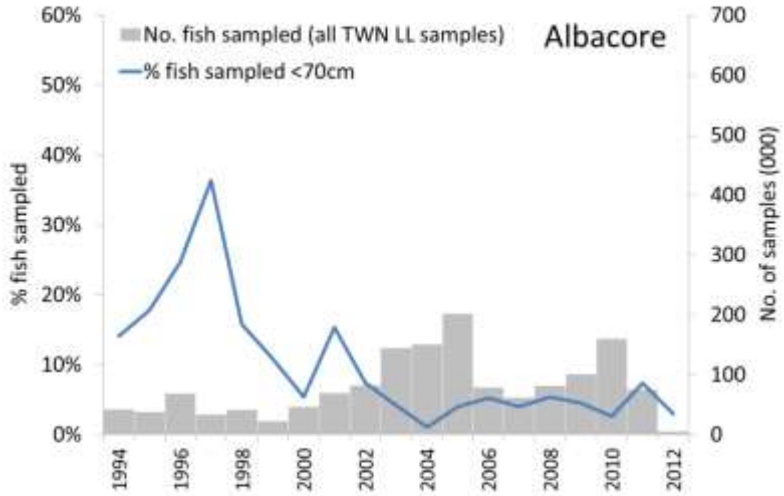
ii. Average lengths of ALB have also increased to some of highest levels since 2002; although, again, the increases are more modest than compared to BET and YFT (i.e., increasing from ≈89cm to 93cm).

iii. The proportion of smaller sized fish (i.e., less than 70cm) also declines from the early-2000s (from around 10-15% in the late 1990s, to around 5% or less after 2002) (Fig. 3c).

Fig. 3(a-c). *Proportion of smaller sized BET/YFT/ALB size fish sampled by Taiwanese DWLL vessels (selected years).*







4.1 Estimation of size frequency weights

Changes in the lengths of BET and YFT samples since 2003 are even more apparent when the size frequency data are converted into round (total) weights[5]. The average weight in each year is calculated by taking the sum of the total length-derived weights from the size data, divided by the number of samples in each year. Since the early 2000s, the average weights of samples for all three species have risen to some of the highest levels recorded by the Taiwanese DWLL fleet:

Bigeye and Yellowfin –

a) Between 2000 and 2006, the average weight of BET samples increased 60%, equivalent to over 20kg (from 35kg to 55.3kg, before declining to around 53kg) (Fig. 4.(a)).

b) Provisional data for 2012 report an average weight of more than 58kg – the highest average weight for BET ever recorded for the DWLL fleet – although the figure should be treated with caution as they represent provisional data for the latest year (albeit of 160,000 samples).

c) Similarly for YFT, between 2000 and 2006 the average weight of samples increased by 50%, equivalent to more than 13kg (from 26.8kg to 40.1kg, before increasing to over 43kg by 2009) (Fig.4.(b)).

Albacore –

a) As with the length distributions for Albacore, increases in the weight of samples are more modest than the other two species, with average weights increasing by around 10% (from 14.6kg to over 16kg by the mid-2000s) – but are nevertheless some of the high levels recorded by the fishery (Fig. 4(c)).

4.2 Comparison of length-based and catch-and-effort derived weights

Further irregularities in the size data appear when length-based average weights are compared with the average weights derived from catch-and-effort data (i.e., total catch in weight divided by catch in number).

As previously noted, vessel logbooks records both the catch-and-effort data and size measuring data. Catch-and-effort reports the total catch (in number and weight) of each trip, while the size data refer to the initial 30 fish sampled from each longline set. As the majority of size data are derived from log-books, the size frequencies can generally be considered a sub-set of the same cohorts reported by the catch-and-effort. Assuming the sampling of fish for lengths is representative across space and time, then comparability between the size data and catch-and-effort should increase relative to the level of sampling coverage. The greater the proportion of catch sampled for size recorded by the catch-and-effort, the more that average weights derived from the each data type should converge.

Since the early 2000s, and for a number of years prior, the sampling coverage of the Taiwan,China longline fleet has been significantly higher than the minimum sampling threshold recommended by the IOTC Secretariat of one fish per tonne of catch (refer to Fig. 2a and 2b.). During the years of highest sampling in 2003-2005, sampling coverage of between 6 to 19 fish per tonne of catch were reported for each species of BET, YFT and ALB. The implication is that

[5] The conversion of lengths to round weights was calculated using the standard formulae recommended by IOTC Secretariat (see http://www.iotc.org/files/proceedings/2013/wpb/Equations.pdf).

differences in average weights between the size data and catch-and-effort data in recent years should not be the result of sampling error from insufficient sampling.

For the comparison of the size data and catch-and-effort, two average weights for size data were calculated:

(1.) The simple average (mean) weight of all samples (as described in Section 4.1).

(2.) The average weight of sample for each 5° square area longitude and latitude, weighted by total catches reported by catch-and-effort in each area.

The latter compensates for differences in the proportion of catch-and-effort sampled in each area, and the effect of under-sampling and over-sampling variations in length distributions associated with different areas. The calculation ensures that samples (and length distributions) associated with areas of higher catches are assigned a higher weight, and conversely for areas of low catch. Areas with less than 300 samples in a given year were also excluded from (2.) so that areas with low sampling, but high catch, do not distort the overall average weight.

In practice, the differences between the two methods are negligible for years in which sampling coverage is above the minimum standard of one fish per tonne of catch – and particularly since the early 2000s when sampling coverage has reached some of its highest levels (see Fig. 4a-c). The indication is that any discrepancies between the size data and catch-and-effort in recent years cannot be explained by differences in the sampling rates of catches by area introducing bias in the overall length distributions.

Results

In the case of BET and YFT, one would expect the average weights derived from lengths and catch-and-effort to be highly correlated – given the high levels of sampling coverage, particularly after 2002:

a) Despite the record numbers of samples of BET and YFT measured for lengths during the mid-2000s, there was no decrease in the gap between average weights reported by size data and catch-and-effort. In the case of BET, the differences between average weights increase to some of their highest levels recorded (e.g., by as much as 10kg for several years, up to 15kg in 2009) (Fig.4a-b).

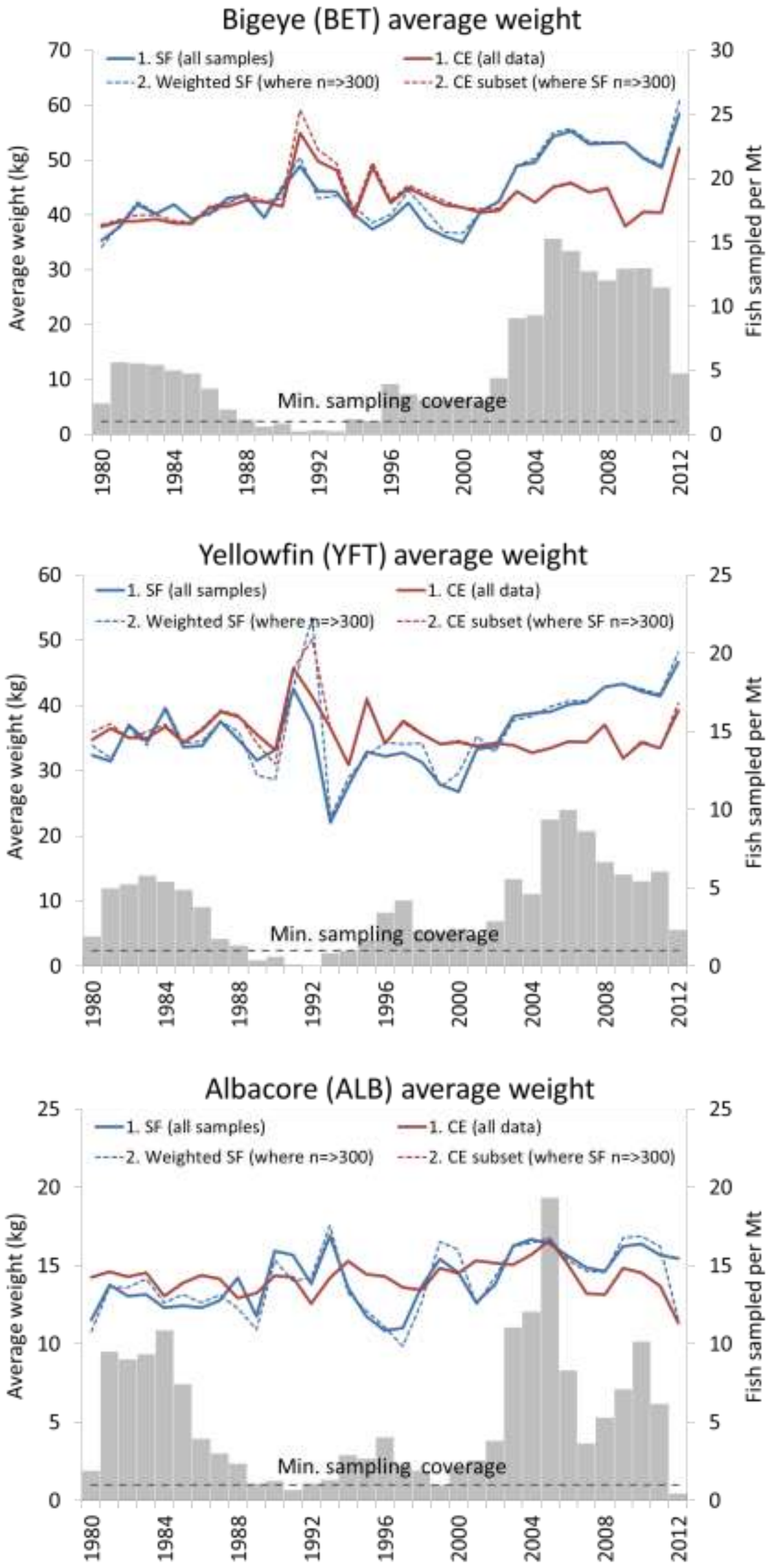
b) BET and YFT average weights reported by size data catch-and-effort data appear to diverge at exactly the same point (i.e., after 2002), coinciding with the year in which the number of samples increased.

c) The catch-and-effort also reports significantly lower average weights for both species, and which are consistent with pre-2002 levels reported by the data (and also the size data pre-2002).

For Albacore, the discrepancies between average weights from the size data and catch-and-effort are not as distinct as the other two species, although there is evidence of consistently higher average weights from the size data from around the mid-2000s. Also the point at which the size data and catch-and-effort diverge occurs later than for BET and YFT, at around 2005 (Fig. 4c).

Fig. 4(a-c). *Comparison of size frequency (SF) and catch-and-effort (CE) average weights for BET, YFT & ALB.*

The minimum sampling coverage refers to the sampling standard one fish per tonne of catch recommended by the IOTC Secretariat.



5. Discussion: factors affecting changes in fish sizes in Taiwanese DWLL

The previous sections have provided an overview the recent increase in the lengths of samples of BET, YFT and ALB recorded by the Taiwanese DWLL fleet.

The reasons for the increase in lengths are unclear; many factors can affect the size of fish in samples including the selectivity of the fishing method, size of fish available, sampling strategy, as well as location which is strongly associated with different sizes of fish for a number of species. For example, albacore caught in tropical areas tend to be larger than those caught in more temperate areas (Bromhead, et al 2009). The following section discusses possible explanations for the changes, beginning with the extent to which trends in the length distribution may be related to changes in the spatial and temporal pattern of specimens sampled by longline vessels.

5.1 Spatial and temporal patterns of changes in length-composition

The spatial size variation of tunas in the Indian Ocean has not previously been described in any detail, but significant spatial changes are possible for BET, YFT and ALB. If there are spatial patterns associated with variation in size, and there are substantial changes in the areas sampled over time, then average sizes (and the length-derived weights) of the samples will also change.

It is useful to identify the spatial effects and temporal effects separately, and this can be achieved by analyzing the data with generalized linear models:

$$length \sim grid + yrqtr + \epsilon$$

The size frequency data and the catch-and-effort data for BET, YFT and ALB were analyzed using this method, and plotted figures showing the spatial effects and the year effects.

Spatial effects

The location plots (Figs. 5-7) indicate that there have been changes through time in the distribution of locations from which fish are sampled. There are similarities in the estimated spatial patterns between the size frequency data and the catch-and-effort data for bigeye, but also some divergence (Fig. 8). According to specimens sampled and measured for size, larger bigeye appear to be caught in the north-western Indian Ocean, with smaller fish south of about 10°S. The catch-and-effort data show a more consistent spatial pattern with similarly large fish to the north-west and north-east.

Yellowfin, on the other hand, show different patterns in the size frequency and the catch-and-effort data. In both cases larger fish are caught in the south west and in the east. However the catch-and-effort data show relatively consistent sizes across the Indian Ocean, while the size frequency data show larger fish in the central Indian Ocean south of the equator.

Year effects

In contrast, the year effects (Fig. 9) show very different patterns between the size data and catch-and-effort for each species, but very similar patterns across species within data types. In the size frequency data the sizes show a moderate level of variability between 1980 and about 1992, but there is subsequently a steep decline, more rapid for bigeye than for yellowfin. After 2001 the average sizes begin to increase again, and reach a higher level than before 1995, with less variability.

The catch-and-effort data also show similar patterns for both species, but these patterns are different from those seen in the size frequency data. Average sizes increase gradually until about 1990, followed by a period of about 5 years with average sizes mostly larger than at any other time. Sizes subsequently drop and are then variable but overall declining until the present.

Standardizing for location effects does not remove the temporal patterns, but makes them clearer and more consistent across species. In other words temporal variations in the size data do not appear to be due to differences in sampling location through time. The consistency of the temporal patterns across species also suggests that the cause of the patterns is the same for all species.

The major size composition change after around 2002 is the disappearance of smaller fish from the samples, as discussed in the previous sections. Any changes in fishing location, and the variation in fish sizes associated with spatial location, are too minor to have caused such a significant change in the length composition of samples. Before 1998, in most locations about 20% of the fish caught were less than 100 cm (Fig. 10). After 2002 the proportion of fish less than 100 cm in most locations dropped to about 5%.

Fig. 5. *Source locations by 5 year period of size frequency samples (top) and catch and effort data (below) for bigeye tuna. The circle areas are proportional to the number of samples (top) and the catch weight (below).*

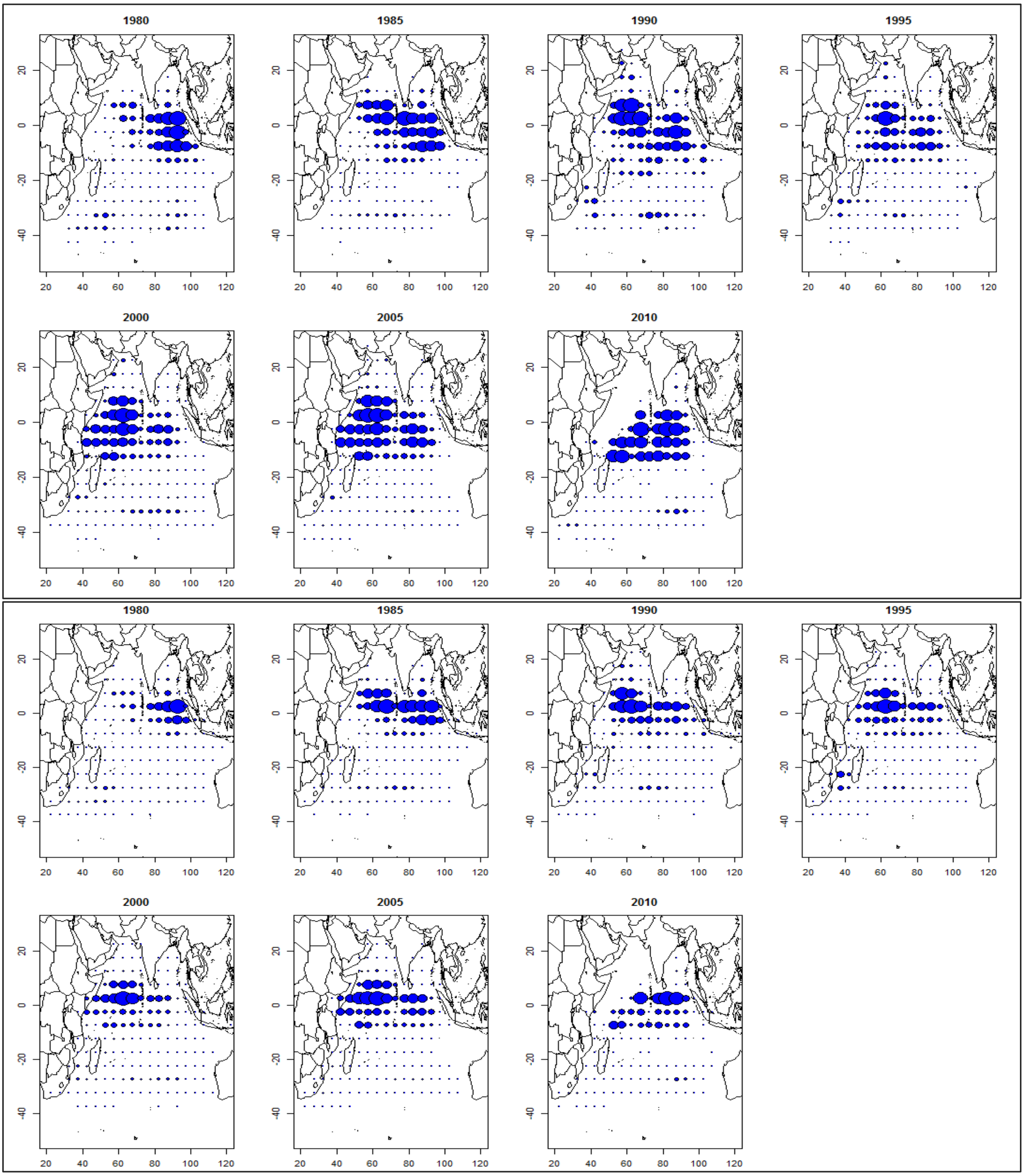


***Fig. 6**: Source locations by 5 year period of size frequency samples (top) and catch and effort data (below) for yellowfin tuna. The circle areas are proportional to the number of samples (top) and the catch weight (below).*

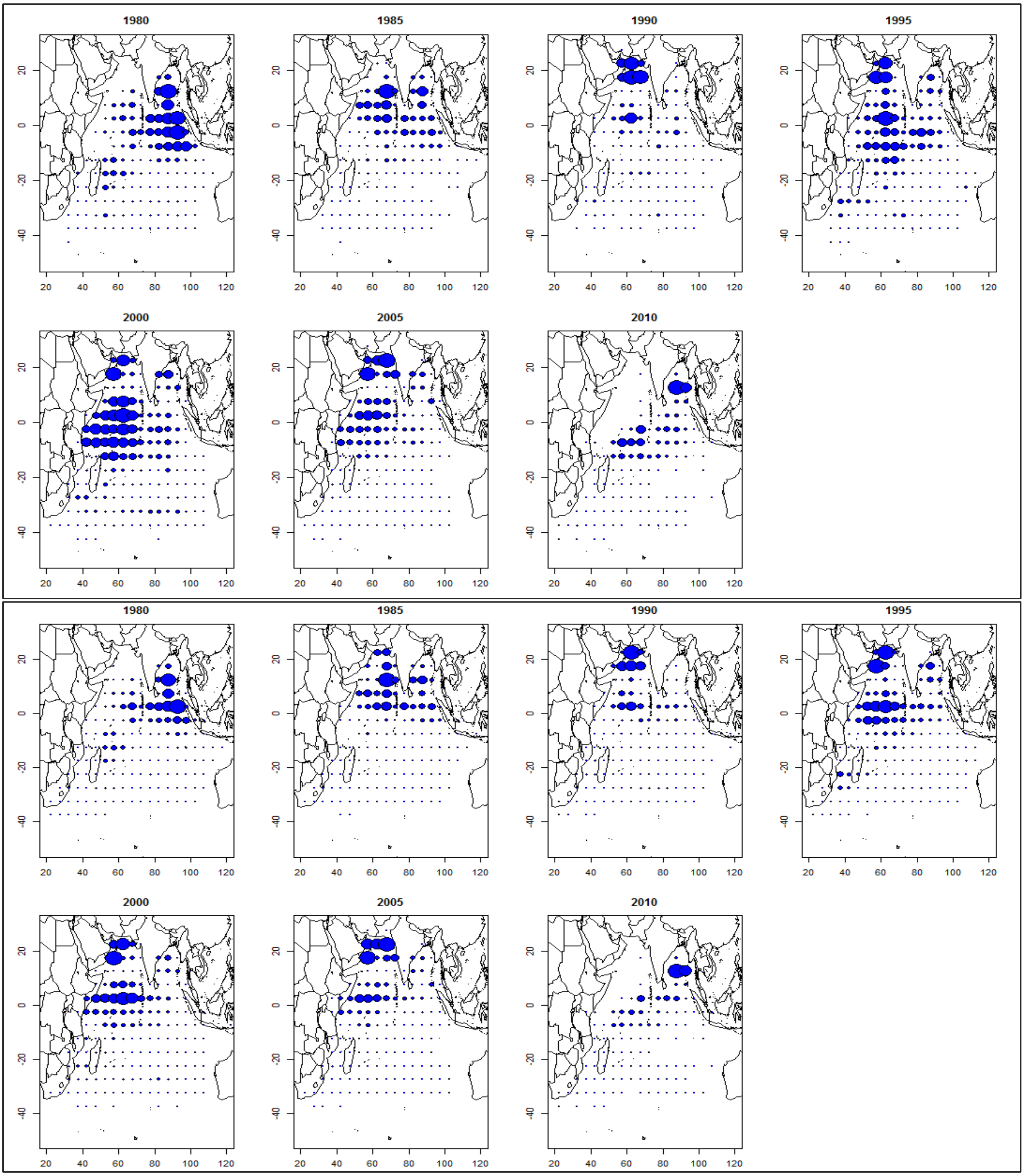
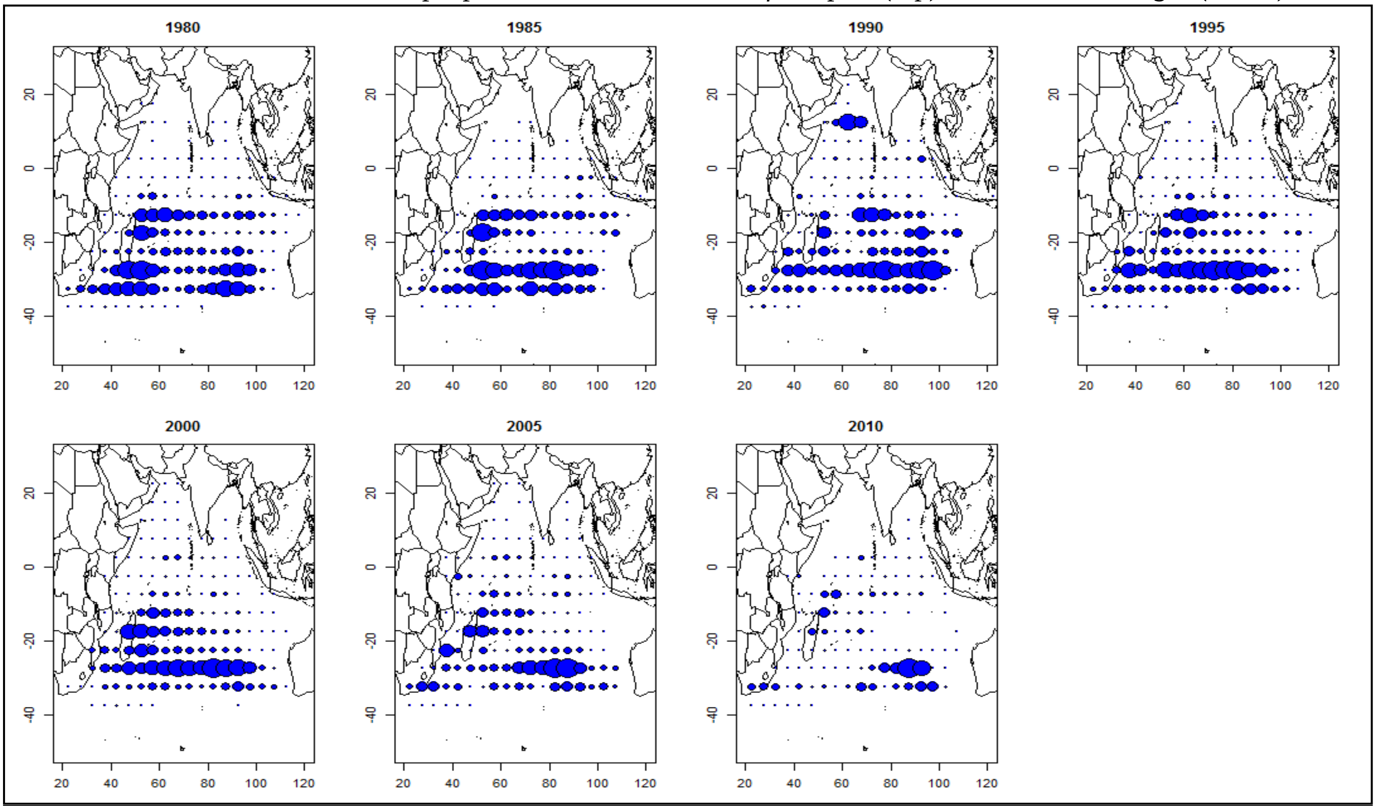


***Fig. 7**: Source locations by 5 year period of size frequency samples (top) and catch and effort data (below) for albacore tuna. The circle areas are proportional to the number of samples (top) and the catch weight (below).*



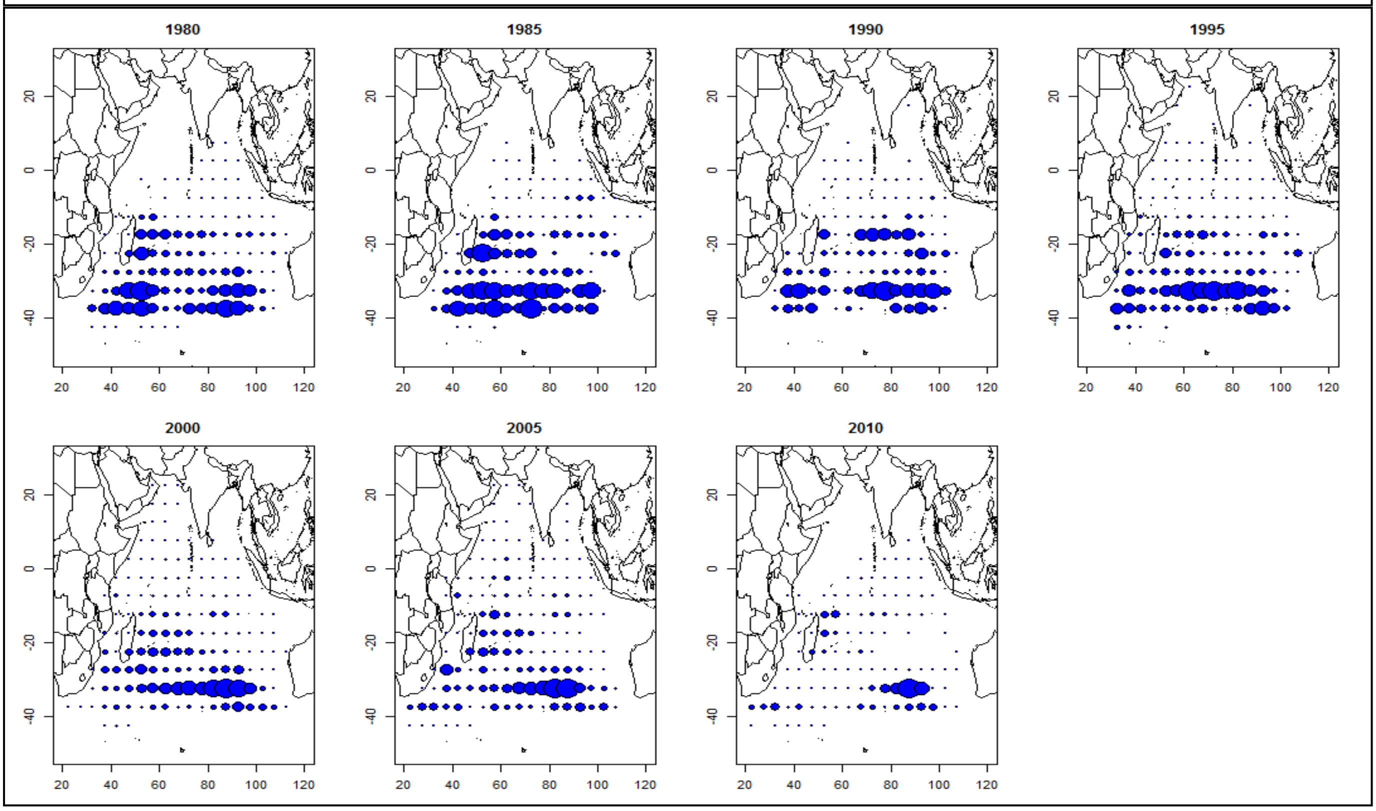


***Fig. 8**: Spatial distributions of mean sizes for bigeye (top), yellowfin (middle) and albacore (bottom) estimated from size frequency (left) and catch-and-effort (right) data. Predicted sizes are for 1980. Darker colours indicate larger sizes.*

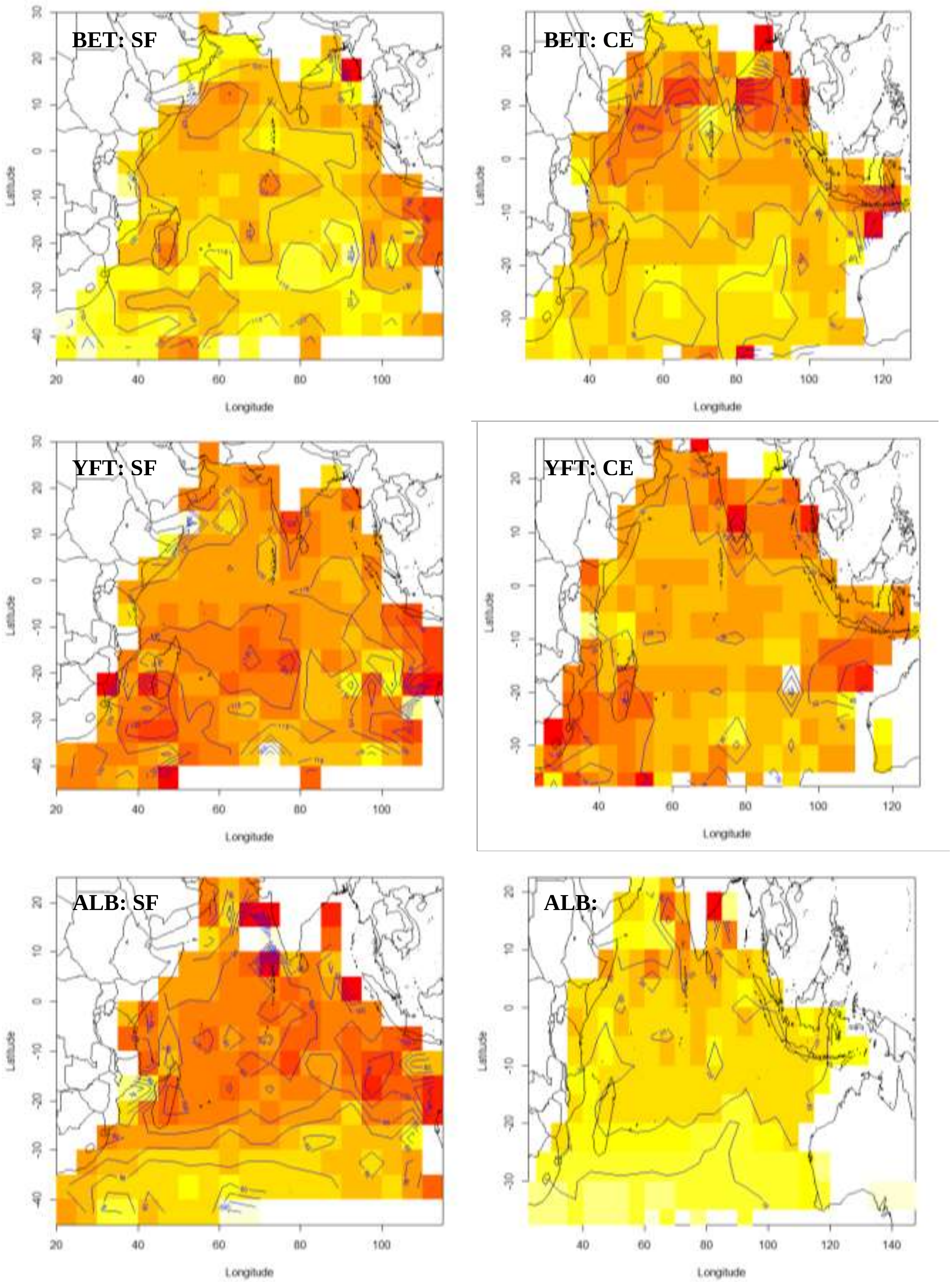


Fig. 9. *Year effects showing the distributions of mean sizes for bigeye (top), yellowfin (middle) and albacore (below) estimated from size frequency (left) and catch-and-effort (right) data. Predicted sizes are averaged across the Indian Ocean.*

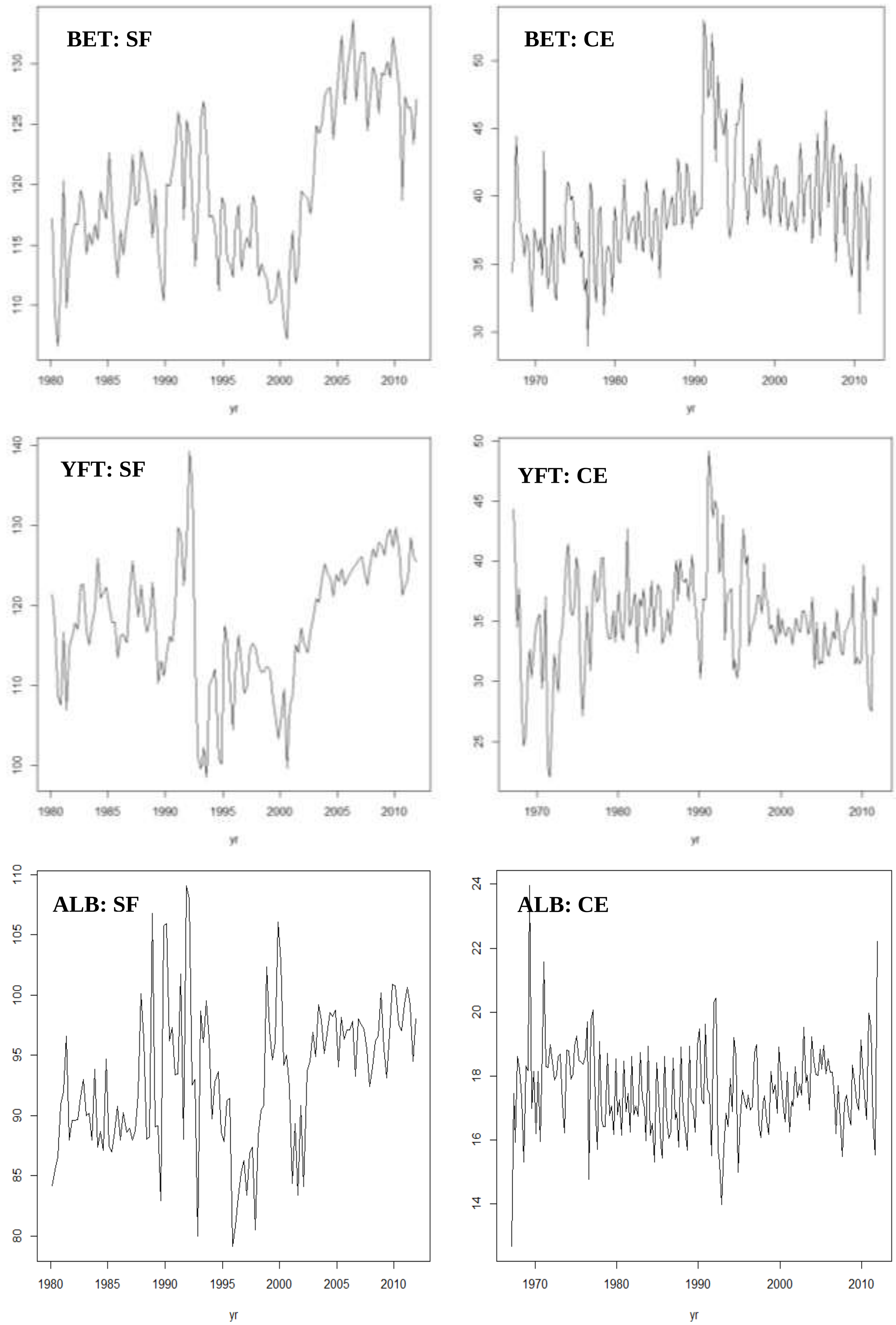
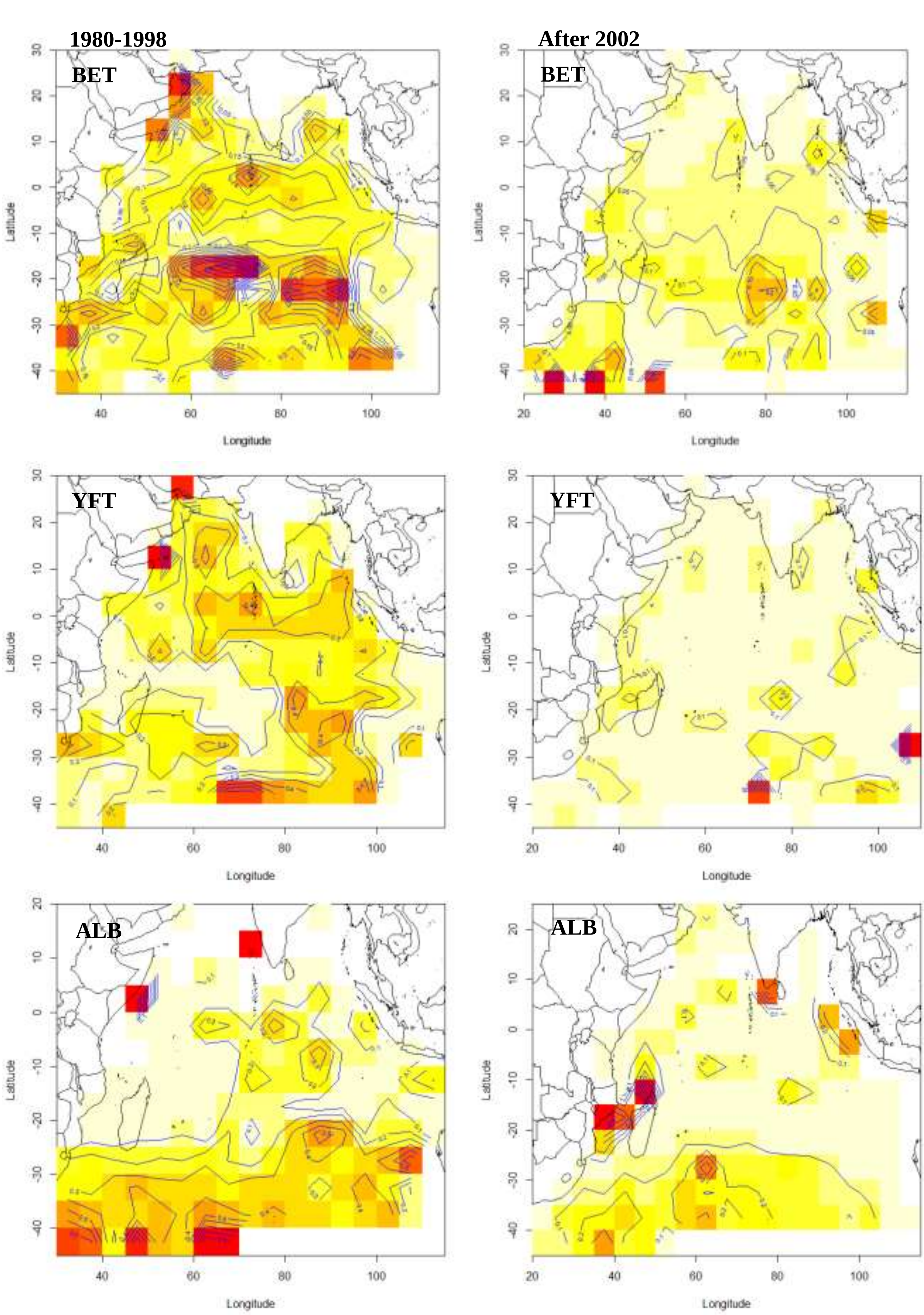


Fig. 10 *(a.) Proportion of fish sampled less than 100cm between 1980-1998 (left), and after 2002 (right) for bigeye (top), yellowfin (middle) and albacore (bottom).*



In summary, the spatial effects of changes in fishing location on sampled lengths are do not appear to account for the extent of changes in average lengths recorded by the fleet. A number of alternative explanations are considered below.

Changes in the underlying population are highly unlikely, given the sudden disappearance of fish less under 100cm sampled compared with the substantial numbers recorded prior to 2003. There is also no decline of smaller fish reported by size frequencies of other fleets operating in the area (e.g., Seychelles longline vessels) to support this theory. Recent changes in the length composition must be either a product of changes in the fishing selectivity that have eliminated the capture of small fish, or the result of changes to the selection of fish sampled or the processing and validation of the size data:

- *Sampling protocols and statistical and data processing systems*
  - One of the largest increases in average weights occurs between 2002 and 2003 – in which BET increased by 15% (from 42.4kg to 48.9kg), YFT by 14% (from 33.7kg to 38.3kg), and ALB by 18% (from 13.8kg to 16.2kg) – coincides with changes to the data collection and format of logbooks around this time, as detailed in section 2.3.
  - The similarity in the increase in average weights and length distributions of BET, YFT and ALB are also highly unlikely in the population, but are highly suggestive of changes in the sampling or processing of the data, i.e., the selection of samples resulting in smaller sized fish no longer being measured for lengths.
  - Although the spatial effects of changes in fishing areas sampled are not considered influential in the recent increase in fish sizes, they are indicative of possible changes in the data collection. The sampling coverage of catch-and-effort by the size data shows some particularly interesting patterns after 2002, with samples for many areas appearing to capture 100% of the catch reported by the catch-and-effort (Fig. 11a-c). Unusual and sudden differences in the areas sampled also occur between individual years in the last decade. In 2005 and 2006 there is a distinctive shift towards sampling of yellowfin in the West Indian Ocean (west of 80°E) compared to 2004, while in 2008 almost 100% of catches in the East Indian Ocean are sampled. Similarly in 2005 for majority of catches of big eye in the West Indian Ocean were sampled, in contrast to the spatial pattern of samples in previous and subsequent years. The extent of almost total enumeration of catches reported by catch-and-effort measured for lengths in many areas makes the disappearance of small sized fish from samples appear even more odd.
  - Details of the procedures for sampling and the processing of the size data – including any changes to the systems in the last decade – have been requested from OFDC by the IOTC Secretariat, however on the basis of the evidence presented in this paper, it appears to be the most likely explanation for the sudden changes in length frequencies after 2002.

Fig. 11(a). *Bigeye: proportion of catch-and-effort sampled for lengths by Taiwanese DWLL, 2000-2011.*

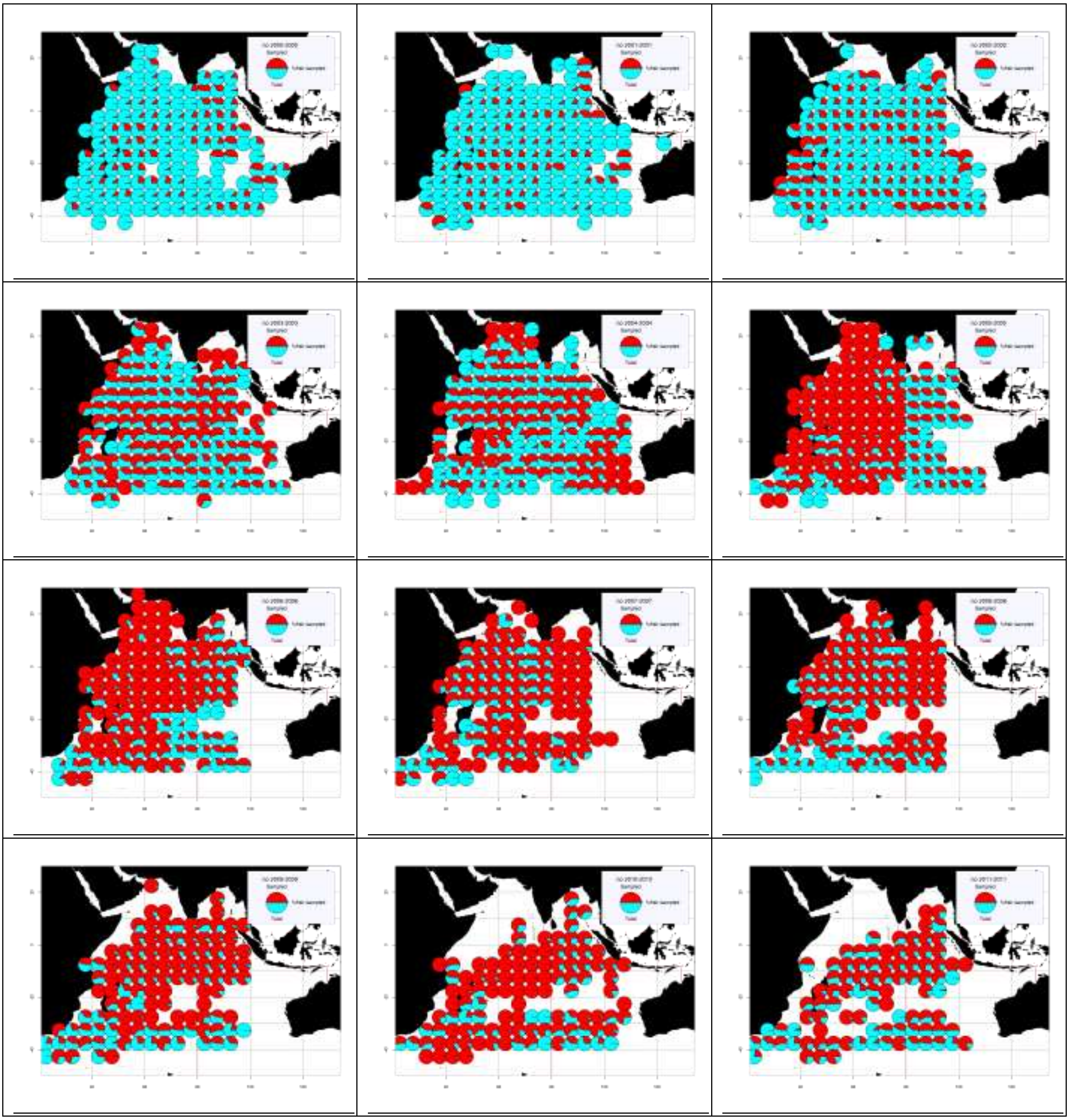


Fig. 11(b). *Yellowfin: proportion of catch-and-effort sampled for lengths by Taiwanese DWLL, 2000-2011.*

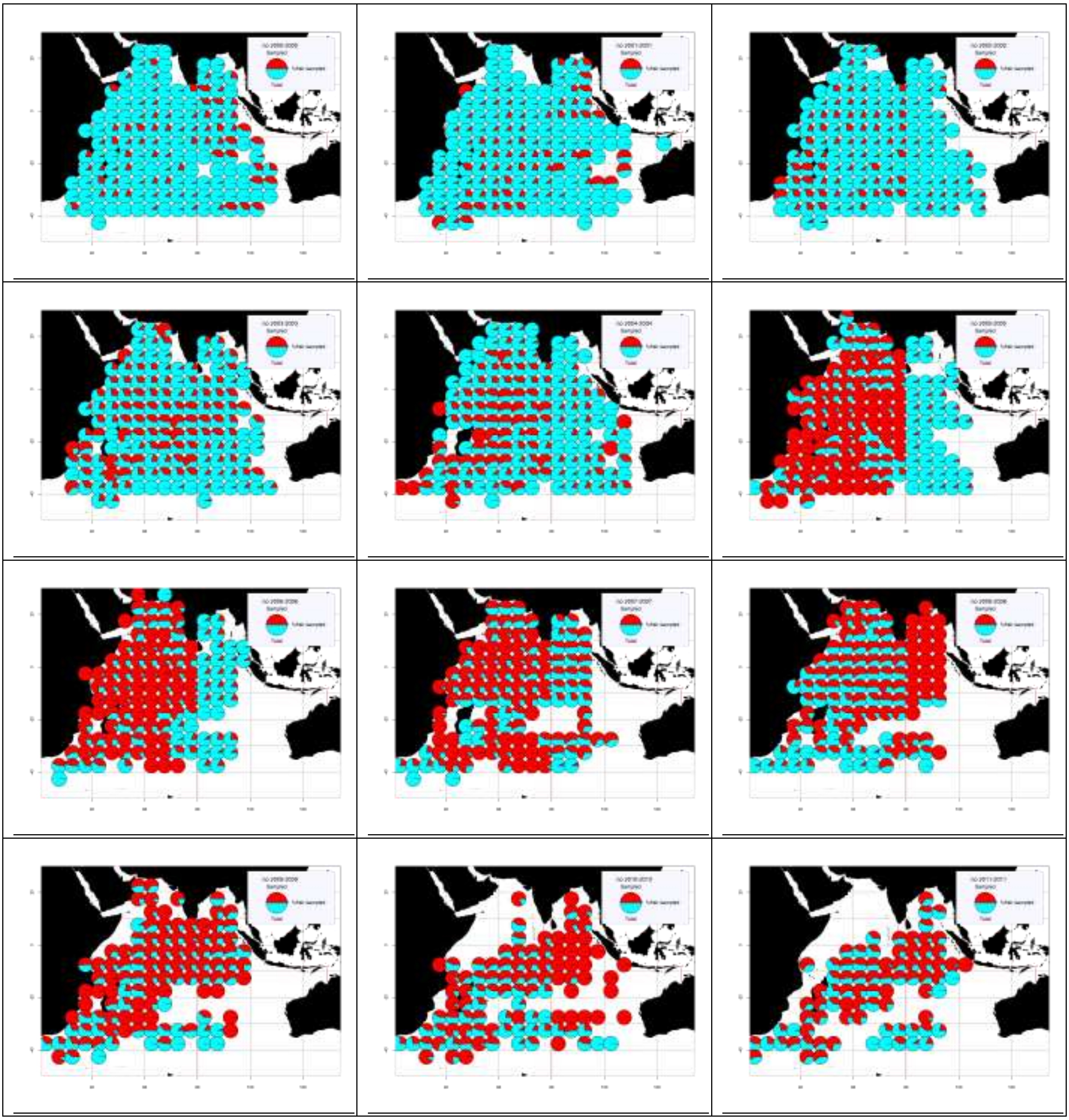
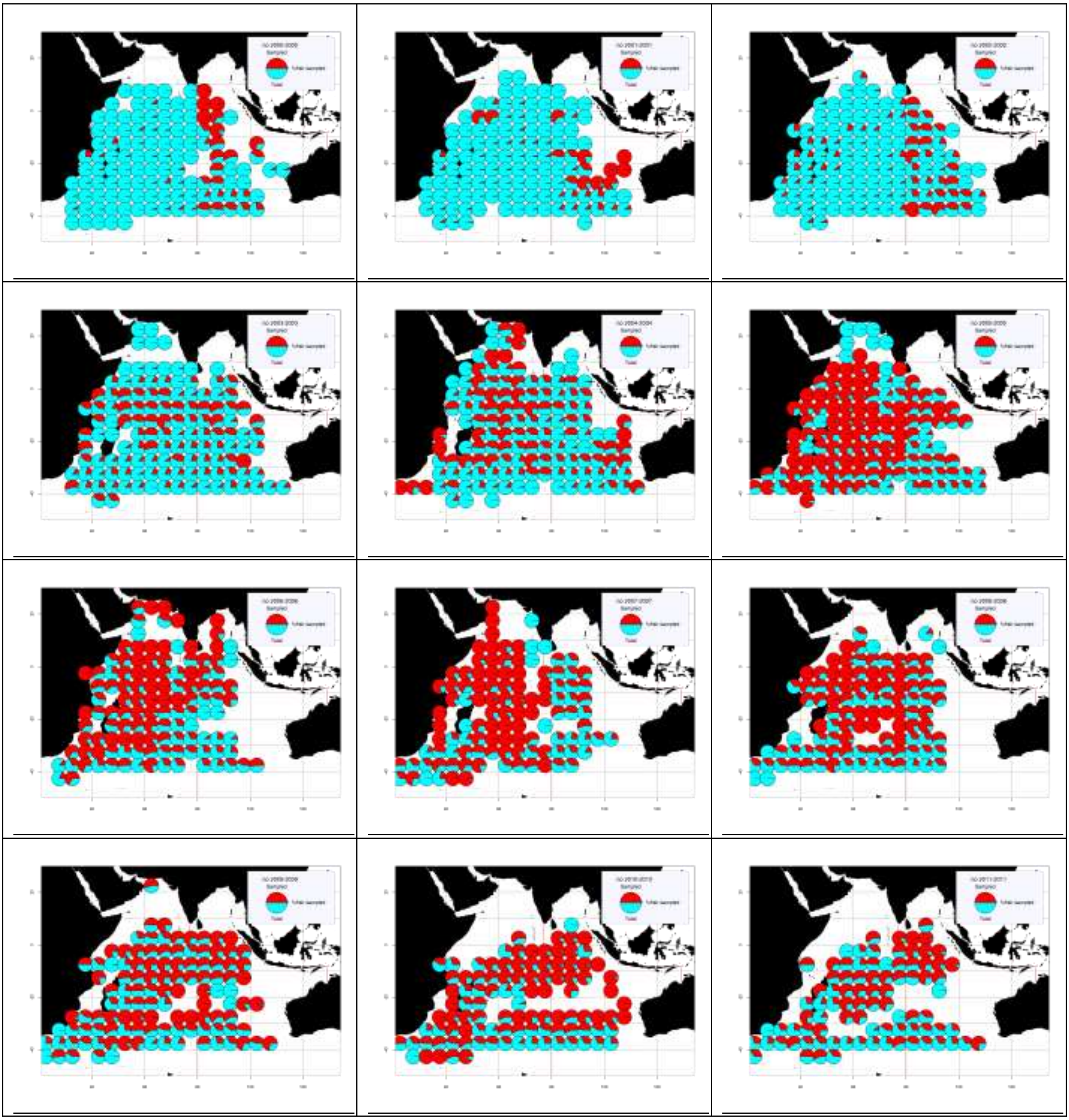


Fig. 11(c). *Albacore: proportion of catch-and-effort sampled for lengths by Taiwanese DWLL, 2000-2011.*



- *Longline targeting strategies*
  - The introduction of quotas in the early-2000s is another possible contributing factor, by affecting a change in the targeting of longline vessels towards catches of larger sized fish and which are then sampled. However again – without further details from OFDC – this is largely speculative and is unlikely to be a major influence. Quotas were only in place around 2003 and do not explain the long-term changes to the length-composition and increase in average weights for later years after 2003.
  - More generally, changes in average weights may be related to longer term changes in the targeting activities that may be reflected in the changes in the species composition and also the size of fish targeted. For example, YFT targeted set may bring smaller BET, than BET night sets. Perceived inconsistencies in the data series may simply be a product of changing targeting practices.
  - Changes in the gear configuration or setting practices may also have an influence upon the size of fish – for example, a switch towards night sets may tend to catch larger specimens in the case of BET – but are unlikely to account for such large effects on size composition, or have such similar effects for both BET and YFT, or also account for the changes to ALB. Neither does a change in gear or setting practices explain the discrepancies observed between the size data and catch-and-effort, given both have been recorded from the same data collection forms since 2005.

- *Export demand and market regulations*
  - Related to changes in targeting, the size of specimens sampled and recorded by logbooks may also be driven by developments in the export market, as logbooks are generally used to record commercial catches only.
  - Fish less that 20kg (i.e., <100cm) are generally considered unsuitable for the sashimi market and rejected for export. However this does not explain why large numbers of smaller sized fish are included in samples before 2003 and not for years after, given there has been no significant change in demand.
  - Another possibility may be the implementation of new market regulations that mean smaller fish are not retained in catches and therefore measured for size; however, again, this does not explain why smaller sized fish continue to be recorded in the catch-and-effort after 2002.

- *Conversion factors between lengths to processed and round (whole) weights*
  - Another possibility is that inconsistencies in average weights between data types are partially the result of differences in the conversions factors when converting processed (gill and gutted) weights to round (whole) weights for the catch-and-effort calculated by Taiwan,China, compared to the conversion of lengths to processed weights and then whole weights of size-frequency data by the IOTC Secretariat.
  - However this offers only a partial explanation of the data – accounting for possible inconsistencies in the average weights between the size data and catch-and-effort, but not for changes in the length-composition distribution from 2003 (see Fig. 2 earlier) that are independent of any length-weight conversion.
  - Differences in the conversion factors are also unlikely to explain the scale of variation in average weights observed between the size-frequency and catch-and-effort data, and which would likely account for around ≈10% difference in average weights at the most.

Conclusion and recommendations

The cause of recent increases in fish sizes sampled by the Taiwanese DWLL fleet remains unclear. There appears to be no evidence that the higher sampling coverage during the mid-2000s are reflecting a fundamental change in the underlying population, or that the differences in lengths are necessarily the effects of changes in areas sampled. Changes in selectivities arising from a shift in targeting, gear configuration, or setting practices may in part be contributing factors, but are unlikely to explain the scale of differences of sampled lengths compared to earlier years.

Based on the evidence presented by paper, the most plausible explanation appears to be changes in the logbook data collection from 2000 onwards – arising from either changes in the sampling protocols and fish selected for sampling, or the processing and validation of the data. The sudden disappearance of smaller sized fish from samples, which have led to average weights increasing by as much as 50-60% since 2000; the extent of uniformity in length distributions after 2003; inconsistencies between the size data and catch-and-effort during years of some of the highest sampling coverage; and most importantly, the degree to which changes in the length distribution are mirrored by BET, YFT and ALB – are all indications that the changes are data driven. It is also important to repeat that the length measurements are not validated at the point of data capture on-board vessels, but only once the data have been submitted and are ready to be processed.

Further consultation between the IOTC Secretariat and OFDC is required to understand these unusual characteristics of the size data. Not least is the unprecedented number of samples collected after 2002, particularly for the period 2003-2005. In 2003 over 546,000 BET were sampled for lengths: nearly 150% higher than in 2002 (221,000 samples), and more than the total BET samples recorded by the Japanese longline fleet across *all years* since 1980. In the case of YFT, 630,000 samples were recorded in 2005: over 560% higher compared to 2002 (95,000 samples), and more than 50% more that all YFT samples recorded by Japanese longline vessels since 1980. OFDC has confirmed that the data represent the original samples that have not been raised or adjusted in any way, and that the higher levels of coverage are the result of improvements in the logbook recovery rate following of the introduction of bigeye Statistical Document in 2002.

In view of the concerns over the reliability of the increase in the lengths of samples by Taiwan,China, and the general lack of information regarding the current procedures for sampling and processing of the data, the IOTC WPDCS may wish to consider the following recommendations:

1. <u>Excluding the size data for BET, YFT and ALB from around the early-2000s for the Taiwanese DWLL fleet for future stock assessments until the cause of changes in the size frequency data have been determined by the WPDCS.</u>
   - Excluding Taiwanese DWLL size data from the early-2000s effectively removes between 90-95**%** of the total samples for each species of BET, YFT and ALB available from future stock assessments, but is justified based on the level of risk to the assessment and management advice of using data with unknown or unrepresentative sampling.
   - There remains the possibility that recent changes in lengths are valid and a reflection of changes in the targeting or selectivities by the Taiwanese DWLL fleet, and that size data in recent years is still of value for the assessments. However further details on the changes in the fishery are required in order that the changes in selectivity can be taken account of by the stock assessment models.

2. OFDC and the related Fishing Agencies of Taiwan,China to collaborate with the IOTC Secretariat to conduct a full and comprehensive assessment of the data quality of the size data *for all years* for the Taiwanese DWLL fleet.
   - The review should include details of the sampling areas, procedures for sampling lengths and processing steps of the size frequency and catch-and-effort datasets, and in particular address any changes to data collection and processing systems introduced in the last decade; in addition to details of changes to the fishery such as targeting or gear configuration.

3. That as part of the review of the Taiwanese DWLL fleet size data, to assess the reasons for discrepancies identified by the IOTC Secretariat, provide a comparison of length frequency sampled collected from commercial and scientific observers, in accordance with the recommendation of the Scientific Committee (SC15.78), which states:

   SC15.78 (para.141) "*NOTING that there were discrepancies in catch, effort and notably size data (low sampling rate, uneven distribution of sampling in regard to the spatial extent of the fishery) in the Japanese and Taiwan,China tropical tuna data sets, the SC RECOMMENDED they review the data to assess reasons for discrepancies identified by the IOTC Secretariat and to report results at the next meeting of the WPTT, including a comparison of length frequency data samples collected from commercial, research and training vessels*."

   - Differences have been have previously noted between samples collected from commercial, research and training vessels, and scientific observers, however there is limited information available on the scale of differences or the extent to which combining size data from multiple sources is affecting changes in length distribution of samples.

4. To endorse the recommendations of the WPTT (WPTT15.05, para.74) proposing an inter-sessional meeting attached to the WPDCS and WPM on *data collection and processing systems from the main longline fleets in the Indian Ocean*, to be carried out in early 2014, and encourage the attendance of Taiwan,China, Japan, Indonesia and other parties having important longline fisheries in the Indian Ocean, as well as other tuna-RFMO Secretariats.

   - Inconsistencies between the longline size data of Taiwan,China and Japan have been noted by the IOTC Secretariat for a number of years.
   - There are indications from other tuna RFMOs that some of the problems identified for length-frequencies of longline fisheries in the Indian Ocean have also been noted for other oceans too.
   - One of the key issues is agreeing the methodology for raising samples to the total catch for each fleet, to explore if differences in the length distributions between fleets are related to differences in targeting practices.

Annex 1. Equations used to convert from standard length into round (whole) weight, per species.
For further details see http://www.iotc.org/files/proceedings/2013/wpb/Equations.pdf

Species	*Gear Type/s*	*From type measurement – To type measurement*	*Equation*	*Parameters*
Yellowfin tuna	Purse seine Pole and Line Gillnet	Fork length – Round Weight(kg)[A]	RND=a*L^b	a= 0.00001886 b= 3.0195
	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
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
	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
Albacore	All gears	Fork length(cm) – Round Weight(kg) [F]	RND= a*L^b	a= 0.0000569070 b= 2.75140

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