Report of the Fifth IOTC CPUE Workshop on Longline Fisheries

Keelung, May 28th – June 1st, 2018.

DISTRIBUTION:	**BIBLIOGRAPHIC ENTRY**
Participants in the Session Members of the Commission Other interested Nations and International Organizations FAO Fisheries Department FAO Regional Fishery Officers	Hoyle, S.D.[1], Kitakado, T[2]., Yeh, Y.M.[3], Wang, S.P.[4], Wu, R.F.[5], Chang, F.C., Matsumoto, T.[6], Satoh, K., Kim, D.N.[7], Lee, S.I., Chassot , E.[8], and Fu, D[9]. IOTC–CPUEWS–05 2018: Report of the Fifth IOTC CPUE Workshop on Longline Fisheries, May 28th–June 1st, 2018. *IOTC–2018–CPUEWS05–R[E]: 27 pp.*

[1] IOTC Consultant, Email: simon.hoyle@gmail.com,
[2] Tokyo University of Marine Science and Technology, Japan Email: kitakado@kaiyodai.ac.jp
[3] Nanhua University, invited Taiwanese expert Email: ymyeh@nhu.edu.tw
[4] National Taiwan Ocean University, invited Taiwanese expert Email: wsp@mail.ntou.edu.tw
[5] Overseas Fisheries Development Council, invited Taiwanese expert Email: fan@ofdc.org.tw and fengchen@ofdc.org.tw
[6] National Research Institute of Far Seas Fisheries, Japan Email: matumot@affrc.go.jp, and kstu21@affrc.go.jp
[7] National Institute of Fisheries Science, Republic of Korea. . Email doonam@korea.kr, and k.sungillee@gmail.com
[8] Seychelles Fishing Authority , Seychelles. Email: mchassot@sfa.sc
[9] IOTC Secretariat, PO Box 1011, Victoria, Seychelles Email: dan.fu@fao.org

Food and Agriculture Organization of the United Nations

Indian Ocean Tuna Commission
Commission des Thons de l'Ocean Indien
iotc ctoi

Contact details:

Indian Ocean Tuna Commission
Le Chantier Mall
PO Box 1011
Victoria, Mahé, Seychelles
Ph: +248 4225 494
Fax: +248 4224 364
Email: secretariat@iotc.org
Website: http://www.iotc.org

ACRONYMS

ALB	Albacore Tuna
BET	Bigeye Tuna
CPCs	Contracting parties and cooperating non-contracting parties
CPUE	Catch per unit of effort
HBF	Hooks between Floats
IOTC	Indian Ocean Tuna Commission
GLM	Generalized Linear Model
LL	Longline
NBF/NHBF	Number of Hooks between Floats
R	R Package for Statistical Computing
SAS	Software for Analyzing Data
SC	Scientific Committee of the IOTC
STD	Standardized
SWO	Swordfish
WP	Working Party of the IOTC
WPB	Working Party on Billfish of the IOTC
WPM	Working Party on Methods of the IOTC
WPTmT	Working Party on Temperate Tunas of the IOTC
WPTT	Working Party on Tropical Tunas of the IOTC
YFT	Yellowfin Tuna

HOW TO INTERPRET TERMINOLOGY CONTAINED IN THIS REPORT

Level 1: ***From a subsidiary body of the Commission to the next level in the structure of the Commission:***
RECOMMENDED, RECOMMENDATION: Any conclusion or request for an action to be undertaken, from a subsidiary body of the Commission (Committee or Working Party), which is to be formally provided to the next level in the structure of the Commission for its consideration/endorsement (e.g. from a Working Party to the Scientific Committee; from a Committee to the Commission). The intention is that the higher body will consider the recommended action for endorsement under its own mandate, if the subsidiary body does not already have the required mandate. Ideally this should be task specific and contain a timeframe for completion.

Level 2: ***From a subsidiary body of the Commission to a CPC, the IOTC Secretariat, or other body (not the Commission) to carry out a specified task:***
REQUESTED: This term should only be used by a subsidiary body of the Commission if it does not wish to have the request formally adopted/endorsed by the next level in the structure of the Commission. For example, if a Committee wishes to seek additional input from a CPC on a particular topic, but does not wish to formalise the request beyond the mandate of the Committee, it may request that a set action be undertaken. Ideally this should be task specific and contain a timeframe for the completion.

Level 3: ***General terms to be used for consistency:***
AGREED: Any point of discussion from a meeting which the IOTC body considers to be an agreed course of action covered by its mandate, which has not already been dealt with under Level 1 or level 2 above; a general point of agreement among delegations/participants of a meeting which does not need to be considered/adopted by the next level in the Commission's structure.

NOTED/NOTING: Any point of discussion from a meeting which the IOTC body considers to be important enough to record in a meeting report for future reference.

Any other term: Any other term may be used in addition to the Level 3 terms to highlight to the reader of and IOTC report, the importance of the relevant paragraph. However, other terms used are considered for explanatory/informational purposes only and shall have no higher rating within the reporting terminology hierarchy than Level 3, described above (e.g. **CONSIDERED**; **URGED**; **ACKNOWLEDGED**).

Executive Summary

A Workshop assessing CPUE trends and techniques used by the IOTC was held in Keelung from May 28th to June 1st, 2018. The aim of the meeting was to validate and improve the methods of collaborative CPUE analysis for tropical and temperate tuna species for main longline distant water fishing fleets operating in the Indian Ocean, to develop joint standardised CPUE indices for yellowfin and albacore tuna, and to develop standardised indices for the national fleet, including Japanese, Taiwanese, Korean, and Seychelles Longline fleet. A hands-on tutorial with a focus on the use of the generic R code was given covering all aspects of the joint analysis including the preparation of the data, descriptive analysis on catch and effort, the clustering analysis, and the CPUE standardizations for individual fleet. The 2018 Joint CPUE analysis included the data from the Japanese (1952-2017), Korean (1971-2017), Taiwanese (2005-2017), and Seychelles (2000-2016).

TABLE OF CONTENTS

OPENING OF THE MEETING AND INTRODUCTORY ITEMS

1. A small Working group (CPUEWG) was held in Keelung from May 28th to June 1st 2018, to validate and improve the methods of developing joint standardized CPUE for tropical and temperate tuna species from main distant water longline fisheries operating in the Indian Ocean, including the Japanese, Korean, Taiwanese, and Seychelles fishing fleets. The meeting was attended by scientists of the main longline fleets in the Indian Ocean, as well as the IOTC Secretariat (see list of participants in Appendix I).

2. The organization of this workshop was recommended based on the SC 2017 (SC20.29), as well as the 4th CPUE Workshop held in Busan in 2017 (IOTC–2017–CPUEWS04–R). The CPUEWG was chaired by Dr. Toshihide Kitakado, the Chair of Working Party on Methods.

3. Dr. Toshihide Kitakado opened the meeting and informed the participants of the scope and expected outcomes of the workshop. The main priority was to develop joint standardized CPUE for yellowfin and albacore tuna, as well as indices for individual fleets, by applying cluster analysis to derive targeting strategies using reliable data for each CPC. The joint standardised indices to be developed during the workshop are expected to be used in the 2018 assessment of yellowfin tuna, and the 2019 assessment for albacore tuna. The agenda was adopted (Appendix II), and the CPUEWG participants agreed on the TOR of the meeting (Appendix III).

4. The IOTC Secretariat summarised the recommendations from previous IOTC Joint-CPUE workshops. The CPUEWG **NOTED** the support from WPTT, WPM, and Scientific Committee for the Joint CPUE analysis to continue. The 2nd session of the Technical Committee on Management Procedures also recommended the use of joint standardization approach to support the Management Procedure Evaluations for different stocks.

5. IOTC would like to thank the lead Principal Investigator, Dr. Simon Hoyle and the CPCs (Dr. Kitakado, Dr. Matsumoto, Dr. Satoh, Dr. Yeh, Dr. Wang, Mr. Wu, Dr. Chang, Dr. Lee, Dr. Kim, and Dr. Chassot) for the excellent work and effort put into the joint analysis produced so far (Appendix IV). IOTC would also like to thank the Taiwanese colleagues for their hospitality in organizing and providing facilities for the meeting.

6. The report of the collaborative study of yellowfin and albacore tuna CPUE from Indian Ocean longline fleets, as well as reports of analyses for individual longline fleets will be finalized after this workshop and presented at the IOTC WPM, WPTT (October 2018) and WPTmT (January, June 2019).

National operational catch-effort data and analysis to-date

7. Japanese, Taiwanese, Korean, and Seychellois participants provided overviews of their national longline fleets operating in the Indian Ocean, as well as CPUE analyses conducted to-date.

8. Dr. Matsumoto gave an overview of Japanese longline fishery and approaches used in the standardization of CPUE. The following summary is provided by the author: "*Japanese longline fishery has been operating in the Indian Ocean since 1952. Its operations concentrated mostly in the tropical area during the initial period, and then spread to almost the entire Indian Ocean. The fishing effort (number of hooks) fluctuated and dropped to a low level recently, particularly in the northwestern area due piracy activities. There were changes in species composition of the catch historically, indicating changes of targeting. Recently albacore is dominant in the catch in number, but not in weight. The logbook contained information on catch, effort, and fishing gear (including hooks per basket, gear material, and bait), although the record of gear material was available only from 1994, and the information on bait was available up to 1993). The proportion of deeper longline and nylon material increased overtime especially in the 1990s. In recent years, standardization for Japanese longline CPUE for bigeye, yellowfin and albacore by national scientists has been conducted with GLM lognormal models using operational-level data. The effects of fishing season (quarter or month), fishing ground (five-degree latitude and longitude blocks or stock assessment subareas), fishing gear (material and number of hooks per basket) and environmental effect (sea surface temperature) and their interactions have been used in the standardizations. There are some differences of the trend between Japanese longline and other longlines indices, as well as the joint CPUE indices, especially for albacore. Size data for Japanese longline fishery were collected based on on-board measurement by the fishermen, training vessels, and scientific observers. The main component of data source depends on period. Recently most of the data were collected by scientific observers, and the number of samples were low especially for yellowfin tuna. There was no obvious difference of fish size among sampling methods*."

9. The CPUEWG **NOTED** that fishing effort of the Japanese longline fleet has continued to decline since 2010 and despite of the alleviation of piracy activities the vessels have not returned to the fishing ground in the Northwestern Indian Ocean.

10. The CPUEWG **NOTED** that there has been a somewhat increase in the proportion of albacore tuna catch in the total catch of tuna and billfish species since the mid-2000s. The reason is not clear as albacore is not a main target species by the Japanese longline fleet.

11. The CPUEWG **NOTED** that there have been a number of changes in fishing strategies employed by the Japanese longline fleet in the Indian Ocean overtime: effort has shifted from the shallow (HBF ≤ 7) to the deep (8 < HBF ≤15) sets and almost all the effort in the 'very deep' category (HBF > 15) appeared (the distribution of the 'very deep' effort predominantly occurred in tropical areas); the new main and branch-line material (Nylon mono-filament) has been used since early 1990s; the type of main bait used has also changed a few times. The CPUEWG **NOTED** the bait is sometimes a good indicator of targeting.

12. Dr. Satoh presented the exploration of area stratification for CPUE standardization of yellowfin tuna by Japanese longline. The following summary is provided by the author: "*This presentation deals with the subarea stratification of yellowfin tuna CPUE standardization process of Japanese longline in the Indian Ocean. This study has already been presented in the previous WPTT meeting. This newly developed area stratification has not been applied because the CPUE standardization process of longline fisheries has moved to the next phase (joint standardizations of including Korean, Taiwanese, and Japanese data). However, the stratification method which accounted for the similarity for the size composition as well as CPUE trend in a specific area is useful for future CPUE standardization process (e.g. the utilization of size composition is helpful for defining fishery with similar selectivity for stock assessment purposes). New spatial sub-areas for yellowfin tuna CPUE standardization of Japanese longline fishery in the Indian Ocean was proposed using the simultaneous tree method. The study also examined performance for the present and new sub-area definition. Relative abundance indices using the two area definitions were compared. The analyses in this study included three components: Analysis 1; using only size data, Analysis 2; using only CPUE data, and Analysis 3; using both size and CPUE data. The trees of the three analyses appeared to show agreement in two points: 1) the first split around 15S, and 2) the second split on around equatorial. The seasonal effect in the analysis 1 was not clear in the analyses 2 and 3. It appeared that CPUE trends have more influence on the simultaneous tree structure than the size distributions. The statistics, U(s), for ranking the candidate stratifications in the analysis 3 (0.154) was larger than the value of 0.117 for the present sub-area definition, which indicated that the new area definition presented more uniform in size composition and CPUE trend rather than the present sub-area definition. Comparison standardized CPUEs using the two area definition showed similar trend with some annual fluctuation*."

13. The CPUEWG **RECALLED** this study was presented to the WPTT in 2014 (IOTC-2014-WPTT16–48) and **NOTED** that the regional stratification proposed in this study for yellowfin tuna was different to that used in recent CPUE standardizations and stock assessments. The CPUEWG **RECALLED** the current yellowfin regional structure was based on fishery data as well as oceanographic conditions. The CPUEWG discussed what should be considered when determining the appropriate regional definition for a species. The CPUEWG **AGREED** that regional definition should take into an account differences in population structure, biological characteristics and/or fleet dynamics.

14. The CPUEWG **NOTED** that with the above approach the relative weighting on the impurity measures of the CPUE trend and the size structure may influence the result. The CPUEWG suggested that the inclusion of weight data could potentially increase statistical power of the analysis, and the analysis could also be improved through the use of boosted regression and/or random forest.

15. Dr. Yeh presented an overview of the Taiwanese large scale (vessels over 100 GT) longline fishery data in the Indian Ocean. The following summary is provided by the author: "*Taiwanese deep-water longline fleet has been mainly targeting bigeye in the tropical area of the Indian Ocean since the 1980s. The total yellowfin catch was significant increasing from 8,000mt in1985 to 60,000 mt in 2005. And then after 2006, the total yellowfin catch was decreasing to 7,618 mt and 4,629 mt in 2016 and 2017 partly because of Taiwanese vessel reduction program. The fleet was composed of about 138 active vessels in 2017. Yellowfin represented 25% of the total and tuna catch over the last decade. The major yellowfin fishing ground were distributed north of 15°S over the whole period*."

16. Dr. Lee presented overviews of Korean longline fisheries in the Indian Ocean and the data for CPUE standardization. The following summary is provided by the author: "*The number of active fishing vessels showed the highest in the mid-1970s, but it decreased thereafter and reduced to 7 vessels in 2011. In 2013, it has somewhat of increasing, and was 13-14 vessels in recent years (2015-2017). The total catch peaked at about 70 thousand mt in 1978 and then decreased significantly. Since 2014 the catch of yellowfin tuna has shown an increasing trend, and bigeye tuna has been stable at low level. In the 1970s and 1980s, the fishing ground of Korean longline fishery was formed at tropical area between 10°N and 10°S in the Indian Ocean, but it gradually moved to the southern Indian Ocean, and was formed mainly between 15°S and 40°S of the western and eastern Indian Oceans in recent years. In addition, since 2015 some vessels have operated at the tropical area to fish for yellowfin and bigeye tuna*."

17. Dr. Chassot presented an overview of the Seychelles industrial longline fishery. The following summary is provided by the author: "*The Seychelles deep-water longline fleet has been mainly targeting bigeye in the tropical area of the Western Indian Ocean since the early 2000s. The fleet was composed of about 25 vessels throughout the 2000s and increased thereafter to reach 47 in 2016. Concurrently, the effort increased from about 15 millions hooks in the late 2000s to more than 30 millions hooks in 2016. The total catch was 13,000 mt in 2016, including >7,000 mt of bigeye and yellowfin tuna. Bigeye represented 50% and 67% of the total and tuna catch during 2000-2016, respectively. Yellowfin represented 25% of the total tuna catch during that period. A few vessels targeted swordfish and albacore south of 20°S while almost no fishing took place north of 10°N over the last decade."*

Current status of joint CPUE STD

18. Dr. Kitakado provided an overview of CPUE standardization, with a focus on selectivity. The following summary is provided by the author: *The main goal of CPUE standardization is to derive relative temporal changes of exploitable biomass by accounting for changes in relative catchability and availability. Some of the important issues include 1) the spatial distribution pattern may change due to fish growth, and therefore the size-selectivity/availability may also change if the population structure is not constant. 2) When producing standardised CPUE by aggregating data over fisheries (e.g. longline), investigation needs to be undertaken to ensure selectivity pattern are similar among the fisheries. Otherwise the resulting joint standardised indices are likely to be biased over time. The use of age/size information for the CPUE standardisation may help alleviate the bias. The author will continue the investigate in these lines including examining the possible utility of size-based or age-based CPUE-STD indices (or using the mean size as a covariate) and will report back the outcomes to relevant Working Parties*.

19. The CPUEWG **NOTED** that CPUE is considered to index exploitable biomass therefore changes in selectivity overtime or amongst fleets may influence the interpretation of standardised indices. The CPUEWG **AGREED** that it is important to define fisheries to ensure the assumption of constant selectivity is not violated (e.g. fleets that are catching different components of the population should be treated as different fisheries in stock assessments). The CPUEWG suggested that the direct modelling of size data is helpful in identifying potential differences in selectivity amongst fleets while accounting for spatial and temporal effects.

20. Dr. Hoyle summarised the progress towards the collaborative analysis and issues pertinent to the development of the joint CPUE indices. The joint CPUE standardisation was initially developed to resolve the inconsistent trends between Japanese and Taiwanese CPUE, particularly for bigeye tuna, and indices developed under this framework have been incorporated into the most recent stock assessments for bigeye, yellowfin, and albacore tuna. The CPUEWG **NOTED** current analytical framework of joint CPUE standardisation involves the following components:

- Exploratory plots to improve understanding of the data.
- Analyse data by fleet, species, and regional structure.
    - Targeting: Cluster analyses to separate fishing strategies.
    - Select useful clusters from each data subset, then combine all fleets.
    - Standardize data using generalized linear models to derive CPUE indices.

21. The CPUEWG discussed a number of issues (as below) which may influence the interpretation of the joint standardised indices and how they were addressed in the present analysis. The CPUEWG **AGREED** that these issues warrant further investigation.

- Assumptions about area with no effort
- Biases due to changing effort distribution
- Spatial and temporal residual patterns in the model fits
- Spike in late 1970s
- Post-piracy spike in 2010
- Size-area patterns
- Probable catchability changes up to 1960~65
- Regional scaling

22. The CPUEWG **NOTED** different assumptions can be made on the biomass trend in areas without fishing effort. In the 2017 analysis a combined approach was explored which involved fitting a model with time-area interaction, and infilling time-area 'holes' with estimates from a time + area model.
23. The CPUEWG **NOTED** that statistical effort weighting (Punsly 1987, Campbell 2004) was used to avoid the potential bias due to shifting effort concentration by giving equal influence to data from each time-area stratum.
24. The CPUEWG **NOTED** that spatial patterns in residuals may indicate varying biomass trend amongst areas. The CPUEWG **NOTED** that the residual analysis was applied to other species in Atlantic Ocean and suggested a similar analysis be performed for the Indian Ocean.
25. The CPUEWG further **NOTED** residual analysis can be used to reveal potential differences between/ within fleets due to factors not accounted in the standardisations such as bait, gear configurations, reporting and fishing behaviour. The CPUEWG suggested possible future options include random effects models and require more advanced modelling tools such as MGCV and VAST.
26. The CPUEWG **NOTED** the spikes in the yellowfin and bigeye indices in the 1970s and in 2010 and **RECALLED** various hypotheses proposed for what could have happened to CPUE with new fishing in areas, such as those affected by piracy. The CPUEWG **AGREED** the causes of these spikes require further investigation.
27. The CPUEWG **NOTED** that there was some evidence in the size data which may indicate that the dramatic decline in the indices for yellowfin tuna between 1960 and 1965 may be related to catchability changes.
28. The CPUEWG **NOTED** that the regional scaling for adjusting for relative abundance among regions were based on a simple model fitted to aggregated data from a short period with widespread fishing and stable targeting. The regional scaling used relative catch rates among regions as a proxy for density.

CPUE Standardization for national fleets

29. Dr. Hoyle introduced the general statistical and modelling approach for the joint analysis, and provided technical training to participants standardisation methods for individual fleets. A hands-on tutorial with a focus on the use of the generic R code was given covering all aspects of the joint analysis including the preparation of the data, descriptive analysis on catch and effort, the clustering analysis, and the CPUE standardizations for individual fleet.
30. The CPUEWG **NOTED** The R scripts and functions developed for the Joint analysis have now been managed through GitHub (www.github.com) , a version control system which allows developers to keep track of the revisions to their code and users to have immediate access the latest version. The use of Github also allows CPC scientists to collaborate on the Joint analysis by contributing the source code directly. The CPUEWG **NOTED** that the many hard-coded scripts have now be made in general.
31. In response to recommendation from the previous CPUEWG, national scientists prepared their own datasets with the assistance provided by the consultant. A preparatory meeting was held before the joint workshop to assist Taiwanese scientists to prepare the dataset for albacore. Scientists from most CPCs are now reasonably familiar with the generic R scripts developed for the analysis. During the workshop, scientists worked independently on standardising the national datasets and reported their progress back to the workshop. Examples from the preliminary clustering and standardisation analyses by each national fleet are shown in Appendix IV (yellowfin) and V (albacore). Full results will be summarized as working papers to be presented to the next WPTT and WPTmT meetings.

Preliminary analyses of yellowfin tuna by fleet

32. The CPUEWG **NOTED** that for the Japanese fleet, the indices using different models (delta-lognormal model and lognormal model with a constant value) showed consistent results except for the region 4, where the positive catch rate of yellowfin was low, around 10 – 20% in recent years. Analyses were conducted to compare results between using all data and using cluster selection criteria: one included clusters with the mean value of yellowfin proportion is high and excluded clusters with high of other species proportion looking at the bean plots. The comparison showed the trends of CPUE series by the two data sets were very similar except for the region 4. The coverage of the region 4 using cluster selection criteria was only 17%, while the coverages of other regions were from 62% to 100%.

33. The CPUEWG **NOTED** that for the Korean fleet a large spike in late 2000s was evident in the indices in the western equatorial region (region 2) when regional structure "regY" was used, but not for regional structure "regY2" (i.e. splitting the region 2 in 2 sub-areas at the equator). CPUEWG **NOTED** that the two analyses may have included different data / vessels as a result of the sub-setting criteria. The CPUEWG suggested further investigation. (e.g. using the same data for both analyses)

34. The CPUEWG **NOTED** that for the Korean fleet, Analyses were conducted to evaluate three alternative cluster selection criteria: high proportion of YFT; >= mean proportion of YFT; >= 0.5 max of YFT. The results showed little difference among the three cluster selection criteria.

35. The CPUEWG **NOTED** that for the Taiwanese fleet, the indices in the western equatorial region (region 2) were reasonably consistent between analyses using different regional structures. Analyses were conducted to evaluate two alternative cluster selection criteria: one excluded clusters with the mean value of yellowfin proportion below the overall mean and the other excluded clusters with very low (close to zero) of yellowfin proportion. The results showed the trends of CPUE series by two cluster selection criteria are very similar.

36. The CPUEWG **NOTED** that for the Seychelles fleet, there are new vessels joining the fleet over the last few years and these vessels have relatively high catch rates.

Preliminary analyses of albacore tuna by fleet

37. The CPUEWG **NOTED** that the shift towards deep and ultra-deep sets by the Taiwanese fleet since mid-2000s south of 10° South was believed to be associated with the shift towards targeting oilfish in the southwest Indian Ocean (region 3) (there has been a large increase in oilfish catches in recent years). Region 4 is considered to be the main fishing ground for the Taiwanese albacore fishery which is appropriate for producing standardised CPUE indices.

38. The CPUEWG **NOTED** that for the Taiwanese fleet, there was a large spike around 2006 in Region 1, which warrants further confirmation.

39. The CPUEWG **NOTED** that for the Japanese fleet, there was a sharp decline in the indices for the early years and the dramatic increase in the indices for the recent years. The initial decline was likely to be due to the shift of target (towards bigeye tuna) and possible catchability change. The CPUEWG **NOTED** that there were some differences in CPUE standardisation between the previous method employed by the national scientist (e.g. no cluster analysis and no vessel id) and the new method, and there were also some differences in CPUE between the model that used all the clusters, and the one that included only the albacore-dominant clusters.

40. The CPUEWG **NOTED** that for the Korean fleet, different cluster selection criteria resulted in different CPUE trends. This requires further investigation.

Towards Joint CPUE Analysis

41. Based on the study of Satoh (2014) and Hoyle et al. (2017), the CPUEWG tentatively proposed a modification to current YFT regional structure (regY, see Figure 1-left) by further subdividing the western equatorial region (region 2) into two regions – the area south of the equator and the area north of the equator (region 2 and 7, see Figure 1-right). This alternative stratification (regY2) accounted for differences in the size distribution of yellowfin within the western equatorial region. The CPUEWG **NOTED** that this subdivision is consistent with what was used for the most recent assessment of IOTC bigeye tuna. The CPUEWG **AGREED** that the CPUE standardizations for yellowfin tuna (joint analysis as well as analyses for individual national fleet) are conducted for both regional structures.

42. The CPUEWG **AGREED** that regional structure is very important to CPUE standardisation as well as the stock assessment. The CPUEWG **REQUESTED** the Scientific Committee to provide advice on the regional structures to be used in next year's assessment.

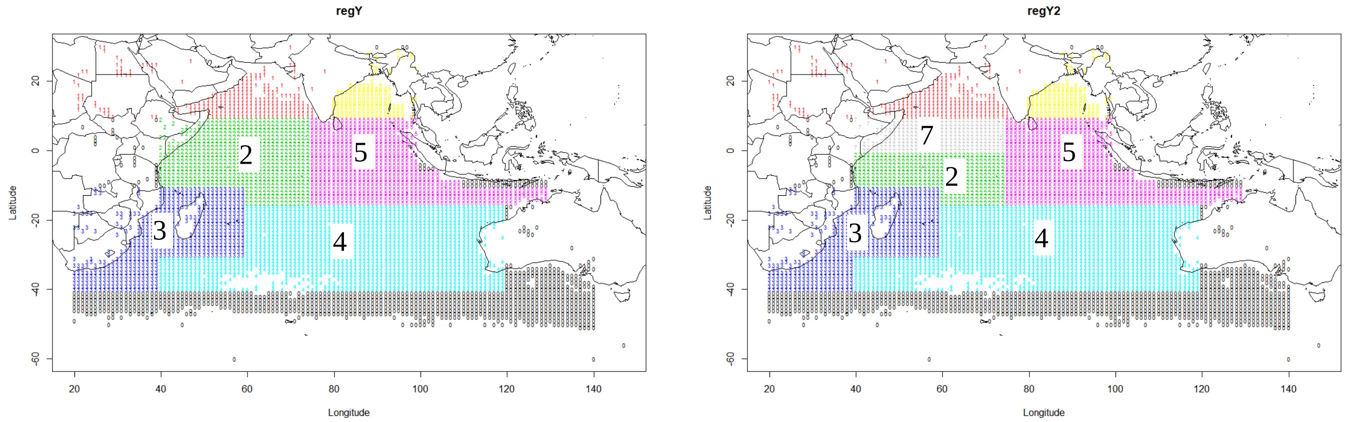

Figure 1: Regional structure "regY" (left) and "regY2" (right) for yellowfin tuna.

43. The CPUEWG also **AGREED** to explore the three alternative regional structure (regA3, regA4, and regA5) for the albacore standardisation ("regA4" is shown in Figure 2). Given the time constraint, CPUE standardizations were conducted for the "regA4" regional structure during the workshop. (previous standardisation was based on "regA3"). The CPUEWG NOTED that this is because the area south of 40S is mainly the fishing ground for southern blue fin tuna.

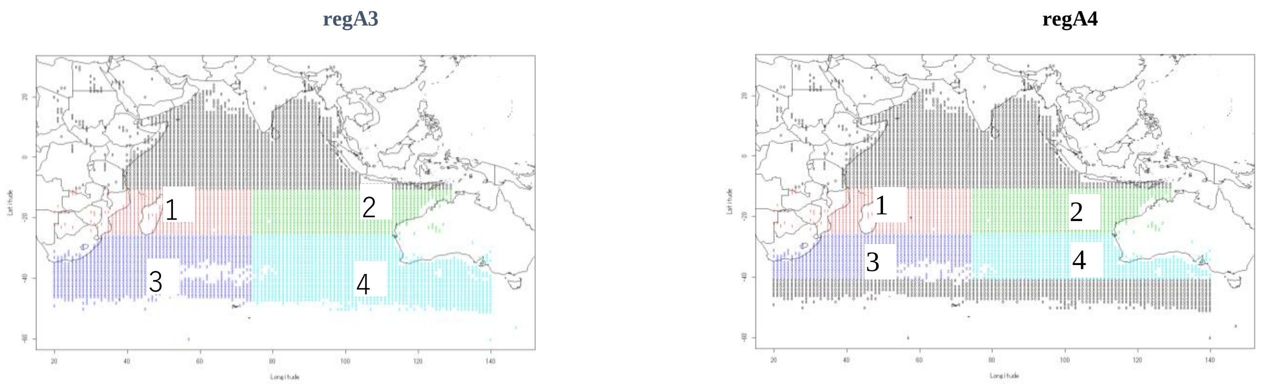

Figure 2: Regional structure "regA3" and "regA4" for albacore tuna.

44. The CPUEWG **NOTED** that the 2018 Joint CPUE analysis included the data from the Japanese (1952-2017), Korean (1971-2017), Taiwanese (2005-2017), and Seychelles (2000-2016). Seychelles data were not included in analyses that used hooks between floats (HBF) as data on HBF only became available from 2009 and only in a subset of the effort. Examples of the standardised CPUE indices for yellowfin (region 2) and albacore (region 4) are shown in Figure 3.

45. The CPUEWG **NOTED** the following criteria were used for sub-setting data for each region in the 2018 standardisation analyses: vessels were included if they had fished for at least 8 quarters in the equatorial regions (or 2 quarters in the temperate regions); vessels, 5° cells, and year-quarters were included if they had at least 100 sets (the actual thresholds could be adjusted depending on the amount of data available in the analysis).

46. The CPUEWG **NOTED** that for most fleets the fishing appears to be intermittent and opportunistic in region 1 (the Arabian sea) and there was almost no effort for the Japanese fleet in the region. Therefore the data in region 1 had not been included in the standardizations.

47. The CPUEWG **NOTED** that the cluster analysis was applied to species composition aggregated by vessel-month as the catch at set-level was often variable due to random encounter of fish. This effectively assumed that the targeting strategy of a vessel remained constant throughout the month, which may not be true for some vessels. The CPUEWG **NOTED** it is worth exploring some other assumptions in terms of how often the vessel change targeting behaviour.

48. The CPUEWG also **NOTED** the clustering was done for individual fleets and regions separately although the targeting behaviour may be similar amongst certain fleets. This is because the sample size of individual fleets / regions was considered to be high enough to ensure sufficient statistical power of the estimates. The CPUEWG further **NOTED** that the number and type of species included in the clustering differed amongst the fleets.

49. The CPUEWG **NOTED** that three basic runs were conducted for each species of interest and for each region in the joint analysis: one with the cluster variable (to indicate targeting), one with the HBF variable, and one with both cluster and HBF variables. In each run, hooks are used as both a measure of effort (on the left hand side of the model equation) and also an explanatory variable indicating targeting.

50. The CPUEWG **NOTED** that the analysis that used the cluster variable in the model removed clusters that have zero catches of the species of interest, and the analysis that did not use the cluster variable removed clusters that have a very low proportion of the species of interest.

51. The CPUEWG **NOTED** that the cluster analysis on species composition was used to identify effort associated with different fishing strategies. The working group **NOTED** that for pelagic longline fisheries, such approaches appear helpful in subtropical areas, but may introduce bias if applied in tropical areas – with the exception of where fisheries are clearly distinct. The CPUEWG suggested examining the effect of using the cluster variable to indicate targeting in the tropical area – by comparing standardizations with and without the cluster variable.

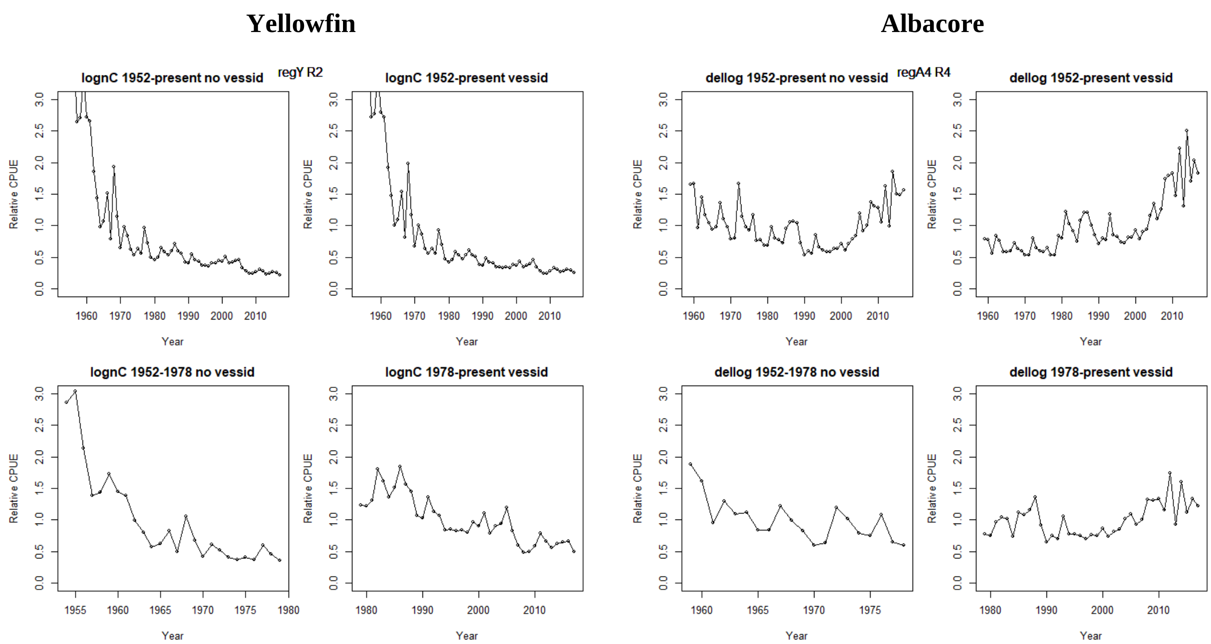

Figure 3: Standardised indices for yellowfin in region 2 (left) and albacore in region 4 (right). For each species, 4 sets of indices are shown: full series 1952-present with no vessel id; full series 1952-present with vessel id; series 1952-1978 with no vessel id; series 1978-present with vessel id.

FUTURE WORKPLAN

52. The CPUEWG discussed the merits of developing a standard set of figures for summarizing each national dataset for the joint analysis, considering that each dataset was produced using the generic R script and had a very similar format. The standard figures could improve communication of the presentation and the report. The CPUEWG **NOTED** that the use of R-markdown could facilitate this process.

53. The CPUEWG **RECOMMENDED** the use of influence plot (Bentley et al. 2012) as a diagnostics tool, which helps understand the influence of individual covariates on the standardised indices.

54. The CPUEWG **NOTED** that the Scientific Committee recommended for the joint Analysis to be extended to cover billfish and shark species. The CPUEWG **NOTED** that as the current data confidentiality agreement for the Joint workshop covers tropical and temperate tuna species only, permissions from relevant national fishery agencies need to

be obtained before the analysis can to be extended to other species. The CPUEWG also **NOTED** that observer data may also be needed to complement logbook data to provide important information on catch rates, particularly for bycatch species.

55. It was **NOTED** that improved modelling approaches should be explored with respect to alternative error distributions and data transformation (e.g. power transformation) to normalise the residuals and to accommodate strata with no zero catch.

56. The CPUEWG **RECOMMENDED** that examining operation level data across the main LL fleets (e.g., Korean, Japanese, Taiwanese, and Seychelles fleets) be continued in 2019. The CPUEWG **RECOMMENDED** a further workshop in 2019, to be led by an external consultant with expertise in CPUE standardization and R development, with dates (and venue) to be decided.

ADOPTION OF THE REPORT

57. The Report of the 5th IOTC CPUE Workshop on Longline fisheries was adopted on 1st June 2018. The Chair thanked all the participants for their dedicated work and discussions, and thanked the rapporteurs for producing the report in a timely manner. IOTC thanked the Chair for facilitating the meeting and leading the discussions.

References

Bentley, N., Kendrick, T.H. Starr, P.J., Breen, P.A. 2012. Influence plots and metrics: tools for better understanding fisheries catch-per-unit-effort standardizations. ICES Journal of Marine Science. Volume 69.

Campbell, R. A. 2014. A new spatial framework incorporating uncertain stock and fleet dynamics for estimating fish abundance. Fish and Fisheries. DOI: 10.1111/faf.12091.

Campbell, R. A. 2004. CPUE standardisation and the construction of indices of stock abundance in a spatially varying fishery using general linear models. Fish Res. 70:209-227.

Hoyle, S.D. , Kitakado, T ., Matsumoto, T., Kim, D.N. , Lee, S.I., Ku, J.E., Lee, M.K., Yeh, Y. , Chang, S.T., Govinden, R ., Lucas, J., Assan, C ., and Dan, F. IOTC–CPUEWS–04 2017: Report of the fourth IOTC CPUE Workshop on Longline Fisheries, July 3rd– 7th 2017. IOTC–2017–CPUEWS04–R[E]: 21pp.

Hoyle, S.D. , Satoh, K., Matsumoto, T. 2017. Selectivity changes and spatial size patterns of bigeye and yellowfin tuna in the early years of the Japanese longline fishery. IOTC-2017-WPTT19-34.

Langley, A. 2016a. Stock assessment of bigeye tuna in the Indian Ocean for 2016 — model development and evaluation. IOTC Working Party Document IOTC-2013-WPTT18-20.

Langley, A. 2016b. An update of the 2015 Indian Ocean Yellowfin Tuna stock assessment for 2016. IOTC Working Party Document IOTC-2013-WPTT18-27.

Punsly, Richard G. 1987. Estimation of the relative annual abundance of yellowfin tuna, Thunnus albacares, in the Eastern Pacific Ocean during 1970-1985. Inter-American Tropical Tuna Commission Bulletin, 19(3), pp. 263-306

Satoh, K. 2014. Exploration of area stratification for CPUE standardization of yellowfin tuna by Japanese longline. IOTC-2014-WPTT16–48.

APPENDIX I: List of Participants

Dr. Simon Hoyle
IOTC consultant, New Zealand
Email: simon.hoyle@gmail.com

Dr. Sung Il Lee
National Institute of Fisheries Science,
Republic of Korea
Email: k.sungillee@gmail.com

Dr. Doo Nam Kim
National Institute of Fisheries Science,
Republic of Korea
Email: doonam@korea.kr

Dr. Keisuke Satoh
National Research Institute of Far Seas Fisheries,
Japan
Email: kstu21@affrc.go.jp

Dr. Takayuki Matsumoto
National Research Institute of Far Seas Fisheries,
Japan
Email: matumot@affrc.go.jp

Dr. Toshihide Kitakado
Tokyo University of Marine Science and Technology
Japan
Email: kitakado@kaiyodai.ac.jp

Dr. Yu-Min Yeh
Nanhua University, Chiayi
invited Taiwanese expert
Email: ymyeh@nhu.edu.tw

Dr. Sheng-Ping Wang
National Taiwan Ocean University, Keelung
invited Taiwanese expert
Email: wsp@ntou.edu.tw

Mr. Ren-Fen WU
Overseas Fisheries Development Council, Taipei
invited Taiwanese expert
Email: fan@ofdc.org.tw

Dr. Feng-Chen Chang
Overseas Fisheries Development Council, Taipei
invited Taiwanese expert
Email: fengchen@ofdc.org.tw

Dr. Emmanuel Chassot
Seychelles Fishing Authority,
Seychelles
Email: mchassot@sfa.sc

Mr. Dan Fu
IOTC Fisheries Officer,
Seychelles
Email: dan.fu@fao.org

APPENDIX II: Agenda for the 5th IOTC CPUE Standardisation Working group Meeting

1. Introductory
   - 1.1 Opening remarks
   - 1.2 Appointment of chair and rapporteurs
   - 1.3 Review of available documents/data/software
2. Development of national CPUE STD
   - 2.1 Issues/lessons arising in the past analyses
   - 2.2 Technical issues
   - 2.3 Testing clustering procedures
   - 2.4 Developing national indices for YFT (and ALB)
3. Current status of the joint CPUE STD
   - 3.1 Issues/lessons arising in the past analyses
   - 3.2 Technical issues
   - 3.3 General statistical approaches
   - 3.4 Data gaps or issues arisen in past applications
4. Toward new joint CPUE analysis
   - 4.1 General issues
   - 4.2 Yellowfin
   - 4.3 Albacore (if possible)
5. Progress in analyses
6. Workplan
   - 6.1 until 2018 WPTT
   - 6.2 until 2019 WPTmT
7. Adoption of report

APPENDIX III: TERMS OF REFERENCE

Food and Agriculture organization of the United Nations
Terms of Reference for Consultant/PSA

Name:	
Job Title: INTERNATIONAL CONSULTANT (Stock assessment) (Category A)	
Division/Department: FIDT/FI	
Programme/Project Number: GCP/INT/258/EC – TF/FIDTD/TFEU110016382; MTF/INT/661/MUL – TF/FIDTD/TFAA970097099	
Location:	
Expected Start Date of Assignment: 01 May 2018	**Duration:**
Reports to: ***Name:*** Dr Chris O'Brien	***Title:*** EXECUTIVE SECRETARY (Interim)

General Description of task(s) and objectives to be achieved

The Indian Ocean Tuna Commission (IOTC) is an intergovernmental organisation responsible for the management of tuna and tuna-like species in the Indian Ocean. The IOTC was established in under Article XIV of the FAO constitution. One of the Commission's key science based functions and responsibilities is to undertake assessments of the status of the IOTC species.

Methods for joint standardisation of catch and effort that incorporate an innovative approach on identifying changes in the targeting of particular fish stocks were developed and incorporated in IOTC stock assessments in 2015 and 2016. Standardised CPUE outputs have been used as abundance indices in the most recent bigeye, yellowfin, and albacore tuna stock assessments in the Indian Ocean. The IOTC Scientific Committee has recommended that the standardized CPUE methods be further developed in 2018, and extended to the other IOTC species such as billfish and sharks – depending on the availability and quality of operational level data.

Based on the recommendations of the IOTC Working Parties, and endorsed by the IOTC Scientific Committee, the IOTC requires a short-term consultant to undertake the following activities:

COLLABORATIVE ANALYSES TO PREPARE CPUE INDICES

1. Validate and improve current methods for developing indices of abundance for the main IOTC species.
2. Provide indices of abundance for selected IOTC species to be presented at the IOTC Working Parties in 2018.
3. Provide support and training to national scientists in their analyses of catch and effort data.
4. The analyses will consider data to be provided by key industrial fisheries operating in the Indian Ocean, including data from Japanese, Taiwanese, and Korean longline fleet.
5. Analyses will be carried out in a series of meetings scheduled during 2018. After preliminary discussions/meetings between the consultant and participating data providers, preparations will be carried out for each dataset and methods for CPUE standardization developed (or further elaborated upon), which will be followed by a joint CPUE meeting between all participating countries and the consultant.

Tasks will include the following, to the extent possible in the available time:

6. Work with the IOTC Stock Assessment Officer to coordinate meetings between data holders and the consultant.
7. Load, prepare, and check each dataset, given that data formats and pre-processing often change between years and data extracts, and important changes to fleets and reporting sometimes occur in new data.

8. Conduct the following analyses to improve CPUE methods and prepare indices:
    - Apply cluster analyses or alternative methods for identifying targeting. Develop CPUE standardizations for main IOTC species using reliable data from each CPC, with priorities given to yellowfin tuna and albacore in 2018. Prepare separate indices for each fleet, and joint indices. Thoroughly check all code and results in order to validate the final standardized indices series.
    - Explore alternative modelling and data transformation methods in order to normalise residuals and to accommodate strata with no zero catches.
    - Explore residual patterns spatially and among clusters, fleets and vessels through time, and change models where necessary to address any problems identified.
    - Apply methods for estimating relative regional weights, so as to apportion relative abundance among regions.
    - Explore other distributions to improve model fit.
9. Document the analyses in accordance with the IOTC *Guidelines for the presentation of CPUE standardisations and stock assessment models*, adopted by the IOTC Scientific Committee in 2014; and to provide draft reports to the IOTC Secretariat no later than 60 days prior to the relevant IOTC Working Party meeting.
10. Undertake any additional analyses deemed relevant by the IOTC Working Parties, Scientific Committee, or IOTC Secretariat.

All work is subject to the agreement of the respective fisheries agencies to make the data available.

V2 09/10

APPENDIX IV: Examples from Preliminary Standardisation Analysis on Yellowfin tuna

The figures below (A1-A4) are examples from the preliminary clustering and standardisation analysis on yellowfin in the western equatorial region (region 2 with regional structure “regY) from Japanese, Taiwanese, Korean, and Seychelles fleets. Each figure includes (a) a tree plot showing the selection of the final clusters; (b) maps showing the spatial distribution of clusters; (c) boxplot showing the distribution of species composition by cluster; (d) standardised CPUE indices.

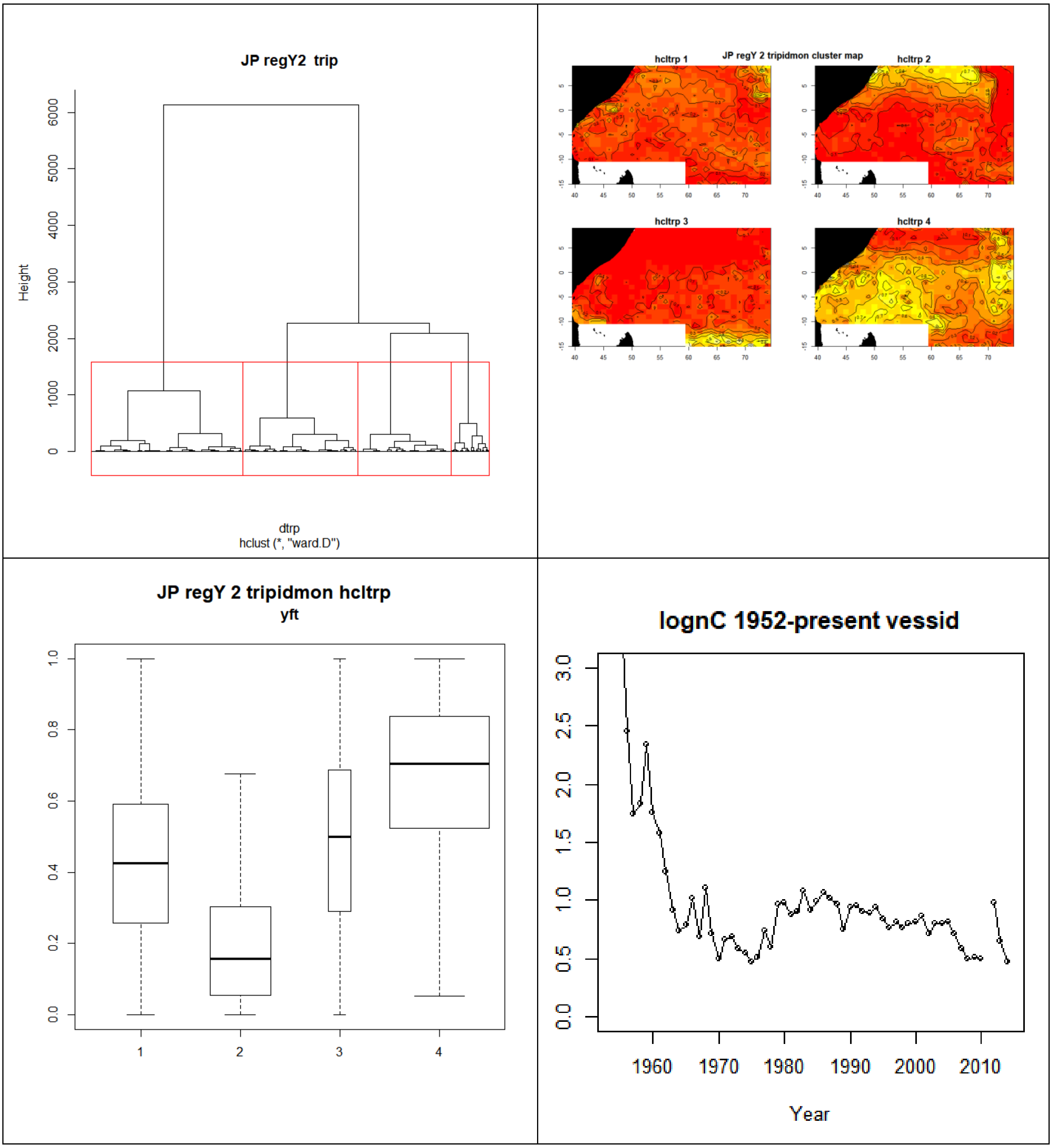

Figure A1: Examples from Japanese fleet on analysis on yellowfin in the western equatorial region (region 2 in “regY”)

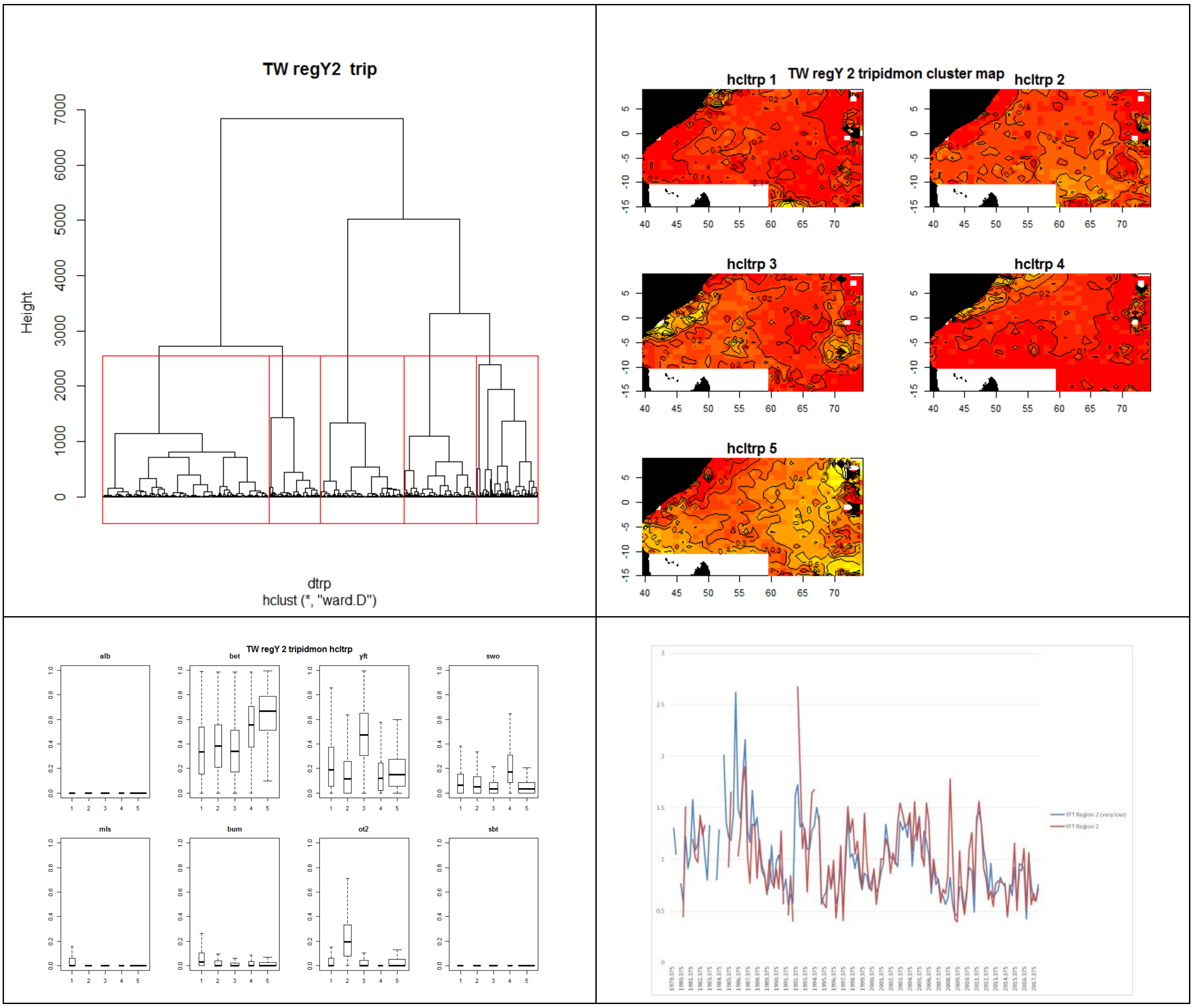

Figure A2: Examples from Taiwanese fleet on analysis on yellowfin in the western equatorial region (region 2 in "regY")

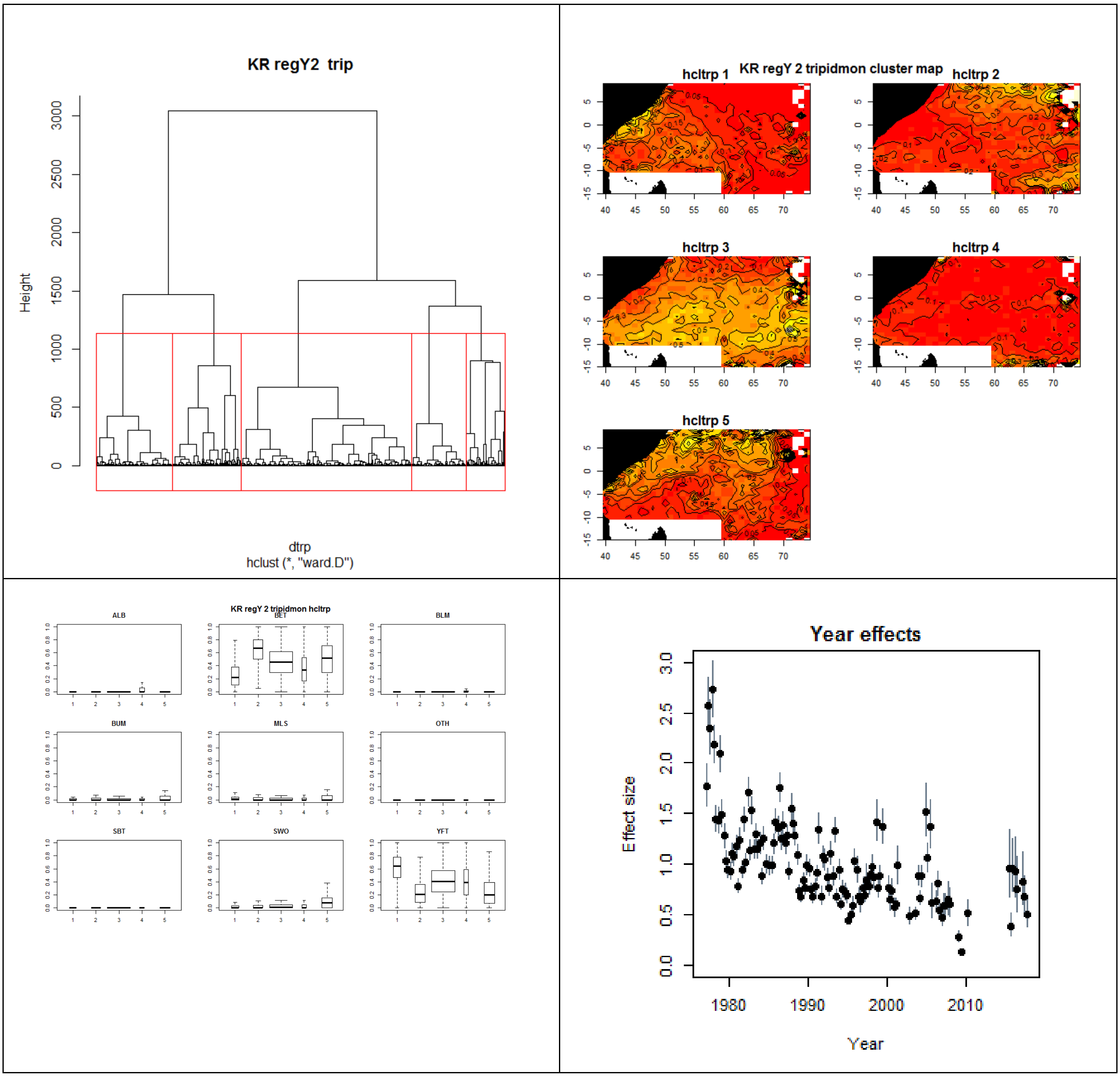

Figure A3: Examples from Korean fleet on analysis on yellowfin in the western equatorial region (region 2 in "regY")

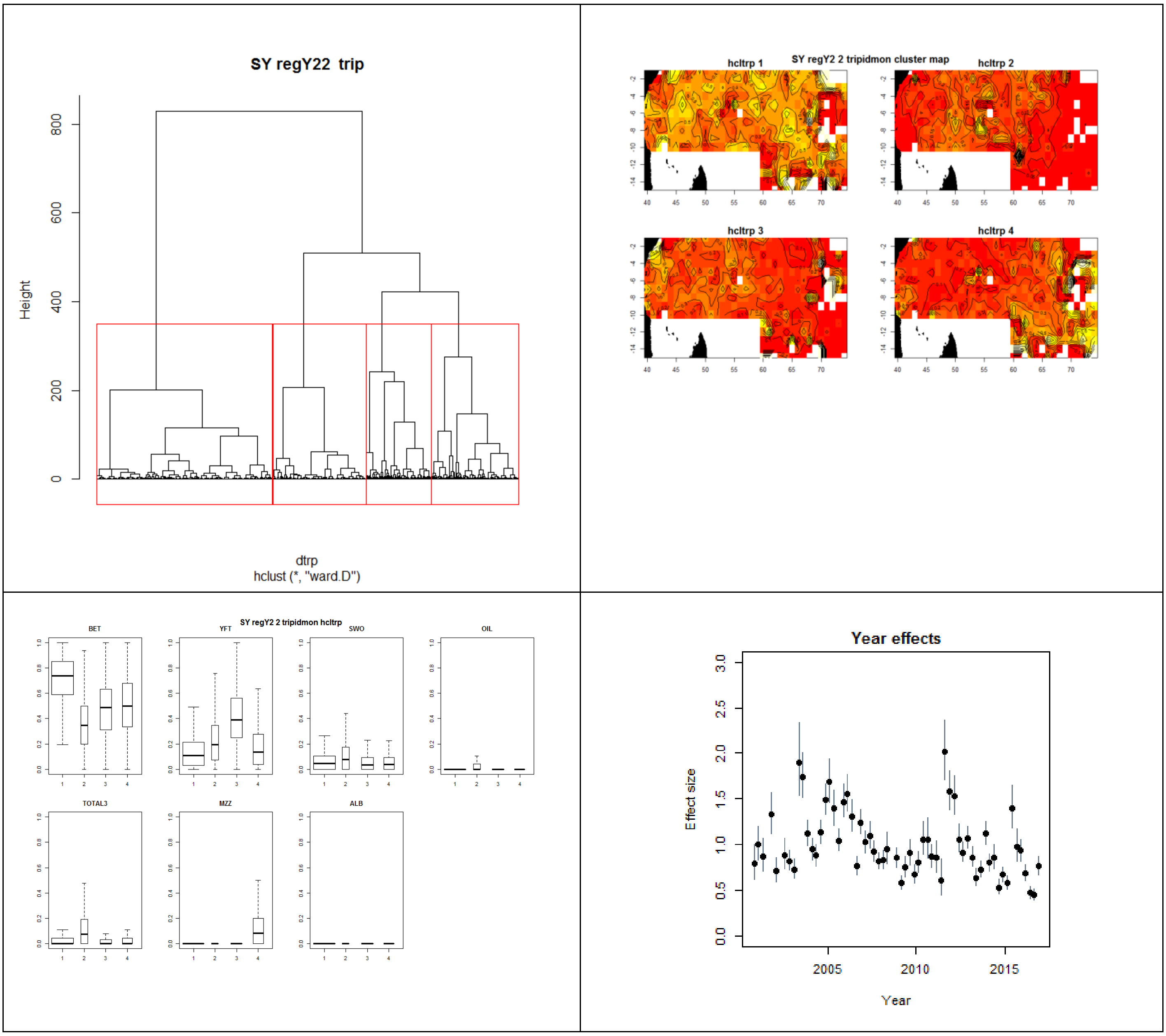

Figure A4: Examples from Seychelles fleet on analysis on yellowfin in the western equatorial region (region 2 in "regY2").

APPENDIX V: Examples from Preliminary Standardisation Analysis on Albacore tuna

The figures below (B1-B3) are examples from the preliminary clustering and standardisation analysis on albacore tuna in the east-southern temperate region (region 4 with regional structure “regA4”) from Japanese, Taiwanese, and Korean fleets. Each figure includes (a) a tree plot showing the selection of the final clusters; (b) maps showing the spatial distribution of clusters; (c) boxplot showing the distribution of species composition by cluster; (d) standardised CPUE indices.

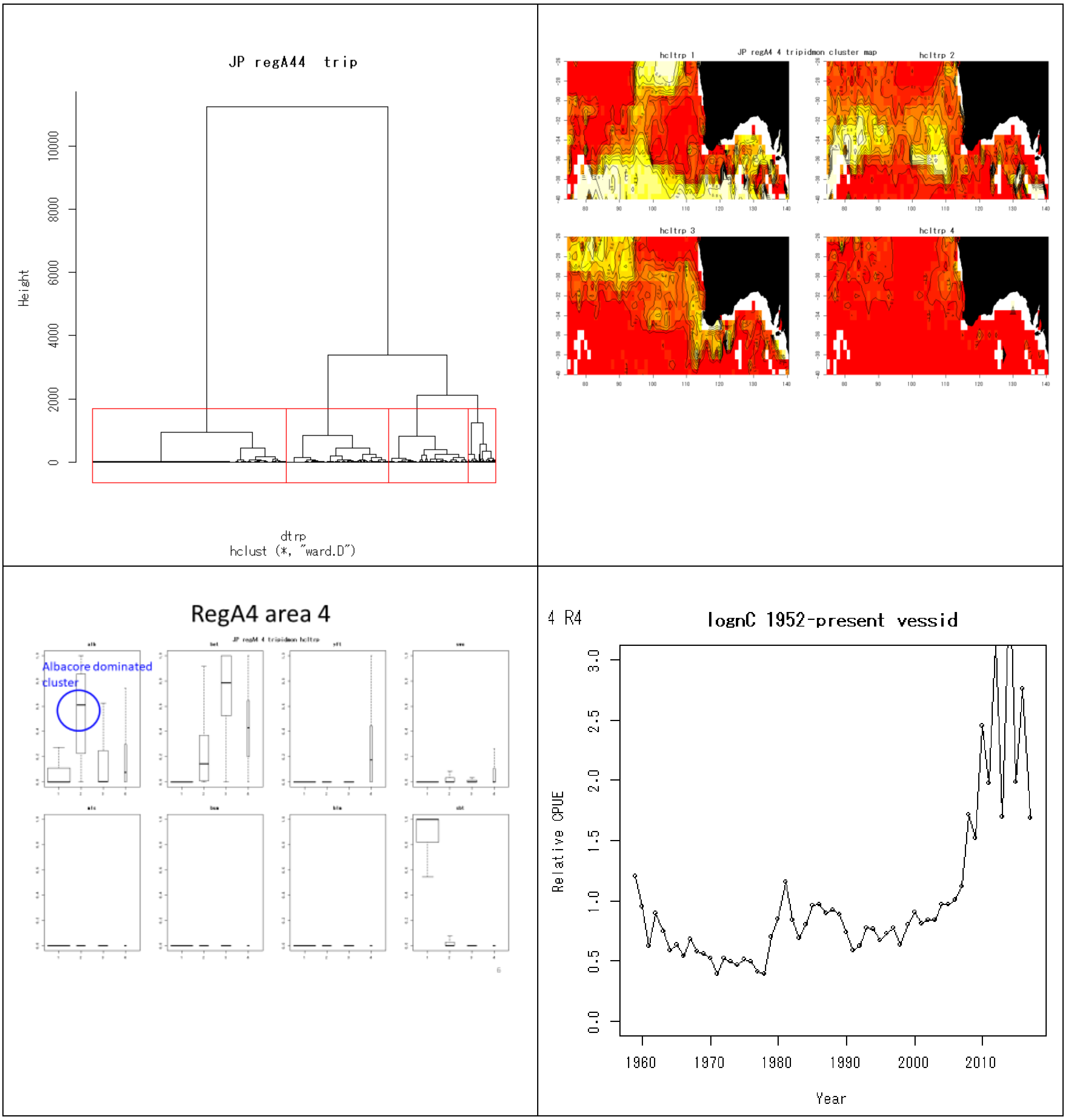

Figure B1: Examples from Japanese fleet on analysis on albacore in the east-southern temperate region (region 4 in “regA4”)

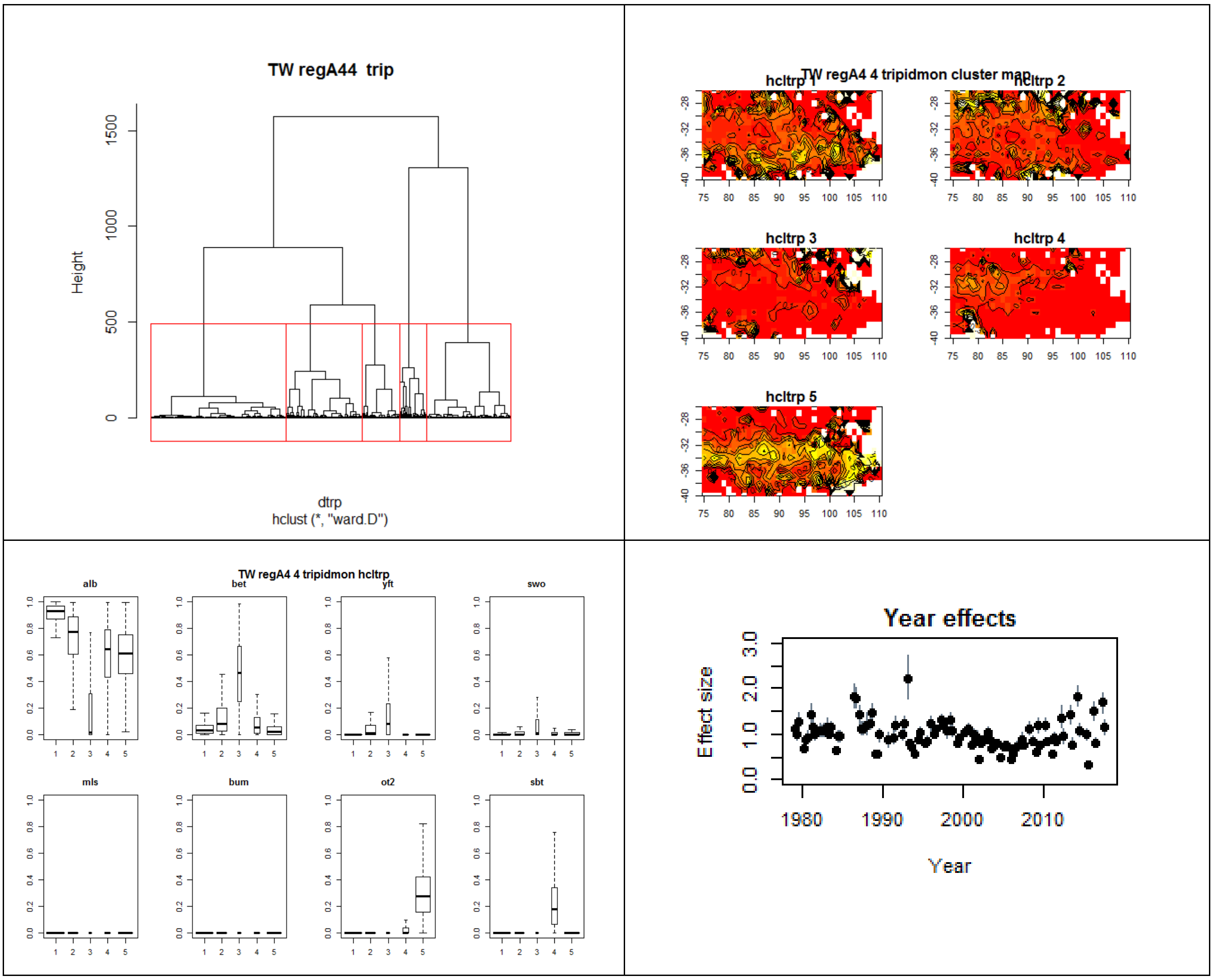

Figure B2: Examples from Taiwanese fleet on analysis on albacore in the east-southern temperate region (region 4 in "regA4")

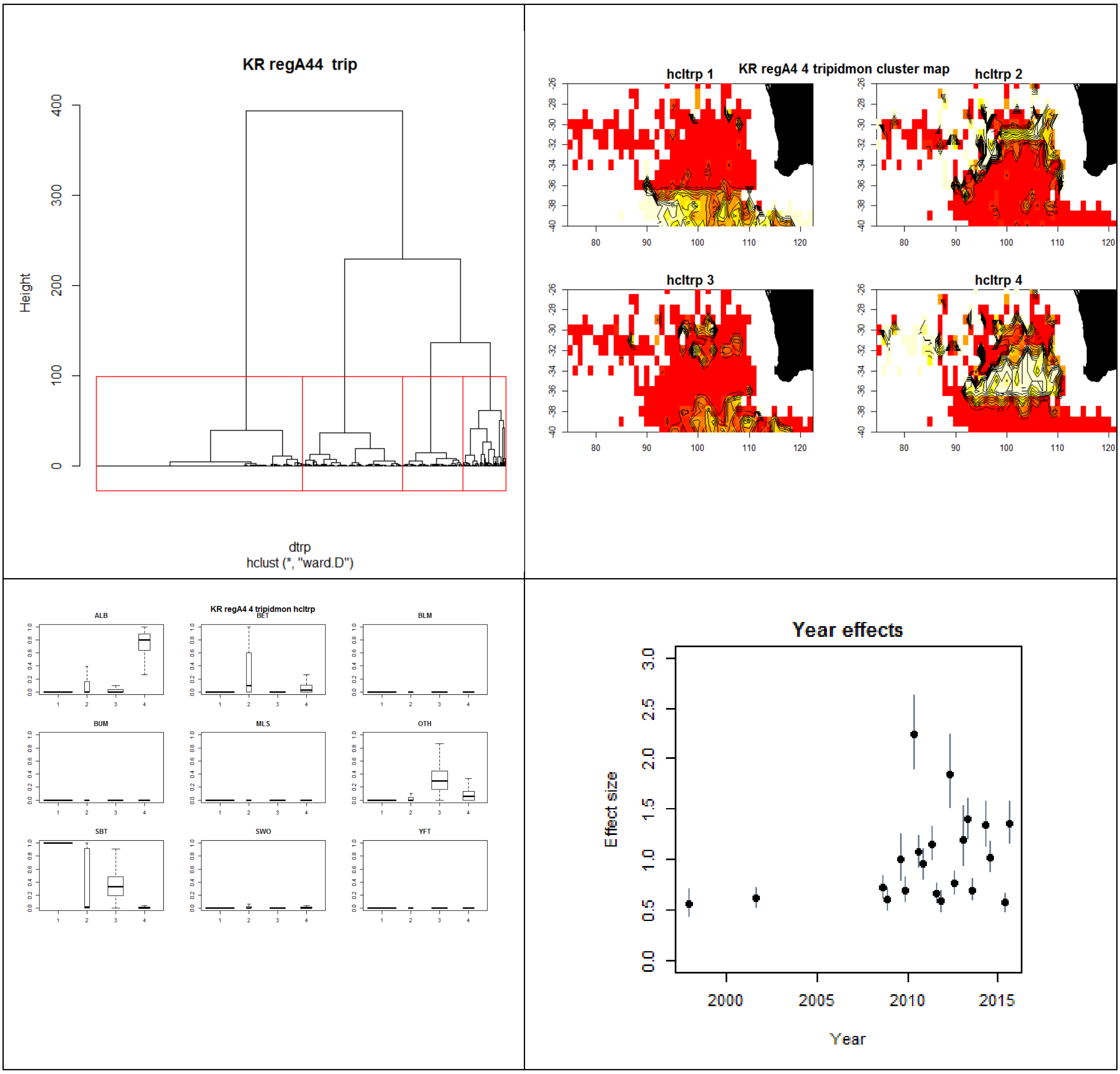

Figure B3: Examples from Korean fleet on analysis on albacore in the east-southern temperate region (region 4 in "regA4")