Report of the Third IOTC CPUE Workshop on Longline Fisheries

Shanghai, July 22nd – 23rd, 2016

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ACRONYMS

BET	Bigeye Tuna
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CPCs	Contracting parties and cooperating non-contracting parties
CPUE	Catch per unit of effort
EU	European Union
EEZ	Exclusive Economic Zone
EOF	Empirical Orthogonal Function
ENV	Environmental Effect
FAD	Fish-aggregating device
FAO	Food and Agriculture Organization of the United Nations
GPS	Geographical Positioning System
HBF	Hooks between Floats
IEO	Instituto Español de Oceanografía, Spain
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IOTC	Indian Ocean Tuna Commission
IRD	Institut de recherche pour le dévelopement, France
GAM	Generalized Additive Model
GLM	Generalized Linear Model
GLMM	Generalized Linear Mixed Model
LL	Longline
MFCL	Multifan-CL
MPF	Meeting Participation Fund
MSY	Maximum sustainable yield
OFCF	Overseas Fishery Cooperation Foundation of Japan
PL	Pole and Line
NBF/NHBF	Number of Hooks between Floats
NFRDI	National Fisheries Research and Development Institute, Korea
PS	Purse-seine
R	R Package for Statistical Computing
ROP	Regional Observer Programme
ROS	Regional Observer Scheme
SAS	Software for Analyzing Data
SC	Scientific Committee of the IOTC
SST	Sea Surface Temperature
STD	Standardized
SWO	Swordfish
tRFMO	tuna Regional Fishery Management Organization
VMS	Vessel Monitoring System
WP	Working Party of the IOTC
WPB	Working Party on Billfish of the IOTC
WPEB	Working Party on Ecosystems and Bycatch of the IOTC
WPM	Working Party on Methods of the IOTC
WPNT	Working Party on Neritic Tunas of the IOTC
WPDCS	Working Party on Data Collection and Statistics 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**).

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OPENING OF THE MEETING AND ADOPTION OF THE AGENDA

1. A small Working Group was held in Shanghai, from July 22nd to 23rd 2016, to assess differences in the standardized CPUE for main distant water longline fleets operating in the Indian Ocean. The meeting was attended by scientists of the main longline fleets in the Indian Ocean, as well as the IOTC Secretariat and scientists from IOTC member countries (see list of participants in Appendix I).
2. The organization of the workshop was recommended by the 18th Session of the IOTC Scientific Committee 2015 (SC18.23) as well as the 2nd CPUE Workshop, held in Taipei in 2015 (IOTC–2015–CPUEWS02–R[5]).
3. The IOTC Secretariat informed participants about the scope of the workshop and the expected outcomes. The agenda was adopted (Appendix II), and the WG participants introduced.
4. IOTC would like to thank the lead Principal Investigator, Dr. Simon Hoyle and the CPC's (Dr. Satoh, Dr Matsumoto, Dr. Yeh, Dr. Chang, Dr. Lee, Dr. D. Kim, and Dr. Z. Kim) for the excellent work and effort put into the report produced so far. The IOTC would also like to thank ISSF for providing funding to support this work (TORs are included in Appendix III).
5. The report of the collaborative study of albacore tuna CPUE from Indian Ocean longline fleets, presented at the IOTC Working Party for Temperate Tunas, held in Shanghai from July 18th to 21st 2016, is also attached in Appendix IV.

OPERATIONAL DATA RESOLUTION AND ISSUES

6. Prior to the analysis, the data were cleaned and filtered for obvious errors, including removal of missing values. Unlikely, but potentially plausible, values (e.g., sets with very large catches of a species) were retained. Each set was allocated to a fishery region (consistent with the definitions in the respective IOTC stock assessments), and data outside these areas ignored. A standard dataset was then produced for each fleet.
7. The Working Group **RECOMMENDED** that more credence should be given to indices based on operational data, since analyses of these data can take more factors into account, and analysts are able to more thoroughly check the data for inconsistencies and errors.
8. The Working Group **NOTED** that Taiwanese CPUE in southern regions is affected by the rapid recent growth of the oilfish fishery. This is a relatively new fishery with significantly lower catchability for tunas. It is important for the CPUE indices to adjust for this change in catchability. The Working Group (WG) **RECOMMENDED** that future tuna CPUE standardizations should use appropriate methods to identify effort targeted at oilfish and, either remove it from the dataset, or include a categorical variable for targeting in the standardization. The WG **RECOMMENDED** that the oilfish data variable should be provided to data analysts producing the CPUE index.
9. The Working Group **RECALLED** that differences between Japanese and Taiwanese BET CPUE series for a series of years were examined, and attributed due to either (i.) low sampling coverage of Taiwanese logbook data (between 1982-2000), or (ii.) misreporting across oceans (e.g., Atlantic and Indian oceans) for BET catches between 2002-2004. In the first case, the Working Group **RECOMMENDED** the development of minimum criteria (e.g., 10% using a simple random stratified sample) for logbook coverage to use data in standardization process, while in the 2nd case, the Working Group **RECOMMENDED** identifying vessels through exploratory analyses that were likely misreporting catches, and excluding them from the dataset in the standardization analysis.
10. The Working Group **RECOMMENDED** that Taiwanese fleets provide all available logbook data to data analysts, representing the best and most complete information possible. This stems from the

[5] Refer to the meeting report IOTC–2015–CPUEWS02–R, http://www.iotc.org/meetings/2nd-cpue-workshop-longline-fisheries

fact that the dataset currently used by the Taiwanese scientists is incomplete and not updated with logbooks that arrived after finalization of the datasets for the collaborative CPUE.

11. The Working Group **ENCOURAGED** that vessel identity information for the Japanese fleets for the period prior to 1979 should be obtained either from the original logbooks, or from other sources, to allow the estimation of changes in catchability during this period and to permit cluster analysis using vessel level data, particularly as there was significant technological change (e.g., introduction of deep freezers) and changes in targeting (e.g., YFT to BET) during this period.

12. The Working Group **NOTED** with thanks the availability of Japanese logbook ID's before 1979, which permits cluster analysis during this period.

RECOMMENDED ANALYSIS AND COVARIATES

13. The Working Group **NOTED** that cluster analysis and related approaches (e.g., PCA methods) to identify effort associated with different fishing strategies should be used when direct measures of directed effort (e.g. HBF) are unavailable or less effective. The Working Group **NOTED** that 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.

11. The Working Group **RECOMMENDED** that examining operation level data across the main LL fleets (e.g., Korea, Japan, and Taiwanese) be continued in 2017. The data provides better information about the fishery and stock since some datasets have low sample sizes or effort in some years, while others have higher sample sizes and effort. The data also provide a more representative sample covering the broadest areas in the Indian Ocean. Time requirements will depend on the availability of test datasets. The group **RECOMMENDED** a further two-part workshop in 2017, to be led by an external consultant with expertise in CPUE standardization and R development, with dates (and venue) to be decided.

FUTURE STEPS FOR FURTHER ANALYSIS

12. It was **NOTED** that clustering approaches and other ways to define targeting should be further explored. The effect of these analyses in defining a subset of operational data (e.g., sets/hauls) and its effects on the standardization should be tested. Alternative cluster aggregations (e.g., vessel-week / vessel-month-HBF / month-HBF-cell) should also be examined. The SBT fishery open/close dates may be useful as additional aggregation boundaries.

13. It was **NOTED** that time-area interactions within regions and among clusters needs further examination.

14. It was **NOTED** that using a subset of vessels to examine Vessel-Year interactions over time would be important to understand vessel-dynamics, and the reasons for their change in efficiency over time.

15. It was **NOTED** that improved modelling approaches should be explored with respect to alternative error distributions.

16. It was **RECOMMENDED** that separate indices should be estimated by fleet, as well as joint indices.

17. The workshop **CONSIDERED** that approaches should be developed to thoroughly test methods outside the workshops, in order to reduce both risks and costs. The CPUE Working Group **REQUESTED** scientists from member countries to explore the following three options:

    - <u>Option 1</u>: Data access agreements.
    - <u>Option 2</u>: Longer data preparation meetings, particularly in Japan.
    - <u>Option 3</u>: Randomize and anonymize operational datasets to create pseudo-operational datasets for development and testing. These datasets must replicate issues that commonly affect analyses, such as dataset sizes, spatial distributions, and variable distributions. For example, vessel codes will be changed, fishing locations changed to 5 degree squares, and

catches altered. The workshop will develop a proposal and example R code for member countries to use to generate test datasets. Member countries will evaluate any confidentiality issues in the data before agreements are reached on arrangements for provision of future datasets.

ADOPTION OF THE REPORT

18. The Report of the 3rd IOTC CPUE Workshop on Longline fisheries was adopted on 23rd July 2016.

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APPENDIX I
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APPENDIX II
MEETING AGENDA

Agenda for IOTC CPUE Standardization Working Group Meeting

July 22 – 23, 2016

1. **Operational data resolution and issues**
   a. Longline Fleets (LL) : Japan
   b. Longline Fleets (LL) : Taiwanese Fleets
   c. Longline Fleets (LL) : Korea

2. **Errors and possible approaches to use**

3. **Final CPUE series for LL fisheries**
   Issue 1: Fishery changes over time (including targeting and technological creep):
   Issue 2: Spatial Structure changes:
   Issue 3: Other CPUE issues
   Issue 4: Differences in fleets and possible attributes for them
   Issue 5: Bias in CPUE and Management Implications

4. **Discussion & Endorsement**

5. **Next Steps**

APPENDIX III TERMS OF REFERENCE

Food and Agriculture organization of the United Nations

Terms of Reference for Consultant/PSA

Name:			
Job Title:	INTERNTATIONAL CONSULTANT (CPUE Standardisation & Stock assessment)		
Division/Department:			
Programme/Project Number:			
Location:			
Expected Start Date of Assignment:		**Duration:**	
Reports to:	***Name:***	***Title:***	EXECUTIVE SECRETARY (Interim)

TERMS OF REFERENCE FOR THE PROVISION OF SCIENTIFIC SERVICES TO THE IOTC: COLLABORATIVE ANALYSIS TO PREPARE CPUE INDICES

Scientific Services to be provided:

Following the development in 2015 of methods for joint standardisation of catch and effort data, and adjustment for target change, the IOTC requires a short term consultancy for the following activities:

COLLABORATIVE ANALYSES TO PREPARE CPUE INDICES

- To organise a series of meetings between data holders and the consultant.
- To validate and improve methods for developing indices of abundance for tropical tunas.
- To provide indices of abundance for bigeye and yellowfin tunas and to draft a working paper to be submitted to the WPTT18 (30 October – 3 November 2016).
- To provide support and training to national scientists in their analyses of catch and effort data.
- To update bigeye and yellowfin tuna abundance indices during WPTmT6 (18 – 21 July 2016), followed by a joint meeting (Japan, Taiwan,China and Korea; 22-23 July 2016) to discuss final abundance indices with national scientists, and to provide training to national scientists in their analyses of catch and effort data.

Data analysis tasks will include the following:

- 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. The format of the Japanese data is expected to change before the joint meeting which will require additional time during this meeting.
- Explore catch and effort data from each CPC to check the reliability and coverage of reporting.
- Apply cluster analyses and bigeye tuna and yellowfin tuna CPUE standardisation using reliable data from each CPC. Change regional structures from the generic 2015 approach to regions that are appropriate for each assessment, including alternate options.

- ➢ Address outstanding issues from 2015 tropical tuna analyses, including a) adjusting for the introduction of vessel effects in late-1970s Japanese data, and b) producing joint indices for temperate areas.
- ➢ Add functionality to provide estimates of relative observation error (Confidence Intervals) by time period.
- ➢ Thoroughly check all code and results in order to validate indices.
- ➢ All work is subject to the agreement of the respective fisheries agencies to make the data available.
- ➢ To 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 meeting of the WPTT18, i.e. **30 August 2016**, and the final report no later than 15 days prior to the meeting of the WPTT18, i.e. **15 October 2016**.
- ➢ To undertake any additional analyses deemed relevant by the WPTT18 or the IOTC Secretariat up to 60 days after the start date of the contract.

Conditions and payment

In total this Service will require 35 days of work.

The IOTC Secretariat will pay the cost of return airfares (based on FAO travel regulations) from the contractor's home to the WPTmT6 meeting in Shanghai, China, and the subsequent joint CPUE meeting. A Daily Subsistence Allowance will also be paid in accordance with FAO procedures for attendance at meetings.

Expected Outputs:	Required Completion Date:
• To provide an updated draft report of the joint CPUE meetings to the IOTC Secretariat no later than 60 days prior to meeting of the WPTT18, i.e**. 30 August 2016**. • To provide the final report of the joint CPUE meetings to the IOTC Secretariat no later than 15 days prior to the meeting of the WPTT18, i.e. **15 October 2016**.	30 August 2016 15 October 2016

APPENDIX IV FINAL REPORT

Hoyle, S. et. al (2016),

'Collaborative study of albacore tuna CPUE from multiple Indian Ocean longline fleets'

Collaborative study of albacore CPUE from multiple Indian Ocean longline fleets

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1. Contents

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2. Executive Summary

In March and April 2016 a collaborative study was conducted between national scientists with expertise in Japanese, Taiwanese, and Korean longline fleets, and an independent scientist. The meetings addressed Terms of Reference covering several important issues related to albacore, bigeye and yellowfin tuna CPUE indices in the Indian Ocean. A further meeting between the parties was held in July 2016 to update the tropical tuna indices. The study was funded by the International Seafood Sustainability Foundation (ISSF) and the Indian Ocean Tuna Commission (IOTC).

Terms of Reference:

1. To validate and improve methods for developing indices of abundance for tropical tunas.
2. To develop methods for providing indices of abundance for albacore tuna.
3. To provide indices of abundance for albacore tuna, and to draft a working paper to be presented at the 2016 WPTmT06 (18 – 21 July 2016).
4. To provide indices of abundance for bigeye and yellowfin tunas and to draft a working paper to be presented at the WPTT18 (5 – 10 November 2016).
5. To provide support and training to national scientists in their analyses of catch and effort data.

This document describes the development of indices of abundance for albacore tunas.

Data were provided for the three fleets in similar formats, with varying combinations of species and variables, due to differences between the fisheries' data collection forms and processes and their changes through time. See Table 9 for a comparison of field availabilities among the three fleets. All datasets reported set date, number of hooks, hooks between floats for at least part of the time series, set location at some resolution, vessel identity for part or all of the dataset, and catch in number of albacore, bigeye, yellowfin, southern bluefin tuna, swordfish, blue marlin, striped marlin, and black marlin.

Japanese operational data were available from 1952-2015, with location reported to 1° of latitude and longitude, vessel call sign from 1979, hooks between floats for much of the time series, and date of trip start (Tables 2 and 3). The Taiwanese operational data were available 1979-2015, but data prior to 2005 were not used in tropical tuna analyses, due to concerns about data quality. Taiwanese vessel call sign was available for the whole time period along with information on vessel size; set location at 5° resolution until 1994, and 1° subsequently; number of hooks between floats from 1995; and catches in number for the species above plus other tuna, other billfish, skipjack, shark, and other species; equivalent values in weight for all species; SST; bait type fields ('Pacific saury', 'mackerel', 'squid', 'milkfish', and 'other'); depth of hooks (m); set type (type of target); remarks (indicating outliers); departure date from port; starting date of operations on a trip; stopping date of operations on a trip; and arrival date at port (Table 4). Korean data were available for 1971 to 2015 (Table 8), with the standard fields and vessel id, operation location to 1°, hooks between floats calculated for each set, and additional species 'other', sailfish, shark, and skipjack. All operational data was available only for the purpose of this collaborating work. No operational data is available after this collaborating work.

Data were cleaned by removing obvious errors and missing values (Figure 5). Unlikely but potentially plausible values (e.g. sets with very large catches of a species) were retained. Each set was allocated to albacore regions according to several alternative regional definitions, and data outside these areas ignored. Standard datasets were produced for each fleet.

We applied cluster analysis methods to identify effort associated with different fishing strategies, using the approaches developed in the 2015 IOTC CPUE standardization workshop (Hoyle *et al.* 2015). Data were aggregated by vessel-month and then clustered on species composition in the catch, using the Ward hclust method. Clustering was carried out by fleet and region, and a fleet/cluster group parameter was assigned to each set. The clustered data for all fleets in a region were combined into a joint dataset. For each region and fleet, clusters were removed if the species of interest was a very small component of the catch.

Data for each region were standardized using regression techniques to estimate indices of abundance. The dependent variable was the presence/absence of the species of interest in the catch (binomial models), or the positive catch of the species of interest in numbers of fish (lognormal models). All models included the explanatory variables year-quarter and 5° cell as categorical variables, a cubic spline on hooks as a covariate, and a categorical variable for cluster. Some models were run with vessel identity as a categorical variable. Models were run for the period 1952-1979 without vessel identity, for the later period 1979-2015 with vessel identity, and for the whole period 1952-2015 both with and without vessel identity. Indices were estimated using both a delta lognormal approach, and lognormal constant generalized linear models.

Figures and tables are provided for each set of indices, including both quarterly and annual indices. Diagnostic plots are also presented.

3. Introduction

In March and April 2016 a collaborative study of longline data and CPUE standardization for bigeye, yellowfin, and albacore tuna was conducted between scientists with expertise in Japanese, Taiwanese, and Korean fleets, and an independent scientist. A further meeting was held in July 2016 to update the tropical tuna analyses with the most recent data. The study was funded by the International Seafood Sustainability Foundation (ISSF) and the Indian Ocean Tuna Commission (IOTC). The study addressed the Terms of Reference outlined below, which cover the most important issues that had previously been highlighted by different working parties. Work was carried out, for those factors relevant to them, for the following:

- Area: Indian Ocean
- Fleets: Japanese longline; Taiwanese longline, Korean longline
- Stocks: Bigeye tuna, yellowfin tuna, albacore tuna.

The current document addresses CPUE standardizations for albacore tuna. The methods description includes approaches used for bigeye, yellowfin, and albacore tunas in order to generalize the report, but to conserve space only albacore tuna results are reported.

3.1. Terms of Reference

- To organize a series of meetings between data holders and the consultant.
- To validate and improve methods for developing indices of abundance for tropical tunas.
- To develop methods for providing indices of abundance for albacore tuna.
- To provide indices of abundance for albacore tuna, and to draft a working paper to be presented at the 2016 IOTC WPTmT06 (18 – 21 July 2016).
- To provide indices of abundance for bigeye and yellowfin tunas and to draft a working paper to be presented at the IOTC WPTT18 (5 – 10 November 2016).
- To provide support and training to national scientists in their analyses of catch and effort data.
- The analyses will consider data to be provided by Japanese, Taiwanese, and Korean research agencies.
- Analyses will be carried out in a series of meetings in March and April, and in a final meeting focusing on tropical tunas following update of the data. After preliminary meetings between the consultant and each participating data provider to prepare each dataset and develop methods, there will be a first joint meeting between all participating parties and the consultant. This joint meeting will develop indices for albacore tuna and develop draft indices for bigeye and yellowfin tunas. A second joint meeting will occur in July or August to prepare final indices for bigeye and yellowfin tuna, and to provide training to national scientists in their analyses of catch and effort data.
- ***Data analysis tasks will include the following***:
- 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. The format of the Japanese data is expected to change before the second joint meeting which will require additional time during this meeting.
- Explore albacore catch and effort data from each CPC to check the reliability and coverage of reporting, as we did for tropical tunas
- Apply cluster analyses and BET + YFT CPUE standardization using reliable data from each CPC. Change regional structures from the generic 2015 approach to regions that are appropriate for each assessment, including alternate options.
- Address outstanding issues from 2015 tropical tuna analyses, including a) adjusting for the introduction of vessel effects in late-1970s Japanese data, and b) producing joint indices for temperate areas.

- Add functionality to provide estimates of relative observation error (CIs) by time period.
- Extend the approach to albacore standardization, i.e. cluster analyses and CPUE standardization with appropriate spatial structures.
- Thoroughly check all code and results in order to validate indices.
-
- All work is subject to the agreement of the respective fisheries agencies to make the data available.
- To 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 meetings of the WPTmT06, i.e. **18 May 2016**, and WPTT18, i.e. **6 September 2016**, and the final report no later than 15 days prior to the meeting of the WPTT18, i.e. **21 October 2016**.
- To undertake any additional analyses deemed relevant by the WPTT18 or the IOTC Secretariat up to 60 days after the start date of the contract.

4. Methods

4.1. Data cleaning and preparation

The three datasets had many similarities but also significant differences. The variables differed somewhat among datasets, as did other aspects such as the sample sizes, the data coverage and the natures of the fleets.

Data preparation and analyses were carried out using R version 3.3.0 (R Core Team 2016).

The approaches used here are based on those applied by Hoyle *et al.* (2015), with modifications where required. For more detail about the Japanese, Korean, and Taiwanese fleets, see the descriptive figures in the following papers (Hoyle *et al.* 2015, Hoyle *et al.* 2015)

4.1.1. Data

In this section we describe the datasets provided by Japanese, Taiwanese, and Korean data managers, and the methods that we used to prepare and clean the data for analysis. As the provided datasets were prepared for this collaborative study, the data do not include all information potentially included in logbook data. The cleaning described here differs from the standard cleaning procedures by national scientists when producing CPUE indices. All operational data were available only for the purpose of this collaborating work. No operational data is available after this collaborating work.

Japanese data were available from 1952-2015 (Figure 2), with fields year, month and day of operation, location to 1° of latitude and longitude, vessel call sign, no. of hooks between floats, number of hooks per set, date of the start of the fishing cruise, and catch in number of southern bluefin tuna, albacore, bigeye, yellowfin, swordfish, striped marlin, blue marlin, and black marlin.

The Taiwanese operational data were available 1979-2015 (Figure 3), but data prior to 2005 were not used in tropical tuna analyses, due to concerns about data quality applying to bigeye tuna in particular (see details in Hoyle *et al.* (2015)). Available fields were year, month and day of operation; vessel call sign; operational area (a code indicating fishing location at 5° resolution); operation location at 1° resolution (from 1994); number of hooks between floats (from 1995); number of hooks per set; catches in number for the species albacore, bigeye, yellowfin, bluefin (from 1993), southern bluefin (from 1994), other tuna, swordfish, striped marlin, blue marlin, black marlin, other billfish, skipjack, shark, and other species; equivalent values in weight for all species; SST; bait type fields for 'Pacific saury', 'mackerel', 'squid', 'milkfish', and 'other'; depth of hooks (m); set type (type of target, from 2006); remarks (indicating outliers); departure date from port; starting date of operations on a trip; stopping date of operations on a trip; arrival date at port (Table 4).

Korean operational data were available for 1971 to 2015 (Table 8, Figure 4), with fields vessel id, operation date, operation location to 1°, number of hooks, number of floats, and catch by species in number for albacore, bigeye, black marlin, blue marlin, striped marlin, other species, southern bluefin, sailfish, shark, skipjack, swordfish, and yellowfin.

The contents and preparation of logbook data is described below for each variable. See Table 9 for a comparison of field availability among the three fleets.
In the Japanese data international call sign was available 1979 - present, and was selected as the vessel identifier. Call sign is unique to the vessel and held throughout the vessel's working life. In the Taiwanese data, the international call sign was available for each set, and was also selected as the vessel identifier. The first digit of the Taiwanese callsign indicated the tonnage of the vessel (Table 5). In the Korean data the callsigns were understood to have changed through time to some extent, and so vessel ids were assigned based on a combination of vessel names and vessel callsigns. For all fleets, the vessel id was rendered anonymous by changing it to an arbitrary integer. Sets without a vessel call sign were allocated a vessel id of '1'. For joint analyses, a fleet code was added to differentiate vessels from different fleets.

In all Japanese and Korean data, and in most Taiwanese data from 1994, latitude and longitude were reported at 1° resolution, with a code to indicate north or south, west or east. Taiwanese fishing locations were otherwise reported at 5° square resolution using a logbook code. All data were adjusted to represent the south-western corner of the 1 x 1° square, and longitudes translated into 360° format. Each set was allocated to regions according to various alternative region definitions, including 2 definitions for yellowfin (Langley 2015), 3 for bigeye (Langley *et al.* 2013), and 6 for albacore. Data outside these areas were ignored. Location information was used to calculate the 5° square (latitude and longitude).

Hooks per set were reported in all datasets, and the few sets without hooks were deleted. For the purposes of further analyses, we cleaned the data by removing data likely to be in error. The criteria were selected after discussion with experts in the respective datasets. In the Japanese and Korean data, hooks per set above 5000 and less than 200 were removed. In the Taiwanese data hooks per set over 4500 and less than 200 were removed. The difference between fleets was unintentional, but there were very few sets with 4500-5000 sets, so there was little or no impact on results. A very high proportion of Taiwanese sets reported 3000 hooks per set, to an increasing degree through time. This difference from the other fleets and remarkable uniformity may be genuine, or may indicate a reporting problem, and warrants further investigation.

The three fleets all reported catch by species in numbers, but for slightly different species. The Japanese reported bigeye, yellowfin, albacore, southern bluefin tuna, swordfish, striped marlin, blue marlin, black marlin. The Taiwanese reported all these but included fields for skipjack, bluefin, sharks, other tunas, other billfish, and other species. The Taiwanese also reported catch by species in weight, but we used only the number information. Korea reported the same species as Japan and also skipjack, sailfish, sharks, and other species. The sailfish category may include shortbill spearfish (Uozumi 1999).

In the Taiwanese logbook, columns for bluefin and southern bluefin tuna were added in 1994. Prior to this bluefin were only recorded in the database when individuals changed the heading in the logbook.

The number of reported bluefin increased substantially in 1994. We reassigned any fish reported as bluefin to the southern bluefin tuna category. The field labelled ‘white marlin’ represents striped marlin in the Indian Ocean. With the three fields for ‘other’ species, ‘other tunas’ are thought to be mostly neritic tunas, ‘other billfish’ may represent mostly sailfish and possibly shortbill spearfish, and ‘other fish’ particularly in recent years mostly oilfish.

In the logbooks of each fleet some very large catches were reported at times for individual species, but were not removed since there was anecdotal evidence that they may be genuine, and because they are unlikely to affect results substantially. Further investigation should consider the pros and cons of retaining these values.

In the Japanese logbook hooks between floats (HBF) were available for almost all sets 1971-2015 (Table 3), and for a high proportion of sets 1958-1966. Sets after 1975 with HBF missing or > 25 were removed. Sets before 1975 with missing HBF were allocated HBF of 5, according to standard practice with Japanese longline data (e.g. Langley *et al.* 2005, Hoyle *et al.* 2013, Ochi *et al.* 2014). In the Taiwanese logbook hooks between floats (HBF) were available from 1995. In the Korean logbook HBF was not available but the number of floats was reported, so we calculated HBF by dividing the number of hooks by the number of floats and rounding it to a whole number.

The remarks section of the Taiwanese dataset indicated outliers and other anomalies. Codes and criteria for outliers changed in 2012. Before 2012 an outlier was flagged if there was catch of more than 5 tons of a species per set, or outliers in the distribution of species catch number per set. From 2012 an outlier was flagged according to the ‘IQR rule’. 1. Arrange average catch numbers per set (within a year) for all vessels in order. 2. Calculate first quartile (Q1), third quartile (Q3) and the interquartile range (IQR=Q3-Q1). 3. Compute Q1-1.5 x IQR and Compute Q3+1.5 x IQR. Anything outside this range is an outlier. This outlier information is used in the standard data cleaning procedures for Taiwanese standardisations. We did not use the outlier information in data cleaning for this paper.

After data cleaning, a standard dataset was produced for each fleet to be used in subsequent analyses (Figure 5).

Each set was allocated to bigeye, yellowfin, and albacore regions. These regions are based on the region definitions used in the stock assessments for each species. Several regional structures were explored for each species, but here we present six options for albacore (Figure 1). Data outside these regions were ignored. Subsequent analyses were performed separately for each region in each regional structure.

4.2. Cluster analysis

Bigeye and yellowfin comprise a large proportion of the catch north of about 15° S, and a lower proportion further south (Figure 6). This pattern applied across all fleets, but there were also spatial and temporal differences in species composition patterns among fleets. The Taiwanese fishery included an oilfish fishery which developed from about 2005 in the southwest Indian Ocean (Figure 7).

We clustered the data using the approach applied by Hoyle *et al.* (2015). We removed all sets with no catch of any of the species, and then aggregated by vessel-month. Set level data contains variability in species composition due to the randomness of chance encounters between fishing gear and schools of fish. This variability leads to some misallocation of sets using different fishing strategies. Aggregating the data tends to reduce the variability, and therefore reduce misallocation of sets. For these analyses we aggregated the data by vessel-month, assuming that individual vessels tend to follow a consistent fishing strategy through time. One trade-off with aggregation in this way is that vessels may change their fishing strategy within a month, which will result in misallocation of sets. For the purposes of this paper we refer to aggregation by vessel-month as trip-level aggregation, although the time scale is (for distant water vessels) in most cases shorter than a fishing trip. For Japanese data prior to 1979 vessel id was not available, but we were able to cluster them by vessel-month because the logbook id, available for the first time in the current data set, could be used to identify sets on the same vessel-trip.

We calculated proportional species composition by dividing the catch in numbers of each species by catch in numbers of all species in the vessel-month. Thus the species composition values of each vessel-month summed to 1, ensuring that large catches and small catches were given equivalent weight. The data were transformed by centring and scaling, so as to reduce the dominance of species with higher average catches. Centring was performed by subtracting the column (species) mean from each column, and scaling was performed by dividing the centred columns by their standard deviations.

We clustered the data using the hierarchical Ward hclust method, implemented with function hclust in R, option 'Ward.D', after generating a Euclidean dissimilarity structure with function 'dist'. This approach differs from the standard Ward D method which can be implemented by either taking the square of the dissimilarity matrix or using method 'ward.D2' (Murtagh and Legendre 2014). However in practice the method gives similar patterns of clusters to other methods, more reliably than ward.D2 (Hoyle et al 2015).

Data were also clustered using the kmeans method, which minimises the sum of squares from points to the cluster centres, using the algorithm of Hartigan and Wong (1979). It was implemented using function kmeans in the R stats package (R Core Team 2014).

4.2.1. Selecting the number of groups

We used several subjective approaches to select the appropriate number of clusters. In most cases the approaches suggested the same or similar numbers of groups. First, we applied hclust to transformed trip-level data and examined the hierarchical trees, subjectively estimating the number of distinct branches. Second, we ran kmeans analyses on untransformed trip-level data with number of groups k ranging from 2 to 25, and plotted the deviance against k. The optimal group number was the lowest value of k after which the rate of decline of deviance became slower and smoother. Third, following Winker et al (2014) we applied the nScree() function from the R nFactors package (Raiche and Magis 2010), which uses various approaches (Scree test, Kaiser rule, parallel analysis, optimal coordinates, acceleration factor) to estimate the number of components to retain in an exploratory PCA. Where there was uncertainty about the number of clusters, we selected the option with more clusters.

4.2.2. Plotting and data selection

We plotted the hclust clusters to explore the relationships between them and the species composition and other variables, such as HBF, number of hooks, year, and set location. Plots included boxplots of a) proportion of each species in the catch, by cluster; b) the distributions of variables by cluster; and c) maps of the spatial distribution of clusters, one map for each cluster.

In some analyses clusters that caught very few of the species of interest were omitted, because they provide little relevant information and may cause analysis problems due to large numbers of zeroes, and memory problems due to large sample sizes. Cluster selection was based on review and discussion of the plots of covariates and species compositions by cluster. Analyses were run both with and without these clusters – see the 'Models and datasets' section.

We pooled data from multiple fleets into a single analysis for years 1952-2015. The pooled dataset included all data from the Japanese (1952-2015) and Korean (1971-2015) fleets. For the Taiwanese fleet 1979-2015 were included for albacore, and 2005-2015 for tropical tunas.

For standardization of each region, data were selected for vessels that had fished for at least N1 quarters in that region. The standard level of N1 was 8 quarters in the equatorial regions and 2 quarters in the southern regions. Subsequently, vessels, 5° cells, and year-quarters were included if they had at least 100 sets. For analyses of the 1952-1979 period this criterion was reduced to 50 sets, to increase the size of the dataset. For datasets with more than 60,000 sets the number of sets in each stratum (5° square * year-quarter) was limited by randomly selecting 60 sets without replacement from strata with more than this number of sets. Testing suggested that this approach did not cause bias, and the effects on trends of random variation were reduced to very low levels at 30 sets per stratum (Hoyle and Okamoto 2011, Hoyle and Okamoto 2011), suggesting that 60 sets was more than adequate.

4.3. CPUE standardization, and fleet efficiency analyses

CPUE standardization methods generally followed the approaches used by Hoyle and Okamoto (2011) with some modifications. The operational data were standardized using generalized linear models in R. A large number of analyses were carried out.

1. Analyses were carried out for each species.
2. Initially analyses were carried out for multiple regional structures, though this was later reduced to one each for bigeye and yellowfin, and two for albacore.
3. Analyses for bigeye and yellowfin were conducted using five alternative models and datasets, described below, while analyses for albacore were conducted using one model and dataset.
4. Separate analyses were run for each region, ranging from one to four regions per structure.
5. Up to three modelling distributions were used: lognormal constant, delta lognormal, and negative binomial. Lognormal constant was used for all species, delta lognormal for bigeye and yellowfin, and negative binomial for albacore.
6. Analyses were run for four alternative data groups, as described below.

4.3.1. Distributions

Lognormal constant analyses were carried out using generalized linear models that assumed a lognormal distribution. In this approach the response variable $\log(CPUE + k)$ was used, and a Normal distribution assumed. The constant *k*, added to allow for modelling sets with zero catches of the species of interest, was 10% of the mean CPUE for all sets.

Delta lognormal analyses (Lo *et al.* 1992, Maunder and Punt 2004) used a binomial distribution for the probability *w* of catch rate being zero and a probability distribution *f(y)* , where y was log(catch/hooks set), for non-zero (positive) catch rates. The index estimated for each year-quarter was the product of the year effects for the two model components, $(1 - w).E(y|y \neq 0)$.

$$\Pr(Y = y) = \begin{cases} w, & y = 0 \\ (1 - w)f(y) & otherwise \end{cases}$$

$\mathrm{g}(w) = (CPUE = 0) \sim covariates + \epsilon$, where g is the logistic function.

$\mathrm{f}(y) = CPUE \sim covariates + \epsilon$

Negative binomial analyses used the function glm.nb from the MASS package (Venables and Ripley 2002) in R, using the default options. The response variable was catch in numbers.

In each case the covariates included year-quarter, (*yrqtr*), 5° cell, (*latlong5*), and cluster (*cl*) fitted as categorical variables, and a cubic spline function h with 10 degrees of freedom applied to the continuous variable *hooks*. Some analyses included the vessel identifier *vessid* as a categorical variable. Some analyses included a cubic spline φ applied to the continuous variable hooks between floats (*hbf*).

Data in all models except the binomial model were 'area-weighted', with the weights of the sets adjusted so that the total weight per year-quarter in each 5° square would sum to 1. This method was based on the approach identified using simulation by Punsly (1987) and Campbell (2004), that for set *j* in area *i* and year-quarter *t*, the weighting function that gave the least average bias was: $w_{ijt} = \frac{log(h_{ijt}+1)}{\sum_{j=1}^{n}\log(h_{ijt}+1)}$. Given the relatively low variation in number of hooks between sets in a stratum, we simplified this to $w_{ijt} = \frac{h_{ijt}}{\sum_{j=1}^{n} h_{ijt}}$.

For the lognormal constant and positive lognormal GLMs, model fits were examined by plotting the residual densities and using Q-Q plots.

4.3.2. Models and datasets

In order to explore alternative approaches to the analysis, the four approaches below were applied for each of the tropical tuna species. Albacore was modelled with the second approach only.

1. Data omitted low-target clusters. Model included HBF but not cluster.
2. Data omitted low-target clusters. Model included cluster but not HBF.
3. Data omitted low-target clusters. Model included neither HBF nor cluster.
4. All data included. Model included HBF but not cluster.

4.3.3. Data periods

Vessel identity information was only available from 1979, so could not be applied uniformly across all years. The discontinuity in 1979 could be addressed in several different ways. We therefore analysed the data in several ways so as to provide the assessment scientists with appropriate data. For each of the approaches above, four analyses were carried out (Table 1).

TABLE 1: ANALYSIS APPROACHES FOR ADDRESSING THE DISCONTINUITY IN AVAILABILITY OF VESSEL IDENTITY.

Analysis	Years	Vessel effects
1	1952-1979	No
2	1979-2015	Yes
3	1952-2015	No
4	1952-2015	Yes

It is possible to standardize the time series with vessel effects by assigning an identical dummy value to all vessels without vessel identity information. This was done for analysis 3). However using a dummy value introduces several problems. First, not all vessels begin to report their callsign at once in 1979, and those that do are self-selected and not randomly selected from the vessel population. Therefore it cannot be assumed that fishing power remains constant after 1979 for the dummy vessel id, so the transition in 1979 may introduce a discontinuity into the time series. The discontinuity can be limited in scope by restricting the overlap between dummy and real vessel IDs to one year – 1979 – and removing sets with missing vessel IDs after this time. Secondly, residuals may be more variable before 1979, without a true vessel ID in the model, which can introduce bias into the standardization. One approach for addressing the discontinuity in analysis 3) is to adjust the time period 1952-1978 so that the relative averages in 1978 and 1979 are the same. as they are in analysis 4), without vessel effects. However we considered that a better approach may be to estimate two time series 1952-1979 without vessel effects, and a second time series 1979-2015 with vessel effects (omitting all sets without vessel IDs). These are analyses 1) and 2) above. Subsequently the analyst can use them as desired, for example concatenating them after adjusting the averages so that the estimates for 1979 are the same.

4.3.4. Covariate effects

The effects of covariates were examined by plotting the predicted effects, with 95% confidence limits, of each parameter at observed values of the explanatory variables. Spatial effects with 95% confidence intervals were plotted by latitude. The cumulative vessel effects through time were examined by plotting each vessel's effect at every time that vessel made a set. An average vessel effect over time was examined by calculating the mean of the vessel effects for all sets made by the fleet during each time period, and this was also plotted. There was insufficient space to include all plots in the report, but these are available on request.

Changes in catchability through time were investigated by fitting to the operational data both with and without a term for individual vessel. The two models were designated respectively the 'base model' and the 'vessel-effects model'. Abundance indices were calculated for each model, and normalized to average 1.

For all model comparisons, the indices estimated for each year-quarter were compared by dividing the base model by the vessel effects model, plotting the time series of ratios, and fitting a log-linear regression. The slope of the regression represented the average annual compounding rate of change in fishing power attributable to changes in the vessel identities; i.e. the introduction of new vessels and retirement of old vessels. Gradients are shown on the figures, together with confidence intervals.

4.3.5. Indices of abundance

Indices of abundance were obtained by applying the R function predict.glm to model objects. Binomial time effects were obtained by generating time effects from the glm and adjusting them so that their mean was the proportion of positive sets across the whole dataset. The main aim with this approach is to obtain a CPUE that varies appropriately, since variability for a binomial is greater when the mean is at 0.5 than at 0.02 or 0.98, and the multiplicative effect of the variability is greater when the mean is lower. The outcomes were normalised and reported as relative CPUE with mean of 1.

Uncertainty estimates were provided by applying the R function predict.glm with type = "terms" and se.fit=TRUE, and taking the standard error of the year-quarter effect. For the delta lognormal models we used only the uncertainty in the positive component. Uncertainty estimates from standardizing commercial logbook data are in general biased low and often ignored by assessment scientists, since they assume independence and ignore autocorrelation associated with (for example) consecutive sets by the same vessels in the same areas. There may be a very large mismatch between the observation error in CPUE indices and the process error in the indices that is estimated in the assessment. This is particularly true for distant water longline CPUE, where very large sample sizes generate small observation errors.

Residual distributions and Q-Q plots were produced for all but the binomial analyses. For the lognormal positive analyses that included cluster in the model, median residuals were plotted by cluster. For all lognormal positive analyses, residuals by year-quarter were plotted by flag; median residuals by year-quarter were plotted by flag; and median residuals by 5° cell were mapped onto a contour plot for each flag.

We compared the indices with the area-specific Japanese bigeye indices from 2013 (Matsumoto *et al.* 2013) and yellowfin indices from 2015 (Ochi *et al.* 2015). The 2013 bigeye indices provided only a whole-of-area index in the southern temperate area, so this was compared with both the east and west joint indices. For each comparison, each dataset was first normalised by dividing through by its mean for 1980-2000, and the datasets plotted on the same axes. Secondly, the joint indices were divided by the matching year-quarter values from the Japanese indices, and these ratios were plotted to show the relative trends of the two time series.

5. Results and Discussion

5.1. Cluster analysis

The aim of the cluster analysis was first to identify separate fishing strategies in the data for each species, regional structure, fleet, and region, and so to better understand the fishing practices; and second to assign each unit of fishing effort to a particular fishing strategy, so that the clusters could be used in standardization.

We clustered the data using hclust and kmeans methods for each region and fleet. Due to space limitations we report clustering results for regional structure A3 only. Results for regional structures A2 and A5 are similar.

The hclust trip and untransformed kmeans set methods separated Japanese, Korean and Taiwanese effort into 3-5 fishing strategies in each region (**Error! Reference source not found.**, Figures 9-12). Please note that the order of the clusters in the dendrograms does not match the cluster numbers.

Species compositions were plotted by cluster for each region and fleet, as were the relative distributions of covariates (Figures 13–20).

In region 1 for all three fleets, we included a cluster characterized by a high proportion of albacore and low to moderate yellowfin, with low levels of other species (*Figure 13*). The main Japanese cluster derived largely from the early period (*Figure 14*). All three fleets covered most of the spatial domain east of Madagascar and south of about 15° S (*Figure 21*). For the Japanese fleet, a second cluster with moderate proportions of albacore and bigeye and relatively high yellowfin was included, mostly from northern areas.

In region 2, only one cluster was selected from each fleet (Figure 15), which for Japan was high in albacore and moderate in bigeye and yellowfin. The Korean cluster included moderate levels of albacore and yellowfin, but slightly more bigeye. The Taiwanese cluster was dominated by albacore. Clusters for all fleets were more concentrated in the earlier parts of the time series (*Figure 16*). The Japanese and Taiwanese clusters were south of about 15 S, as in region 1, but the Korean cluster was further north (Figure 22), probably because there was very little Korean effort further south in region 2.

In region 3, one cluster was selected for the Japanese and Korean fleets, but two clusters for the Taiwanese fleet (Figure 17). The Japanese cluster had good coverage across most of the time series, as did the Taiwanese cluster, whereas the Korean cluster was less evenly distributed (Figure 18). The spatial coverage of the Japanese and Taiwanese clusters was also broad (Figure 23). There were some striking patterns of changing species composition in the Japanese time series at 30S and 35S, which were not seen in any other fleet or region. These may warrant further investigation.

In region 4, a single cluster was selected for Japan and 2 clusters each for the Korean and Taiwanese fleets (Figure 19). The Japanese cluster was based mostly on albacore, with small proportions of bigeye and southern bluefin tuna. The cluster had good temporal coverage, as did the Taiwanese clusters (Figure 20). For Japan and Korea the clusters were focused north of about 37 S, with more southern effort in southern bluefin tuna clusters. For Taiwan the albacore clusters included most of the effort in region 4, which for the Taiwanese fleet went only as far south as 40 S (Figure 24).

5.2. CPUE indices

We estimated indices for all regions of regional structure A3 (Tables **Error! Reference source not ound.**–**Error! Reference source not found.**, Figures 25–28), and for the single region of regional structure A5 (Tables **Error! Reference source not found.**–**Error! Reference source not found.**, Figure 29). A limited range of diagnostics indicated reasonably normal distributions of residuals (Figures 30–32).

Indices in the northern areas were characterized by steep or very steep declines in standardized CPUE prior to 1975, particularly in region 1. After 1980 the region 1 CPUE increased until 1995 and then decreased. For the north-eastern region 2, data were sparse after about 1990, with no clear signal in the estimates. Fish sizes are larger in northern areas, so catch rates here may reflect abundance trends of older fish.

The southwestern area region 3 also showed a steep decline until about 1970, followed by more stable catch rates from 1970–2010. There were indications of a drop in catch rates after 1985, followed by recovery of catch rates after the mid-1990s, and further increase beginning in about 2005. The south-eastern area region 4 was the only region in which no steep decline in catch rates was observed prior to 1970. After 1980 the index declines somewhat, followed by an increase beginning in about 2005.

The CPUE trends estimated here address a number of concerns about indices used in previous assessments. Models are run separately for different areas, which addresses concerns about differing parameter estimates and uncertainty distributions in different areas (Chang *et al.* 2011). The models use 5° cell area effects, as recommended by the 2013 IOTC CPUE workshop (Anon 2013) to account for changes in effort distribution, and adjusts statistical weights to allow for changing effort concentration (Punsly 1987, Campbell 2004). The models include vessel effects, which accounts for some effects of changing fishing power and targeting within the fleet (Hoyle and Okamoto 2011). It also uses cluster analysis based on species composition in order to identify target change, and to separate out effort using different fishing strategies (He *et al.* 1997).

However, concerns remain about the indices estimated in this study. The declines in the indices before 1970 are too steep to represent abundance change, given the relatively low catches taken during this period. Similar declines are seen in albacore indices in other oceans (e.g. Hampton *et al.* 2005), even after clustering (Bigelow and Hoyle 2012). Factors causing the declines are unclear, but in addition to unresolved effects of target change may include changing catchability due to removal of the most vulnerable individuals (Gulland 1974, Maunder *et al.* 2006).

The indices also show increasing CPUE from 2005, during a period when Japanese effort began targeting albacore tuna. There is a strong suggestion that cluster analysis may not have fully accounted for target change, and that indices may be biased upward during this period. Further investigation is needed to explore this issue, which should include investigating residuals by fleet, the effects of piracy on fleet distribution, exploring the timing of the changes seasonally, and possibly relationship with target switching by the southern bluefin tuna fleet after quotas have been met.

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8. Tables

Table 2: Data format for Japanese longline dataset.

Items	Type	1952-1957	1959-1966	1967-1975	1976-1993	1994-2014
operation year	integer	YES	YES	YES	YES	YES
operation month	integer	YES	YES	YES	YES	YES
operation day	integer	YES	YES	YES	YES	YES
operation latitude	integer	YES	YES	YES	YES	YES
operation latitude code	integer	YES	YES	YES	YES	YES
operation longitude	integer	YES	YES	YES	YES	YES
operation longitude code	integer	YES	YES	YES	YES	YES
call sign	character	NO	NO	NO	YES	YES
no. of hooks between float	integer	NO	YES	NO	YES	YES
total no. of hooks per set	integer	YES	YES	YES	YES	YES
SBT catch in number	integer	YES	YES	YES	YES	YES
albacore catch in number	integer	YES	YES	YES	YES	YES
bigeye catch in number	integer	YES	YES	YES	YES	YES
yellowfin catch in number	integer	YES	YES	YES	YES	YES
swordfish catch in number	integer	YES	YES	YES	YES	YES
striped marlin catch in number	integer	YES	YES	YES	YES	YES
blue marlin catch in number	integer	YES	YES	YES	YES	YES
black marlin catch in number	integer	YES	YES	YES	YES	YES
shark catch in number	Integer	YES	YES	YES	YES	YES
prefecture code	character	YES	YES	YES	YES	YES
logbook ID	integer	YES	YES	YES	YES	YES
day of cruise start	integer	NO	YES	NO	YES (79-93)	YES

Table 3: Number of available data by variable in the Japanese longline dataset.

YEAR	No. of operation	Operation Date	Latitude	Longitude	Call sign	HBF	Total number of hooks per set	SBT catch in number	ALB catch in number	BET catch in number	YFT catch in number	SWO catch in number	MLS catch in number	BUM catch in number	BLA catch in number	day of cruise start
1952	136	136	136	136	0	0	136	136	136	136	136	136	136	136	136	0
1953	1065	1065	1065	1065	0	0	1065	1065	1065	1065	1065	1065	1065	1065	1065	0
1954	4289	4289	4289	4289	0	0	4289	4289	4289	4289	4289	4289	4289	4289	4289	0
1955	6411	6411	6411	6411	0	0	6411	6411	6411	6411	6411	6411	6411	6411	6411	0
1956	11293	11293	11293	11293	0	0	11293	11293	11293	11293	11293	11293	11293	11293	11293	0
1957	7833	7833	7833	7833	0	99	7833	7833	7833	7833	7833	7833	7833	7833	7833	103
1958	8149	8149	8149	8149	0	6055	8149	8149	8149	8149	8149	8149	8149	8149	8149	7086
1959	9983	9983	9983	9983	0	7048	9983	9983	9983	9983	9983	9983	9983	9983	9983	9111
1960	13701	13701	13701	13701	0	10139	13701	13701	13701	13701	13701	13701	13701	13701	13701	12546
1961	12553	12553	12553	12553	0	10103	12553	12553	12553	12553	12553	12553	12553	12553	12553	11655
1962	22365	22365	22365	22365	0	11759	22365	22365	22365	22365	22365	22365	22365	22365	22365	21195
1963	23315	23315	23315	23315	0	11397	23315	23315	23315	23315	23315	23315	23315	23315	23315	23278
1964	28868	28868	28868	28868	0	13686	28865	28868	28868	28868	28868	28868	28868	28868	28868	28868
1965	28631	28631	28631	28631	0	25152	28631	28631	28631	28631	28631	28631	28631	28631	28631	28631
1966	32773	32773	32272	32773	0	31574	32773	11057	32773	32773	32773	32773	19904	17978	13959	32773
1967	58000	58000	57853	58000	0	9215	58000	51436	58000	58000	58000	58000	53732	53166	51628	9343
1968	40033	40033	40033	40033	0	0	40033	40033	40033	40033	40033	40033	40033	40033	40033	0
1969	36172	36172	36172	36172	0	0	36172	36172	36172	36172	36172	36172	36172	36172	36172	0
1970	29393	29393	29393	29393	0	0	29393	29393	29393	29393	29393	29393	29393	29393	29393	0
1971	27402	27402	27402	27402	0	26248	27402	27402	27402	27402	27402	27402	27402	27402	27402	0
1972	21220	21220	21220	21220	0	20571	21220	21220	21220	21220	21220	21220	21220	21220	21220	0
1973	24968	24968	24968	24968	0	24036	24968	24968	24968	24968	24968	24968	24968	24968	24968	0
1974	28492	28492	28492	28492	0	27700	28492	28492	28492	28492	28492	28492	28492	28492	28492	0
1975	30287	30287	30287	30287	0	29062	30287	30287	30287	30287	30287	30287	30287	30287	30287	0
1976	26590	26590	26590	26590	0	26039	26590	26590	26590	26590	26590	26590	26590	26590	26590	0
1977	22150	22150	22150	22150	0	21780	22150	22150	22150	22150	22150	22150	22150	22150	22150	0
1978	22530	22530	22530	22530	0	22080	22530	22530	22530	22530	22530	22530	22530	22530	22530	0
1979	28551	28551	28551	28551	27857	23552	28551	28551	28551	28551	28551	28551	28551	28551	28551	28551
1980	31506	31506	31506	31506	30464	30454	31506	31506	31506	31506	31506	31506	31506	31506	31506	31506
1981	31368	31368	31368	31368	30288	30929	31368	31368	31368	31368	31368	31368	31368	31368	31368	31368
1982	32732	32732	32732	32732	31638	31994	32732	32732	32732	32732	32732	32732	32732	32732	32732	32732
1983	40153	40153	40153	40153	39541	38643	40153	40153	40153	40153	40153	40153	40153	40153	40153	40153

1984	42800	42800	42800	42800	41992	41438	42800	42800	42800	42800	42800	42800	42800	42800	42800	42800
1985	46245	46245	46245	46245	45431	45332	46245	46245	46245	46245	46245	46245	46245	46245	46245	46245
1986	42564	42564	42564	42564	41657	41762	42564	42564	42564	42564	42564	42564	42564	42564	42564	42564
1987	35539	35539	35539	35539	34475	35150	35539	35539	35539	35539	35539	35539	35539	35539	35539	35539
1988	28739	28739	28739	28739	28302	28638	28739	28739	28739	28739	28739	28739	28739	28739	28739	28739
1989	25988	25988	25988	25988	25818	25317	25988	25988	25988	25988	25988	25988	25988	25988	25988	25988
1990	17475	17475	17475	17475	17450	17218	17475	17475	17475	17475	17475	17475	17475	17475	17475	17475
1991	20227	20227	20227	20227	20227	19354	20227	20227	20227	20227	20227	20227	20227	20227	20227	20227
1992	19672	19672	19672	19672	19672	19338	19672	19672	19672	19672	19672	19672	19672	19672	19672	19672
1993	17153	17153	17153	17153	17153	16990	17153	17153	17153	17153	17153	17153	17153	17153	17153	17153
1994	25637	25637	25637	25637	25637	25471	25637	25637	25637	25637	25637	25637	25637	25637	25637	25637
1995	30588	30588	30588	30588	30588	30437	30588	30588	30588	30588	30588	30588	30588	30588	30588	30588
1996	35991	35991	35991	35991	35991	35713	35991	35991	35991	35991	35991	35991	35991	35991	35991	35991
1997	40691	40691	40691	40691	40691	40459	40691	40691	40691	40691	40691	40691	40691	40691	40691	40691
1998	37609	37609	37609	37609	37609	37262	37609	37609	37609	37609	37609	37609	37609	37609	37609	37609
1999	33249	33249	33249	33249	33249	32875	33249	33249	33249	33249	33249	33249	33249	33249	33249	33249
2000	32199	32199	32199	32199	32199	31767	32199	32199	32199	32199	32199	32199	32199	32199	32199	32199
2001	34827	34827	34827	34827	34827	34204	34827	34827	34827	34827	34827	34827	34827	34827	34827	34827
2002	31471	31471	31471	31471	31471	30926	31471	31471	31471	31471	31471	31471	31471	31471	31471	31471
2003	23827	23827	23827	23827	23827	23021	23827	23827	23827	23827	23827	23827	23827	23827	23827	23827
2004	30271	30271	30271	30271	30271	29330	30271	30271	30271	30271	30271	30271	30271	30271	30271	30271
2005	34389	34389	34389	34389	34389	33294	34389	34389	34389	34389	34389	34389	34389	34389	34389	34389
2006	34021	34021	34021	34021	34021	33634	34021	34021	34021	34021	34021	34021	34021	34021	34021	34021
2007	30708	30708	30708	30708	30708	30675	30708	30708	30708	30708	30708	30708	30708	30708	30708	30708
2008	25552	25552	25552	25552	25552	25519	25552	25552	25552	25552	25552	25552	25552	25552	25552	25552
2009	20454	20454	20454	20454	20454	20421	20454	20454	20454	20454	20454	20454	20454	20454	20454	20454
2010	12286	12286	12286	12286	12286	12286	12286	12286	12286	12286	12286	12286	12286	12286	12286	12286
2011	10131	10131	10131	10131	10131	10131	10131	10131	10131	10131	10131	10131	10131	10131	10131	10131
2012	10607	10607	10607	10607	10607	10607	10607	10607	10607	10607	10607	10607	10607	10607	10607	10607
2013	9974	9974	9974	9974	9974	9974	9974	9974	9974	9974	9974	9974	9974	9974	9974	9974
2014																

Table 4: Data format for Taiwanese longline dataset.

Items	Type	Column	1979-1994	1995-2005	2006-2013	Remarks
call sign	character	1-5	YES	YES	YES	See below re first digit
operation year	integer	6-9	YES	YES	YES	
operation month	integer	10-11	YES	YES	YES	
operation day	integer	12-13	YES	YES	YES	
operational area	integer	14-17	YES	YES	YES	Reference to map
no. of hooks between floats	integer	18-20	NO	YES	YES	
total no. of hooks per set	integer	21-25	YES	YES	YES	
albacore catch in number	integer	26-29	YES	YES	YES	
bigeye catch in number	integer	30-33	YES	YES	YES	
yellowfin catch in number	integer	34-37	YES	YES	YES	
bluefin catch in number	integer	38-41	YES	YES	YES	
southern bluefin catch in number	integer	42-45	YES	YES	YES	
other tuna catch in number	integer	46-49	YES	YES	YES	
swordfish catch in number	integer	50-53	YES	YES	YES	
white marlin catch in number	integer	54-57	YES	YES	YES	
blue marlin catch in number	integer	58-61	YES	YES	YES	
black marlin catch in number	integer	62-65	YES	YES	YES	
other billfish catch in number	integer	66-69	YES	YES	YES	
skipjack catch in number	integer	70-73	YES	YES	YES	
shark catch in number	integer	74-77	YES	YES	YES	
other species catch in number	integer	78-81	YES	YES	YES	
albacore catch in weight	integer	82-86	YES	YES	YES	
bigeye catch in weight	integer	87-91	YES	YES	YES	
yellowfin catch in weight	integer	92-96	YES	YES	YES	
bluefin catch in weight	integer	97-101	YES	YES	YES	
southern bluefin catch in wt	integer	102-106	YES	YES	YES	
other tuna catch in wt	integer	107-111	YES	YES	YES	
swordfish catch in wt	integer	112-116	YES	YES	YES	
white marlin catch in wt	integer	117-121	YES	YES	YES	
blue marlin catch in wt	integer	122-126	YES	YES	YES	
black marlin catch in wt	integer	127-131	YES	YES	YES	
other billfish catch in wt	integer	132-136	YES	YES	YES	
skipjack catch in number	integer	137-141	YES	YES	YES	
shark catch in number	integer	142-146	YES	YES	YES	
other spp catch in number	integer	147-151	YES	YES	YES	
SST	Integer	152-153	YES	YES	YES	
bait type: pacific saury	integer	154	YES	YES	YES	
bait type: mackerel	integer	155	YES	YES	YES	
bait type: squid	integer	156	YES	YES	YES	
bait type: milkfish	integer	157	YES	YES	YES	
bait type: others	integer	158	YES	YES	YES	
Depth of hooks (m)	Integer	159-161	NO	YES	YES	
set type (type of target)	character	162-163	NO	NO	YES	1.BET, 2. ALB, 3.both
Remark	integer	164-165	NO	NO	YES	See below
operation latitude code	character	166-166	NO	YES	YES	N: 4, S: 3
operation latitude	Integer	167-168	NO	YES	YES	
operation longitude code	Character	169-169	NO	YES	YES	E: 1, W: 2
operation longitude	Integer	170-172	NO	YES	YES	
departure date from port	Integer	176-183	YES	YES	YES	
starting date to operation	Integer	185-192	NO	YES	YES	
stop date to operation	Integer	194-201	NO	YES	YES	
arrival date at port	Integer	203-210	YES	YES	YES	

Table 5: Tonnage as indicated by first digit of TW callsign.

First digit	Tonnage
1	>= 5 and < 10 tonnes
2	>= 10 and < 20 tonnes
3	>= 20 and < 50 tonnes
4	>= 50 and < 100 tonnes
5	>= 100 and < 200 tonnes
6	>= 200 and < 500 tonnes
7	>= 500 and < 1,000 tonnes
8	>= 1,000 tonnes

Table 6: Codes in the Remarks field of the TW dataset, indicating outliers.

Dates	Code	Outliers
2007-2011	G1	extremely high BET catch
	G4	extremely high ALB
	G6	extremely high YFT catch
	G8	extremely high SWO;
	SF	for a given year and vessel, record only single species catch for 3 successive months
2012-2013	G1	extremely high ALB catch
	G2	extremely high BET
	G3	extremely high YFT catch
	G7	extremely high SWO
	GH	abnormal total no. of hooks per set
	GL	more than one anomaly
	SF	for a given year and vessel, only record single species catch for 3 successive months

2007-2011:
1.G1:extremely high BET catch (> 5 tons per set or outliers in the distribution of bet catch number per set) ; G4: extremely high ALB;
G6: extremely high YFT catch; G8: extremely high SWO;
SF: for a given year and a given vessel, record only single species catch for three successive months.

2012-2014:
G1: extremely high ALB catch (Based on definition of IOTC BET regions, for a given year and a given region, average catch numbers per set for a given vessel. Then use the IQR Rule[*]. Remark all sets by the vessel which reported the outlier for the given year and region);
G2: extremely high BET;
G3: extremely high YFT catch; G7: extremely high SWO;
GH: abnormal total no. of hooks per set;
GL: if there are more than one anomaly.
SF: for a given year and a given vessel, only record single species catch for three successive months.

Criteria for outliers
(> 5 tons per set or outliers in the distribution of bet catch number per set)

[*]IQR Rule for Outliers
1. Arrange average catch numbers per set for all vessels in order.
2. Calculate first quartile (Q1), third quartile (Q3) and the interquartile range (IQR=Q3-Q1).
3. Compute Q1-1.5 x IQR and Compute Q3+1.5 x IQR. Anything outside this range is an outlier.

Table 7a: Taiwanese data sample sizes by variable.

Year	No. of ops	Cruise start date	Cruise end date	Op start date	Op end date
1979	16,056	15,996	16,056	0	0
1980	21,021	20,682	21,021	0	0
1981	16,969	16,835	16,969	0	0
1982	23,110	23,110	23,110	0	0
1983	22,048	22,048	22,048	0	0
1984	17,551	17,551	17,551	0	0
1985	13,531	13,531	13,531	0	0
1986	13,257	13,257	13,257	0	0
1987	14,431	14,431	14,431	0	0
1988	12,497	12,497	12,497	0	0
1989	9,045	9,045	9,045	0	0
1990	7,181	7,181	7,181	0	0
1991	5,738	5,738	5,738	0	0
1992	3,499	3,499	3,499	0	0
1993	17,869	17,869	17,869	0	0
1994	20,315	7,726	7,726	1,359	2,021
1995	19,341	19,341	19,196	19,077	19,341
1996	24,492	24,402	24,492	24,492	24,492
1997	25,503	23,137	25,503	25,503	25,503
1998	24,041	23,653	24,041	24,041	24,041
1999	29,608	29,037	29,608	29,563	29,608
2000	31,664	30,489	31,569	31,593	31,569
2001	40,636	39,073	40,486	40,486	40,486
2002	42,017	41,522	42,017	42,017	42,017
2003	69,329	68,205	65,718	69,329	69,329
2004	80,508	77,186	76,430	80,508	80,508
2005	72,204	68,983	63,761	72,204	72,204
2006	51,798	47,281	47,784	51,798	51,798
2007	44,016	36,749	37,705	44,016	44,016
2008	31,809	24,716	25,335	31,809	31,809
2009	40,097	31,527	31,265	40,097	40,097
2010	29,856	26,057	23,609	29,801	29,801
2011	22,544	19,182	17,000	22,544	22,544
2012	21,697	16,085	15,698	21,697	21,697

Table 7b: Taiwanese data sample sizes by variable.

Year	No. of ops	Set type	Lat & long in 1°	NHBF	After cleaning
1979	16,056	0	0	0	12,758
1980	21,021	0	0	0	16,889
1981	16,969	0	0	0	13,561
1982	23,110	0	0	0	17,786
1983	22,048	0	0	0	17,129
1984	17,551	0	0	0	14,339
1985	13,531	0	0	0	11,888
1986	13,257	0	0	0	10,491
1987	14,431	0	0	0	11,018
1988	12,497	0	0	0	10,434
1989	9,045	0	0	0	7,099
1990	7,181	0	0	0	5,787
1991	5,738	0	0	0	4,993
1992	3,499	0	0	0	2,907
1993	17,869	0	0	0	11,662
1994	20,315	0	20,315	0	15,635
1995	19,341	0	12,051	7,116	15,319
1996	24,492	0	18,408	10,884	18,760
1997	25,503	0	20,565	9,495	20,255
1998	24,041	0	19,785	10,022	20,482
1999	29,608	0	24,603	14,198	26,090
2000	31,664	0	26,723	16,022	27,429
2001	40,636	0	37,853	32,575	36,308
2002	42,017	0	38,204	40,768	37,475
2003	69,329	0	53,455	69,183	37,338
2004	80,508	0	76,388	80,402	70,125
2005	72,204	0	70,135	72,204	57,497
2006	51,798	51,798	50,987	51,798	38,910
2007	44,016	44,016	43,506	44,016	32,622
2008	31,809	31,809	31,176	31,809	23,602
2009	40,097	40,097	39,355	40,097	30,773
2010	29,856	29,856	29,756	29,856	23,342
2011	22,544	22,544	22,544	22,544	17,701
2012	21,697	21,697	21,696	21,697	14,723

Table 8: Korean data description.

Year	No. of ops	VESSEL NAME_rev	Vessel id coverage (%)	Hooks	Floats	Op date
1971	34	34	100.0	34	34	34
1972	3265	53	1.6	3265	3265	3265
1973	508	508	100.0	508	241	508
1974	1255	1255	100.0	1255	93	1255
1975	5313	5051	95.1	5021	334	5313
1976	119	119	100.0	119	119	119
1977	3714	3714	100.0	3714	3714	3736
1978	23191	22882	98.7	23191	23191	23191
1979	10509	10433	99.3	10509	10509	10651
1980	20446	19874	97.2	20446	20446	20408
1981	15566	15527	99.7	15566	15566	15585
1982	17119	16593	96.9	17119	17119	17176
1983	19255	18216	94.6	19255	19255	19255
1984	7912	7684	97.1	7912	7912	8080
1985	11386	10887	95.6	11386	11386	11530
1986	14374	14157	98.5	14374	14374	14462
1987	14810	14660	99.0	14810	14810	14810
1988	17568	17409	99.1	17568	17568	17568
1989	18771	18127	96.6	18771	18771	18771
1990	14162	14073	99.4	14162	14162	14162
1991	4533	4533	100.0	4533	4533	4533
1992	7005	7005	100.0	7005	7005	7005
1993	9569	9569	100.0	9569	9569	9569
1994	10141	9065	89.4	10141	10141	10141
1995	7577	5332	70.4	7577	7577	7577
1996	12218	7501	61.4	12218	12218	12218
1997	13740	8031	58.4	13740	13740	13740
1998	5165	2239	43.3	5165	5165	5165
1999	2833	1783	62.9	2833	2833	2833
2000	4236	2394	56.5	4236	4236	4236
2001	3162	1929	61.0	3162	3162	3162
2002	1479	1341	90.7	1479	1479	1638
2003	2627	1474	56.1	2627	2627	2627
2004	4345	3004	69.1	4345	4345	4345
2005	2443	2443	100.0	2443	2443	2444
2006	3597	3508	97.5	3597	3597	3597
2007	3371	3197	94.8	3371	3371	3371
2008	2330	2330	100.0	2330	2330	2330
2009	3273	3273	100.0	3273	3273	3273
2010	1851	1851	100.0	1851	1851	1851
2011	1658	1658	100.0	1658	1658	1658
2012	1295	1295	100.0	1295	1295	1295
2013	1659	1659	100.0	1659	1659	1659
2014	1802	1802	100.0	1802	1802	1802

Table 9: Comparison of field availability among the three fleets.

Items	JP	TW	KR
call sign	1979-	Y	Y
operation date	Y	Y	Y
Location – 5x5	Y	Y	Y
Location – 1x1	Y	1994-	Y
no. of hooks between float	*	#	&
total no. of hooks per set	Y	Y	Y
albacore catch in number	Y	Y	Y
bigeye catch in number	Y	Y	Y
yellowfin catch in number	Y	Y	Y
southern bluefin catch in number	Y	1994-	Y
other tuna catch in number	N	Y	N
swordfish catch in number	Y	Y	Y
striped marlin catch in number	Y	Y	Y
blue marlin catch in number	Y	Y	Y
black marlin catch in number	Y	Y	Y
sailfish catch in numbers	N	^	Y
skipjack catch in number	N	Y	Y
shark catch in number	N	Y	Y
other species catch in number	N	Y[1]	Y[1]
Bait type: Pacific saury	Y	N	N
Bait type: mackerel	Y	N	N
Bait type: squid	Y	N	N
Bait type: milkfish	Y	N	N
Bait type: others	Y	N	N

* High coverage since 1971, variable earlier

Coverage increasing from 1994 to reach 100% by 2003

& number of floats reported for full dataset, and HBF estimated as HBF= hooks/floats

$ No field for SBT before 1994, only reported when skipper changed the field code

^ Reported in ‘other billfish catch’

[1] Different species mix between TW and KR.

Table 10: Numbers of clusters identified in sets from each region and fishing fleet.

Species/design	Region	JP	TW	KR
Y0	2	4	4	4
	3	4	4	4
	4	5	5	5
	5	4	4	4
A2	1	4	4	4
	2	4	4	4
	3	4	4	4
	4	4	4	4
A3	1	4	4	4
	2	4	3	4
	3	4	3	4
	4	4	3	4
A5	1	5	5	5
B2	1	5	5	4
	2	5	5	4
	3	4	4	4
	4	4	4	4

Table 11: Clusters included in indices for each fleet and region

Species/design	Region	JP	KR	TW
Y0	2	1,3	1,2,3,4	1,3
	3	1	1,2	3
	4	3	3	3
	5	1,2	2,3	1,2,3
A2	1	2,4	3,4	1
	2	3	3	1
	3	3,4	3,4	1,2
	4	1,3	4	1,4
A3	1	2,3	4	1
	2	3	3	1
	3	3	4	1,2
	4	2	2,4	1,2
A5	1	2,4	5	1,2,4
B2	1	1,4,5	1,2,3,4	2,4
	2	1,2,3	1,2	1,2,4,5
	3	2,4	2,3	2
	4	1	1,2	2

Table 12: Indices for 1952-79 without vessel effects for region 1 of structure ALB3 joint model.

Year-qtr	Estimate	2.5%	97.5%
1955.125	1.583	1.428	1.754
1955.375	NA	NA	NA
1955.625	NA	NA	NA
1955.875	NA	NA	NA
1956.125	NA	NA	NA
1956.375	NA	NA	NA
1956.625	NA	NA	NA
1956.875	NA	NA	NA
1957.125	NA	NA	NA
1957.375	NA	NA	NA
1957.625	NA	NA	NA
1957.875	NA	NA	NA
1958.125	1.203	1.041	1.389
1958.375	NA	NA	NA
1958.625	NA	NA	NA
1958.875	3.190	2.909	3.497
1959.125	1.854	1.672	2.056
1959.375	NA	NA	NA
1959.625	NA	NA	NA
1959.875	2.110	1.942	2.293
1960.125	1.883	1.697	2.090
1960.375	NA	NA	NA
1960.625	1.428	1.302	1.565
1960.875	1.947	1.818	2.085
1961.125	NA	NA	NA
1961.375	NA	NA	NA
1961.625	1.193	1.083	1.314
1961.875	1.360	1.281	1.444
1962.125	1.270	1.165	1.385
1962.375	1.321	1.224	1.427
1962.625	0.985	0.922	1.053
1962.875	0.955	0.898	1.016
1963.125	0.770	0.720	0.823
1963.375	1.377	1.271	1.491
1963.625	0.858	0.795	0.926
1963.875	0.845	0.792	0.901
1964.125	1.175	1.097	1.259
1964.375	0.885	0.823	0.953
1964.625	0.931	0.872	0.994
1964.875	0.993	0.936	1.053
1965.125	0.732	0.686	0.781
1965.375	1.004	0.916	1.100
1965.625	0.831	0.774	0.893
1965.875	0.751	0.705	0.800
1966.125	0.897	0.833	0.966
1966.375	0.622	0.577	0.671
1966.625	0.802	0.748	0.860
1966.875	0.723	0.683	0.766
1967.125	0.795	0.747	0.847
1967.375	0.762	0.713	0.815
1967.625	0.591	0.552	0.634
1967.875	0.628	0.592	0.666
1968.125	0.510	0.465	0.558
1968.375	0.837	0.773	0.905
1968.625	0.815	0.757	0.877
1968.875	0.769	0.722	0.819
1969.125	0.557	0.523	0.594
1969.375	0.630	0.587	0.675
1969.625	0.663	0.618	0.712
1969.875	0.665	0.612	0.723
1970.125	0.557	0.518	0.599
1970.375	NA	NA	NA
1970.625	NA	NA	NA
1970.875	0.555	0.521	0.591
1971.125	0.546	0.508	0.588
1971.375	NA	NA	NA
1971.625	NA	NA	NA
1971.875	NA	NA	NA
1972.125	NA	NA	NA
1972.375	NA	NA	NA
1972.625	NA	NA	NA
1972.875	NA	NA	NA
1973.125	NA	NA	NA
1973.375	NA	NA	NA
1973.625	NA	NA	NA
1973.875	NA	NA	NA
1974.125	NA	NA	NA
1974.375	NA	NA	NA
1974.625	NA	NA	NA
1974.875	NA	NA	NA
1975.125	NA	NA	NA
1975.375	NA	NA	NA
1975.625	NA	NA	NA
1975.875	NA	NA	NA
1976.125	NA	NA	NA
1976.375	NA	NA	NA
1976.625	NA	NA	NA
1976.875	NA	NA	NA
1977.125	NA	NA	NA
1977.375	NA	NA	NA
1977.625	NA	NA	NA
1977.875	NA	NA	NA
1978.125	NA	NA	NA

1978.375	NA	NA	NA
1978.625	NA	NA	NA
1978.875	0.303	0.246	0.372
1979.125	NA	NA	NA
1979.375	NA	NA	NA
1979.625	0.337	0.274	0.415

Table 13: Indices for 1979-2014 with vessel effects for region 1 of structure ALB3 joint model.

Year-qtr	Estimate	2.5%	97.5%
1979.125	0.725	0.526	0.999
1979.375	NA	NA	NA
1979.625	1.392	1.161	1.668
1979.875	0.705	0.624	0.796
1980.125	0.653	0.577	0.740
1980.375	1.751	1.505	2.038
1980.625	1.267	1.063	1.510
1980.875	0.923	0.825	1.033
1981.125	0.775	0.677	0.886
1981.375	NA	NA	NA
1981.625	0.663	0.567	0.775
1981.875	0.912	0.816	1.020
1982.125	0.695	0.608	0.794
1982.375	NA	NA	NA
1982.625	NA	NA	NA
1982.875	1.165	1.049	1.294
1983.125	0.874	0.782	0.976
1983.375	NA	NA	NA
1983.625	0.690	0.614	0.775
1983.875	1.027	0.924	1.141
1984.125	0.870	0.763	0.993
1984.375	NA	NA	NA
1984.625	NA	NA	NA
1984.875	0.771	0.690	0.862
1985.125	0.647	0.565	0.742
1985.375	NA	NA	NA
1985.625	NA	NA	NA
1985.875	0.842	0.745	0.952
1986.125	0.755	0.673	0.848
1986.375	NA	NA	NA
1986.625	NA	NA	NA
1986.875	0.969	0.868	1.083
1987.125	1.303	1.165	1.456
1987.375	NA	NA	NA
1987.625	NA	NA	NA
1987.875	1.233	1.114	1.366
1988.125	1.051	0.910	1.215
1988.375	NA	NA	NA
1988.625	NA	NA	NA
1988.875	0.947	0.833	1.078
1989.125	NA	NA	NA
1989.375	NA	NA	NA
1989.625	NA	NA	NA
1989.875	NA	NA	NA
1990.125	NA	NA	NA
1990.375	NA	NA	NA
1990.625	NA	NA	NA
1990.875	NA	NA	NA
1991.125	NA	NA	NA
1991.375	NA	NA	NA
1991.625	1.148	0.987	1.335
1991.875	NA	NA	NA
1992.125	NA	NA	NA
1992.375	1.145	1.008	1.301
1992.625	0.731	0.638	0.839
1992.875	NA	NA	NA
1993.125	NA	NA	NA
1993.375	NA	NA	NA
1993.625	NA	NA	NA
1993.875	1.172	1.054	1.303
1994.125	1.715	1.507	1.951
1994.375	NA	NA	NA
1994.625	1.452	1.293	1.630
1994.875	1.505	1.369	1.655
1995.125	0.809	0.712	0.919
1995.375	0.993	0.843	1.169
1995.625	2.282	1.995	2.610
1995.875	0.937	0.845	1.039
1996.125	0.768	0.679	0.868
1996.375	NA	NA	NA
1996.625	2.242	1.956	2.569
1996.875	1.187	1.091	1.291
1997.125	1.118	1.023	1.220
1997.375	0.877	0.699	1.100
1997.625	NA	NA	NA
1997.875	0.990	0.912	1.076
1998.125	0.985	0.909	1.068
1998.375	NA	NA	NA
1998.625	NA	NA	NA
1998.875	1.336	1.237	1.444
1999.125	0.895	0.819	0.979
1999.375	0.536	0.426	0.674
1999.625	NA	NA	NA
1999.875	0.882	0.820	0.950
2000.125	0.926	0.855	1.003
2000.375	NA	NA	NA

2000.625	0.969	0.847	1.110
2000.875	1.250	1.160	1.348
2001.125	1.121	1.036	1.214
2001.375	NA	NA	NA
2001.625	0.994	0.911	1.084
2001.875	1.080	1.004	1.162
2002.125	0.849	0.780	0.925
2002.375	0.976	0.894	1.066
2002.625	1.043	0.967	1.126
2002.875	0.929	0.862	1.001
2003.125	0.673	0.623	0.728
2003.375	1.619	1.438	1.822
2003.625	0.762	0.692	0.839
2003.875	1.061	0.983	1.146
2004.125	0.846	0.783	0.914
2004.375	NA	NA	NA
2004.625	0.895	0.825	0.970
2004.875	0.803	0.744	0.867
2005.125	0.677	0.624	0.734
2005.375	1.174	1.022	1.349
2005.625	0.869	0.795	0.949
2005.875	0.739	0.684	0.798
2006.125	0.766	0.710	0.826
2006.375	1.076	0.982	1.178
2006.625	0.998	0.919	1.083
2006.875	0.570	0.526	0.617
2007.125	0.851	0.784	0.925
2007.375	1.356	1.246	1.474
2007.625	1.046	0.957	1.143
2007.875	0.811	0.752	0.875
2008.125	0.699	0.639	0.764
2008.375	2.017	1.809	2.248
2008.625	0.844	0.749	0.951
2008.875	0.629	0.580	0.683
2009.125	0.751	0.692	0.814
2009.375	1.310	1.192	1.439
2009.625	0.975	0.886	1.071
2009.875	0.873	0.807	0.945
2010.125	0.696	0.641	0.755
2010.375	NA	NA	NA
2010.625	0.977	0.873	1.094
2010.875	0.950	0.867	1.042
2011.125	0.557	0.494	0.628
2011.375	NA	NA	NA
2011.625	NA	NA	NA
2011.875	0.767	0.666	0.885
2012.125	0.654	0.550	0.778
2012.375	1.373	1.021	1.846
2012.625	1.233	1.054	1.442
2012.875	0.979	0.871	1.100
2013.125	0.677	0.597	0.767

Table 14: Indices for 1952-79 without vessel effects for region 2 of structure ALB3 joint model.

Year-qtr	Estimate	2.5%	97.5%
1954.375	2.018	1.829	2.226
1954.625	1.919	1.730	2.129
1954.875	NA	NA	NA
1955.125	2.286	2.027	2.577
1955.375	NA	NA	NA
1955.625	2.636	2.284	3.042
1955.875	1.715	1.551	1.895
1956.125	1.165	1.057	1.285
1956.375	3.671	3.256	4.138
1956.625	0.977	0.858	1.113
1956.875	NA	NA	NA
1957.125	1.504	1.368	1.654
1957.375	0.953	0.851	1.066
1957.625	NA	NA	NA
1957.875	NA	NA	NA
1958.125	1.588	1.418	1.778
1958.375	NA	NA	NA
1958.625	0.976	0.815	1.170
1958.875	1.442	1.328	1.564
1959.125	1.400	1.251	1.567
1959.375	1.052	0.967	1.144
1959.625	1.119	1.006	1.245
1959.875	NA	NA	NA
1960.125	1.307	1.201	1.421
1960.375	NA	NA	NA
1960.625	0.904	0.826	0.990
1960.875	NA	NA	NA
1961.125	NA	NA	NA
1961.375	1.268	1.133	1.419
1961.625	NA	NA	NA
1961.875	0.814	0.755	0.877
1962.125	0.941	0.868	1.020
1962.375	1.108	1.013	1.212
1962.625	0.920	0.836	1.013
1962.875	0.685	0.631	0.743
1963.125	0.697	0.649	0.748
1963.375	0.856	0.782	0.936
1963.625	0.757	0.689	0.833
1963.875	0.787	0.727	0.851

1964.125	0.821	0.762	0.884
1964.375	0.920	0.841	1.007
1964.625	0.899	0.828	0.977
1964.875	0.688	0.641	0.738
1965.125	0.625	0.581	0.673
1965.375	1.155	1.054	1.267
1965.625	0.689	0.632	0.751
1965.875	0.801	0.743	0.863
1966.125	0.599	0.554	0.648
1966.375	0.944	0.856	1.042
1966.625	NA	NA	NA
1966.875	0.804	0.747	0.866
1967.125	0.718	0.672	0.767
1967.375	0.775	0.718	0.836
1967.625	0.697	0.634	0.766
1967.875	0.726	0.662	0.795
1968.125	0.620	0.576	0.668
1968.375	0.666	0.600	0.740
1968.625	0.743	0.669	0.825
1968.875	0.611	0.552	0.676
1969.125	0.494	0.455	0.537
1969.375	NA	NA	NA
1969.625	0.620	0.561	0.686
1969.875	NA	NA	NA
1970.125	NA	NA	NA
1970.375	0.860	0.775	0.954
1970.625	0.792	0.712	0.881
1970.875	0.498	0.464	0.534
1971.125	NA	NA	NA
1971.375	NA	NA	NA
1971.625	NA	NA	NA
1971.875	NA	NA	NA
1972.125	NA	NA	NA
1972.375	NA	NA	NA
1972.625	NA	NA	NA
1972.875	NA	NA	NA
1973.125	NA	NA	NA
1973.375	NA	NA	NA
1973.625	NA	NA	NA
1973.875	NA	NA	NA
1974.125	0.397	0.360	0.438
1974.375	0.434	0.391	0.482
1974.625	0.684	0.619	0.756
1974.875	NA	NA	NA
1975.125	NA	NA	NA
1975.375	0.409	0.363	0.461
1975.625	0.445	0.395	0.501
1975.875	NA	NA	NA
1976.125	0.401	0.359	0.449

Table 15: Indices for 1979-2014 with vessel effects for region 2 of structure ALB3 joint model.

Year-qtr	Estimate	2.5%	97.5%
1979.875	1.023	0.887	1.179
1980.125	0.960	0.822	1.121
1980.375	0.852	0.697	1.041
1980.625	0.671	0.582	0.774
1980.875	0.997	0.870	1.143
1981.125	1.248	1.077	1.447
1981.375	0.406	0.322	0.512
1981.625	NA	NA	NA
1981.875	0.826	0.667	1.024
1982.125	0.719	0.544	0.951
1982.375	NA	NA	NA
1982.625	NA	NA	NA
1982.875	1.159	1.004	1.338
1983.125	1.463	1.265	1.691
1983.375	NA	NA	NA
1983.625	0.637	0.555	0.731
1983.875	0.762	0.673	0.862
1984.125	0.576	0.499	0.664
1984.375	NA	NA	NA
1984.625	1.056	0.763	1.463
1984.875	0.644	0.562	0.739
1985.125	NA	NA	NA
1985.375	1.636	1.106	2.422
1985.625	0.809	0.608	1.077
1985.875	0.738	0.536	1.017
1986.125	NA	NA	NA
1986.375	NA	NA	NA
1986.625	0.921	0.777	1.092
1986.875	1.793	1.550	2.073
1987.125	1.707	1.409	2.068
1987.375	NA	NA	NA
1987.625	0.845	0.737	0.970
1987.875	1.256	1.096	1.439
1988.125	1.152	0.967	1.373
1988.375	NA	NA	NA
1988.625	0.621	0.527	0.731
1988.875	0.848	0.727	0.989
1989.125	NA	NA	NA
1989.375	NA	NA	NA
1989.625	0.506	0.412	0.621
1989.875	NA	NA	NA
1990.125	NA	NA	NA

1990.375	NA	NA	NA
1990.625	NA	NA	NA
1990.875	NA	NA	NA
1991.125	NA	NA	NA
1991.375	NA	NA	NA
1991.625	NA	NA	NA
1991.875	NA	NA	NA
1992.125	NA	NA	NA
1992.375	NA	NA	NA
1992.625	NA	NA	NA
1992.875	NA	NA	NA
1993.125	NA	NA	NA
1993.375	NA	NA	NA
1993.625	NA	NA	NA
1993.875	1.175	0.821	1.680
1994.125	1.113	0.869	1.426
1994.375	NA	NA	NA
1994.625	NA	NA	NA
1994.875	NA	NA	NA
1995.125	NA	NA	NA
1995.375	NA	NA	NA
1995.625	NA	NA	NA
1995.875	NA	NA	NA
1996.125	1.341	1.108	1.624
1996.375	NA	NA	NA
1996.625	NA	NA	NA
1996.875	6.688	4.927	9.078
1997.125	NA	NA	NA
1997.375	NA	NA	NA
1997.625	0.291	0.204	0.414
1997.875	0.427	0.298	0.612
1998.125	NA	NA	NA
1998.375	NA	NA	NA
1998.625	NA	NA	NA
1998.875	NA	NA	NA
1999.125	NA	NA	NA
1999.375	NA	NA	NA
1999.625	0.673	0.520	0.872
1999.875	NA	NA	NA
2000.125	NA	NA	NA
2000.375	0.967	0.788	1.186
2000.625	0.920	0.740	1.144
2000.875	0.974	0.737	1.289
2001.125	0.406	0.329	0.502
2001.375	0.402	0.323	0.500
2001.625	0.454	0.360	0.572
2001.875	0.465	0.358	0.604
2002.125	0.499	0.399	0.624
2002.375	0.667	0.539	0.826
2002.625	0.742	0.606	0.909
2002.875	0.701	0.586	0.838
2003.125	0.981	0.820	1.173
2003.375	NA	NA	NA
2003.625	0.343	0.257	0.458
2003.875	NA	NA	NA
2004.125	1.174	0.866	1.592
2004.375	NA	NA	NA
2004.625	NA	NA	NA
2004.875	NA	NA	NA
2005.125	1.904	1.368	2.648
2005.375	NA	NA	NA
2005.625	NA	NA	NA
2005.875	NA	NA	NA
2006.125	NA	NA	NA
2006.375	NA	NA	NA
2006.625	NA	NA	NA
2006.875	NA	NA	NA
2007.125	NA	NA	NA
2007.375	NA	NA	NA
2007.625	NA	NA	NA
2007.875	NA	NA	NA
2008.125	NA	NA	NA
2008.375	NA	NA	NA
2008.625	0.859	0.626	1.178

Table 16: Indices for 1952-79 without vessel effects for region 3 of structure ALB3 joint model.

Year-qtr	Estimate	2.5%	97.5%
1960.625	2.53	2.30	2.78
1960.875	NA	NA	NA
1961.125	NA	NA	NA
1961.375	NA	NA	NA
1961.625	2.08	1.84	2.34
1961.875	1.37	1.20	1.55
1962.125	NA	NA	NA
1962.375	NA	NA	NA
1962.625	2.39	2.23	2.56
1962.875	1.44	1.30	1.59
1963.125	NA	NA	NA
1963.375	1.06	0.96	1.17
1963.625	2.05	1.92	2.19
1963.875	NA	NA	NA
1964.125	NA	NA	NA
1964.375	1.83	1.68	1.99
1964.625	2.26	2.12	2.42

1964.875	1.11	1.03	1.21
1965.125	NA	NA	NA
1965.375	1.74	1.59	1.90
1965.625	2.11	1.97	2.27
1965.875	NA	NA	NA
1966.125	NA	NA	NA
1966.375	1.37	1.27	1.49
1966.625	2.03	1.90	2.16
1966.875	1.22	1.13	1.33
1967.125	0.88	0.80	0.97
1967.375	1.34	1.26	1.42
1967.625	1.57	1.48	1.66
1967.875	1.08	0.99	1.17
1968.125	NA	NA	NA
1968.375	1.37	1.28	1.46
1968.625	1.33	1.25	1.41
1968.875	0.76	0.71	0.82
1969.125	0.60	0.56	0.64
1969.375	1.00	0.95	1.06
1969.625	0.95	0.90	1.00
1969.875	0.52	0.49	0.56
1970.125	0.51	0.47	0.54
1970.375	0.66	0.62	0.69
1970.625	0.76	0.72	0.80
1970.875	0.50	0.46	0.54
1971.125	0.49	0.46	0.53
1971.375	0.66	0.62	0.71
1971.625	0.63	0.60	0.67
1971.875	0.54	0.50	0.58
1972.125	NA	NA	NA
1972.375	0.47	0.43	0.52
1972.625	0.63	0.59	0.68
1972.875	0.41	0.38	0.44
1973.125	0.42	0.38	0.47
1973.375	0.50	0.46	0.54
1973.625	0.55	0.51	0.58
1973.875	0.39	0.35	0.44
1974.125	NA	NA	NA
1974.375	0.67	0.63	0.72
1974.625	0.51	0.48	0.55
1974.875	0.33	0.30	0.36
1975.125	NA	NA	NA
1975.375	0.44	0.41	0.47
1975.625	0.43	0.40	0.46
1975.875	NA	NA	NA
1976.125	0.49	0.44	0.53
1976.375	0.60	0.55	0.65
1976.625	0.62	0.58	0.67
1976.875	NA	NA	NA
1977.125	NA	NA	NA
1977.375	NA	NA	NA
1977.625	0.46	0.41	0.51
1977.875	NA	NA	NA
1978.125	NA	NA	NA
1978.375	NA	NA	NA
1978.625	0.33	0.30	0.36

Table 17: Indices for 1979-2014 with vessel effects for region 3 of structure ALB3 joint model.

Year-qtr	Estimate	2.5%	97.5%
1979.125	0.881	0.806	0.964
1979.375	1.109	1.030	1.193
1979.625	1.286	1.202	1.376
1979.875	NA	NA	NA
1980.125	1.595	1.429	1.780
1980.375	1.498	1.389	1.615
1980.625	0.997	0.933	1.066
1980.875	NA	NA	NA
1981.125	0.975	0.892	1.065
1981.375	1.502	1.404	1.606
1981.625	1.367	1.277	1.464
1981.875	NA	NA	NA
1982.125	1.420	1.305	1.545
1982.375	1.400	1.321	1.484
1982.625	1.171	1.102	1.244
1982.875	1.092	1.001	1.191
1983.125	0.861	0.800	0.927
1983.375	1.199	1.128	1.275
1983.625	1.210	1.138	1.287
1983.875	1.206	1.077	1.351
1984.125	1.252	1.153	1.360
1984.375	1.047	0.983	1.116
1984.625	1.405	1.320	1.497
1984.875	NA	NA	NA
1985.125	1.014	0.941	1.093
1985.375	1.156	1.082	1.235
1985.625	1.551	1.448	1.661
1985.875	1.579	1.378	1.809
1986.125	1.298	1.194	1.411
1986.375	1.558	1.459	1.664
1986.625	1.576	1.472	1.687
1986.875	NA	NA	NA
1987.125	1.302	1.181	1.436
1987.375	1.317	1.225	1.415
1987.625	1.251	1.163	1.345
1987.875	NA	NA	NA

1988.125	1.186	1.084	1.297	2000.125	0.890	0.835	0.948
1988.375	0.900	0.844	0.959	2000.375	0.838	0.794	0.886
1988.625	0.931	0.876	0.990	2000.625	1.131	1.071	1.194
1988.875	NA	NA	NA	2000.875	0.761	0.711	0.814
1989.125	NA	NA	NA	2001.125	1.056	0.988	1.129
1989.375	0.636	0.591	0.684	2001.375	0.890	0.846	0.936
1989.625	0.780	0.726	0.837	2001.625	0.966	0.921	1.014
1989.875	NA	NA	NA	2001.875	0.997	0.943	1.054
1990.125	NA	NA	NA	2002.125	0.652	0.614	0.693
1990.375	0.954	0.883	1.031	2002.375	0.884	0.839	0.931
1990.625	0.880	0.824	0.939	2002.625	0.948	0.896	1.003
1990.875	NA	NA	NA	2002.875	0.779	0.713	0.852
1991.125	0.705	0.630	0.789	2003.125	0.561	0.527	0.599
1991.375	0.651	0.596	0.710	2003.375	0.782	0.741	0.826
1991.625	0.743	0.696	0.794	2003.625	0.958	0.902	1.017
1991.875	NA	NA	NA	2003.875	1.198	1.108	1.296
1992.125	0.750	0.675	0.834	2004.125	0.607	0.568	0.650
1992.375	0.728	0.684	0.774	2004.375	0.871	0.830	0.915
1992.625	0.791	0.743	0.841	2004.625	0.878	0.833	0.925
1992.875	NA	NA	NA	2004.875	0.885	0.822	0.953
1993.125	NA	NA	NA	2005.125	0.576	0.541	0.612
1993.375	0.893	0.841	0.948	2005.375	0.726	0.691	0.762
1993.625	0.843	0.796	0.893	2005.625	1.034	0.978	1.092
1993.875	0.780	0.715	0.852	2005.875	1.049	0.960	1.147
1994.125	1.012	0.945	1.084	2006.125	0.416	0.383	0.453
1994.375	0.653	0.620	0.689	2006.375	0.851	0.806	0.898
1994.625	1.113	1.049	1.181	2006.625	0.937	0.887	0.989
1994.875	1.162	1.058	1.277	2006.875	0.729	0.670	0.792
1995.125	0.750	0.689	0.815	2007.125	NA	NA	NA
1995.375	0.917	0.867	0.969	2007.375	1.046	0.983	1.113
1995.625	1.078	1.012	1.148	2007.625	1.077	1.017	1.140
1995.875	0.639	0.587	0.695	2007.875	1.015	0.946	1.089
1996.125	0.948	0.889	1.011	2008.125	0.580	0.539	0.623
1996.375	0.833	0.790	0.877	2008.375	1.446	1.361	1.537
1996.625	0.968	0.917	1.021	2008.625	1.282	1.206	1.361
1996.875	1.071	0.994	1.155	2008.875	1.187	1.101	1.279
1997.125	0.912	0.856	0.971	2009.125	0.898	0.839	0.961
1997.375	1.076	1.023	1.132	2009.375	1.155	1.084	1.230
1997.625	1.301	1.235	1.370	2009.625	1.126	1.060	1.196
1997.875	1.012	0.926	1.105	2009.875	0.591	0.549	0.637
1998.125	0.745	0.691	0.803	2010.125	0.718	0.670	0.769
1998.375	0.958	0.913	1.006	2010.375	1.295	1.219	1.376
1998.625	1.143	1.083	1.207	2010.625	1.280	1.192	1.375
1998.875	0.925	0.853	1.003	2010.875	0.633	0.584	0.687
1999.125	0.614	0.576	0.654	2011.125	0.821	0.765	0.880
1999.375	0.718	0.682	0.756	2011.375	1.662	1.529	1.807
1999.625	0.780	0.739	0.824	2011.625	1.385	1.288	1.488
1999.875	0.519	0.479	0.562	2011.875	NA	NA	NA

2012.125	0.799	0.739	0.863
2012.375	1.355	1.265	1.450
2012.625	1.432	1.329	1.543
2012.875	1.039	0.936	1.153
2013.125	0.618	0.549	0.696
2013.375	1.019	0.953	1.090
2013.625	0.831	0.773	0.894
2013.875	0.788	0.726	0.855

Table 18: Indices for 1952-79 without vessel effects for region 4 of structure ALB3 joint model.

Year-qtr	Estimate	2.5%	97.5%
1961.875	0.378	0.319	0.449
1962.125	1.737	1.541	1.957
1962.375	NA	NA	NA
1962.625	NA	NA	NA
1962.875	0.530	0.458	0.614
1963.125	0.856	0.726	1.009
1963.375	NA	NA	NA
1963.625	NA	NA	NA
1963.875	1.086	0.972	1.212
1964.125	1.083	0.978	1.199
1964.375	NA	NA	NA
1964.625	NA	NA	NA
1964.875	0.786	0.717	0.863
1965.125	0.860	0.793	0.933
1965.375	0.717	0.629	0.817
1965.625	NA	NA	NA
1965.875	0.775	0.708	0.847
1966.125	0.760	0.682	0.848
1966.375	NA	NA	NA
1966.625	NA	NA	NA
1966.875	0.698	0.620	0.787
1967.125	1.318	1.216	1.429
1967.375	1.342	1.252	1.439
1967.625	1.386	1.290	1.488
1967.875	NA	NA	NA
1968.125	0.808	0.750	0.870
1968.375	1.095	1.015	1.182
1968.625	1.072	1.001	1.148
1968.875	1.082	1.007	1.162
1969.125	0.728	0.669	0.792
1969.375	1.006	0.928	1.092
1969.625	1.426	1.324	1.535
1969.875	NA	NA	NA
1970.125	NA	NA	NA
1970.375	0.865	0.787	0.950
1970.625	0.994	0.917	1.077
1970.875	0.709	0.639	0.788
1971.125	0.673	0.617	0.733
1971.375	0.762	0.706	0.822
1971.625	0.866	0.807	0.930
1971.875	1.253	1.134	1.384
1972.125	NA	NA	NA
1972.375	1.405	1.263	1.562
1972.625	1.701	1.542	1.877
1972.875	NA	NA	NA
1973.125	NA	NA	NA
1973.375	1.051	0.967	1.142
1973.625	1.124	1.038	1.216
1973.875	0.822	0.754	0.897
1974.125	NA	NA	NA
1974.375	1.044	0.963	1.131
1974.625	1.234	1.153	1.321
1974.875	0.695	0.629	0.769
1975.125	NA	NA	NA
1975.375	1.075	0.989	1.169
1975.625	0.778	0.718	0.843
1975.875	NA	NA	NA
1976.125	NA	NA	NA
1976.375	1.420	1.285	1.570

Table 19: Indices for 1979-2014 with vessel effects for region 4 of structure ALB3 joint model.

Year-qtr	Estimate	2.5%	97.5%
1979.125	1.489	1.324	1.675
1979.375	NA	NA	NA
1979.625	NA	NA	NA
1979.875	NA	NA	NA
1980.125	0.857	0.756	0.972
1980.375	NA	NA	NA
1980.625	NA	NA	NA
1980.875	NA	NA	NA
1981.125	1.328	1.146	1.539
1981.375	1.232	1.119	1.356
1981.625	1.149	1.036	1.275
1981.875	NA	NA	NA
1982.125	NA	NA	NA
1982.375	1.315	1.194	1.449
1982.625	1.471	1.320	1.638
1982.875	NA	NA	NA
1983.125	1.254	1.109	1.417
1983.375	1.501	1.379	1.633
1983.625	1.254	1.130	1.392
1983.875	NA	NA	NA
1984.125	0.926	0.839	1.023

1984.375	1.144	1.042	1.255	1996.375	1.048	0.981	1.120
1984.625	0.934	0.850	1.027	1996.625	0.955	0.891	1.023
1984.875	NA	NA	NA	1996.875	NA	NA	NA
1985.125	NA	NA	NA	1997.125	NA	NA	NA
1985.375	NA	NA	NA	1997.375	1.087	1.011	1.169
1985.625	NA	NA	NA	1997.625	0.804	0.749	0.863
1985.875	NA	NA	NA	1997.875	0.767	0.699	0.843
1986.125	NA	NA	NA	1998.125	1.528	1.385	1.685
1986.375	NA	NA	NA	1998.375	0.896	0.840	0.956
1986.625	1.289	1.178	1.411	1998.625	0.880	0.820	0.945
1986.875	NA	NA	NA	1998.875	0.509	0.420	0.616
1987.125	1.590	1.437	1.759	1999.125	NA	NA	NA
1987.375	1.147	1.047	1.257	1999.375	0.776	0.726	0.828
1987.625	1.100	1.001	1.210	1999.625	0.684	0.629	0.743
1987.875	NA	NA	NA	1999.875	NA	NA	NA
1988.125	1.400	1.191	1.646	2000.125	0.520	0.470	0.575
1988.375	1.317	1.202	1.443	2000.375	1.158	1.090	1.231
1988.625	1.498	1.335	1.682	2000.625	1.256	1.170	1.348
1988.875	NA	NA	NA	2000.875	NA	NA	NA
1989.125	NA	NA	NA	2001.125	0.907	0.826	0.995
1989.375	0.642	0.582	0.709	2001.375	1.151	1.073	1.234
1989.625	1.085	0.960	1.227	2001.625	0.541	0.506	0.579
1989.875	NA	NA	NA	2001.875	0.380	0.336	0.430
1990.125	NA	NA	NA	2002.125	0.547	0.496	0.603
1990.375	NA	NA	NA	2002.375	0.822	0.768	0.880
1990.625	NA	NA	NA	2002.625	0.698	0.649	0.751
1990.875	NA	NA	NA	2002.875	0.619	0.551	0.696
1991.125	NA	NA	NA	2003.125	0.834	0.762	0.912
1991.375	1.023	0.918	1.140	2003.375	1.037	0.971	1.108
1991.625	NA	NA	NA	2003.625	0.760	0.708	0.816
1991.875	0.780	0.683	0.891	2003.875	NA	NA	NA
1992.125	NA	NA	NA	2004.125	1.141	1.056	1.233
1992.375	0.968	0.868	1.079	2004.375	0.924	0.865	0.986
1992.625	1.020	0.914	1.138	2004.625	0.534	0.500	0.571
1992.875	NA	NA	NA	2004.875	NA	NA	NA
1993.125	NA	NA	NA	2005.125	1.089	1.002	1.183
1993.375	0.929	0.856	1.008	2005.375	1.008	0.941	1.079
1993.625	0.738	0.682	0.799	2005.625	0.789	0.737	0.844
1993.875	NA	NA	NA	2005.875	0.418	0.377	0.464
1994.125	0.590	0.537	0.648	2006.125	0.664	0.615	0.717
1994.375	1.155	1.059	1.260	2006.375	0.973	0.900	1.053
1994.625	1.340	1.192	1.507	2006.625	0.843	0.790	0.900
1994.875	0.595	0.525	0.674	2006.875	NA	NA	NA
1995.125	0.771	0.717	0.830	2007.125	NA	NA	NA
1995.375	0.686	0.635	0.741	2007.375	1.222	1.129	1.322
1995.625	0.955	0.874	1.043	2007.625	1.060	0.991	1.133
1995.875	0.547	0.500	0.597	2007.875	0.542	0.489	0.600
1996.125	0.851	0.779	0.930	2008.125	NA	NA	NA

2008.375	1.363	1.278	1.454
2008.625	1.028	0.965	1.095
2008.875	NA	NA	NA
2009.125	0.865	0.779	0.961
2009.375	1.427	1.317	1.547
2009.625	0.807	0.752	0.866
2009.875	NA	NA	NA
2010.125	NA	NA	NA
2010.375	1.773	1.656	1.898
2010.625	1.033	0.968	1.102
2010.875	NA	NA	NA
2011.125	0.678	0.612	0.752
2011.375	1.373	1.276	1.477
2011.625	0.901	0.842	0.964
2011.875	NA	NA	NA
2012.125	NA	NA	NA
2012.375	2.398	2.224	2.584
2012.625	0.817	0.756	0.883
2012.875	NA	NA	NA
2013.125	NA	NA	NA
2013.375	1.269	1.174	1.371
2013.625	1.029	0.947	1.117

Table 20: Indices for 1952-79 without vessel effects for the sole region of the structure ALB5 joint model.

Year-qtr	Estimate	2.5%	97.5%
1958.625	1.885	1.689	2.103
1958.875	2.767	2.541	3.013
1959.125	3.009	2.681	3.376
1959.375	NA	NA	NA
1959.625	NA	NA	NA
1959.875	2.038	1.856	2.237
1960.125	2.109	1.927	2.308
1960.375	NA	NA	NA
1960.625	1.297	1.196	1.408
1960.875	NA	NA	NA
1961.125	NA	NA	NA
1961.375	NA	NA	NA
1961.625	NA	NA	NA
1961.875	1.402	1.302	1.509
1962.125	1.470	1.311	1.647
1962.375	NA	NA	NA
1962.625	1.088	1.003	1.180
1962.875	1.315	1.214	1.424
1963.125	1.107	1.008	1.216
1963.375	NA	NA	NA
1963.625	0.954	0.864	1.052
1963.875	0.971	0.880	1.072
1964.125	0.587	0.541	0.636
1964.375	NA	NA	NA
1964.625	1.007	0.928	1.093
1964.875	0.931	0.873	0.992
1965.125	0.807	0.745	0.873
1965.375	NA	NA	NA
1965.625	NA	NA	NA
1965.875	1.032	0.950	1.121
1966.125	NA	NA	NA
1966.375	NA	NA	NA
1966.625	1.225	1.127	1.331
1966.875	1.106	1.034	1.183
1967.125	1.139	1.063	1.220
1967.375	0.787	0.745	0.831
1967.625	0.686	0.649	0.725
1967.875	0.804	0.754	0.858
1968.125	0.791	0.737	0.850
1968.375	0.758	0.707	0.812
1968.625	0.670	0.632	0.711
1968.875	0.788	0.742	0.837
1969.125	0.629	0.583	0.678
1969.375	0.637	0.596	0.680
1969.625	0.633	0.598	0.670
1969.875	0.659	0.610	0.712
1970.125	0.594	0.548	0.644
1970.375	0.521	0.482	0.563
1970.625	0.561	0.521	0.603
1970.875	0.668	0.619	0.721
1971.125	0.606	0.563	0.653
1971.375	0.435	0.407	0.466
1971.625	0.462	0.435	0.490
1971.875	NA	NA	NA
1972.125	NA	NA	NA
1972.375	NA	NA	NA
1972.625	0.869	0.793	0.952
1972.875	NA	NA	NA
1973.125	NA	NA	NA
1973.375	0.848	0.778	0.925
1973.625	0.632	0.572	0.699
1973.875	NA	NA	NA
1974.125	NA	NA	NA
1974.375	0.645	0.596	0.698
1974.625	0.634	0.586	0.685
1974.875	NA	NA	NA
1975.125	NA	NA	NA
1975.375	NA	NA	NA
1975.625	0.440	0.404	0.478

Table 21: Indices for 1979-2014 with vessel effects for the sole region of the structure ALB5 joint model.

Year-qtr	Estimate	2.5%	97.5%
1979.125	0.834	0.783	0.889
1979.375	0.886	0.827	0.949
1979.625	1.087	1.028	1.151
1979.875	1.055	0.995	1.119
1980.125	0.785	0.739	0.832
1980.375	0.961	0.906	1.018
1980.625	0.964	0.911	1.020
1980.875	1.171	1.106	1.241
1981.125	1.332	1.250	1.418
1981.375	1.340	1.265	1.421
1981.625	0.963	0.912	1.016
1981.875	0.947	0.895	1.001
1982.125	1.291	1.221	1.365
1982.375	1.361	1.289	1.437
1982.625	1.227	1.167	1.290
1982.875	1.069	1.001	1.140
1983.125	1.133	1.073	1.196
1983.375	1.099	1.041	1.160
1983.625	0.954	0.908	1.001
1983.875	0.903	0.851	0.959

1984.125	0.770	0.731	0.811
1984.375	0.980	0.924	1.039
1984.625	0.948	0.899	1.000
1984.875	0.796	0.748	0.848
1985.125	0.733	0.686	0.783
1985.375	1.036	0.956	1.123
1985.625	0.953	0.886	1.026
1985.875	1.028	0.935	1.130
1986.125	1.525	1.407	1.653
1986.375	1.786	1.661	1.920
1986.625	1.107	1.044	1.174
1986.875	1.026	0.950	1.108
1987.125	1.377	1.292	1.469
1987.375	1.238	1.164	1.316
1987.625	0.930	0.879	0.983
1987.875	1.038	0.974	1.106
1988.125	1.115	1.040	1.195
1988.375	1.196	1.123	1.275
1988.625	0.858	0.809	0.909
1988.875	NA	NA	NA
1989.125	0.618	0.576	0.663
1989.375	0.515	0.483	0.549
1989.625	0.626	0.581	0.674
1989.875	NA	NA	NA
1990.125	NA	NA	NA
1990.375	0.820	0.735	0.916
1990.625	0.732	0.677	0.790
1990.875	NA	NA	NA
1991.125	NA	NA	NA
1991.375	1.053	0.975	1.138
1991.625	0.982	0.919	1.049
1991.875	0.645	0.597	0.697
1992.125	NA	NA	NA
1992.375	0.731	0.677	0.790
1992.625	0.848	0.787	0.913
1992.875	0.768	0.693	0.850
1993.125	0.882	0.822	0.947
1993.375	0.949	0.900	1.001
1993.625	0.838	0.792	0.886
1993.875	0.813	0.774	0.854
1994.125	0.717	0.684	0.752
1994.375	1.237	1.174	1.304
1994.625	0.978	0.934	1.024
1994.875	1.178	1.117	1.243
1995.125	0.845	0.803	0.890
1995.375	0.923	0.876	0.973
1995.625	1.027	0.976	1.082
1995.875	0.930	0.882	0.979
1996.125	1.071	1.022	1.122
1996.375	1.048	0.997	1.101
1996.625	1.161	1.107	1.218
1996.875	1.295	1.231	1.363
1997.125	1.235	1.172	1.302
1997.375	1.396	1.328	1.468
1997.625	1.027	0.975	1.081
1997.875	1.102	1.038	1.171
1998.125	1.161	1.097	1.229
1998.375	1.106	1.056	1.158
1998.625	0.882	0.841	0.924
1998.875	0.942	0.891	0.997
1999.125	0.785	0.743	0.828
1999.375	0.920	0.877	0.965
1999.625	0.849	0.809	0.891
1999.875	0.895	0.848	0.944
2000.125	0.843	0.799	0.890
2000.375	1.310	1.256	1.366
2000.625	1.195	1.146	1.247
2000.875	1.103	1.038	1.171
2001.125	0.972	0.925	1.022
2001.375	1.018	0.975	1.063
2001.625	0.783	0.753	0.815
2001.875	1.043	0.999	1.089
2002.125	0.759	0.725	0.796
2002.375	0.987	0.948	1.027
2002.625	0.736	0.706	0.766
2002.875	0.801	0.759	0.844
2003.125	0.712	0.681	0.745
2003.375	0.879	0.839	0.921
2003.625	0.852	0.818	0.888
2003.875	0.744	0.701	0.790
2004.125	0.823	0.785	0.862
2004.375	1.086	1.036	1.139
2004.625	0.734	0.703	0.766
2004.875	0.875	0.826	0.927
2005.125	0.841	0.803	0.880
2005.375	1.006	0.955	1.060
2005.625	0.752	0.717	0.789
2005.875	0.686	0.642	0.732
2006.125	0.772	0.729	0.817
2006.375	1.041	0.983	1.102
2006.625	0.940	0.890	0.992
2006.875	0.932	0.864	1.006
2007.125	NA	NA	NA
2007.375	1.354	1.267	1.447
2007.625	0.785	0.742	0.829
2007.875	0.752	0.705	0.801

2008.125	NA	NA	NA
2008.375	1.454	1.380	1.532
2008.625	1.017	0.961	1.076
2008.875	NA	NA	NA
2009.125	0.799	0.746	0.855
2009.375	1.198	1.131	1.269
2009.625	1.030	0.973	1.091
2009.875	1.204	1.099	1.319
2010.125	1.301	1.213	1.396
2010.375	1.573	1.481	1.670
2010.625	1.031	0.973	1.093
2010.875	NA	NA	NA
2011.125	0.737	0.690	0.787
2011.375	1.204	1.123	1.290
2011.625	0.837	0.783	0.895
2011.875	NA	NA	NA
2012.125	NA	NA	NA
2012.375	1.721	1.603	1.847
2012.625	0.863	0.798	0.934
2012.875	NA	NA	NA
2013.125	NA	NA	NA
2013.375	1.459	1.363	1.562
2013.625	1.124	1.040	1.215

9. Figures

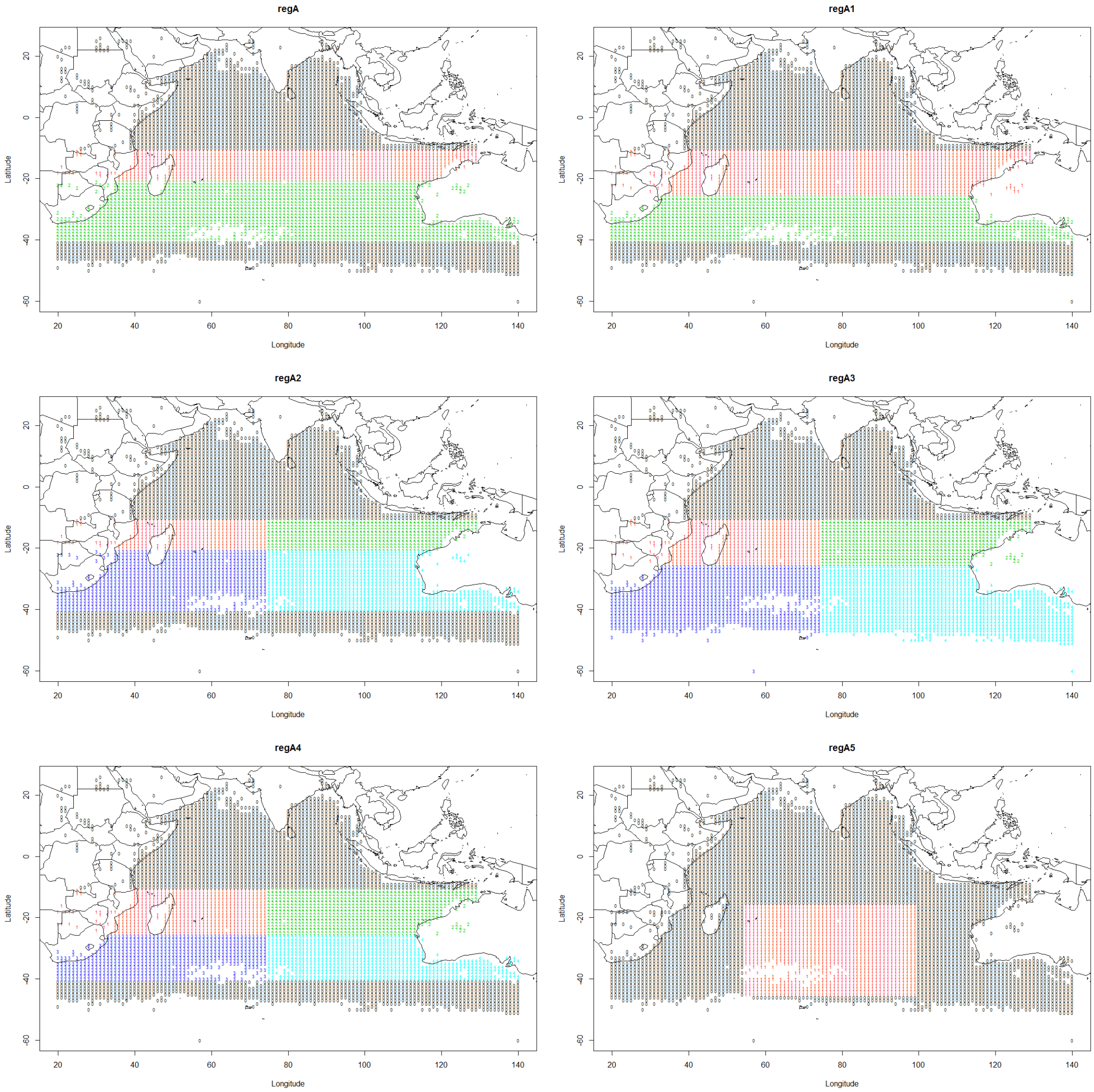


Figure 1: Maps of the alternative regional structures used to estimate albacore CPUE indices.

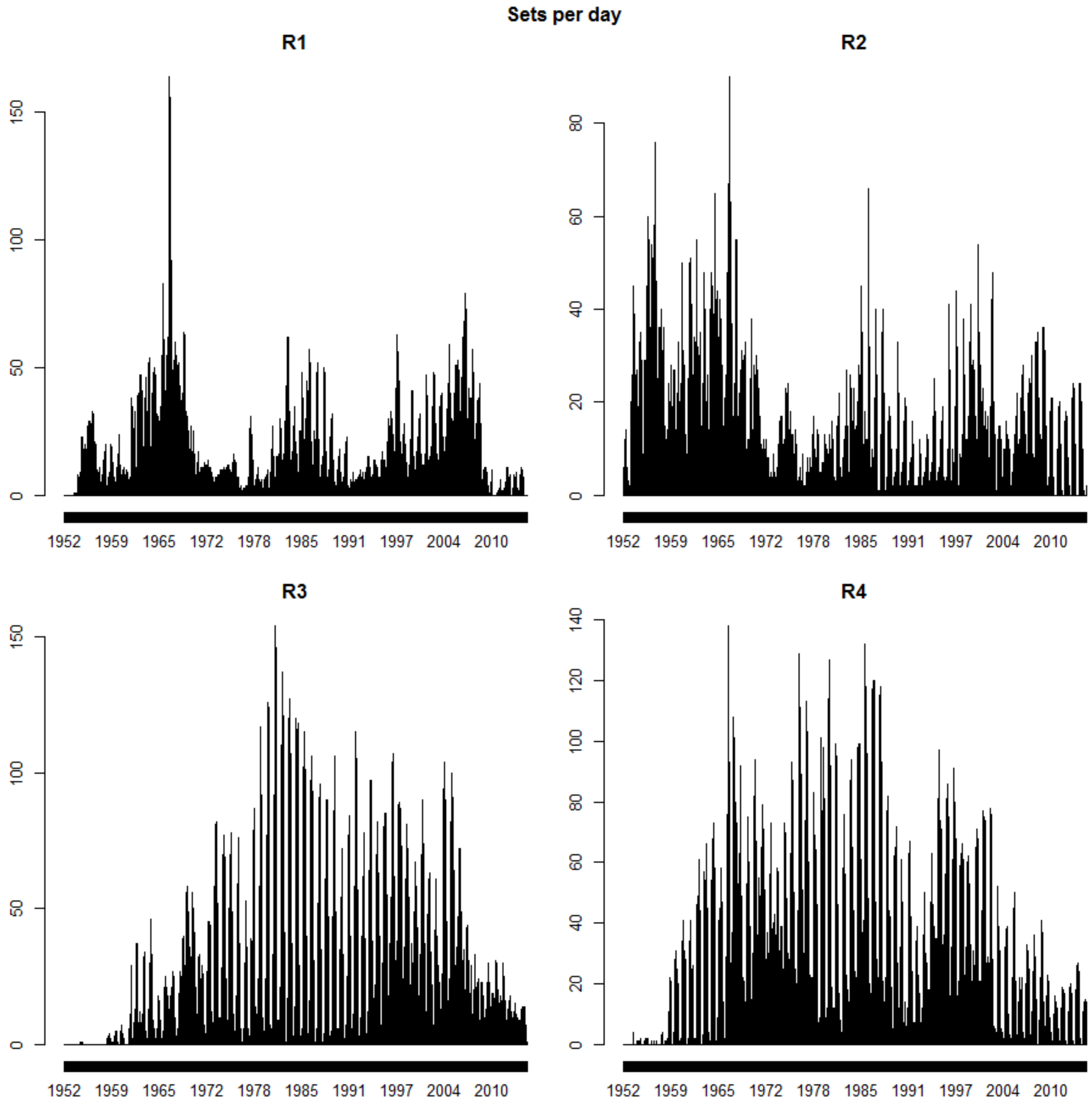


Figure 2: Sets per day by region for the Japanese fleet in regional structure A2.

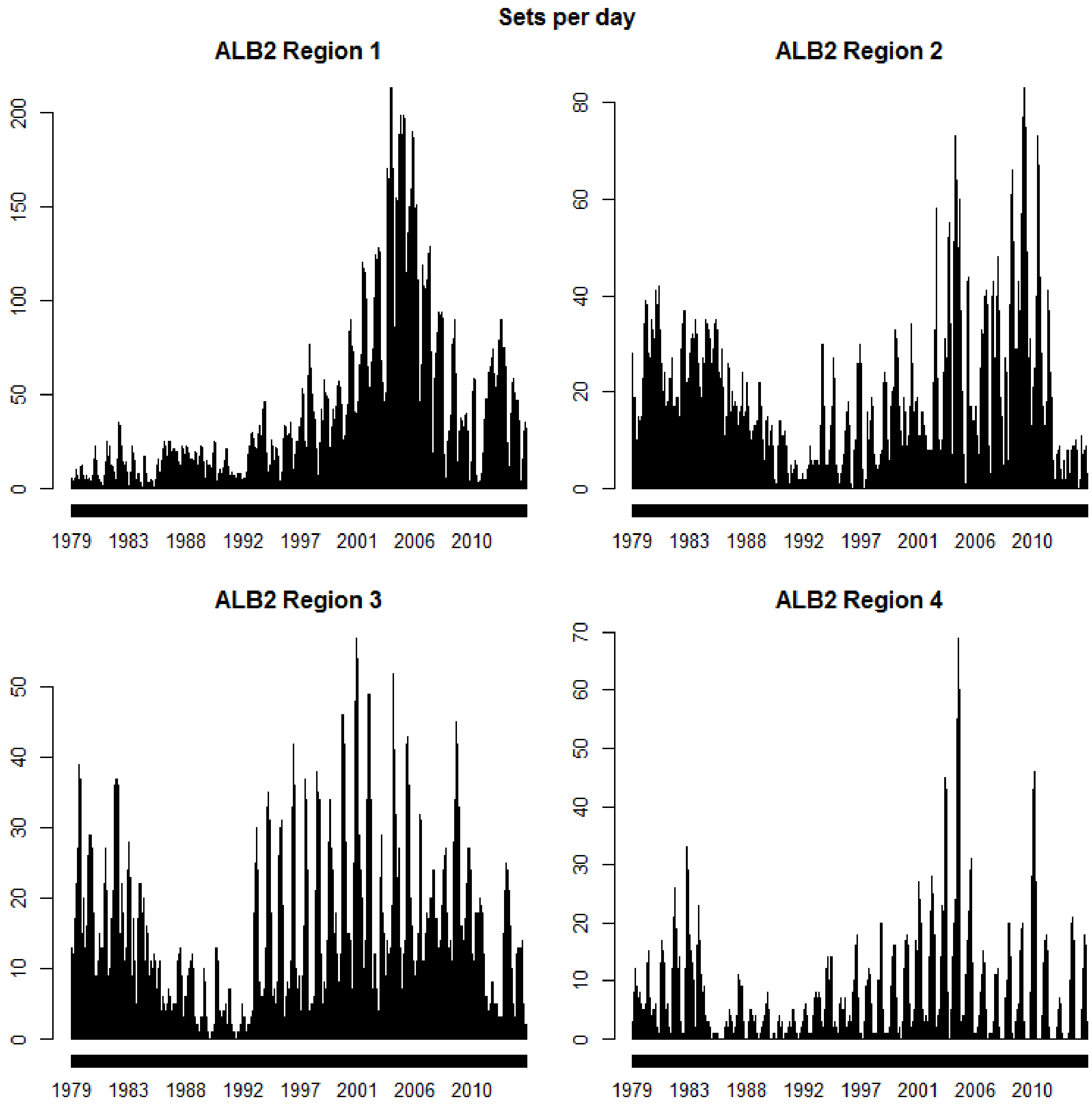


Figure 3: Sets per day by region for the Taiwanese fleet in regional structure A2 .

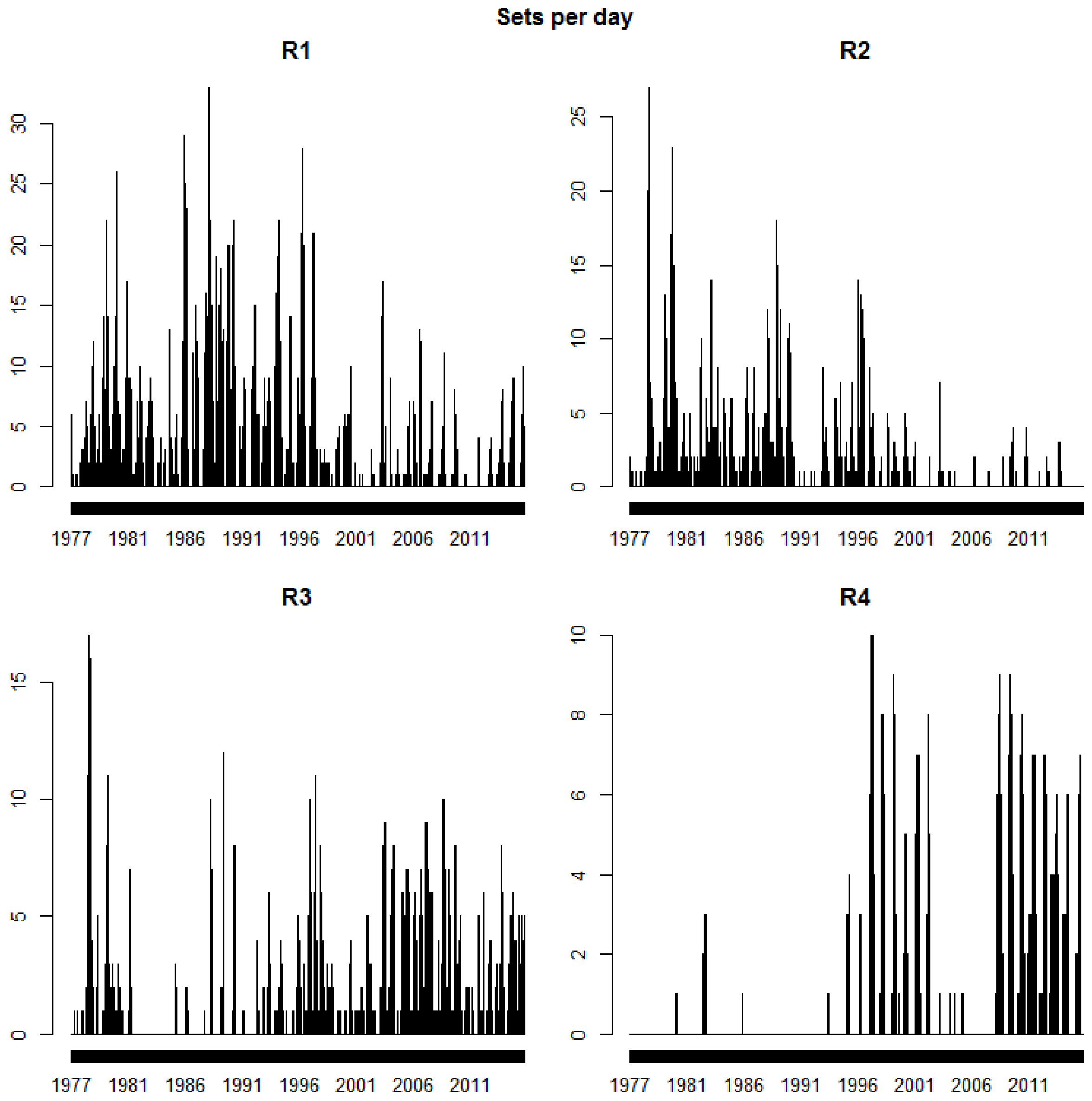


Figure 4: Sets per day by region for the Korean fleet in regional structure A2.

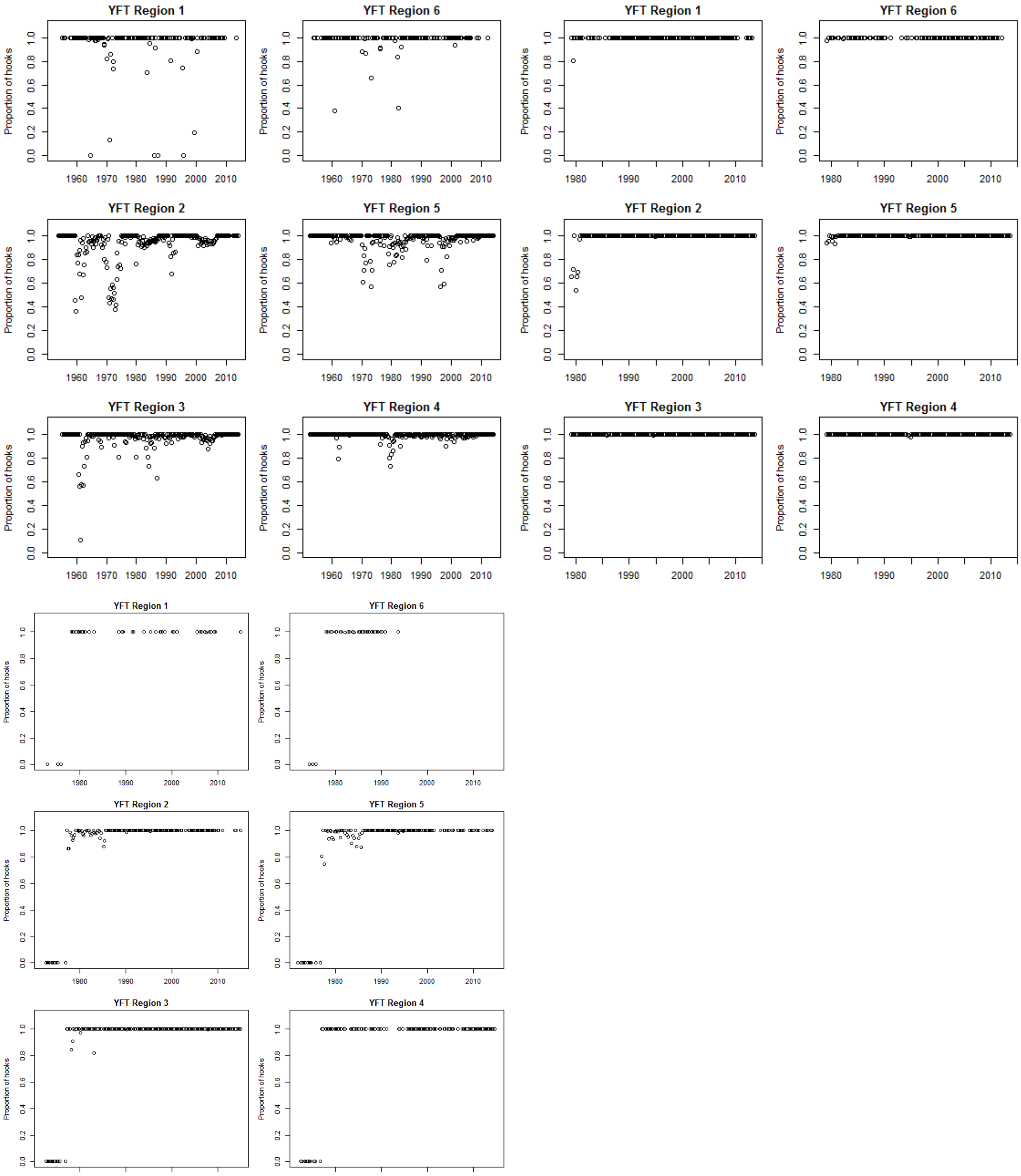


Figure 5: Proportions of sets retained after data cleaning for analyses in this paper, by region and yrqtr, for Japanese (top left), Taiwanese (top right), and Korean (bottom left) data.

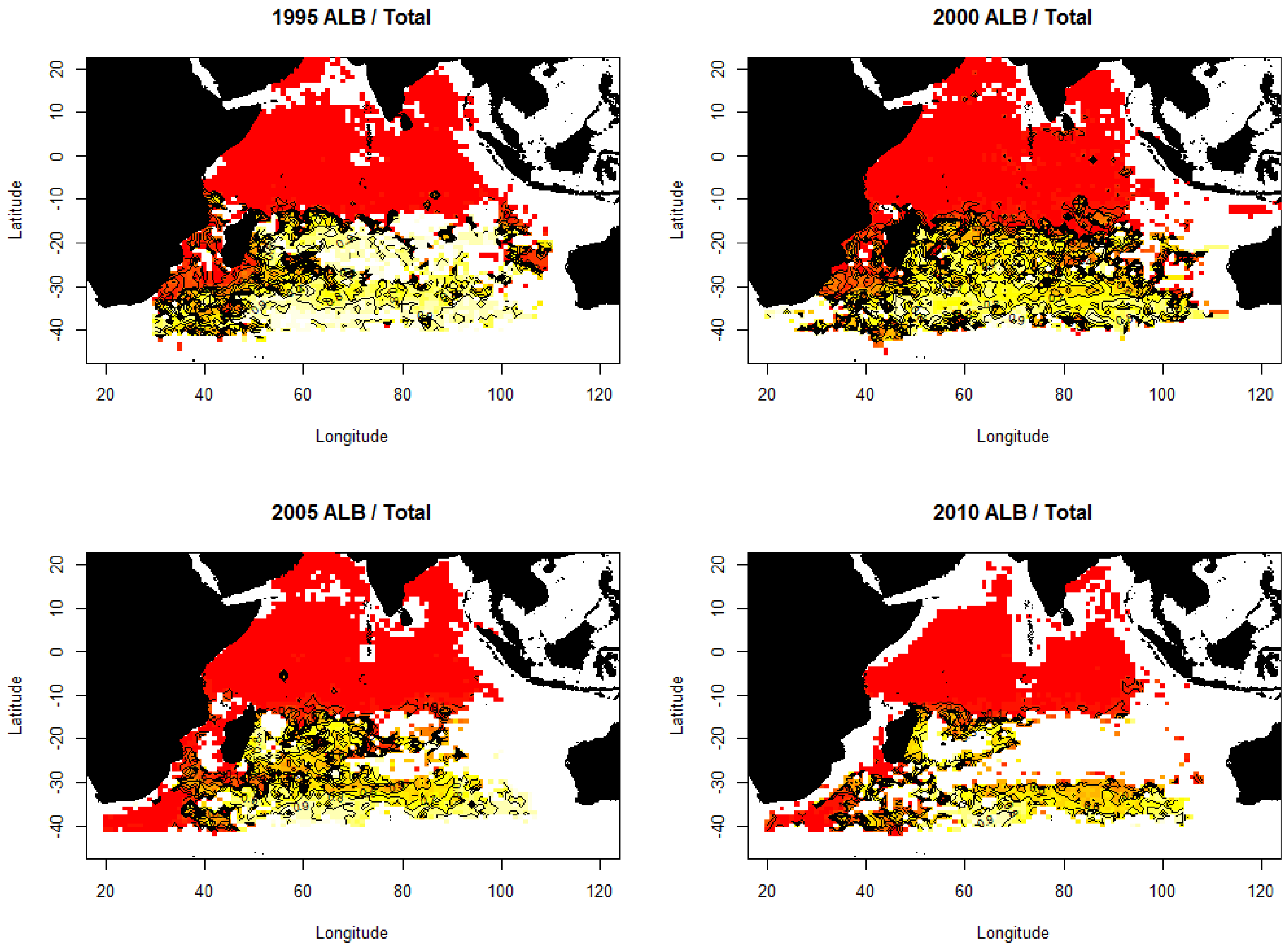


Figure 6: Proportions of Taiwanese catch in number reported as albacore, by 5 year period, mapped by 1° square. More yellow indicates a higher percentage of albacore. Contour lines occur at 5% intervals.

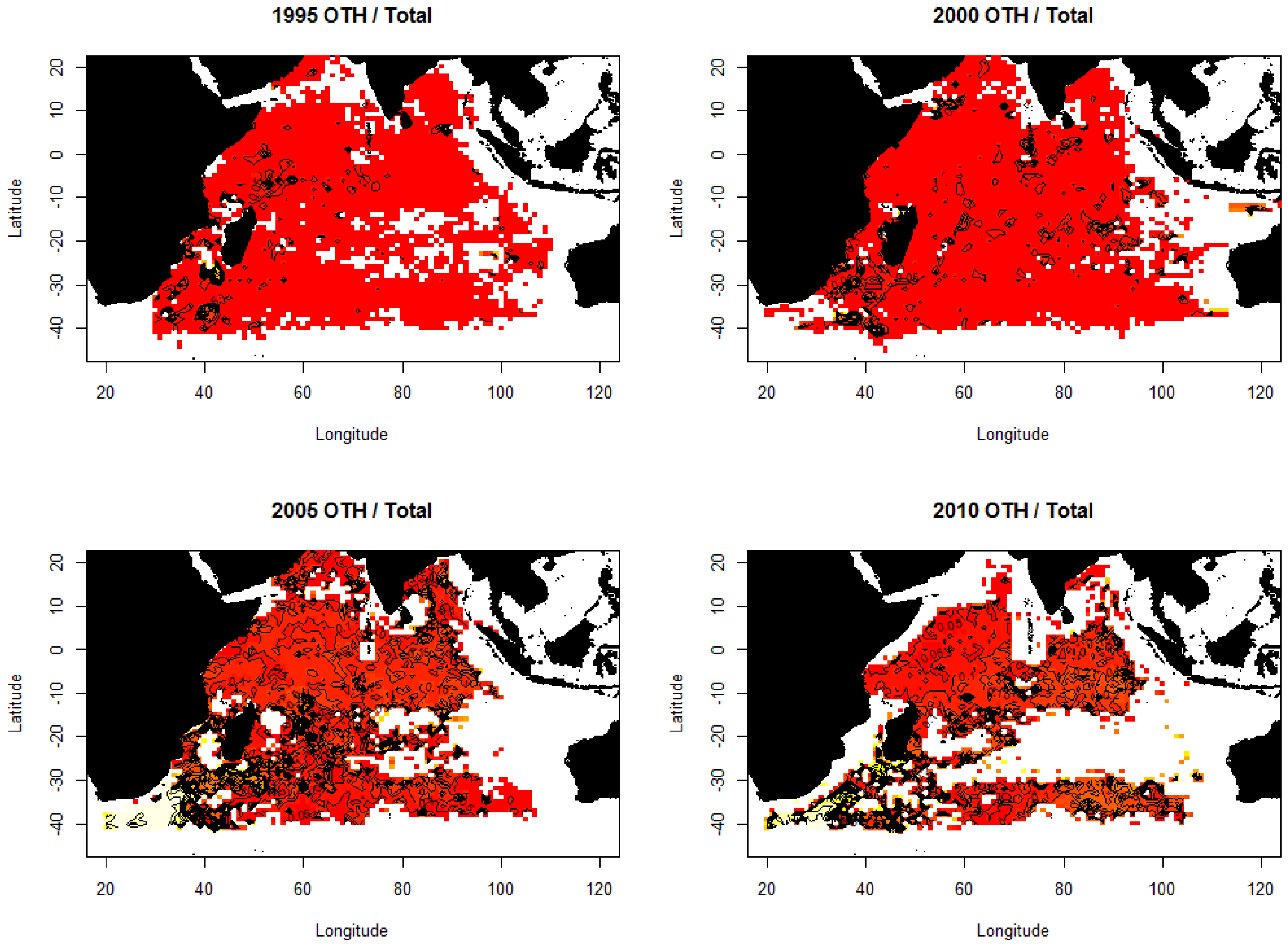


Figure 7: Proportions of Taiwanese catch in number reported as 'other' species, by 5 year period, mapped by 1° square. More yellow indicates a higher percentage of 'other' species. Contour lines occur at 5% intervals.

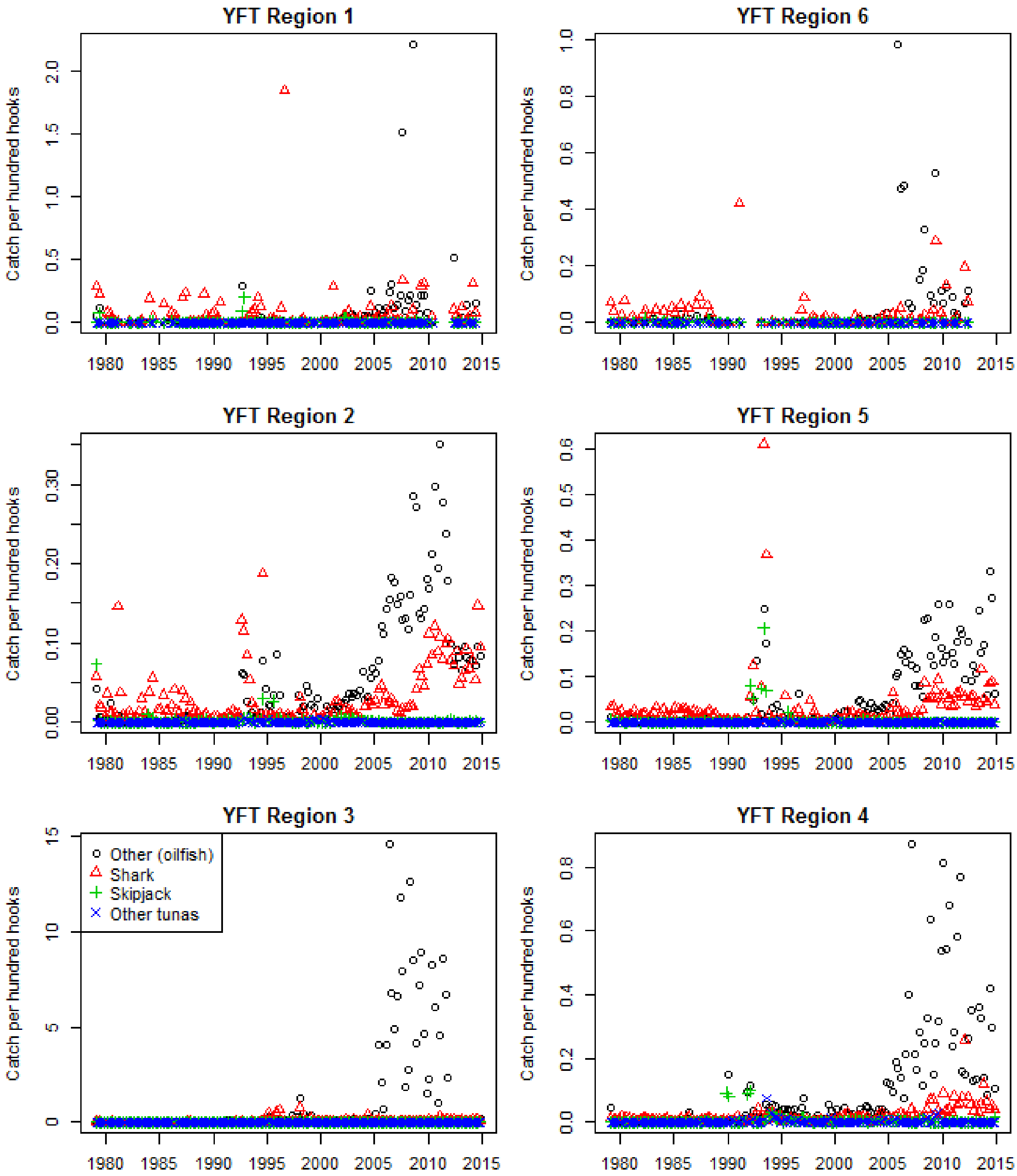


Figure 8: Taiwanese catch rates per hundred hooks of oilfish, sharks, skipjack, and other tunas, by region and year-qtr.

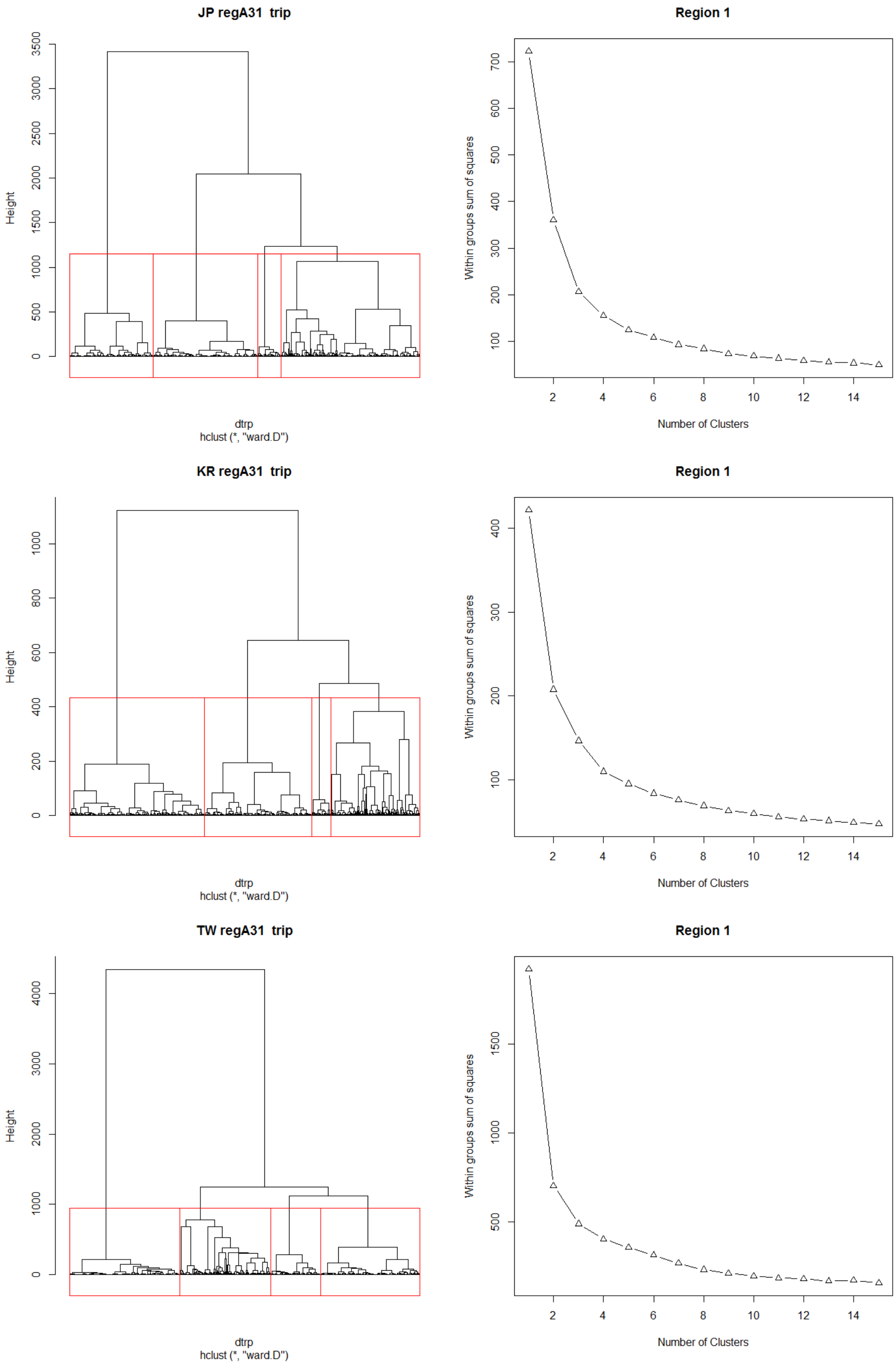


Figure 9: Plots showing analyses to estimate the number of distinct classes of species composition in A3 region 1 for Japanese, Korean, and Taiwanese effort. These are based on a hierarchical Ward clustering analysis of trip-level data (left); and within-group sums of squares from kmeans analyses with a range of numbers of clusters (right).

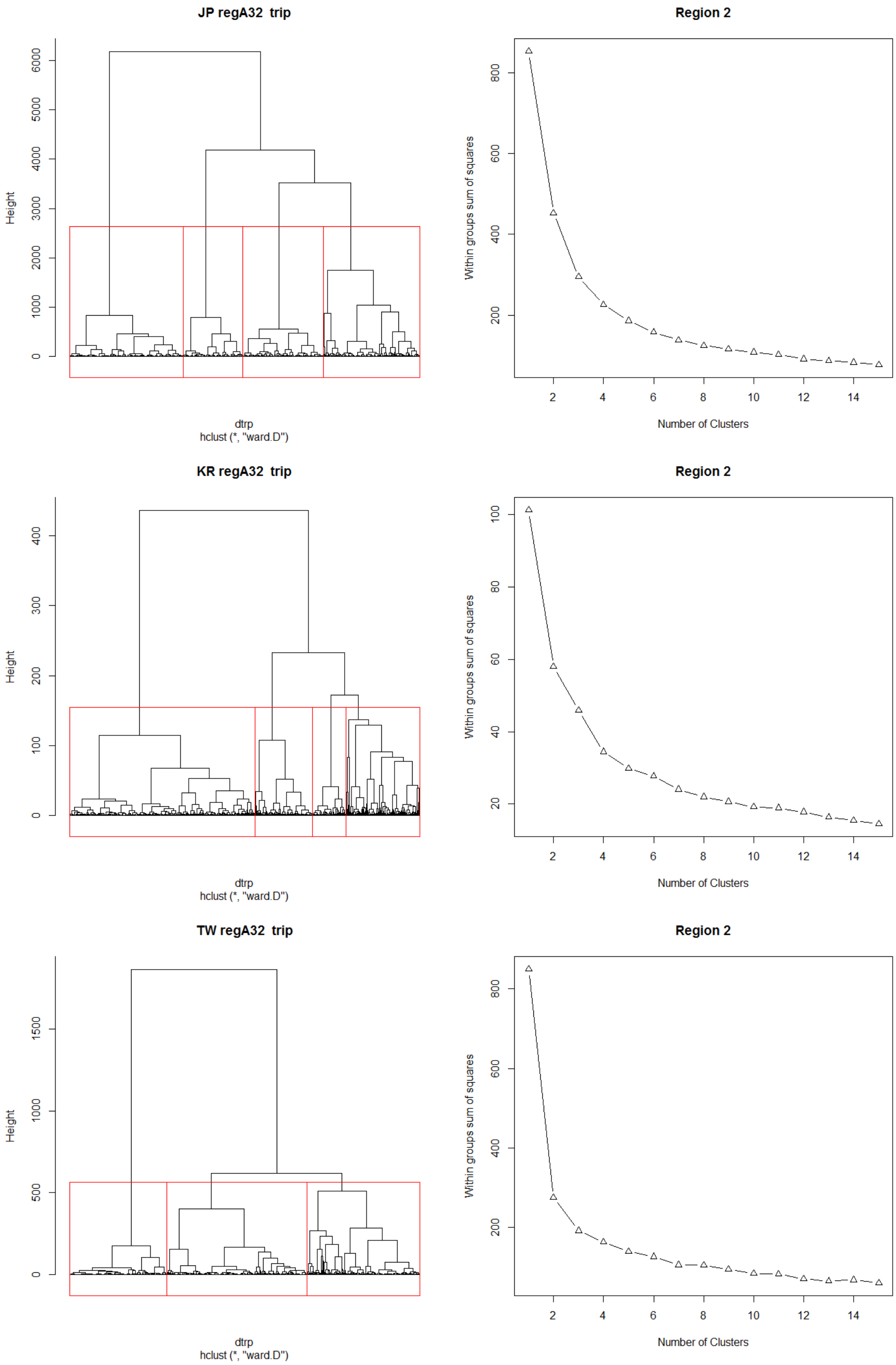


Figure 10: Plots showing analyses to estimate the number of distinct classes of species composition in A3 region 2 for Japanese, Korean, and Taiwanese effort. These are based on a hierarchical Ward clustering analysis of trip-level data (left); and within-group sums of squares from kmeans analyses with a range of numbers of clusters (right).

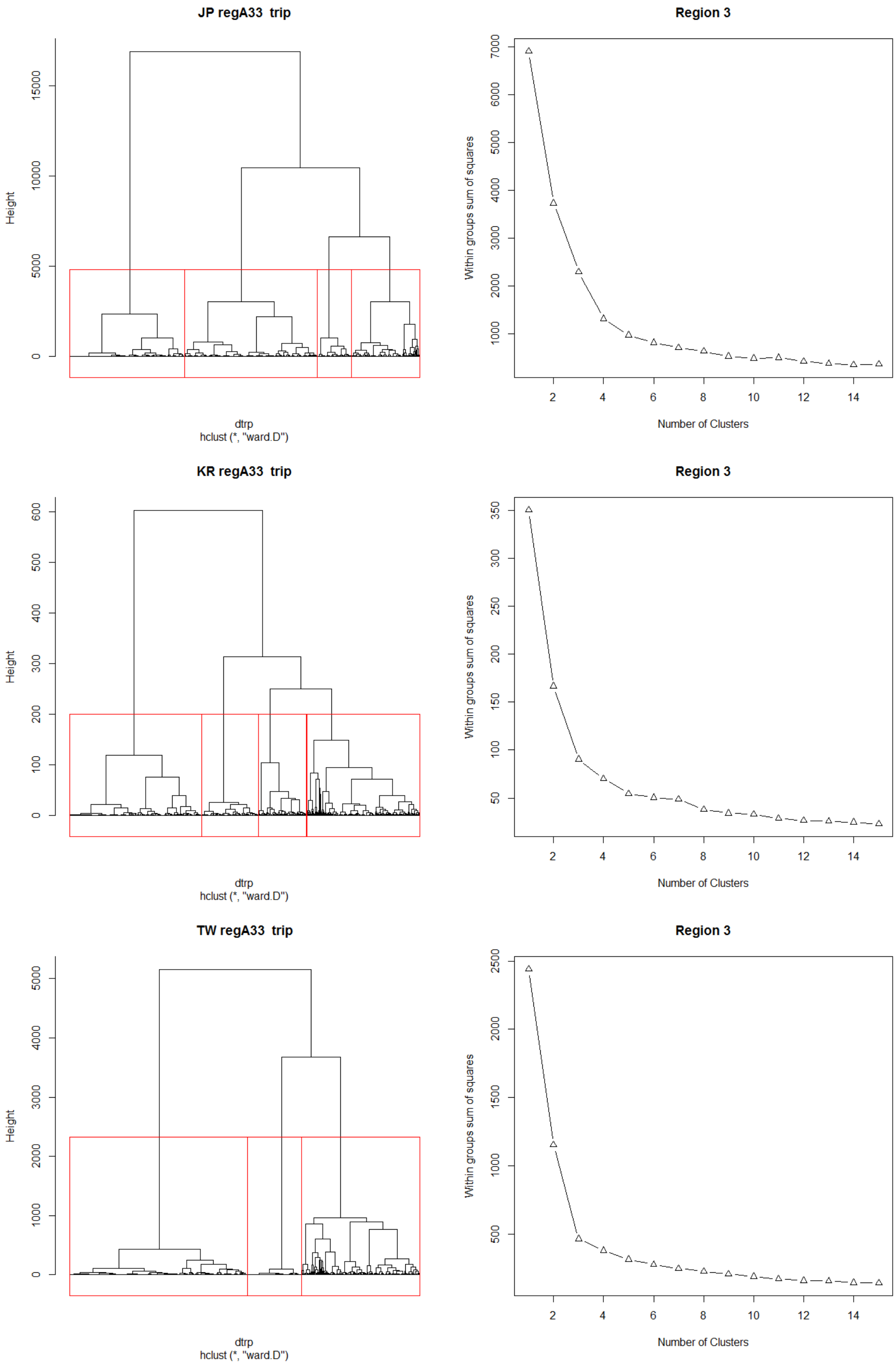


Figure 11: Plots showing analyses to estimate the number of distinct classes of species composition in A3 region 3 for Japanese, Korean, and Taiwanese effort. These are based on a hierarchical Ward clustering analysis of trip-level data (left); and within-group sums of squares from kmeans analyses with a range of numbers of clusters (right).

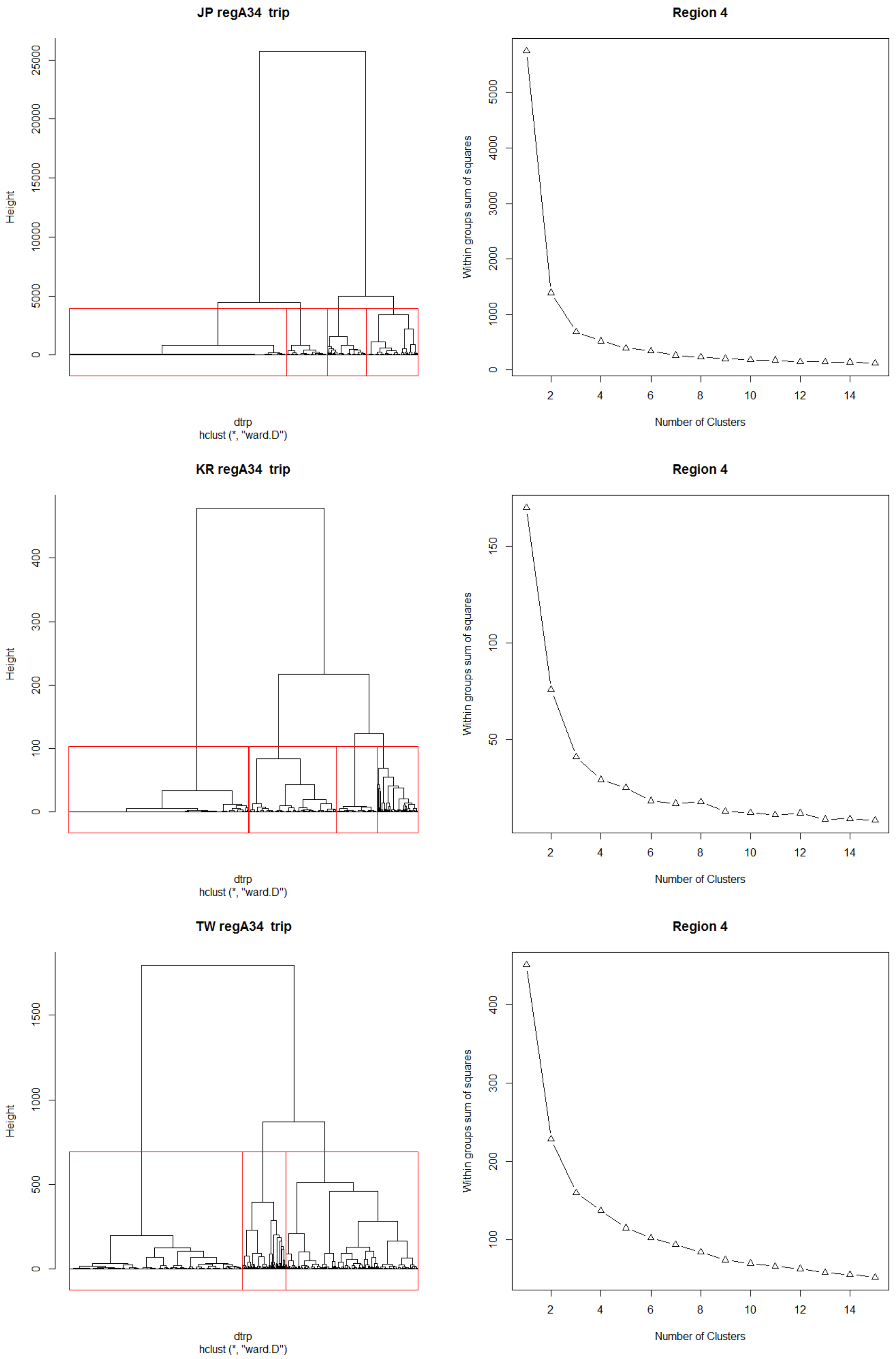
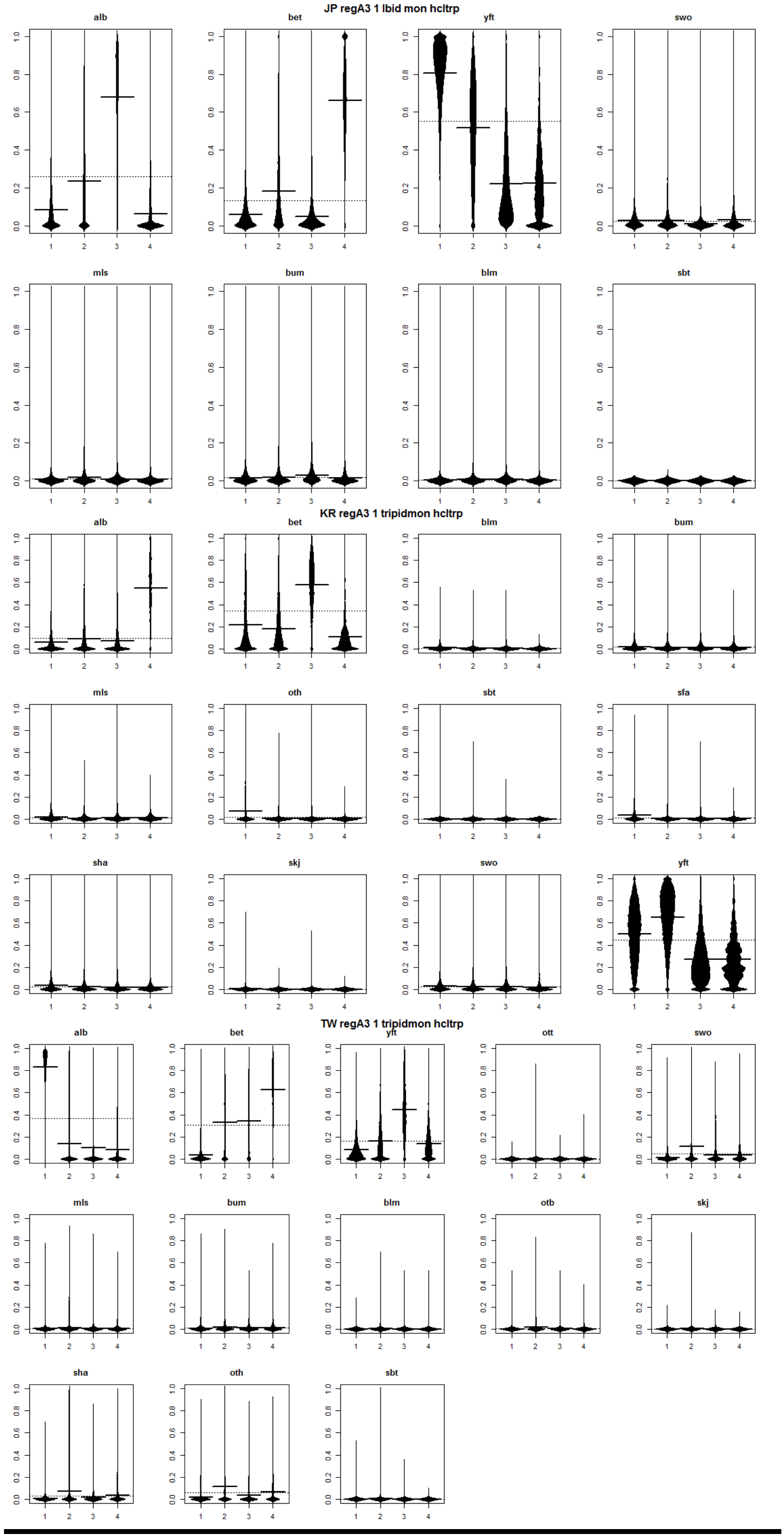


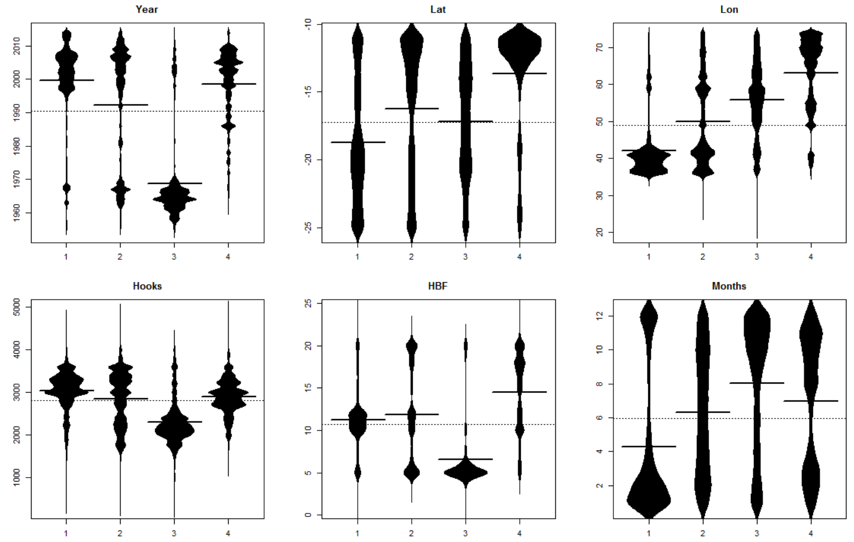
Figure 12: Plots showing analyses to estimate the number of distinct classes of species composition in A3 region 4 for Japanese, Korean, and Taiwanese effort. These are based on a hierarchical Ward clustering analysis of trip-level data (left); and within-group sums of squares from kmeans analyses with a range of numbers of clusters (right).



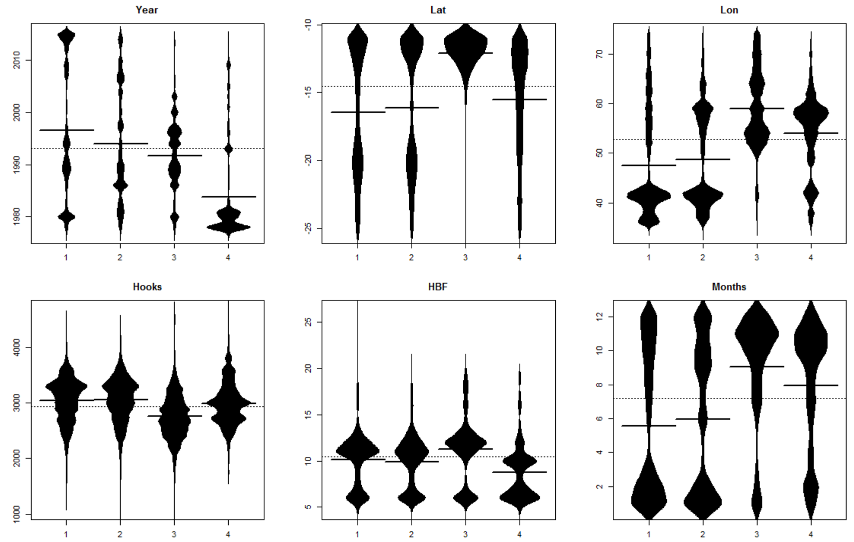
1.2.1.1.1.1.1

FIGURE 13: BEANPLOTS FOR REGION 1 OF REGIONAL STRUCTURE A3 SHOWING SPECIES COMPOSITION BY CLUSTER FOR JAPANESE (TOP), KOREAN (MIDDLE) AND TAIWANESE (BOTTOM) EFFORT. THE HORIZONTAL BARS INDICATE THE MEDIANS.

JP regA3 1 lbid mon hcltrp



KR regA3 1 tripidmon hcltrp



TW regA3 1 tripidmon hcltrp

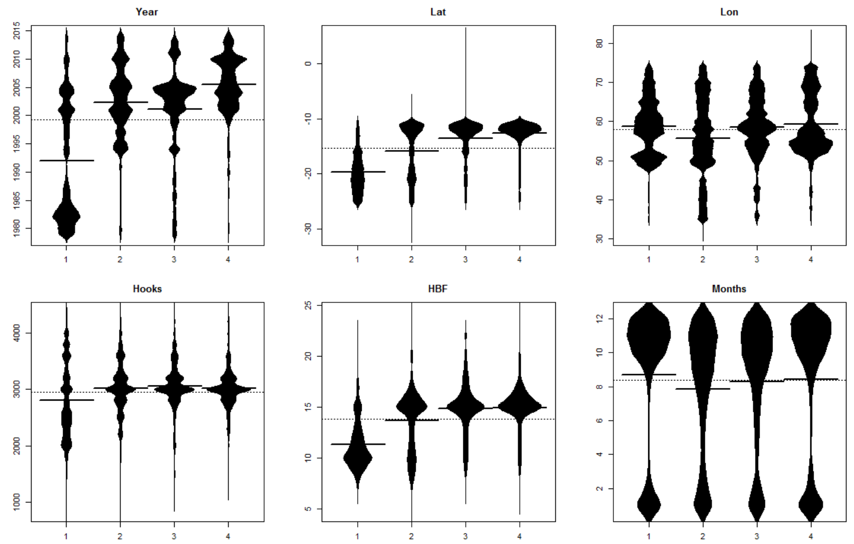


FIGURE 14: BEANPLOTS FOR REGION 1 OF REGIONAL STRUCTURE A3 SHOWING NUMBER OF SETS VERSUS COVARIATE BY CLUSTER FOR JAPANESE (TOP), KOREAN (MIDDLE) AND TAIWANESE (BOTTOM) EFFORT. THE HORIZONTAL BARS INDICATE THE MEDIANS.

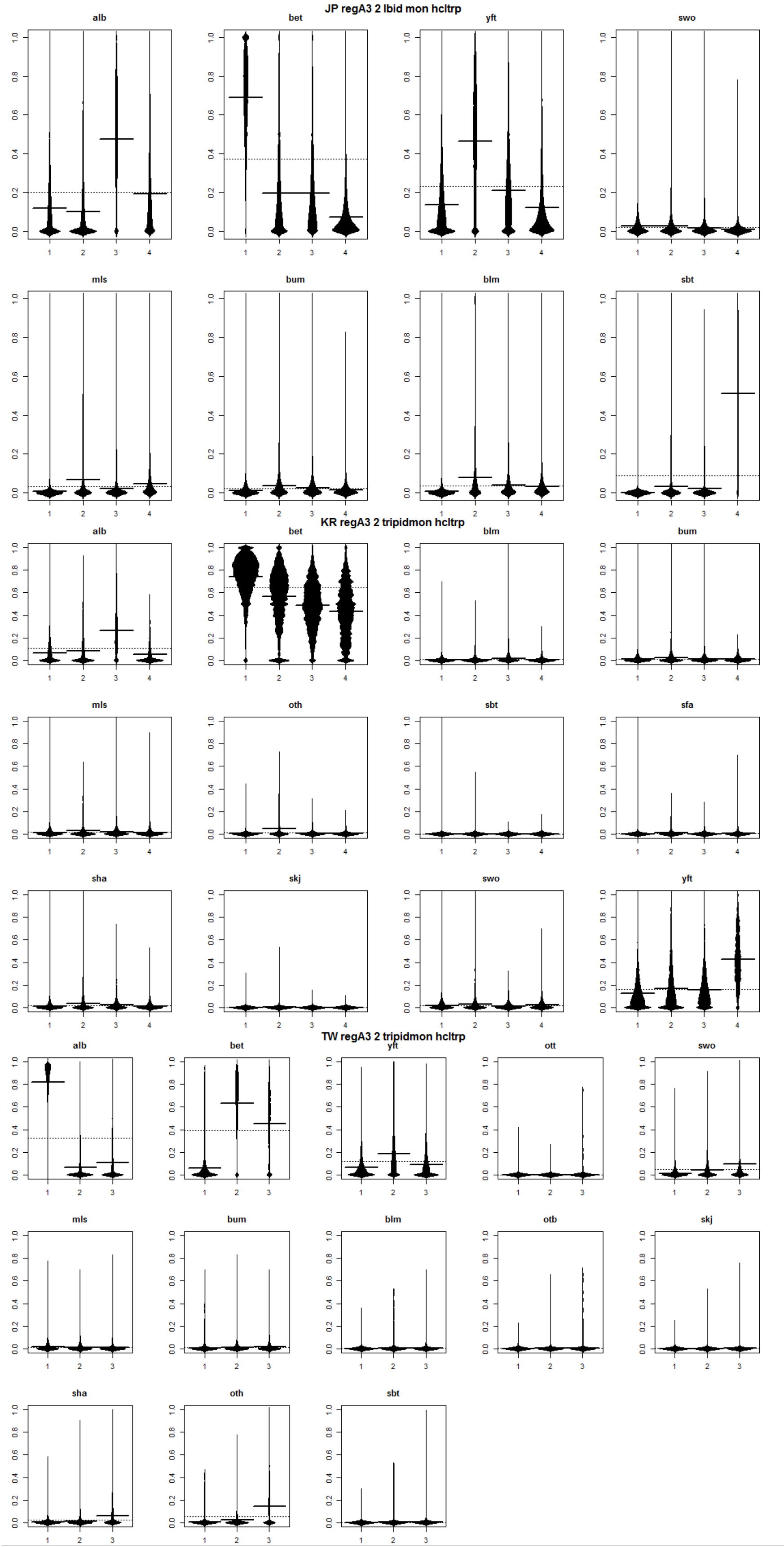


Figure 15: Beanplots for *region 2* of regional structure A3 *showing species composition by cluster for Japanese (top), Korean (middle) and Taiwanese (bottom) effort. The horizontal bars indicate the medians.*

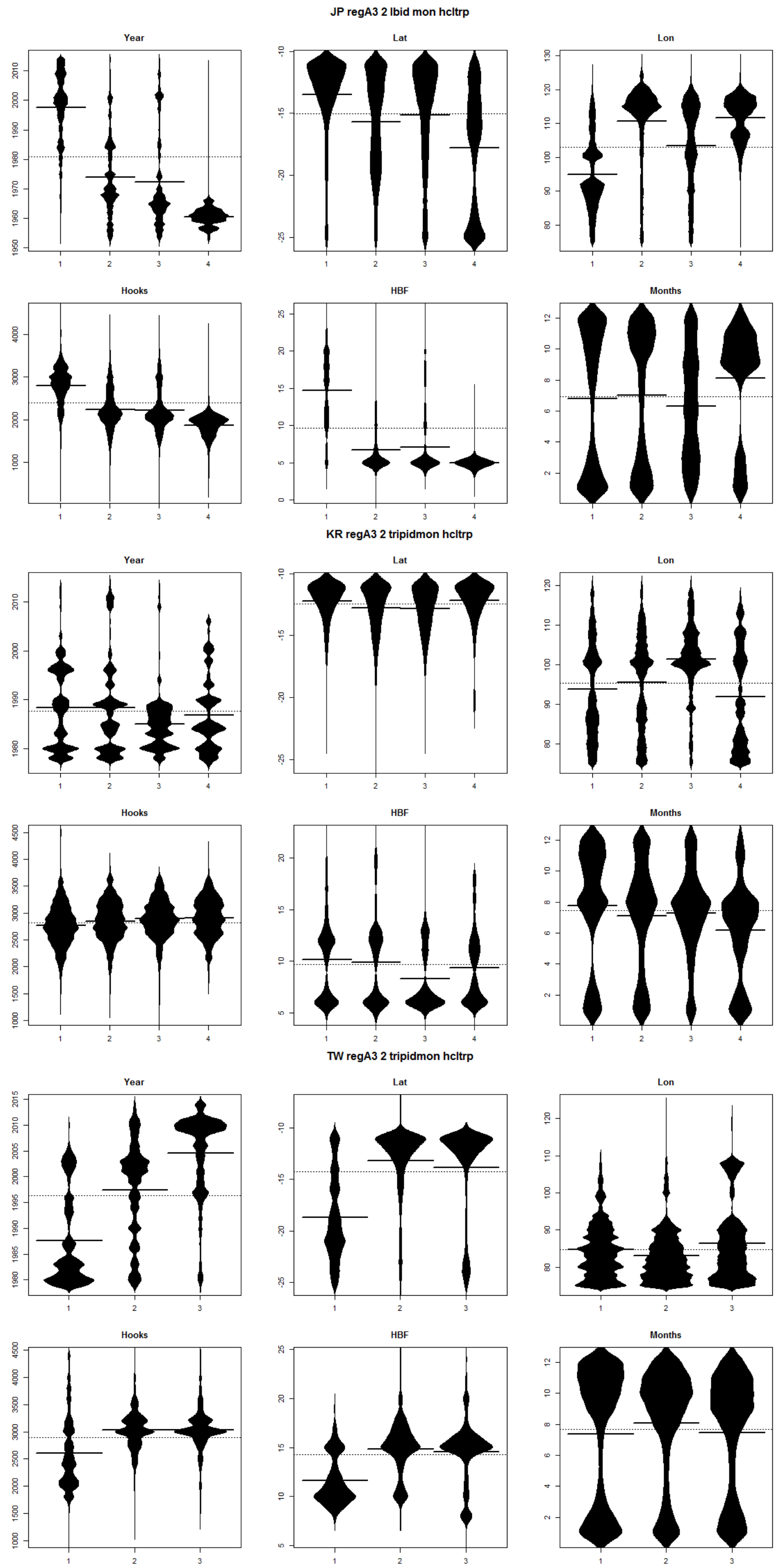


***FIGURE 16*: BEANPLOTS FOR REGION 2 OF REGIONAL STRUCTURE A3 SHOWING NUMBER OF SETS VERSUS COVARIATE BY CLUSTER FOR JAPANESE (TOP), KOREAN (MIDDLE) AND TAIWANESE (BOTTOM) EFFORT. THE HORIZONTAL BARS INDICATE THE MEDIANS.**

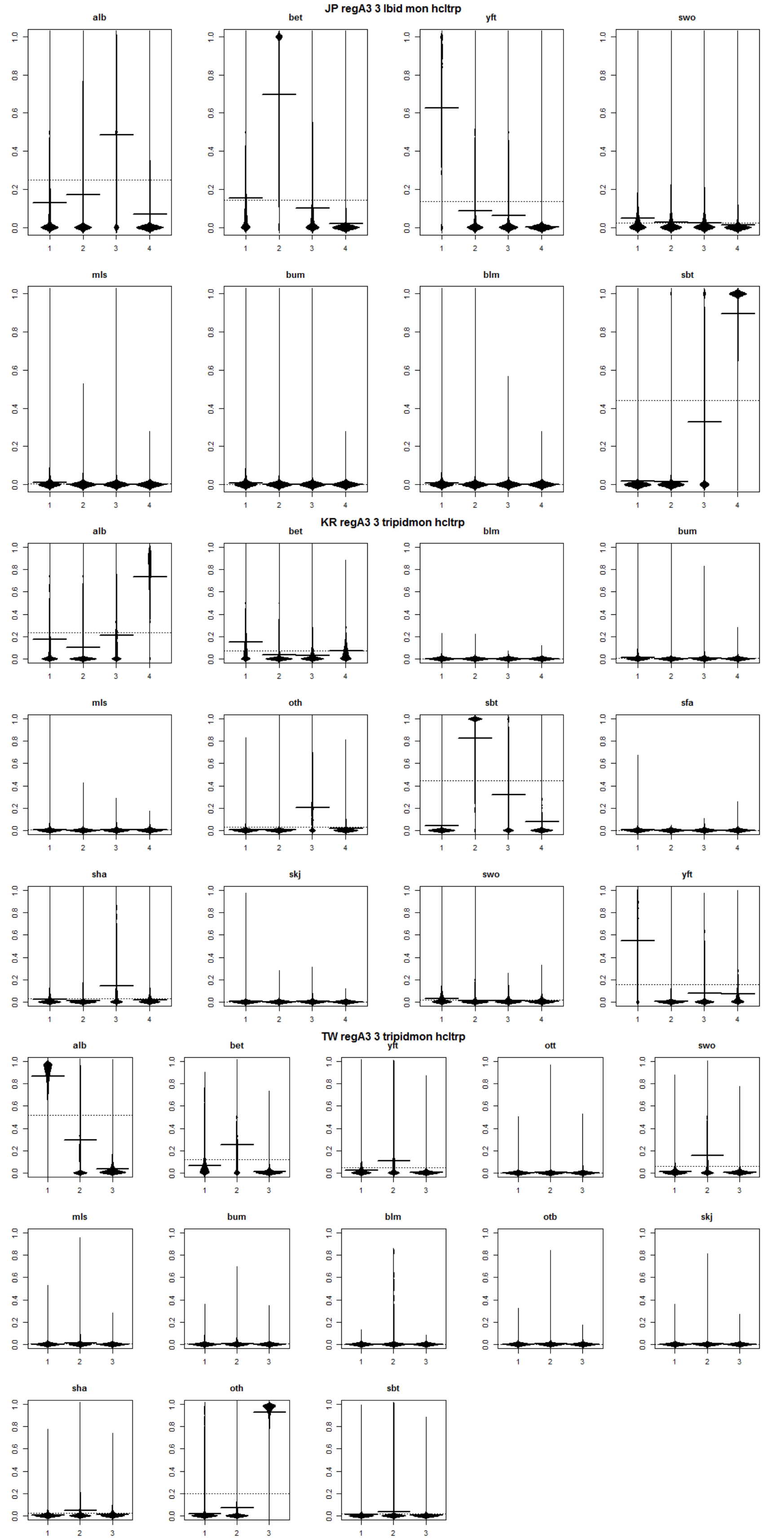


Figure 17: Beanplots for *region 3* of regional structure A3 *showing species composition by cluster for Japanese (top), Korean (middle) and Taiwanese (bottom) effort. The horizontal bars indicate the medians.*

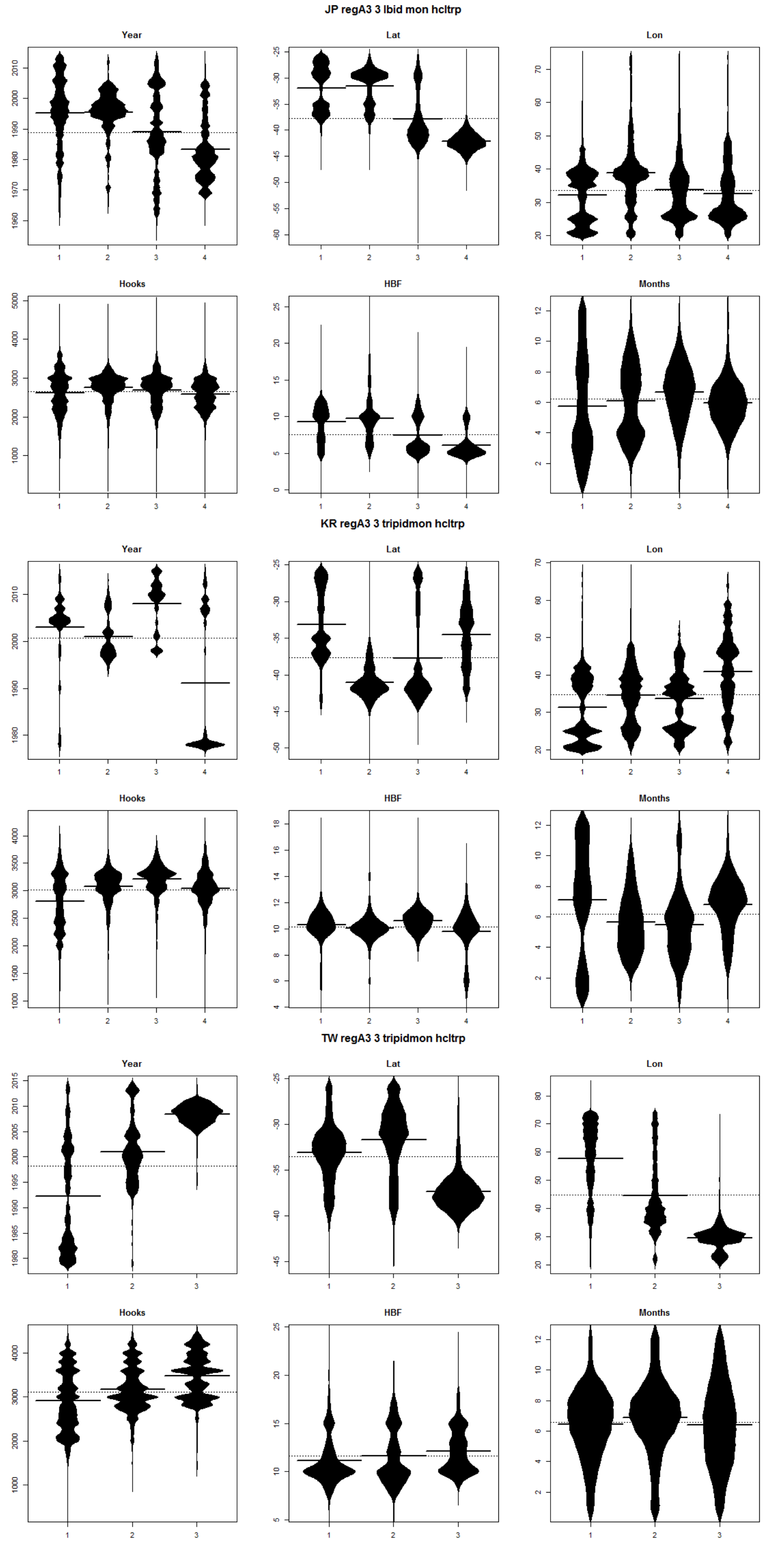


***Figure 18*: Beanplots for region 3 of regional structure A3 showing number of sets versus covariate by cluster for Japanese (top), Korean (middle) and Taiwanese (bottom) effort. The horizontal bars indicate the medians.**

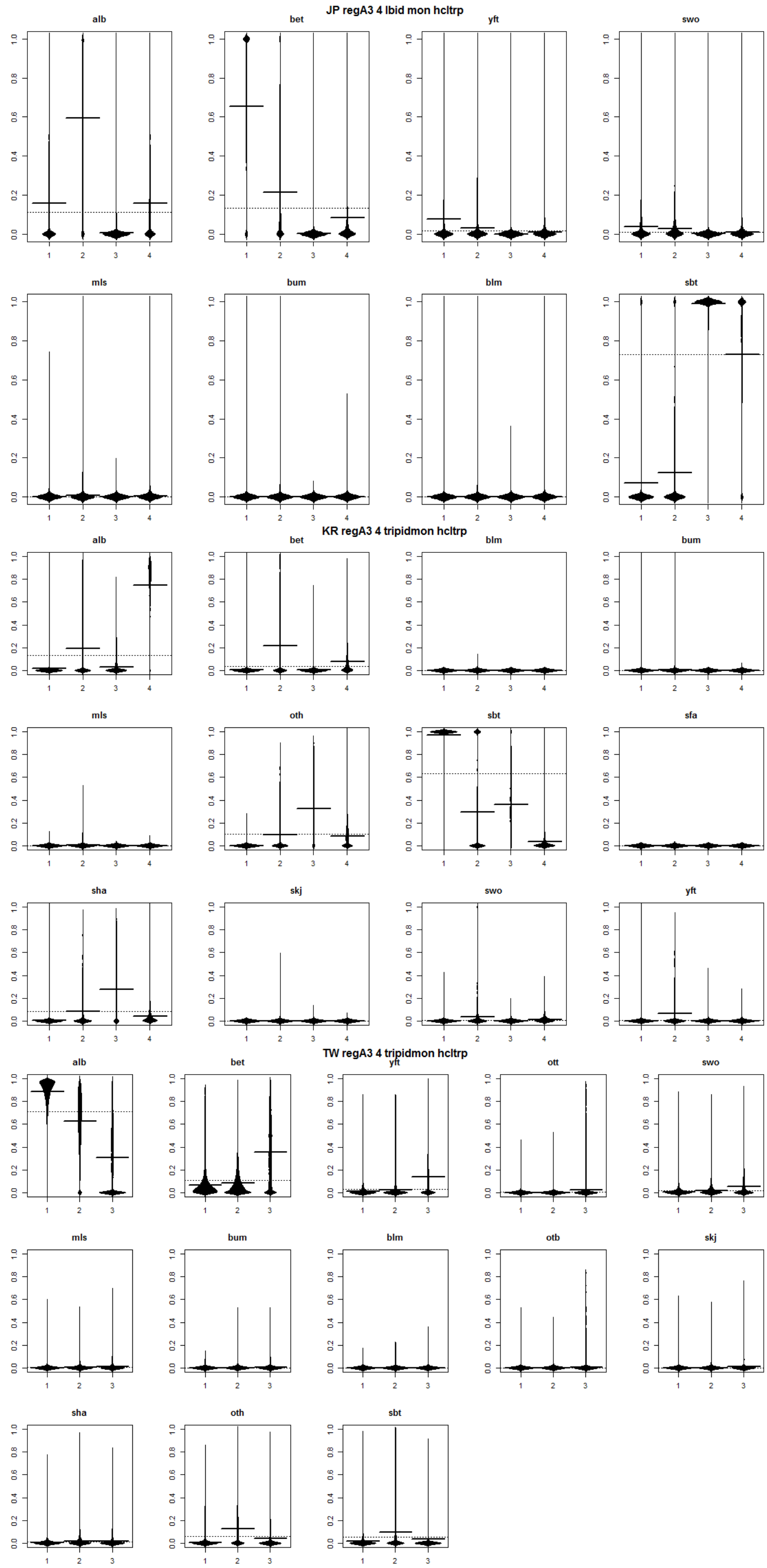


Figure 19: Beanplots for *region 4* of regional structure A3 *showing species composition by cluster for Japanese (top), Korean (middle) and Taiwanese (bottom) effort. The horizontal bars indicate the medians.*

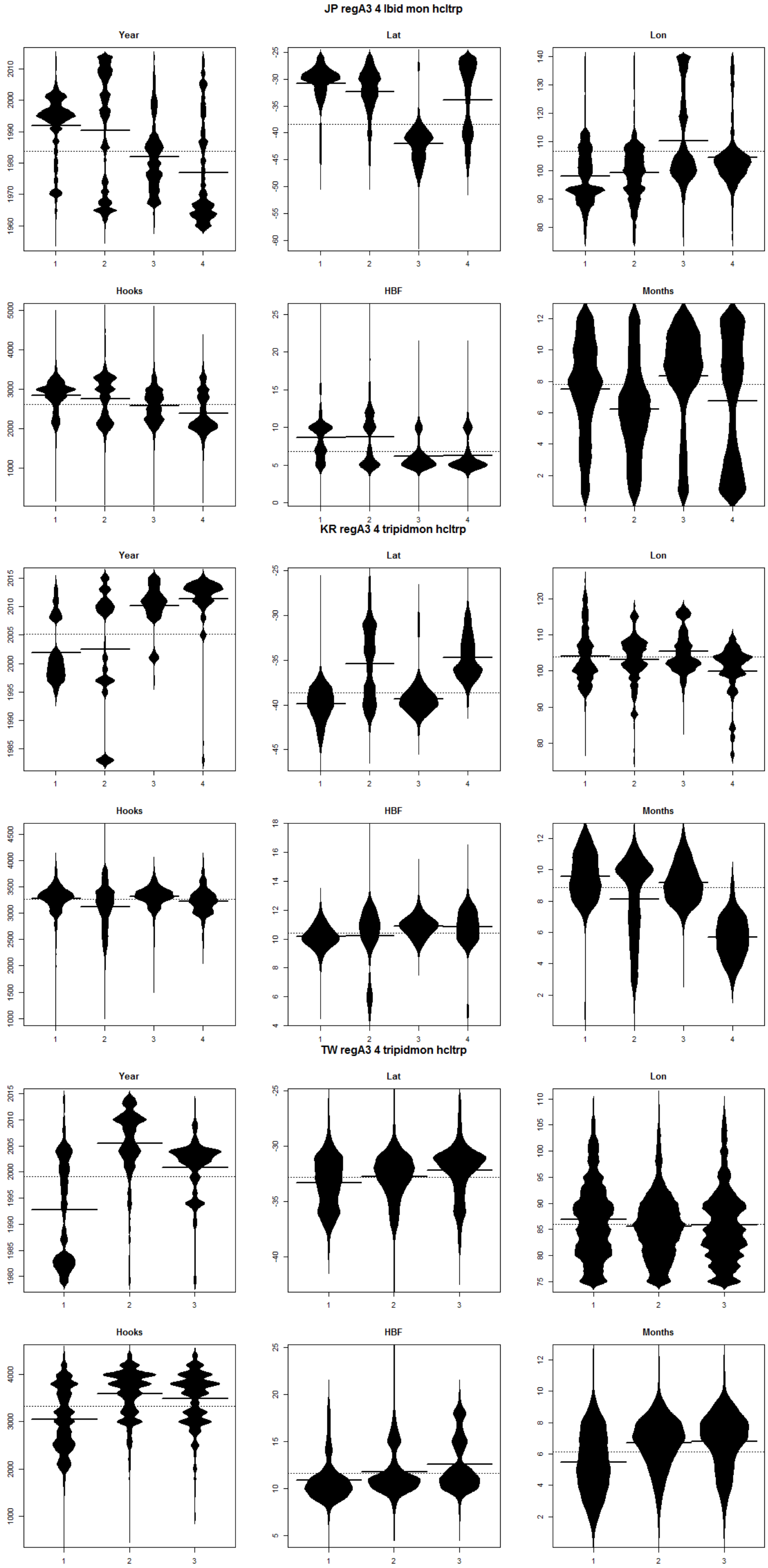
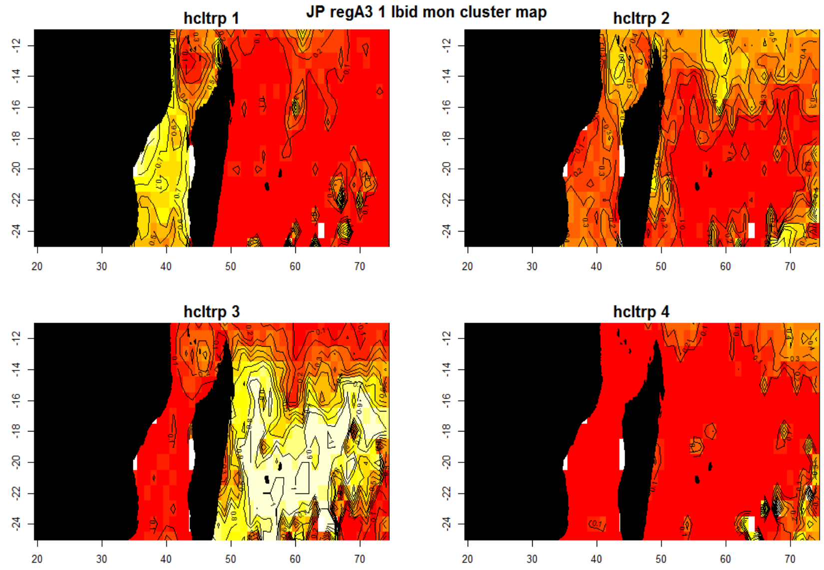
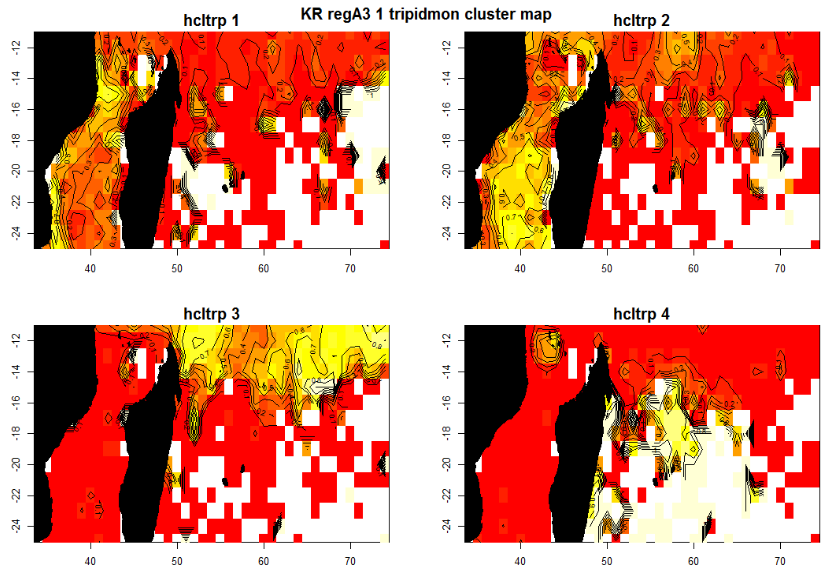


FIGURE 20: BEANPLOTS FOR REGION 4 OF REGIONAL STRUCTURE A3 SHOWING NUMBER OF SETS VERSUS COVARIATE BY CLUSTER (RIGHT) FOR JAPANESE (TOP), KOREAN (MIDDLE) AND TAIWANESE (BOTTOM) EFFORT. THE HORIZONTAL BARS INDICATE THE MEDIANS.


JP regA3 1 lbid mon cluster map
hcltrp 1
hcltrp 2
hcltrp 3
hcltrp 4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hcltrp 1
hcltrp 2
hcltrp 3
hcltrp 4

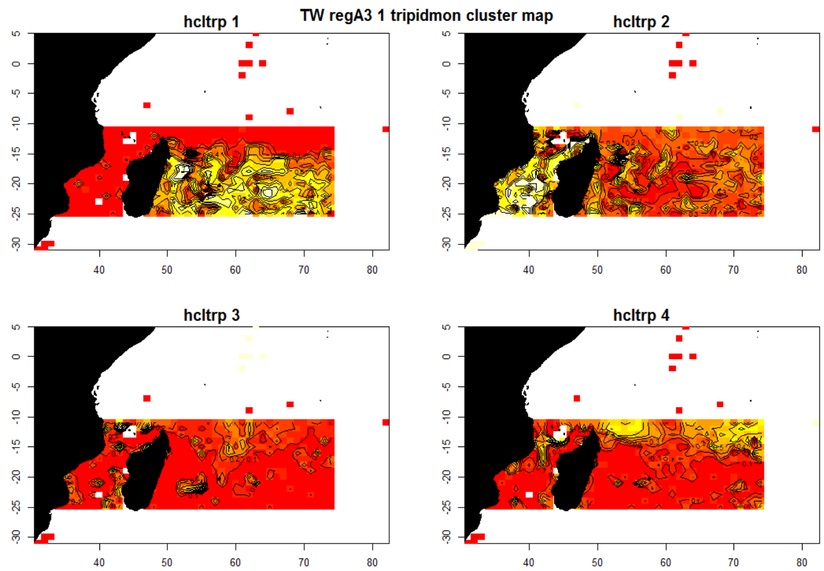
TW regA3 1 tripidmon cluster map
hcltrp 1
hcltrp 2
hcltrp 3
hcltrp 4

Figure 21: Maps of the spatial distributions of clusters in region 1 of regional structure A3, for Japanese, Korean, and Taiwanese effort.

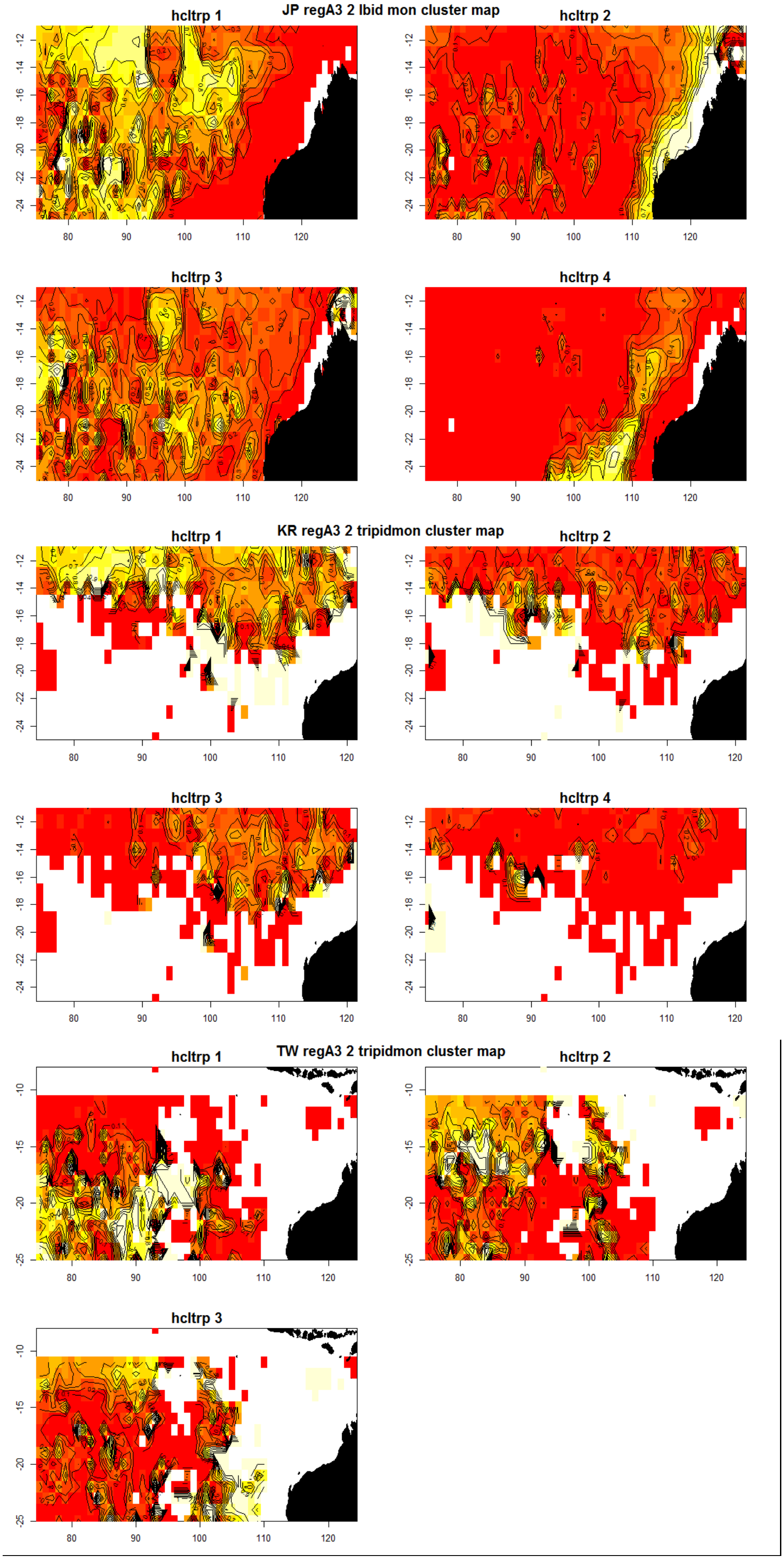

Figure 22: Maps of the spatial distributions of clusters in region 2 of regional structure A3, for Japanese, Korean, and Taiwanese effort.

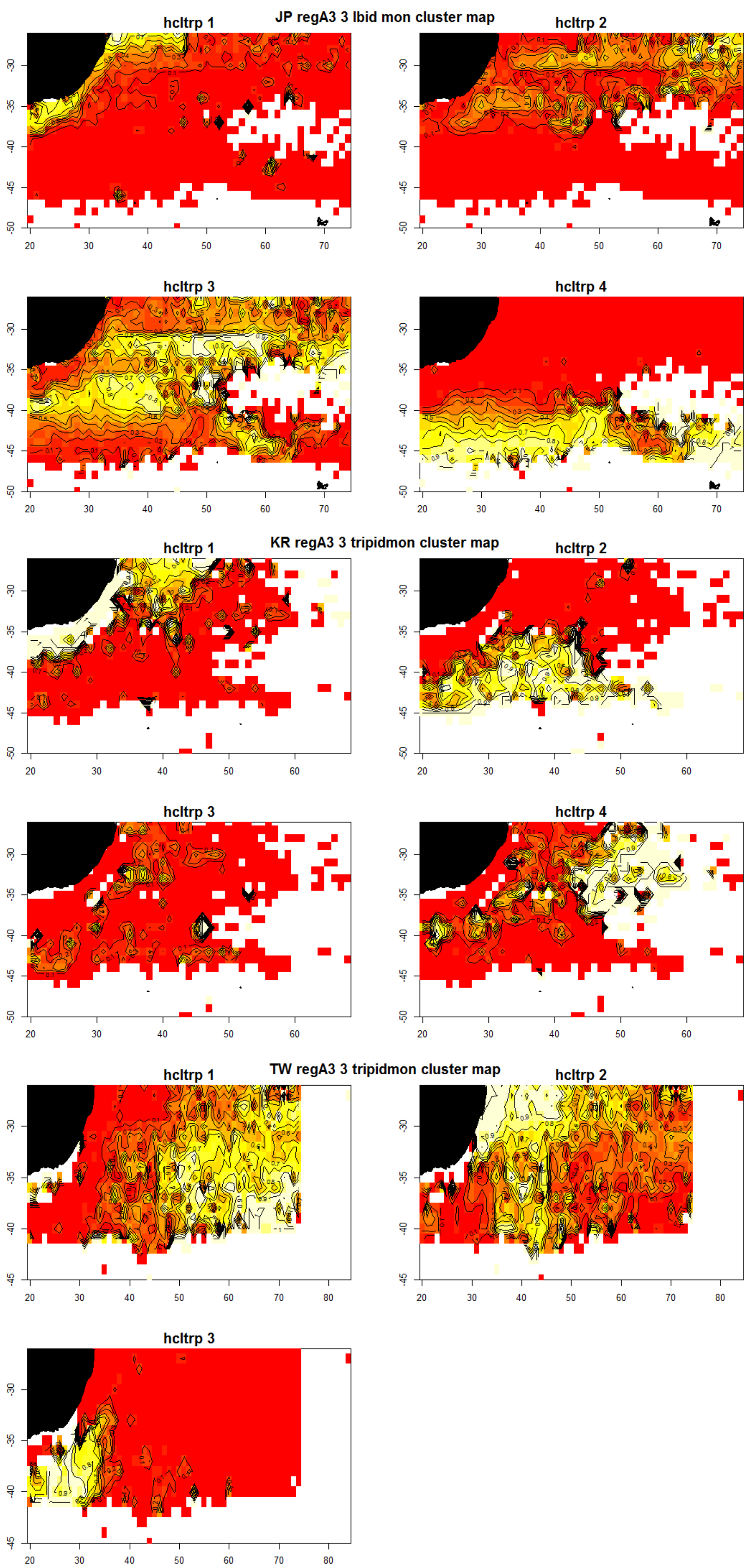

Figure 23: Maps of the spatial distributions of clusters in region 3 of regional structure A3, for Japanese, Korean, and Taiwanese effort.

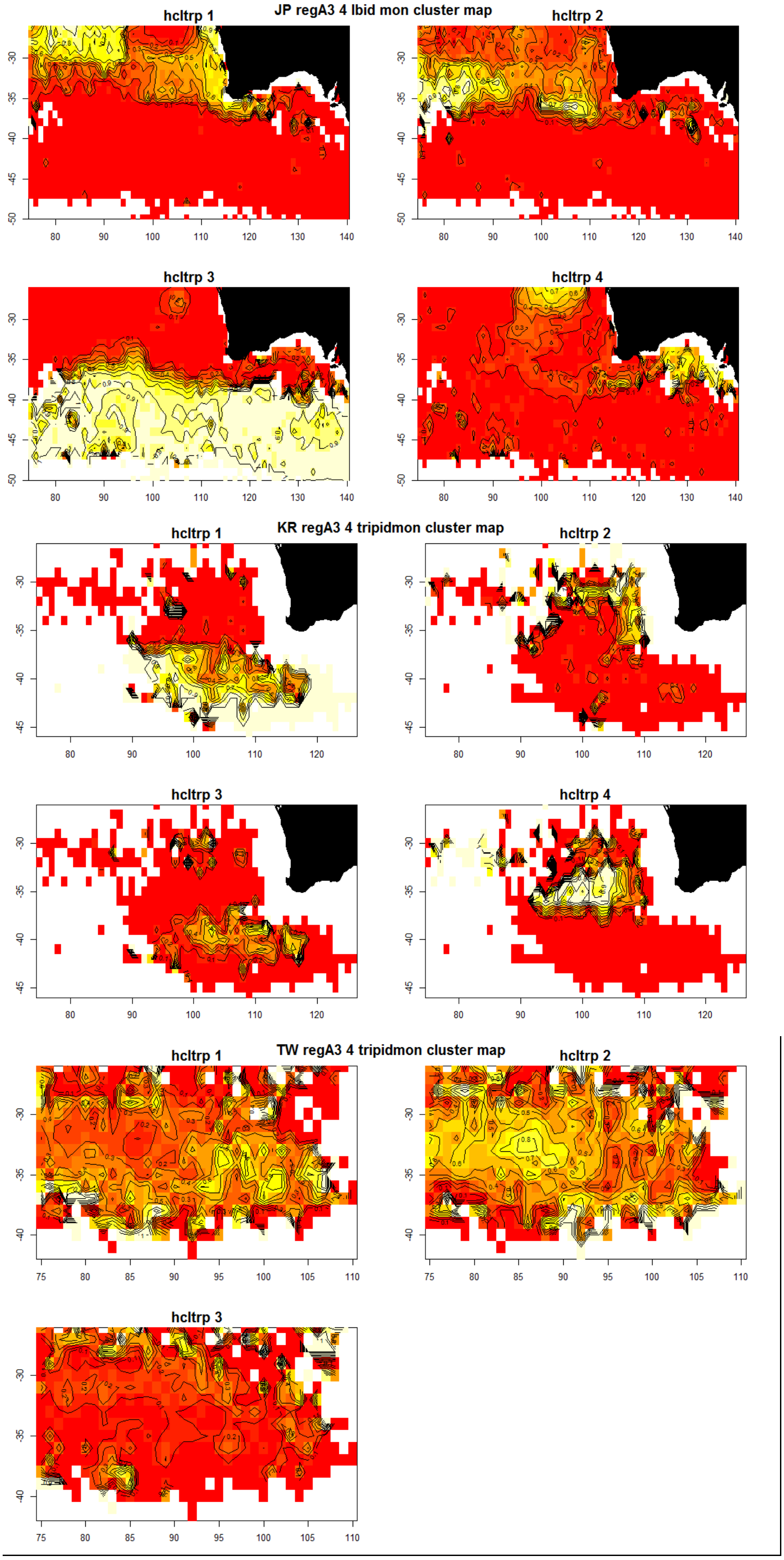

Figure 24: Maps of the spatial distributions of clusters in region 4 of regional structure A3, for Japanese, Korean, and Taiwanese effort.

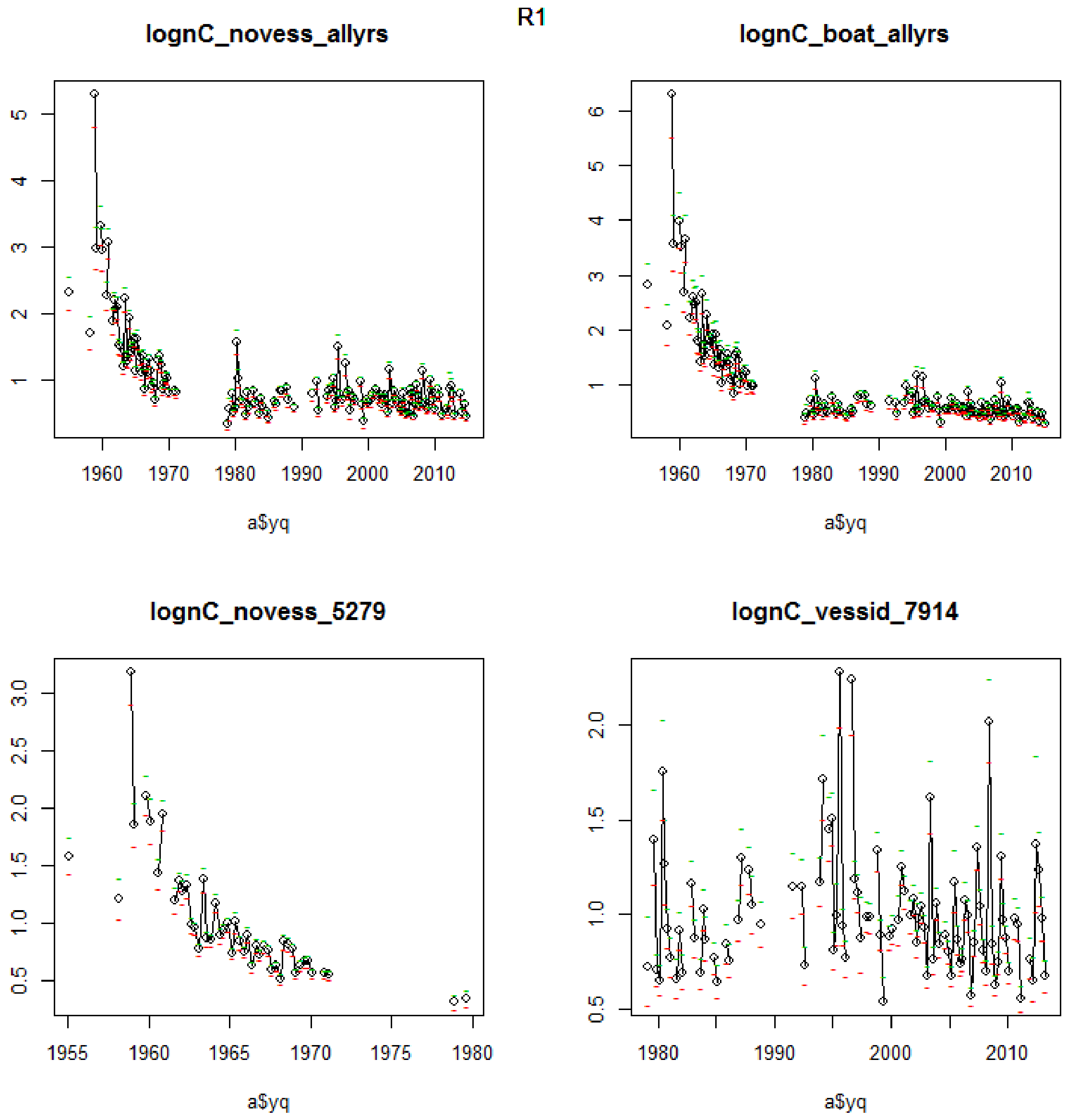

Figure 25: Estimated CPUE series for region 1 of the A3 regional structure, including time series for all years (top) both with (right) and without (left) vessel effects, and time series for 1952-79 without vessel effects, and 1979-2014 with vessel effects.

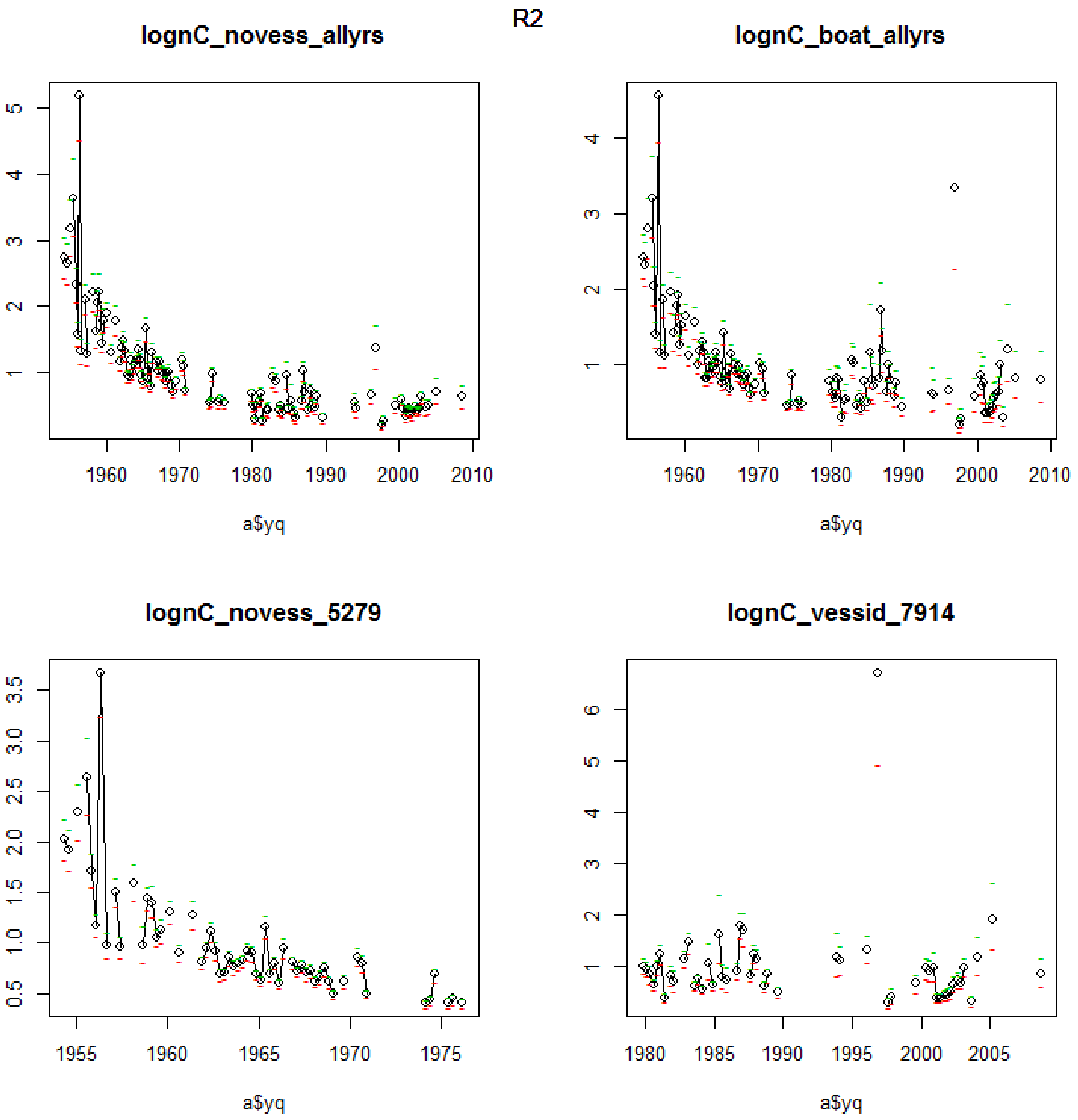

Figure 26: Estimated CPUE series for region 2 of the A3 regional structure, including time series for all years (top) both with (right) and without (left) vessel effects, and time series for 1952-79 without vessel effects, and 1979-2014 with vessel effects.

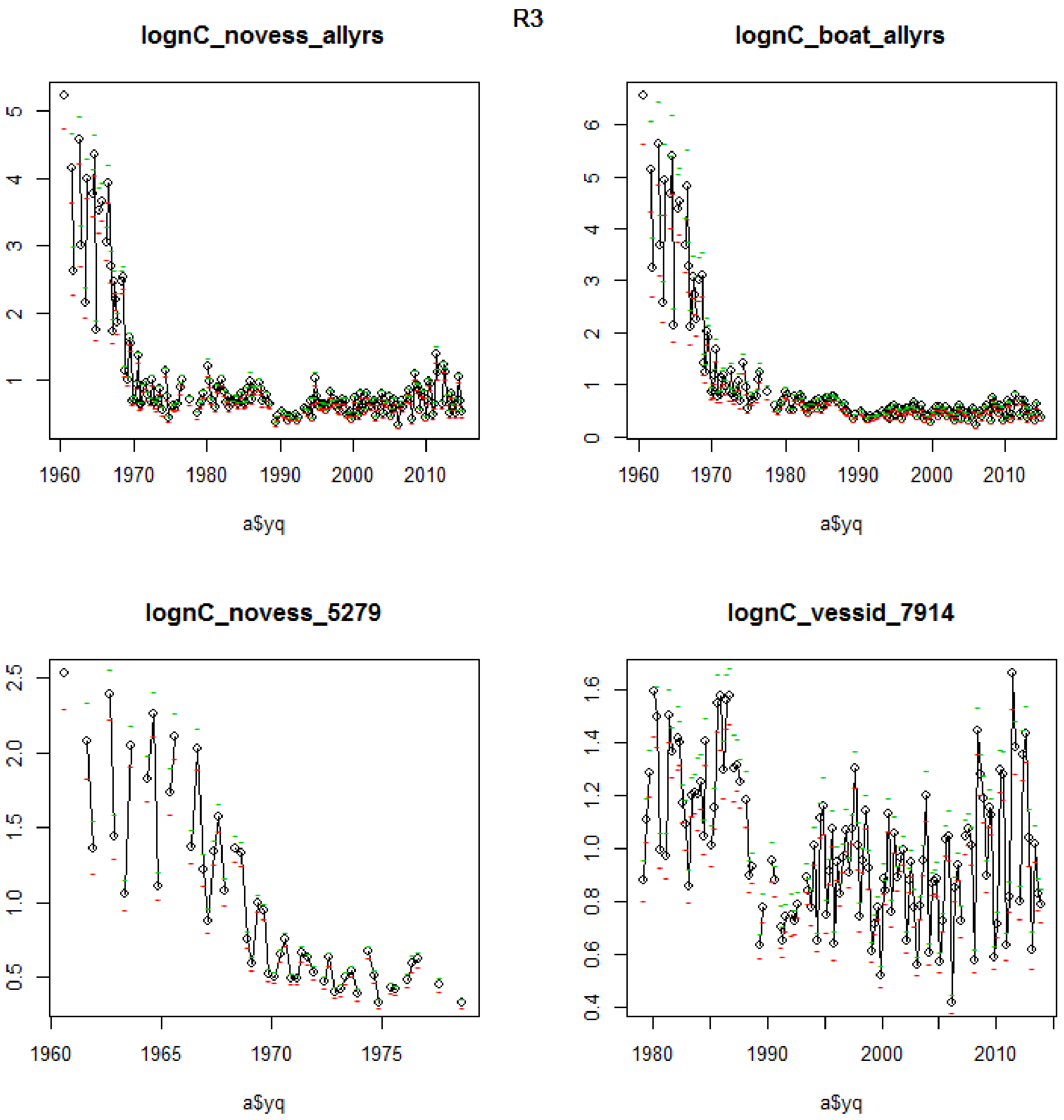

Figure 27: Estimated CPUE series for region 3 of the A3 regional structure, including time series for all years (top) both with (right) and without (left) vessel effects, and time series for 1952-79 without vessel effects, and 1979-2014 with vessel effects.

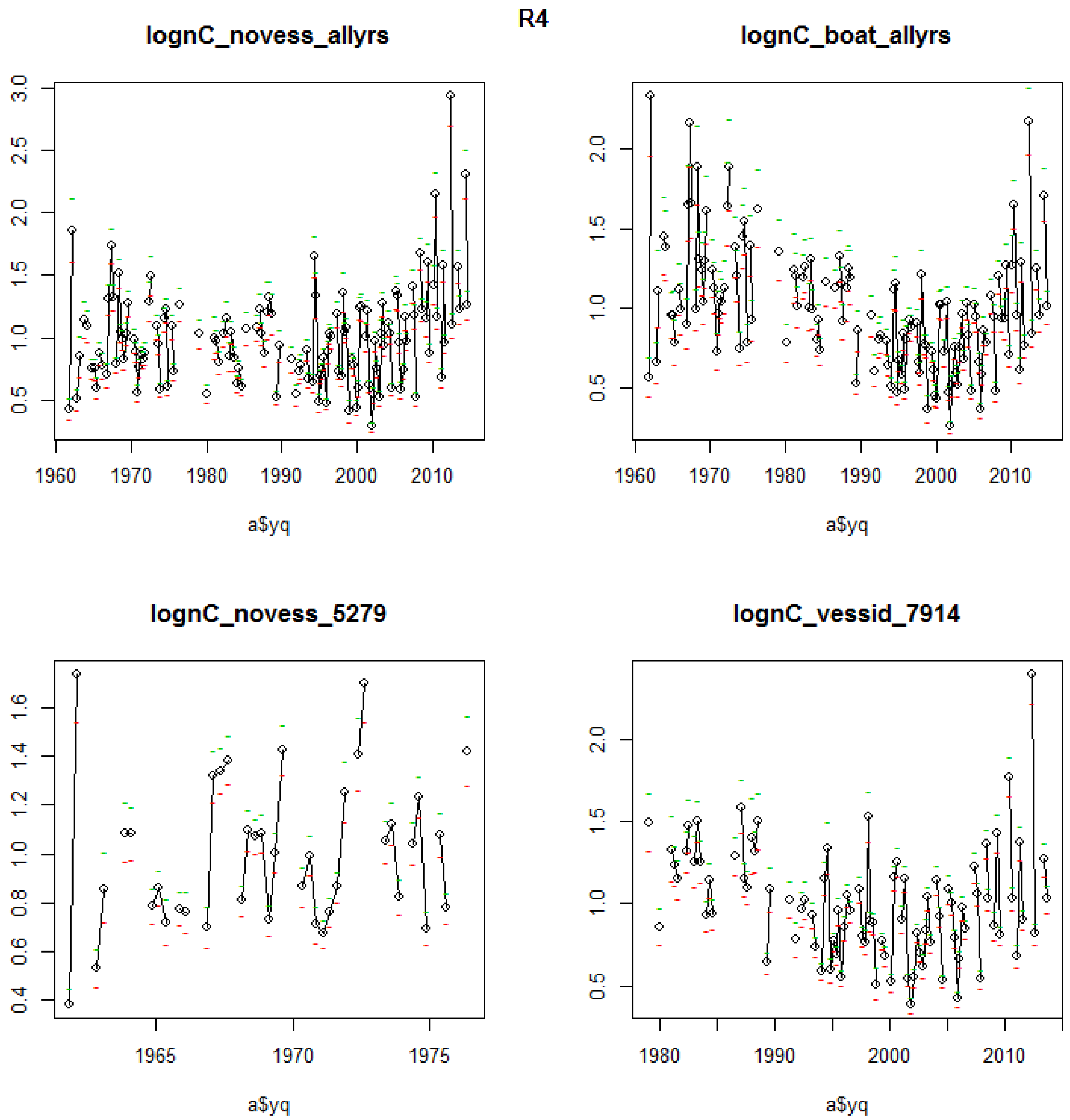

Figure 28: Estimated CPUE series for region 4 of the A3 regional structure, including time series for all years (top) both with (right) and without (left) vessel effects, and time series for 1952-79 without vessel effects, and 1979-2014 with vessel effects.

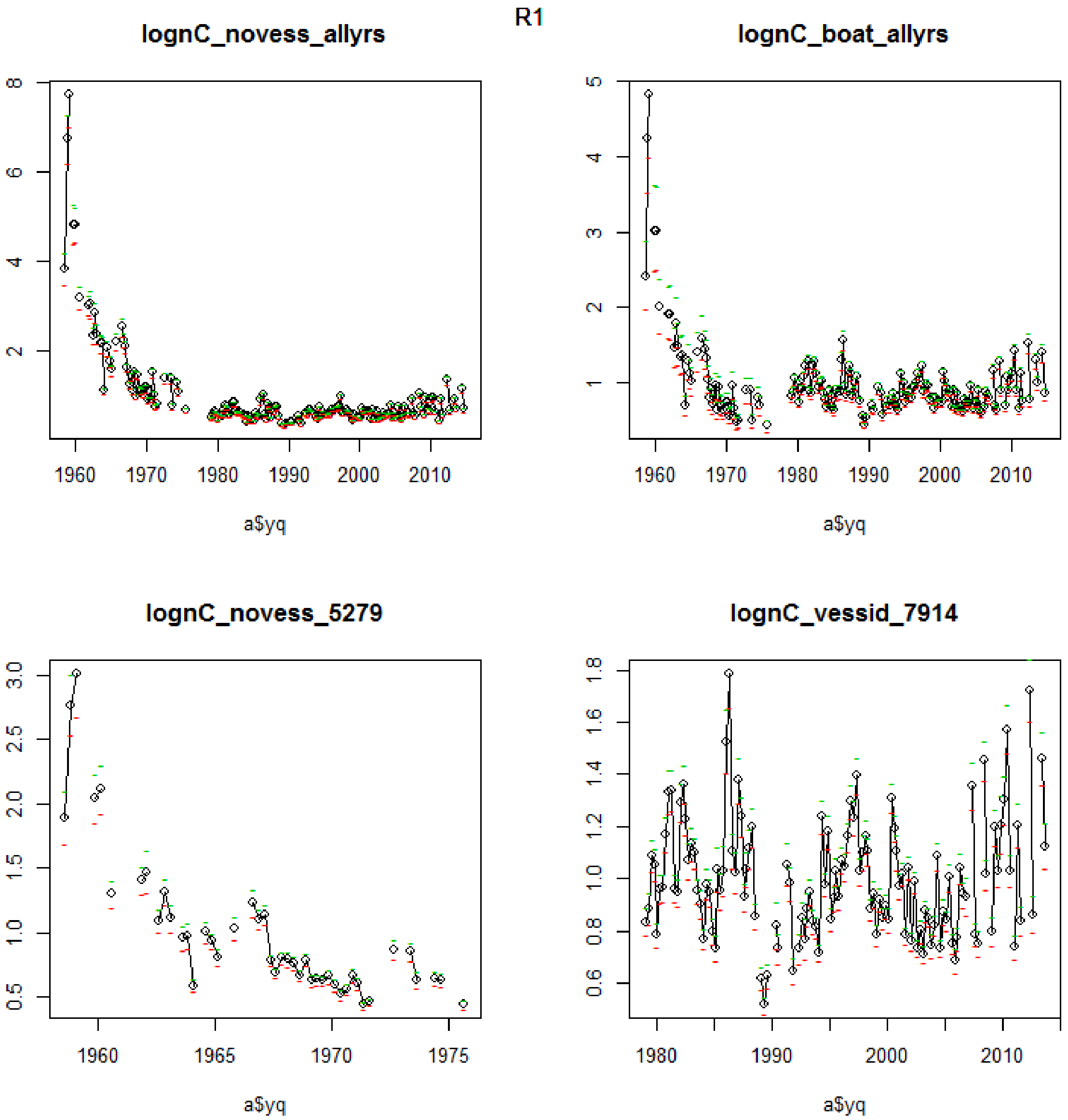

Figure 29: Estimated CPUE series for the single region of the A5 regional structure, including time series for all years (top) both with (right) and without (left) vessel effects, and time series for 1952-79 without vessel effects, and 1979-2014 with vessel effects.

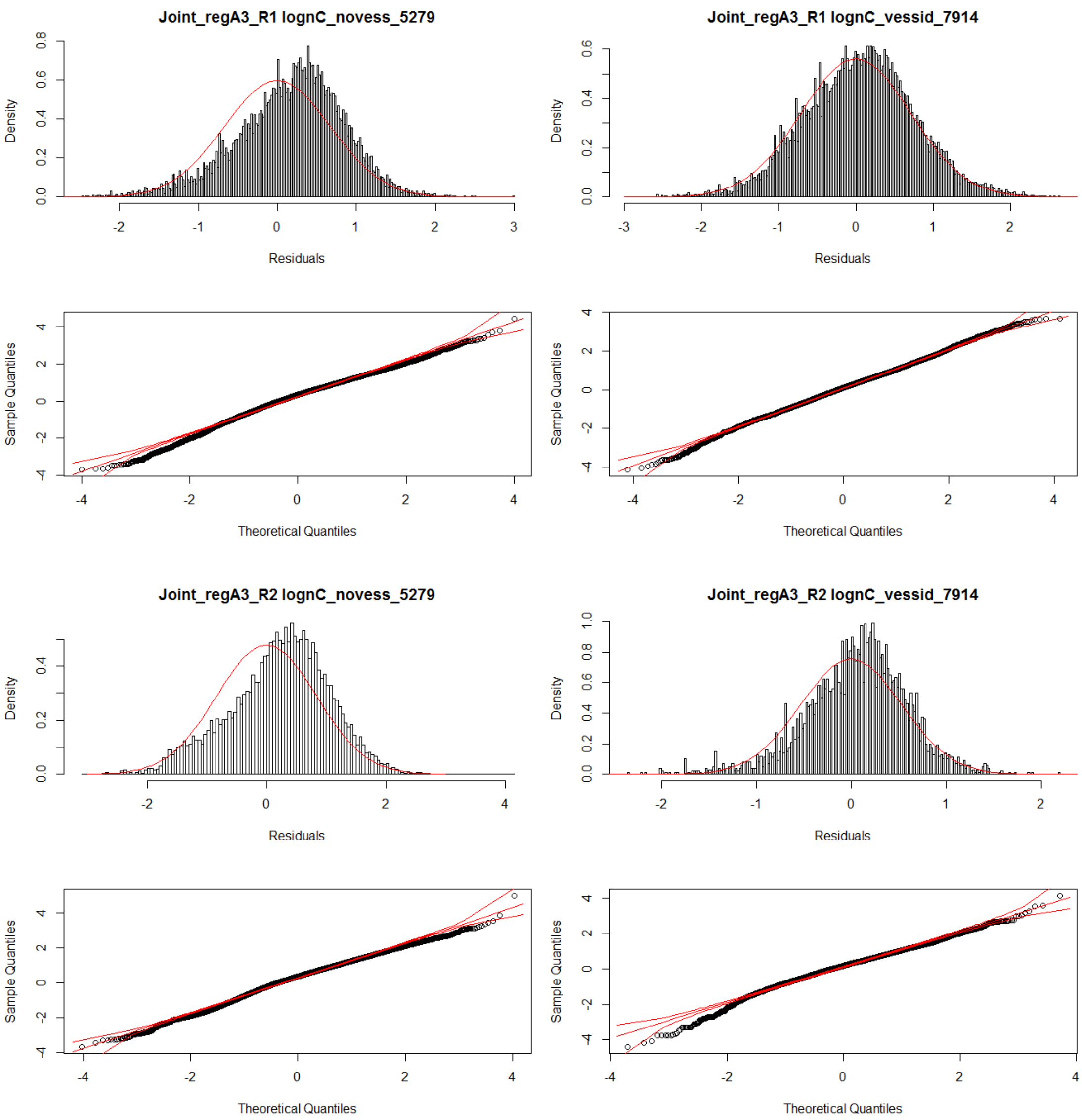

Figure 30: Diagnostics plots for lognormal constant models in regions 1 and 2 of the A3 regional structure, for 1952-79 without vessel effects (left) and for 1979-2014 with vessel effects (right).

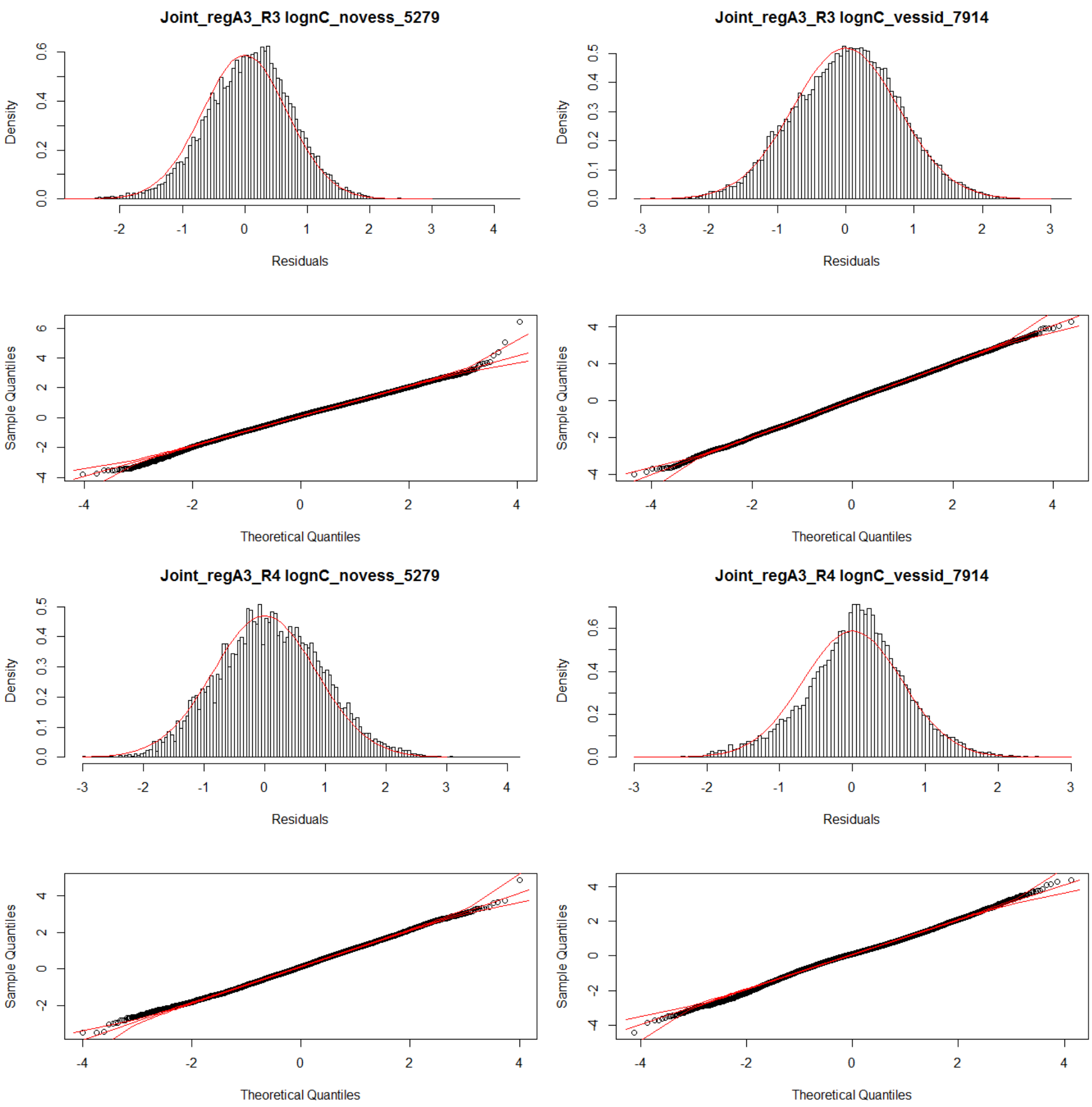

Figure 31: Diagnostics plots for lognormal constant models in regions 3 and 4 of the A3 regional structure, for1952-79 without vessel effects (left) and for 1979-2014 with vessel effects (right).

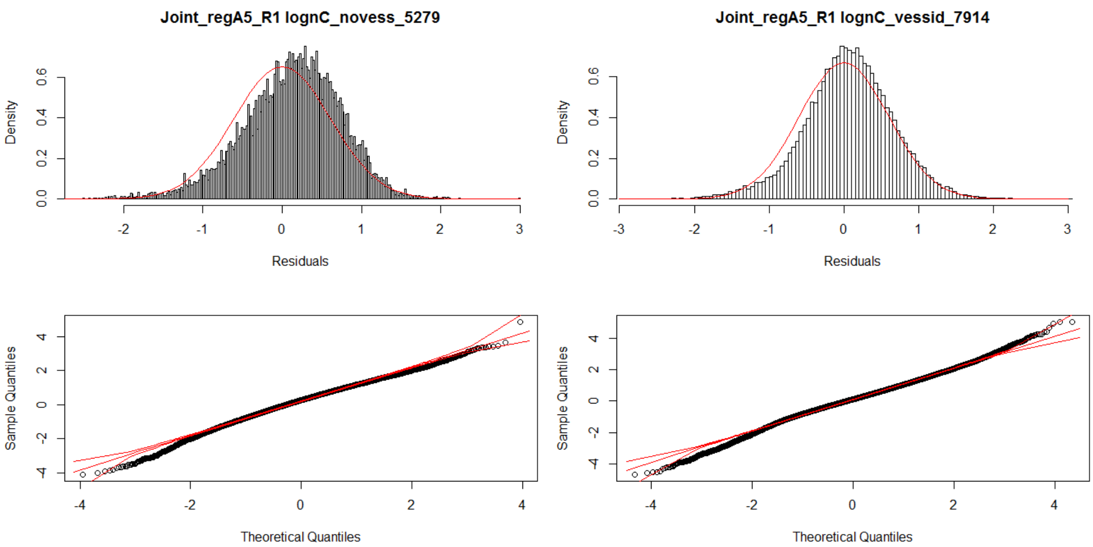

Figure 32: Diagnostics plots for lognormal constant models in the single region of the A5 regional structure, for1952-79 without vessel effects (left) and for 1979-2014 with vessel effects (right).