INTER-AMERICAN TROPICAL TUNA COMMISSION

WORKSHOP TO IMPROVE THE LONGLINE INDICES OF ABUNDANCE OF BIGEYE AND YELLOWFIN TUNAS IN THE EASTERN PACIFIC OCEAN

La Jolla, California (USA)

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REPORT OF THE MEETING

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EXECUTIVE SUMMARY

1. Longline indices of abundance are the primary abundance indices for the yellowfin and bigeye tuna assessments. The indices were based on catch and effort from the Japanese fleet, which was once the main longline fleet in the EPO, but now is a minor component.
2. The workshop was organized to follow up on a SAC recommendation that the major longline fleets "1) share the operational-level data with the IATTC through an appropriate way; and/or 2) collaborate with IATTC staff and other CPCs with large-scale longline fleets to develop improved abundance indices." The staff executed Project H1.b "Improve indices of abundance based on longline CPUE data" which included not only this workshop, but also research work. Collaboration with national scientists from the main longline fleets, Japan, Korean, Chinese Taipei and China, was possible through a series of MoUs, which also facilitated the access to operational level data by the staff on a temporary basis.
3. A review of the operational-level CPUE data and national regulations relevant to their industrial longline fisheries was presented.
4. The staff presented a comparison of the CPUE and hooks-between-floats (HBF) for Japan, Korea, Chinese Taipei and China in the area and for the years where the fleets overlap (Area 1: 10°N and 10°S and 110°W and 150°W). Japan has shown a steady decrease in the operations in the EPO since the mid 1990's while China increased their operations mainly after 2010. Korea and Chinese Taipei's effort had stayed relatively constant in recent years. The HBF transitioned from low values (5-6) in the 1980's to high values (16-17) to the 2000's, in the Japanese fleet, while Korea followed a similar pattern slightly later. The CPUE for the main species showed similar patterns in space and time for all fleets, except for China, which showed high albacore tuna CPUE and zero bigeye CPUE from 0 to 10°N, while other fleets showed the opposite pattern. Concerns over species identification were discussed.
5. Trends in nominal CPUE for Japan and Korea showed discrepancies when compared over wide spatial scales and remarkable similarities when the comparisons were done for restricted areas, indicating the need for detailed data with fine-scale spatial resolution when comparing fleets.
6. Experiences from other oceans and from the Western and Central Pacific Ocean showed that indices from operational-level data are better than indices based on aggregated data because analysts can check the data for inconsistencies and errors, analyses can take more factors into account, and target changes can be accounted for in the standardization. Long-time availability of the data for scientific analysis in the WCPFC allowed development of research relevant for CPUE standardization such as development of fleet-combined indices, use of spatio-temporal models and comparison of use of local versus regional covariates in the standardization. In ICCAT and IOTC the operational level data was analysed over one-week workshops.
7. GLM, GAMM and spatiotemporal models have been used to standardize CPUE for deriving indices of abundance for tuna stocks (in R libraries *Cpue.rfmo* and *VAST*). Spatiotemporal models estimate the spatial and spatiotemporal correlation in CPUE, which can be equal in all directions or present anisotropy but is constant in space.
8. When combining multiple fleets there should be a focus on diagnostics.
9. Addressing the size-composition associated with the index is also a key part the development of an index. The common assumption is simply to use the catch size composition. However, there is strong spatial variation in size of tropical tunas across the Pacific Ocean, and within the current assessment regions. It was suggested that size composition data should be weighted by the index of abundance (CPUE) to represent the population size composition, or it should be included in the standardization. Preliminary results of adding size composition to the spatiotemporal models were presented.
10. Comparisons of length frequencies obtained by the crew and the observers for the Japanese fleet showed large variation.

11. Preliminary results of a simulation study on addressing effects of preferential sampling indicated that spatiotemporal models were better at addressing the issue.
12. Addressing targeting effect is a key issue when using fisheries data to construct indices of abundance. A review of international regulations in the Pacific Ocean for longline fisheries that may cause changes in fish target was presented.
13. Cluster methods have been used to detect changes in target and included by either dropping some clusters from the standardization model or adding cluster as a covariate. Preliminary comparisons of methods for estimating targeting outside of the CPUE standardization model were shown, including a new hybrid method.
14. Preliminary results on estimation of targeting effects in the EPO using Hoyle's cluster method for Japan and Korea in four areas of the EPO were shown. The results showed that all clusters have about the same average CPUE for bigeye tuna, this could indicate that changes in fishing strategies to catch other species (e.g., secondary targets) may not strongly impact the ability to catch BET. The cluster analysis was also done using the Pacific-wide multiple fleets dataset held by SPC. Distinct albacore and swordfish clusters were detected, but bigeye and yellowfin tuna were difficult to differentiate in clusters.
15. An overview of strategies for estimating targeting and fishing strategies effects was presented. First, the targeting should be identified using one of these three approaches: fishing strategies / métiers (e.g.) (Longline vs trawl; Longline for oilfish vs albacore (Indian Ocean); Longline for bigeye/yellowfin vs yellowfin/bigeye vs bigeye/swordfish), Gear-based or data-based indicators (HBF, number of hooks, location, season, vessel, Lightsticks, set time, bait type), species composition (including bycatch species). If using species composition, three strategies could be used: 1. Identify targeting first, then fit CPUE model, 2. Fit CPUE model first, then identify targeting from residuals, 3. Estimate targeting and other covariates simultaneously. The later approach was attempted for the Japanese data on a 1°latitude by 1°longitude scale for Area 1: 10°N and 10°S and 110°W and 150°W, by adding vessel effects to the spatiotemporal model, followed by adding proportion of bigeye, yellowfin, and swordfish as catchability covariates. A shift from vessels with low efficiency to vessels with high efficiency was detected in the mid-1990, as low efficiency vessels left the EPO during that period, and including vessel effect changed the results, while including the covariate effects did not.
16. Spatiotemporal models with the Korean data for the same area showed a smaller decline for bigeye than the Japanese index did. The difference may be due to fine spatial scale variation and different spatial distributions of the two fleets.
17. Abundance indices for bigeye tuna using three fleets separately and jointly were derived using the GLM/GAM approach. The Chinese data was not used due to the short time series. The joint index of abundance included vessel effects and clusters to account for changes in targets (but without HBF effects). The Chinese Taipei data consists of the shortest and most variable time series. The Japanese and Korean indices presented opposite trends in their ratio to the combined index. The index done using spatio-temporal model and the joint GLM have two marked differences: at the beginning of the period the spatio-temporal model estimated larger abundance than the GLM, at the end of the period the pattern reversed.
18. Future work should continue investigating whether data from different fleets should be combined, investigate targeting effects, and continue comparisons between length data measured by crew or observer, and expand to other species (yellowfin tuna).
19. A list of recommendations to be considered when collecting and treating longline CPUE data to produce indices of abundance in general and for the EPO was made during the workshop and endorsed by all the participants (Appendix A).

1. BACKGROUND

The ninth meeting of the Scientific Advisory Committee (SAC) made the following recommendations to the Commission (Appendix 1 in SAC-09-RPT, IATTC-93-3) regarding the longline abundance indices: "The SAC notes that the primary abundance indices for the yellowfin and bigeye tuna assessments are currently based on data from the Japanese longline fleet. However, Japanese longline effort in the EPO has decreased substantially, from about 101 million hooks in 2003 to about 31 million hooks in 2016 and is now a minor component (<20%) of reported longline effort in the EPO. Therefore, to improve the abundance indices, the SAC recommended that CPCs with large scale longline fleets: 1) share the operational-level data with the IATTC through an appropriate way; and/or 2) collaborate with IATTC staff and other CPCs with large-scale longline fleets to develop improved abundance indices."

In response, the staff prepared the Project H1.b "Improve indices of abundance based on longline CPUE data" (IATTC-93-06c) with the following objectives:

- improve the yellowfin and bigeye indices of relative abundance from longline data;
- determine methods to identify targeting in longline fisheries;
- develop spatiotemporal models for creating indices of relative abundance from longline data;
- develop appropriate longline length composition data for the index of abundance and for the catch.

The project listed a series of activities in its workplan, of which only a one-week workshop was funded by the commission. This report encompasses the workshop (Appendices A and B) as well as preparatory work.

The workshop continues previous work done within and outside the IATTC:

- CAPAM workshop on the development of spatiotemporal models of fishery catch-per-unit-effort data to derive indices of relative abundance http://www.capamresearch.org/Spatio-Temporal-Modelling-Mini-Workshop;
- Staff publications on spatiotemporal models (SAC-09-09, Xu et al 2019[1] , Maunder et al 2020[2], Thorson et al 2020[3]);

Staff collaboration with Japanese scientists (*e.g.* SAC-08-Pres, SAC-04-05b, Satoh et al 2021[4]);
collaborative work in other t-RFMO to estimate indices of abundance from combined operational level CPUE data sets (*e.g.* Hoyle *et al.* 2018a,b, McKechnie *et al.* 2015 WCPFC-SC11-2015/SA-WP-02).

The workshop goals were:

- **data:** review and revise longline catch, effort and size data with spatial information for the main longline CPCs;
- **analyses:**
    - Improve the indices of relative abundance for yellowfin and bigeye tuna based on longline catch and effort data;
    - determine methods to identify targeting in longline fisheries;
    - develop spatio-temporal models;

[1] https://doi.org/10.1016/j.fishres.2019.01.013

[2] https://doi.org/10.1016/j.fishres.2020.105594

[3] https://doi.org/10.1016/j.fishres.2020.105611

[4] https://doi.org/10.1016/j.fishres.2021.106065

- develop appropriate longline length composition data for the index of abundance and for the catch.

2. PREPARATORY WORK

Considerable work was undertaken in preparation for the workshop which included:

- Signature of *Memorandum of Understanding* with the main distant water fleets CPCs to make the operational level data available for the staff and external collaborator (Dr. Simon Hoyle) (Table 1), as well as 1 by 1 – month data (C/E and size composition) from Japan (20/12/2018 – 17/05/2019)

Table 1. Availability of the operational level data for analyses

CPC	CPUE data	Size composition data	Spatial range
Korea	Nov 08 2018 – May 17 2019	Nov 08 2018 – May 17 2019	Pacific Ocean
Chinese Taipei	Dez 27 2018 – May 17 2019		Pacific Ocean
China	Jan 20 2019 – May 17 2019		Eastern Pacific Ocean
Japan	Jan 21 2019 – Fev 15 2019	Jan 21 2019 – Fev 15 2019	Pacific Ocean

- Visit of CPCs scientists to collaborate with the staff on analyses: Dr. Sung Il Lee (Korea, 8/11/2018 – 28/11/2018), Dr. Keisuke Satoh (Japan, 21/01/2019-16/02/2019)
- Visit of external collaboration Dr. Simon Hoyle (28/01/2019 – 15/02/2019), with partial support from the International Seafood Sustainability Foundation.

3. LONGLINE-BASED INDICES

3.1 GENERAL ISSUES WHEN USING CPUE FOR INDICES OF ABUNDANCE

Mark Maunder presented a key-note talk "CPUE as an index of relative abundance: the issues" (link to the talk here) . In stock assessment an index of abundance is needed to estimate depletion level and absolute abundance in combination with a population dynamics model that adjust for recruitment, growth and natural mortality. Catch per unit of effort is needed when assessing many stocks because no surveys or tagging studies area available as indices of abundance.

When using CPUE, some points to be mindful are:

- precision;
- sampling error;
- (random) process error;
- model misspecification related to the index.

The assumptions typically done when using CPUE as indices of abundance are:

- CPUE is proportional to abundance;
- catchability does not change systematically over time;
- the proportion of the population (size, sex, …) represented by the CPUE is known, or can be estimated, and does not change systematically over time.

Those assumptions may be violated in many ways, which can cause problems. The violation of the assumptions needs to be investigated and addressed in orders to retain the ability to do an assessment of the population.

3.2 LONGLINE-BASED INDICES USED IN THE 2018 ASSESSMENT

Carolina Minte-Vera presented the talk "Current indices of relative abundance for bigeye and yellowfin in the EPO from standardized longline data, and their potential problems" (link to the presentation here) The main characteristics of the indices of relative abundance from standardized longline data, used in the 2018 bigeye (SAC-09-05) and yellowfin (SAC-09-06) in the EPO area:

- The data used are Japanese catch in number and effort in numbers of hooks by hooks per basket category by 5-degree cell – month from 1975 to 2017 (see IATTC bulletins *e.g.* Matsumoto and Bayliff 2008 for description of the Japanese longline fleet in the IATTC).
- The methodology is a delta-lognormal general linear model in which the explanatory variables are latitude (5°) as factor, longitude (5 °) as factor, hooks between floats (HBF) as factor, and quarter-year as factor (Hoyle and Maunder 2006 SAR-7-07).
- The longline-based indices of abundance had strong weight in both the 2018 assessments of bigeye tuna (CV fixed at 0.15) and yellowfin tuna (CV fixed at 0.20).

The fishing depth of the gear is related to the number of hooks per basket. When there are more hooks between a float, some of the hooks will fish much deeper than when less hooks between floats (HBF) are used. However, other factors such as main line material, hook type, main line length, currents, and setting speed also impact the fishing depth of the longline hooks but were not used on those indices. The catch rate increased with HBF for bigeye, as expected given that bigeye forage at depth, and average hook depth tends to increase with HBF. Catch rate of yellowfin declined with HBF (Hoyle and Maunder 2006).

The potential problems with those indices are:

- retraction of the effort of the Japanese fleets: smaller sample sizes, non-random distribution of the fleet due to "preferential sampling";
- the increase uncertainty in the index not reflected in the stock assessment, the uncertainty is underestimated in the assessment model;
- increase in vessel efficiency not considered;
- for yellowfin tuna, mismatch between the longline-based index the purse-seine based ones;
- length composition data is not standardized to represent the indices of abundance;
- possible changes in target species: recent years an increased emphasis in swordfish and albacore in certain areas of the EPO;
- only HBF is used as gear configuration in the standardization, HBF changed over time and maybe confounded with changes over time of other variables.

Despite the potential problems, opportunities to improve the indices were detected:

- new stock assessment for bigeye tuna: will revise the spatial definitions;
- potential inclusion of data for other fleets in the standardization;
- use of spatial- temporal models; (iv) analyze operational level data

4. REVIEW OF OPERATIONAL-LEVEL CPUE DATA AND NATIONAL REGULATIONS

4.1. JAPAN

Keisuke Satoh presented "Review of operational level CPUE data and national regulations for longline in the Pacific Ocean – JAPAN" (link to the presentation here) with a description of the operational level data for the Japanese longline fleet. The operational level data for the Japanese longline fleet is available from logbook data since 1952 in the Pacific Ocean.

The longline catch and effort database includes seven formats of logbooks: 1952-1957, (ii) 1958-1965, (iii)

1966, (iv) 1967-1970, (v) 1971-1978, (vi) 1979-1993, (vii) from 1994 on. Some data fields where introduced in different dates: (i) after 1971 - type of vessel (commercial and training); (ii) after 1975 – hooks between float (HBF); (iii) after 1979 – call sign, license number, vessel tonnage; (iv) after 1994 – type of target (swordfish, shark and tuna), main and branch line materials (nylon, other). After November 2016 to current, the system allows for a 10-day logbook report available by email, but the main logbook is still on paper.

Availability of information of catch by species is as follows: (i) Tuna species and swordfish are available for whole period since 1952, (ii) 1958-1965; marlin species are not available, (iii) Before 1993; sharks are not reported by species, (iv) After 1994; blue shark, salmon shark (porbeagle), shortfin mako and whitetip shark are recorded by species, format for other species catch are available (but not fully recorded). The recorded species are: albacore (ALB) catch in number (weight is available after 1994), bigeye (BET), yellowfin (YFT), swordfish (SWO), striped marlin *Kajikia audax* (WHM), blue marlin *Makaira mazara* (BUM), black marlin *Istiompax indica* (BLM), "saispear" - mix of sailfish *Istiophorus platypterus* and shortbill spearfish *Tetrapturus angustirostris,* sharks - mix of shark species (after 1994 some shark species separately recorded), sailfish *Istiophorus platypterus* (SAI), and shortbill spearfish *Tetrapturus angustirostris* (SPF). There are no limitations on the number of species reported, but the "other species" filed is frequently not filled adequately.

The information about unique vessel identifiers before 1979 is also being recovered. The bait type information (saury, squid, live bait and other) was only available until 1993, only for large vessels. The baits used after 1994 differ from those used before 1994. After 1994, the baits are often mix squid and fish bait. Bait type will be a field available in the logbooks in the future. The gear configuration fields currently available are: HBF, material of the main line, material of the branch line, length of the branch line (m), and length of the float line (m).

The coverage of the logbooks (operational level data) is nearly 100%, it needs to be raised to the total (value submitted to the tRFMOs). The information on the total number of operations by sub-areas and month provided by the fishermen's association (Federation of Japan Tuna Fisheries Co-operative Association) had been used to raise the logbook data to the total catch. Since 2008, Vessel Monitoring System (VMS) information has been utilized to raise the logbook data. The position of the set is recorded as shown in Figure 1.

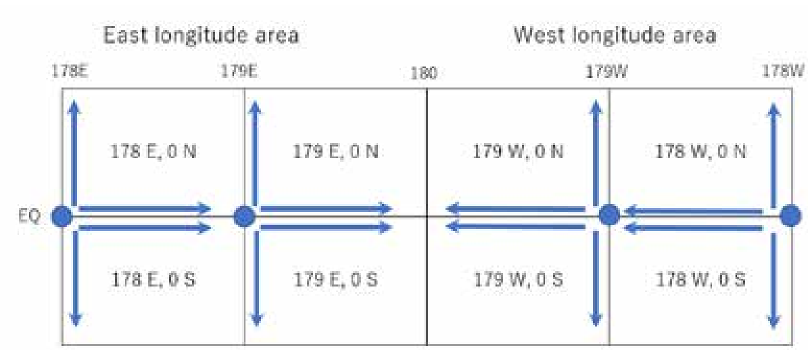


FIGURE 1. Recorded position in the Japanese operational level data available for the Pacific Ocean. The position of the set is rounded to the corner of the 1° by 1° cell, according to the hemisphere (N,S or E,W) as shown in the figure.

The Japanese longline vessels are classified into three categories: (i) coastal, those under 19 GRT (logbook is available only after 1994); (ii) offshore: under 120 GRT; (iii) distant: over 120 GRT. The offshore vessels where active in the EPO in the 1980's, but not after. The distant water vessels where active in the EPO in the 1980's to now. The highest number of vessels of the fleet fishing in the EPO was in 1991 (about 450 vessels, about a quarter of those fished also in the western Pacific Ocean, and about 10% fished also in other oceans), corresponding to the period with the largest effort (Figure 2). The number of vessels declined since then until 2007. In 1999 there was a domestic measure aiming at reducing the number of longline vessels to about 20% in all oceans. Another similar measure was taken by Japan in 2008, but did not affect the EPO, on the opposite, a few vessels from other oceans came to the EPO. From 2006 about 2008, the number of vessels was stable and decreased again in 2013. The IATTC catch quota for Japan is not implemented as vessel limit.

The catches of swordfish increased in 1994, while the HBF also increased, which is counterintuitive as swordfish are generally caught in shallowed hooks (less HBF). The increase in bycatch species also indicates that the fishing is being done at shallower depths. It is unclear what the reasons are, but this increase in the catches of swordfish when using more HBF indicates that some changes might have occurred in the fisheries.

Two interviews were done with captains of the Japanese vessels and both mention that their main target is bigeye tuna, and they may have secondary targets such as yellowfin tuna, swordfish or albacore. There is field "target" in the Japanese logbook, but it is not clear if it is filled before or after fishing (that is after seeing what was caught).

Keisuke Satoh did a second presentation entitled "Review of size composition data from longline in the Pacific Ocean, Japan" (link to the presentation here) were details of the collection of those data and patterns in size composition were shown. There are four types of length data: weight and length, for commercial vessel and training vessel. Finer spatial resolution (1x1) length data from commercial vessel is basically available after 1986, whereas for previous years is available in 10X20, 2X10 and 5X5 resolution. In the 1970's and 1990's most of the size data available were from training vessels, which usually have smaller size than the commercial vessels (SAC-07-03d). Weight data in predominant before 1989 and it was converted into length data before reporting to the IATTC. In 2016, the data was re-submitted in the original measurement units.

Similar changes in rounding practices reported by Hoyle et al (2017, IOTC-2017-WPTT19-35), for the Indian Ocean (Figure 15 in IOTC-2017-WPTT19-35) were found for the Eastern Pacific Ocean. The unit of 7 (2 cm) is common size unit before 1988, after that the unit 6 (1 cm) is usually applied. Odd numbers for the size classes are common before 1988. Thus, in case the size class is odd number in length and the unit is 7 (2 cm) and the year us before 1988, the size class could be center value instead of upper limit, however there is no evidence to support this hypothesis at this stage

Rounding of length measures: There has been two change points in the rounding of length data (rounding up, rounding down, rounding up). This issue should be analyzed, as may account for differences up to 2cm The size measurements were traditionally taken by the crew, after 2012 observers started collecting the size measurements. The observed coverage is close to only 5%. But the crew now reports both the catch in numbers and total weight.

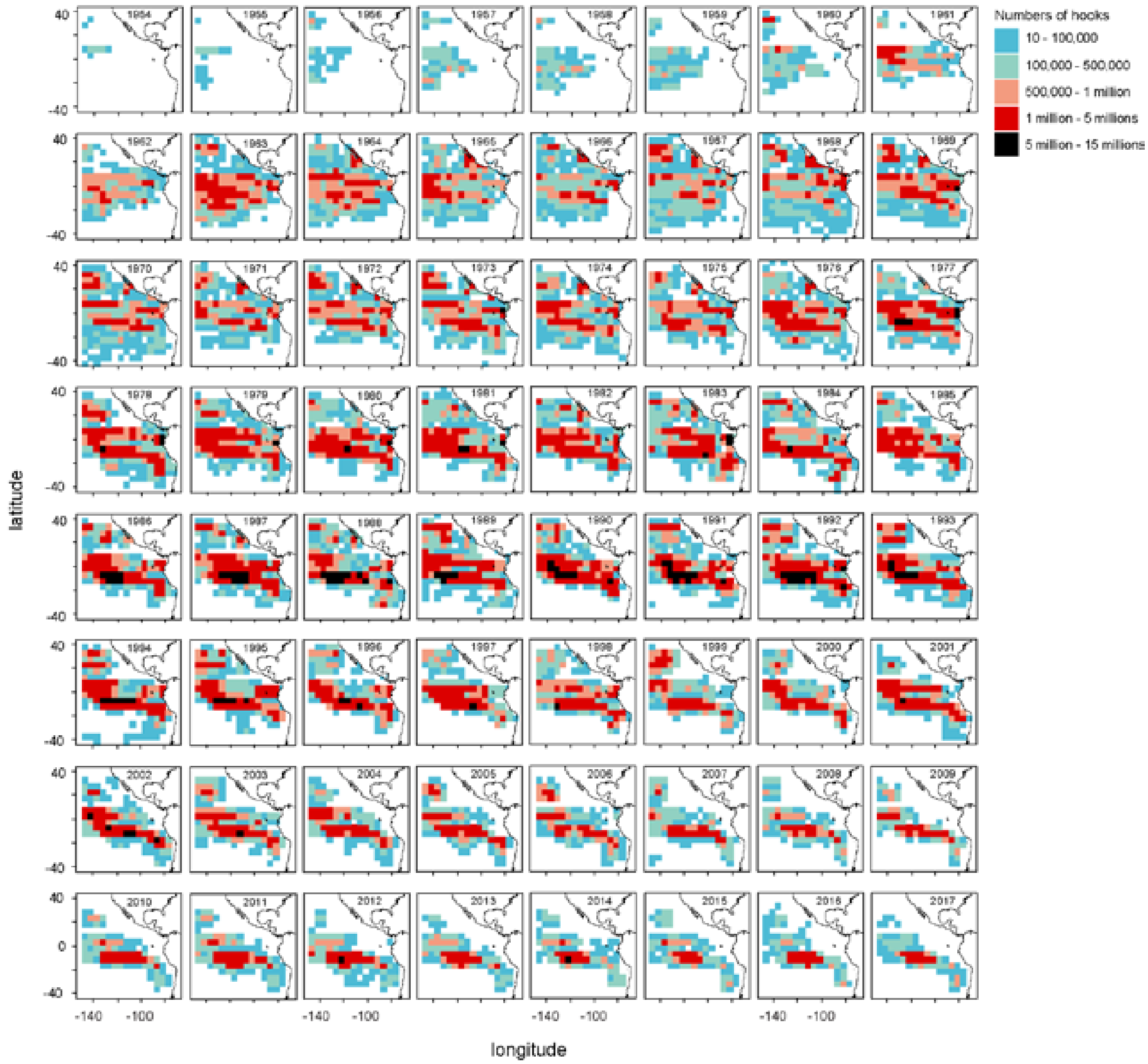


FIGURE 2. Effort distribution of the Japanese fleet in the eastern Pacific Ocean from 1954 to 2017 (Source: IATTC public domain data).

Carolina Minte-Vera presented an exploratory data analysis of the Japanese size frequency data for YFT and BET. A link to the presentation is here.

Discussion:

- Before comparison of commercial and training, there should be a standardization by location, some of the differences may be due to different locations of operation of the commercial versus the training vessels.
- There was a change in rounding (up vs down) 1970 and 1988-89.
- How are the measurement taken?
    - Observers use calipers, so did fishermen.
    - No fishermen training how to measure. But there are paper instructions.

- What are the effect of regulations and changes in data collection protocol (e.g. size data being measured by observers instead of crew members)?
    - Coupled catch and effort and size-composition
- What are effects of the measurements be taken by the observers versus the vessel crew?

Recommendation:

- Compare length measurements taken by crew versus observers

A preliminary analysis was done in the workshop. See item 7.3 for the preliminary results.

4.2 KOREA

Sung Il Lee presented a description of the Korean data collection system for the longline fleet (link to presentation here, Figure 3), as described below. Data reporting and collection system in Korea has put in place since 1970s. In the past, the paper logbook was submitted to the National Institute of Fisheries Science (NIFS) within 30 days (home-based) or 60 days (foreign based) after completion of their operations. In case of this practice, it was impossible not only to meet the timely submission of data but also to have a chance to review the data. Hence, the data reporting and collection system has been changed to improve the quantity and the quality of data. At present, fishermen report their fishing information every day through the Electronic Reporting System, and the NIFS reviews the data in real time. In addition, the data coverage has been achieved 100% since 2012.

The operational level data for the Korean tuna longline fleet operating in the Pacific Ocean is available from logbook data since 1971. In the early 1970's many Korean tuna longline vessels were operating out of Samoa. Although the vessels carried logbooks, that information is not in the Korea National database. The most reliable data start after 1973. The coverage has been more than 60% after 1985, except for 2005 and 2008, when it was apparently lower (Figure E1.3). Until November 2012, fishermen used paper logbook. In December 2012 logbooks in electronic format (excel) were implemented, which included information on discard/release ecologically related species (sharks, sea birds, sea turtles, etc.). In September 2015, the logbook system was upgraded to the Electronic Reporting System, which allows for real-time reporting and data-reviewing by the National Institute of Fisheries Science (NIFS). Also, the information is cross-checked with data from Vessel monitoring system (VMS) and Catch Documentation Scheme (CDS). In the past, many fishers did not record sets with zero catches in the logbooks. The information is cross-checked with data of VMS (Vessel monitoring system) and CDS. The vessels unique identifiers are the "call signs", but among the past data there is also a unique code given by the NIFS staff to a vessel whose information has not been identified, which starts with a "Z". The same vessel could be given more than one "Z" if it operated in non-consecutive years. According to recent scientific observer records, is anecdotical reporting that some vessels use light-sticks. Currently the data reporting system do not have a field to record the use of light-stick. In recent years, the catch of swordfish has also increased, while the number of hooks between floats has increased.

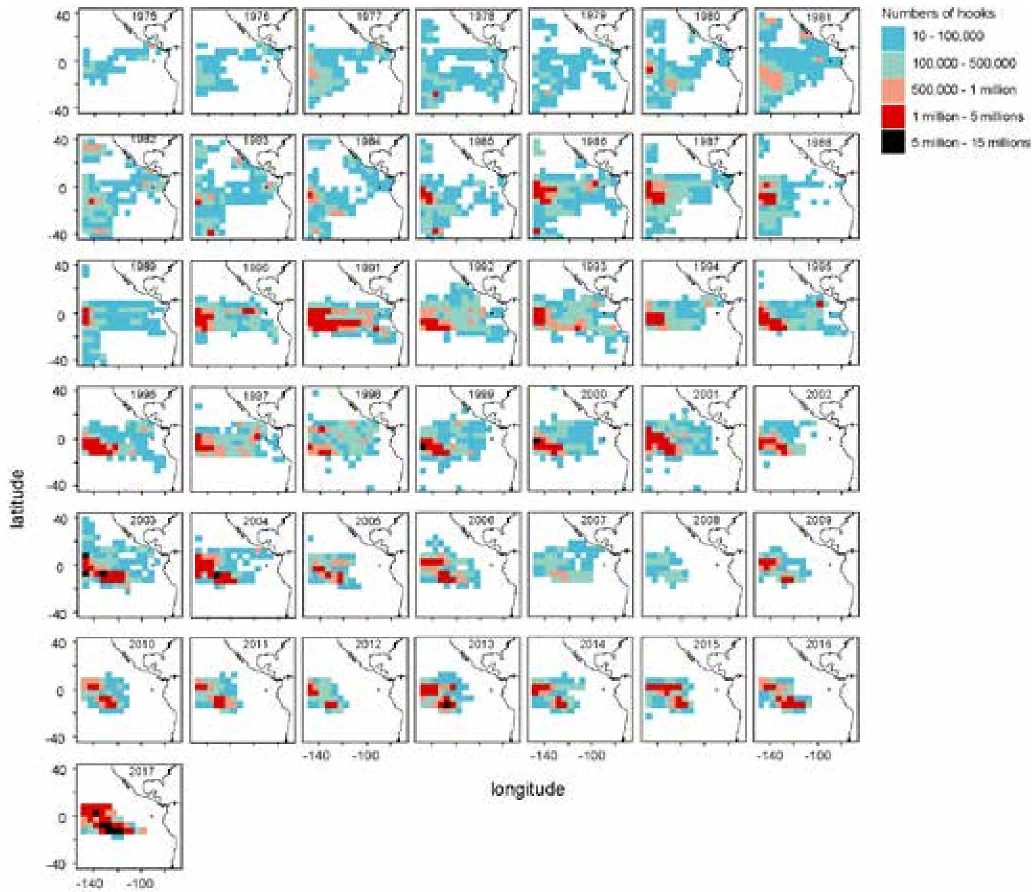


FIGURE 3. Effort distribution of the Korean fleet in the eastern Pacific Ocean from 1975 to 2017 (Source: IATTC public domain data).

Sung Il Lee did a second presentation describing the size-composition data available for Korea entitled "Review of size data from Korean longline fisheries in the Pacific Ocean". Size data has been collected on board fishing vessel by scientific observers and by fishermen. There are instructions for the fishermen on how to measure fish. Typically, one fish per ton of catch per species should be measured, which is bases on the guidance from the Indian Ocean Tuna Commission (IOTC). The data available for the collaborative work span from 2004 to 2017, and include fishing date and position, species, length, weight (round and processed weight) and sex, and is only collected by observers, as the data collected by fishermen was being checked

4.3 CHINA

Jiangfeng Zhu presented "Review of national regulation and data collection for longline in the Pacific Ocean-China". A link to the presentation is here.

The national legislation that regulates the distant water fisheries in China is the order no. 27 of the Ministry of Agriculture of 18 April 2003. This regulation is currently being revised. A mandatory logbook system for the tuna fisheries was implemented in 2008 (*Nongbanyu* -Decree 2008 no.44). In 2014, a mandatory vessel monitoring system was implemented for the distant water fleet (*Nongbanyu* -Decree 2014 no.58). The national observer program for the distant water fleet was implemented in 2016 (*Nongbanyu* -Decree 2016 no.72).

The National Data Centre for Distant-water Fisheries (NCFC) of China was established in 2015 and it is held at the Shanghai Ocean University. The goals of the center are to collect, compile, evaluate, store and analyze all the relevant data of China's distant-water fisheries for management and scientific research. The center oversees the logbook, observer and port sampling program and as well as other related research such as the exploratory fishing.

The longline logbook program is mandated by the Bureau of Fisheries of the Ministry of Agriculture and Rural Affairs. The program is managed by the NCFC. The China Overseas Fisheries Association does the distribution of the logbooks to the fishing companies. The fishing companies return the logbooks to the NCFC, which prepares reports to the government and to the industry. Current logbook system started to be implemented in January 1st, 2009.The logbooks were in paper, every tuna vessel had to return the previous-year logbook by 31st March. The time to enter the data was long and the quality of some data was low, for example some species were recorded in a group and not individually. An electronic version of the logbook system started to be implemented in 2015. The protocols and manuals used by the Western and Central Pacific Commission (WCPFC) were used. Detailed species identification instruction was distributed, which increased the quality of the information. There is encouragement to return the logbooks as EXCEL sheets by email. The catch in weight and number by species, day and set is recorded, as well as the position. There is a pre-written list of species, but there is also a field "other" for species that might not be in the list. Uncommon species are required to be recorded in paper-based logbooks before implementation of e-logbook. The location of the set is cross-checked with the VMS positions. All interactions (*e.g.* marine mammals) are required to be recorded on logbook, however mis-reporting or under-reporting may happen. There are about 600 vessels in the logbook database over the four years since the electronic version of the logbooks was implemented. The logbook coverage increases when the electronic version was implemented, from about 8-10% in 2011-2013 to about 40-50% in 2014-2017. It is not clear whether there are differences between the vessels that report the logbooks and those that do not report.

The NCFC also designed and oversees the on-board observer program, which also follows the protocols and manuals used by the WCPFC. The observers are trained in safety, conservation and management measures, species identification, length measurements, biological sampling, equipment and material preparation, form filling and reporting. After observers returned, they are required to make a presentation and submitted report and data (*i.e.* debriefing). The observers are assigned to the vessels randomly, also considering the feasibility to have an observer aboard.

The effort in the EPO has been increasing in recent years (Figure 4). There are large catches of yellowfin tuna around 10 N, but almost no catch of bigeye tuna. It is unclear if misidentification may be occurring.

China-does not ask fishermen to measure fish. They have data from observers.

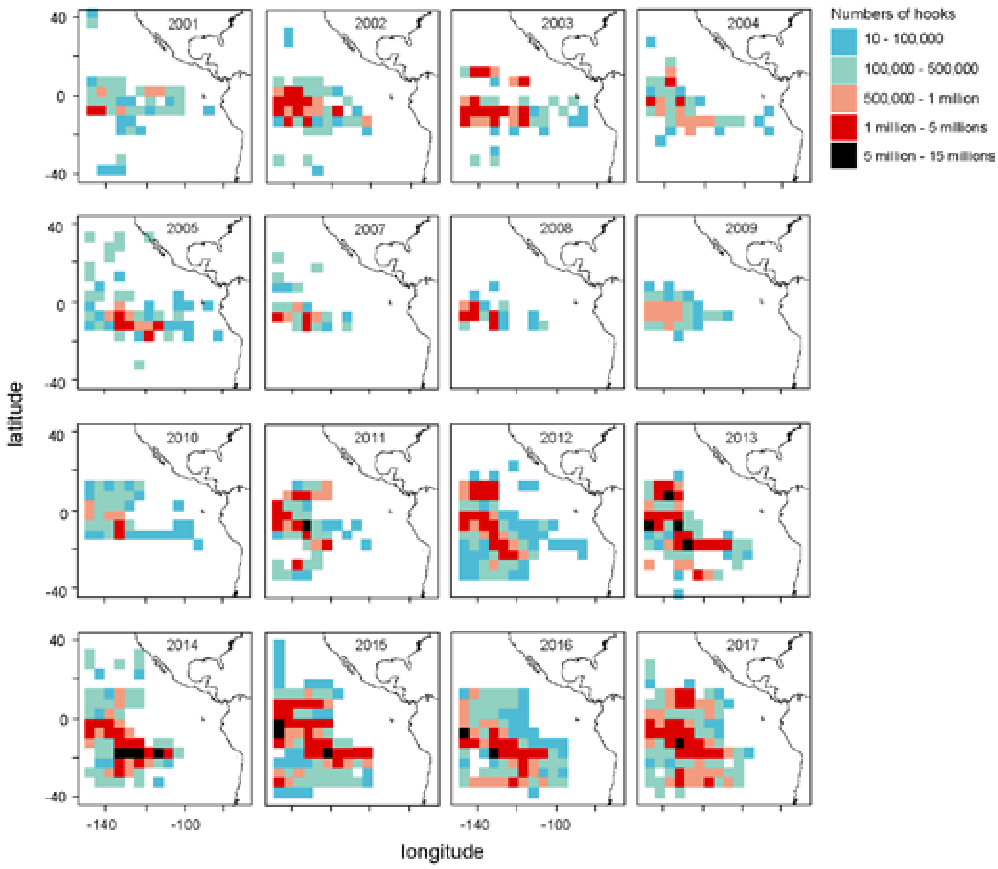


FIGURE 4. Effort distribution of the Chinese fleet in the eastern Pacific Ocean from 2001 to 2017 (Source: IATTC public domain data).

Discussion

- Recording of interactions (e.g. with marine mammal) should be recorded but misreporting or under-reporting may occur.

4.4 CHINESE TAIPEI

Sheng-Ping Wang presented a description of the operational level data for the Chinese Taipei longline fleet. A link to the presentation is here.

The operational level time series for Chinese Taipei for the EPO spans from 1964 to 2017. Two categories of longliners operate in the EPO: large- (gross registered tonnage – GRT > 100) and small- (GRT < 100) tuna longliners. The large vessels started fishing in the EPO in early 1960s, while the small started fishing in the EPO in late 1990s. Most of the effort was concentrated in the south Pacific Ocean (5-40°S and west of 160°E - 130°W, Figure 5) before the middle of 1990s, and then gradually expanded northwardly and eastwardly in the entire Pacific Ocean. However, the fishing fleet shrunk in the middle of 2000s for less catch and higher operation cost. It is not clear whether the vessels that moved west due to fuel prices and catch rates are different from those that stayed in EPO.

Electronic logbooks were implemented in 2014 for the large longliners (and for the distant-water purse seiner) in 2014, and for the small, in 2015. The large longliners are required to report weekly and the small longlines, monthly. The logbook field are: vessel ID, fishing date (year, month and day), fishing location (longitude and latitude by 5 degree), hooks, number of hooks between float (after 1994), catch in number/weight by species fishing location (longitude and latitude by 1 degree, after 1994), among others. The species fields are: albacore, bigeye tuna, yellowfin tuna, Pacific bluefin tuna, southern bluefin tuna, other tunas, swordfish, striped marlin, blue marlin, black marlin, other billfishes, skipjack, sharks, and there is also a field to report other" species. Bait, sea water temperature and hook depth are also listed in the logbook but there are large amounts of missing values for these fields. The hook depth information may be especially unreliable because the vessels carry no CTD (conductivity, temperature, and depth) probes.

Th size data from needs to be checked before use. The fishers were required to measure the first 30 fish of each set. This requirement was too cumbersome for the fishers, the data is not reliable. There will be a revision of this regulation so to increase compliance. Also, when using observer data, it is noteworthy that the observers work only for 8 h. The set retrieval can last more than 8 h, the observer may not be able to work for the whole duration of the set retrieval.

By-catch: there are information for some shark species, but most are not recorded at species level, just as "others" (*e.g.* dorado). Increase in shark catches: May be increase on reporting due to regulations. Reports are on fish caught but it is difficult to check for local data.

Regarding the size data, Dr. Wang commented that the size data from the Chinese Taipei fleet needs to be checked before use. The fishers were required to measure the first 30 fish of each set. This requirement was too cumbersome for the fishers, the data is not reliable. There will be a revision of this regulation so to increase compliance. Also, when using observer data it is noteworthy that the observers work only for 8 h. The set retrieval can last more than 8 h, the observer may not be able to work for the whole duration of the set retrieval.

<u>Discussion</u>

- They are reviewing the size data in the Indian Ocean. They found some issues and they are reviewing the data for all oceans.
- The fishermen may be only reporting the large fish. They have calipers but may not use it. They measure the first 30 independent of species. Fishermen say too many.
- What are the ultra-deep sets' (15-30 hooks between floats, HBF) target species? Probably bigeye tuna.
- Not much increase in swordfish in the catches
- In 2000, there was an increase in HBF and this is when started catching more BET and other species
- They check logbook position with VMS
- More sharks being reported, but not sure if it is more catch or reporting rate of sharks.
- Supposed to record everything that is retained. What about discards? Can look at observer data to see what is discarded. Could compare observer data with logbook data to see what logbook record? They have compared logbook and observer data. Observer not whole set, but just 8 hours so hard to check, need to take this into consideration.
- There are more swordfish when HBF increased. Did not check if SWO is caught in shallow sets.
- Each vessel is given a quota, can transfer between vessels.By-catch: there are information for some shark species, but most are not recorded at species level, just as "others" (e.g. dorado).
- Increase in shark catches: May be increase on reporting due to regulations. Reports are on fish caught but it is difficult to check for local data.
- Bias in coverage: possible overestimation when observers only works 7-8 hours. Full set assumed to be observed when not. Seems to be the case for all countries, but bias might not be the same.

- What are the HBF used since the year 2000?
- Taiwan used to have two-year lag for data submission, but electronic logbook will minimize the lag. Historically data that was not provided in time was left out of the data supplied to scientists, and never was updated.

Recommendation. Ask Chinese Taipei to provide unfinalized historical data.

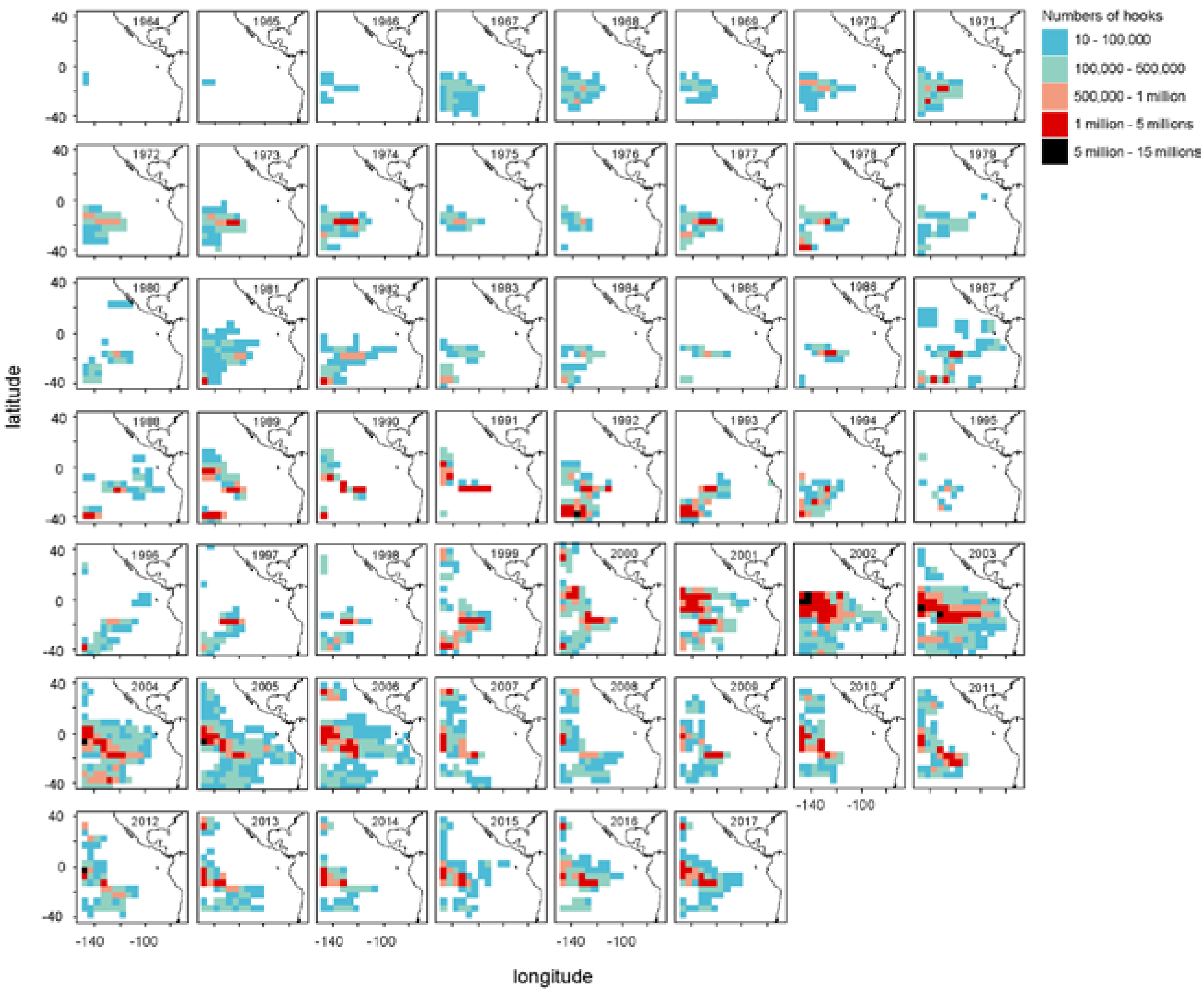


FIGURE 5. Effort distribution of the Chinese Taipei fleet in the eastern Pacific Ocean from (Source: IATTC public domain data).

4.5 FLEETS' COMPARISON

Carolina Minte-Vera presented a comparison of the four fleets in an area of their overlap in the EPO (10°N – 10°S, 110°W-150°W, Area 1 defined in WSBET-02-02 . A link to the presentation is here. This is one of the areas for which indices of abundance of bigeye tuna need to be obtained. The fleet with the longest time series in that area is Japan, followed by Chinese Taipei, however there are few records before the year 2000 (Figure 5). The fleet with the largest number of sets recorded in the operational level data Japan, followed by Korea (Table 2). For China, the data is substantial only in the last four years of the series (2014-2017, Figure 6).

Table 2. Operational level data for the area 10°N and 10°S and 110°W and 150°W

	Number of sets	Year start	Year end
Japan	1,078,051	1954	2018
Korea	267,776	1971	2017
Taiwan	88,692	1964	2017
China	28,254	2010	2017

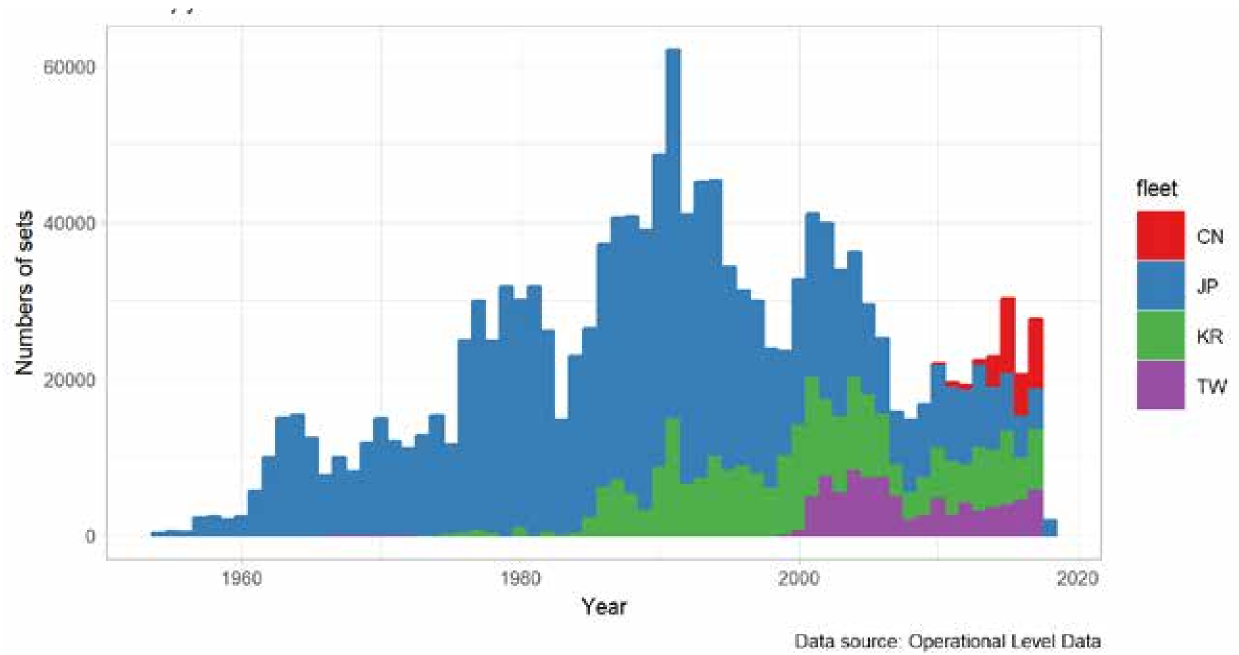


FIGURE 6. Number of sets in the operational level datasets for Area 1 (10°N and 10°S and 110°W and 150°W).

Changes in the number of hooks between floats (HBF) occurred in the Japanese fleet in the late 1970's, from about 5HBF to about 10HBF, and kept increasing to level off at about 16-17 HBF (Figure 7). A similar pattern was followed by the Korean fleet with a delay of about 5 years. The Chinese Taipei fleet from the early 2000 on is using 16-17 HBF. Most of the HBF data for the Chinese fleet is missing, but those that reported recorded more than 25 HBF.

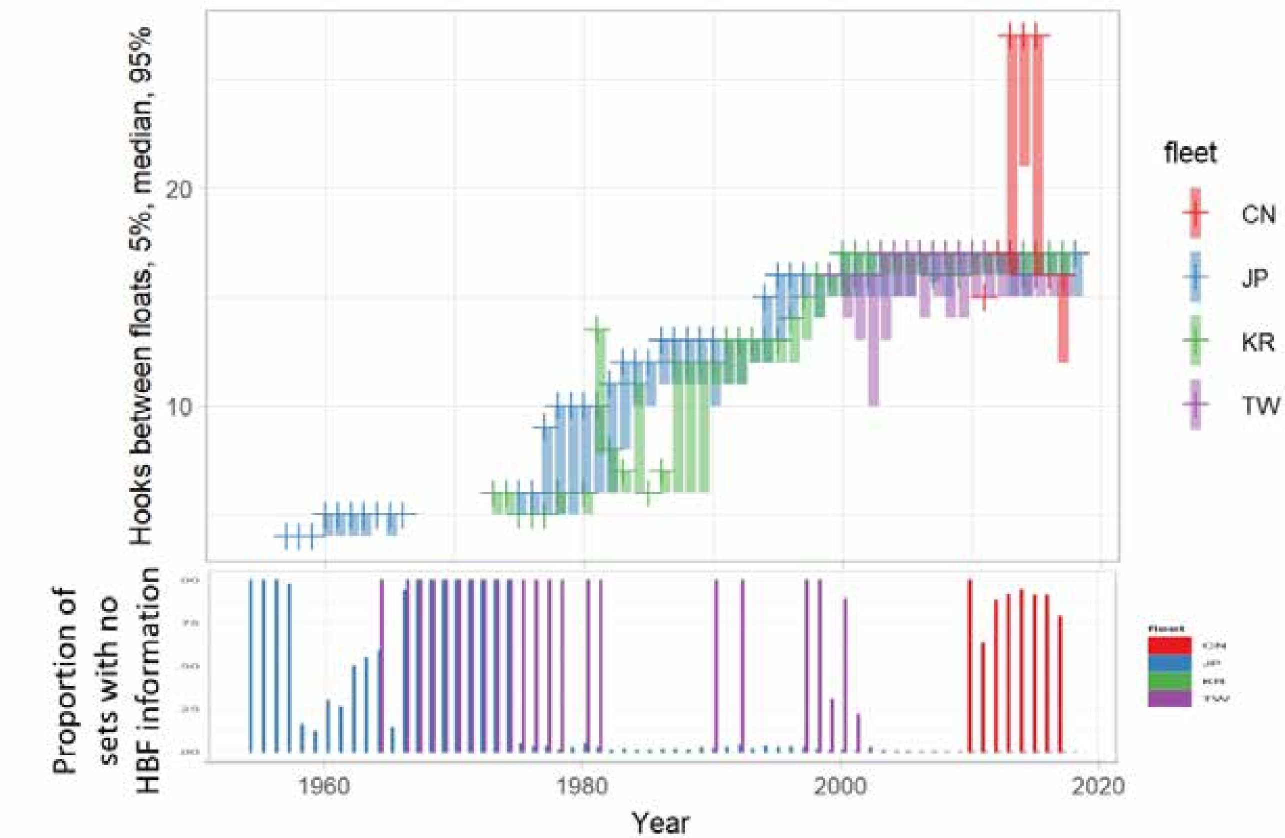
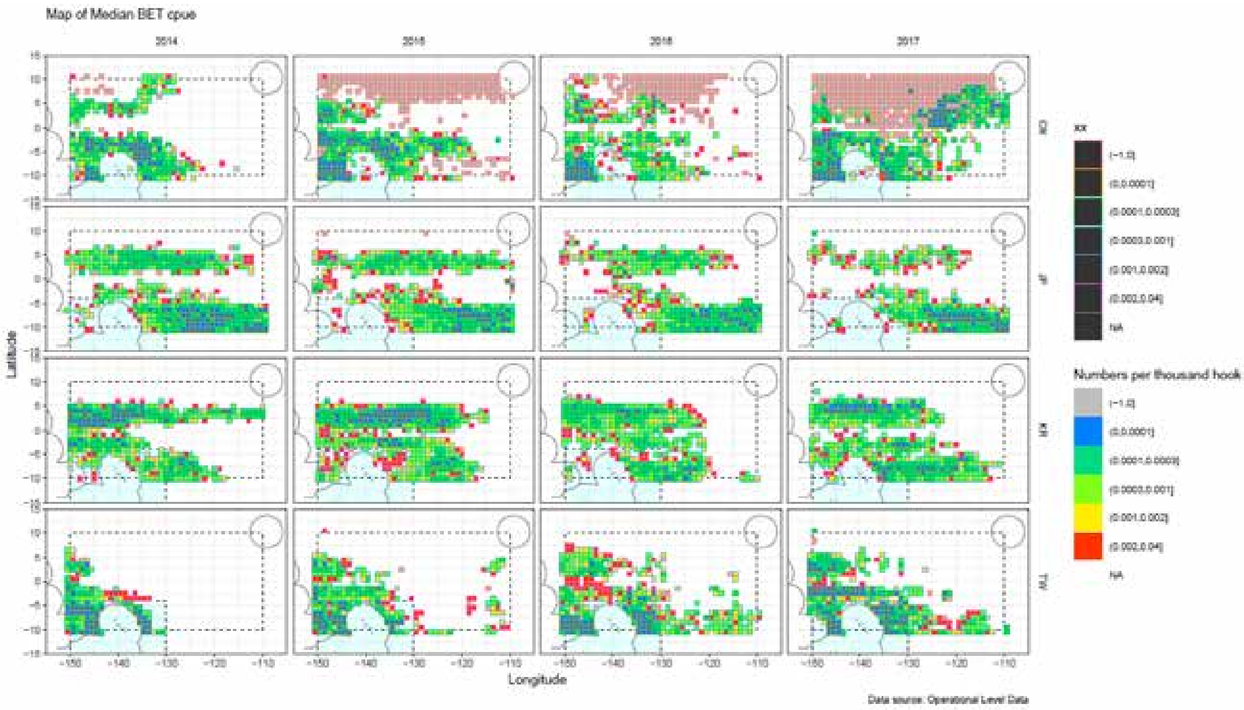


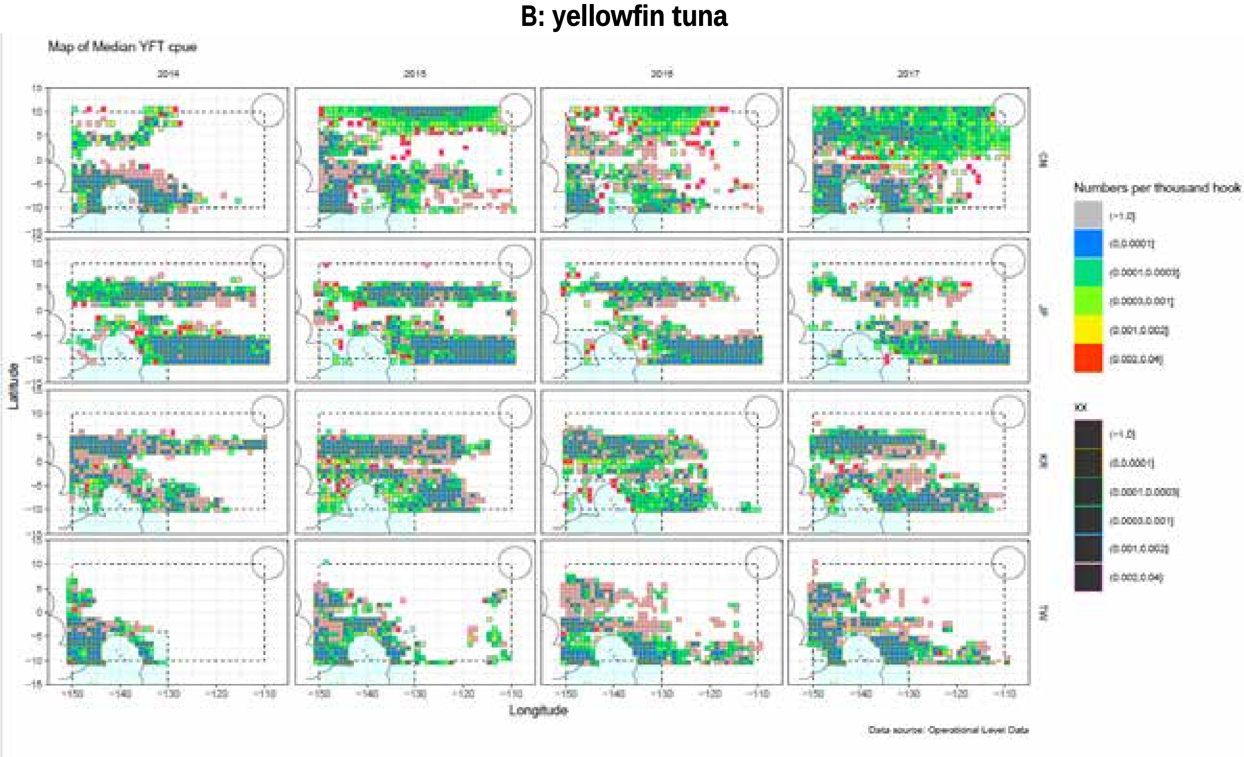
FIGURE 7. Hooks between floats as registered in the operational level datasets for Area 1 (10N and 10S and 110W and 150W).

Maps of the nominal catch per unit of effort for 2014-2017, when all four fleets have good coverage of Area 1, show that the Chinese fleet is fishing mostly in the Northern Hemisphere, and tending to concentrate in the western area, while the other fleets area mostly south of 5°N and towards the east. The Chinese fleet does not show catches of bigeye tuna along some of the 0-5°N region, where other fleets show catches of bigeye tuna. In those areas the Chinese fleet catches yellowfin tuna and albacore tuna (Figure 8). Other fleets show no catches of albacore tuna north of the equator were China shows catches of that species.

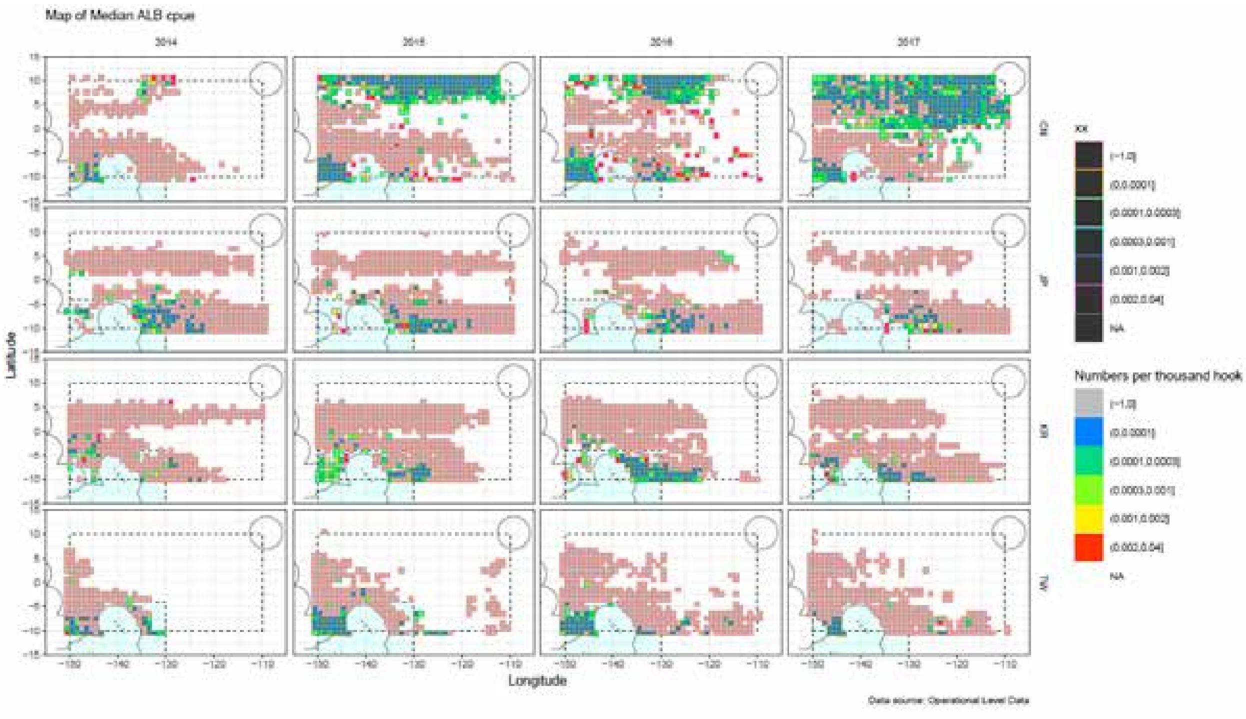
A: bigeye tuna



B: yellowfin tuna



C: albacore tuna



D: swordfish

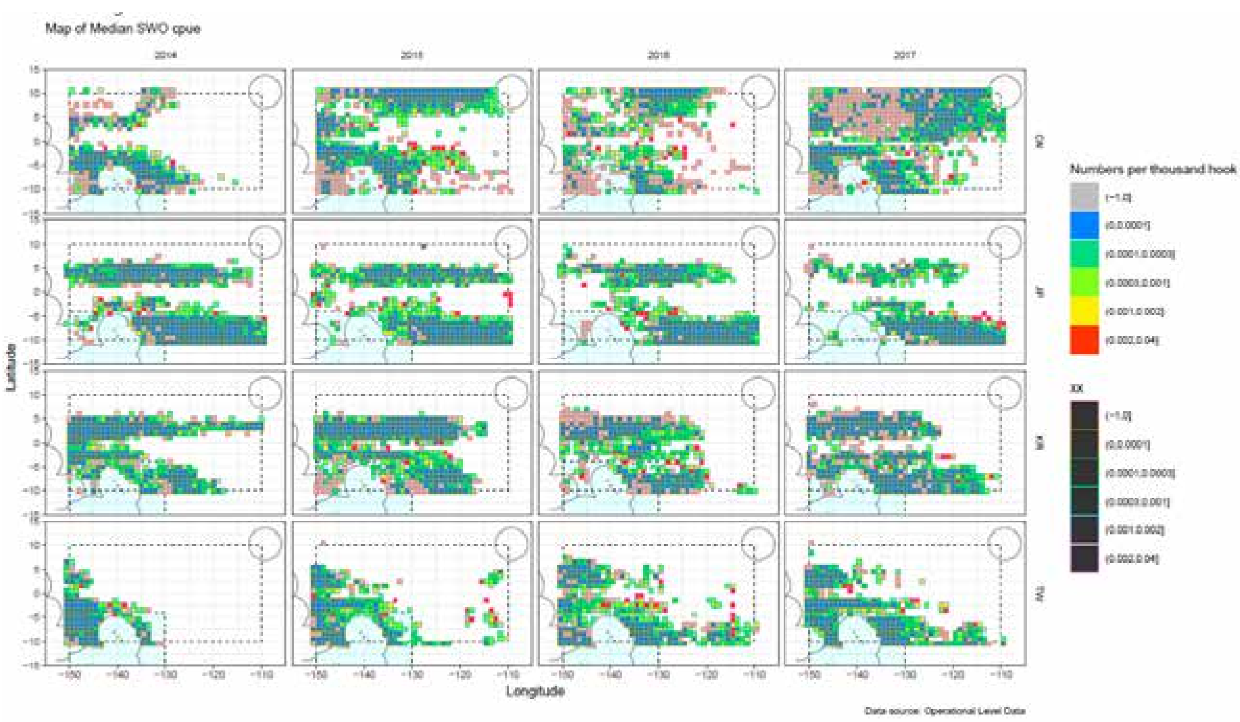


FIGURE 8. Median CPUE for bigeye, yellowfin, albacore tunas, and swordfish.

Discussion:

- China targeting yellowfin/SWO in the north?
- In China they are not catching BET in the north area where other countries catch BET. Is it a species ID problem?
- Why don't other countries fish in Northeast? Korean BET quota is by vessel, but not transferable, China has fuel subsidies so they may go further. Always been band of no fishing on equator where currents are strong, but in historic past fished in the Est but now less.
- Different size vessels may fish in different areas.
- For all countries, the observers do not register the whole set and the would be a bias in coverage: possible overestimation when observers only works 7 hours. Full set assumed to be observed when not. Seems to be the case for all countries, but bias might not be the same.
- Given the shorter time series available for Chinese Taipei and China in Area 1 and the different behavior of the Chinese fleet, the group decided to explore indices that will combine the Japanese and the Korean data.

4.6. COMPARISON OF JAPAN AND KOREA

The nominal bigeye tuna CPUE for Japan and Korea in area 1 showed discrepancies (Figure 9). It was hypothesized that the discrepancies were due to different areas of operation of the two fleets (Figure 10), as well as different size of vessels, since the Japanese fleet has small and large vessels operating in the EPO until mid-1980 (Appendix B), while the Korean fleet only had large vessels.

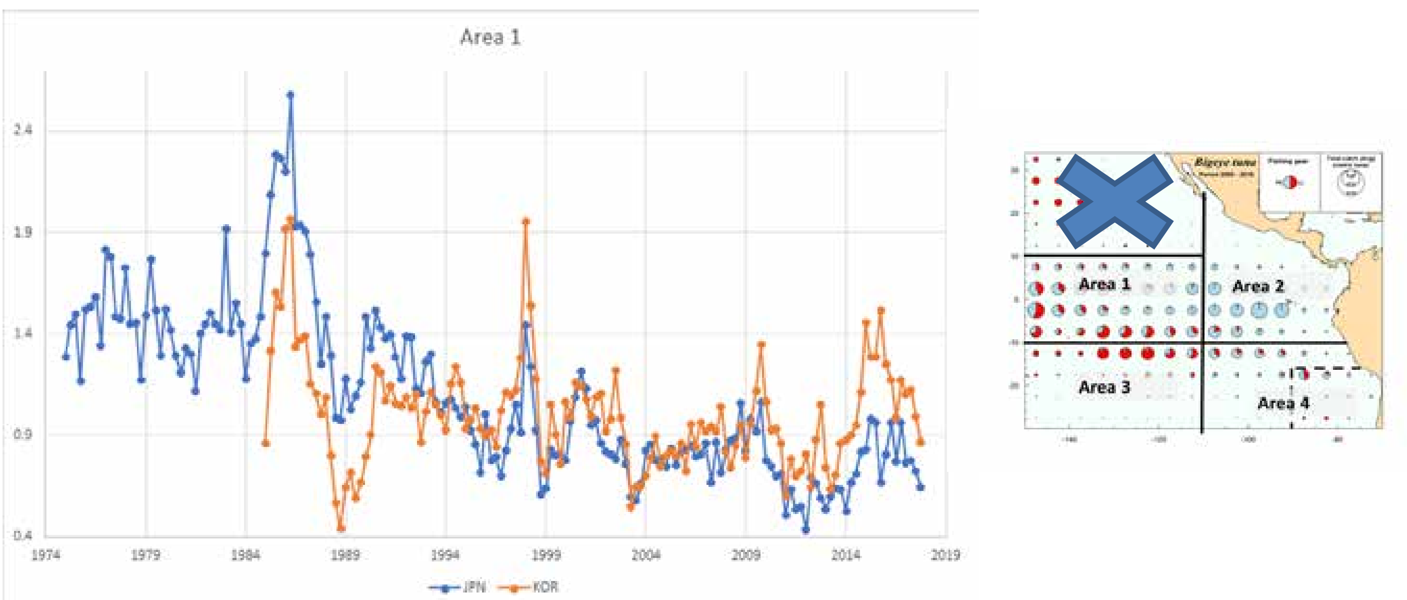


FIGURE 9. Nominal bigeye tuna CPUE for Japan and Korea in area 1 defined as shown in the right figure.

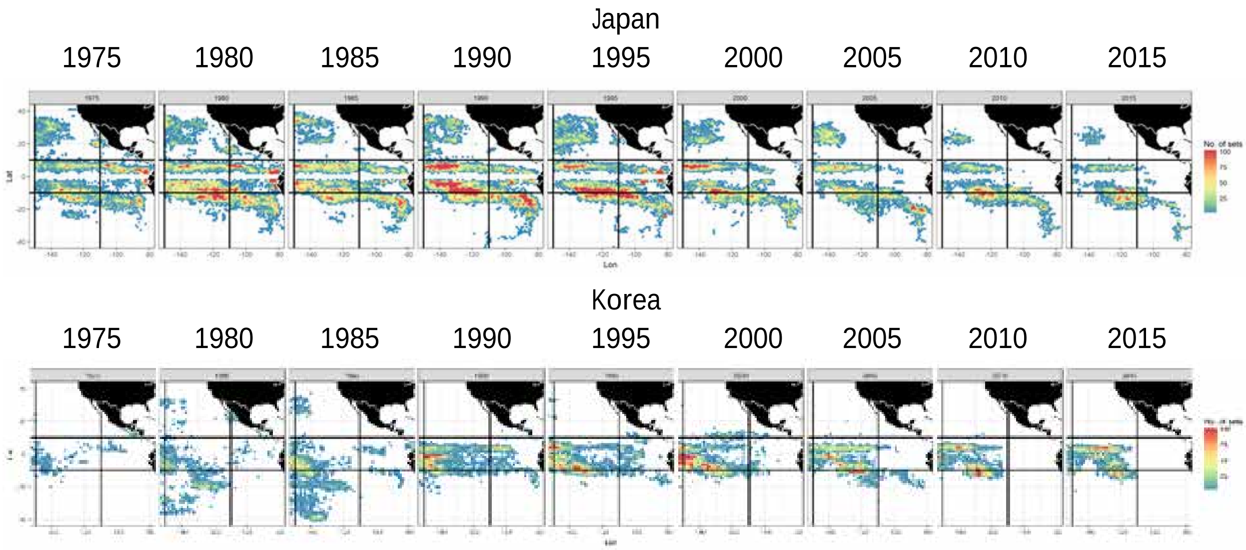


FIGURE 10. Spatial distribution of effort (number of sets) of the Japanese and Korean fleet in the EPO. The horizontal lines are at 10°N and 10°S and the vertical line 110°W.

<u>Discussion:</u>

- Time trends in difference between raw and standardized CPUE.
- Yellowfin is more variable, is the difference because of spatial difference in bigeye tuna density and the spatial distribution of different HBF values?
- To combine fleets, it is needed to make sure data is well understood, so the caused for potential differences can be pinpointed.
- Differences may be due to what is done with the small fish:
  - Japan sometimes discards small fish.
  - Korea records small fish.
  - Small, discarded fish is minor component. So, it should not affect the CPUE.
  - In US fleet, fish less than 60-70 cm of fork length is of lower value than larger fish. In Japan, the same is true for fish smaller than 10KG
- Differences may be due to vessels:
  - However, multiple vessels were included, and vessel effects were estimated.
  - Are vessel effects between nations the same as within nations? A plot vessel effects by flag should be done to investigate this question. In WCPO flag effects have been estimated.
  - Korean vessels are all large and fish tropical area. Japan has a wider range of vessel sizes with wider spatial range.
  - Japanese data has information gross tonnage. The vessel effect could be plotted against tonnage to explore cause for variation in vessel effects.
- Recommendations:
  - Run VAST with just large vessels.
  - Use Japan to predict Korea.
  - Use Simon Hoyle's model.

To inspect the hypotheses of differences due to vessel sizes and spatial area of operations, the nominal CPUE was computed for more restricted areas, and only for the large vessels (>200 GRT), of both Japan and Korea (Figure 11). The nominal bigeye tuna CPUE showed remarkable similarity for the Japanese larger vessels and Korean fleet within the two restricted areas chosen for comparison (northern equatorial area: 3°N-6°N 150°W-120°W, southwestern area: 15°S-5°S 135°W-110°W), at least after 1990 when the Korean fleet had fully expanded in the EPO. The trend for the Japanese small vessels also showed similarities to the other trends within and area but showed more interannual variability. These results indicated the need to compare datasets using data in high spatial resolution and with multiple covariates available (such as vessel size).

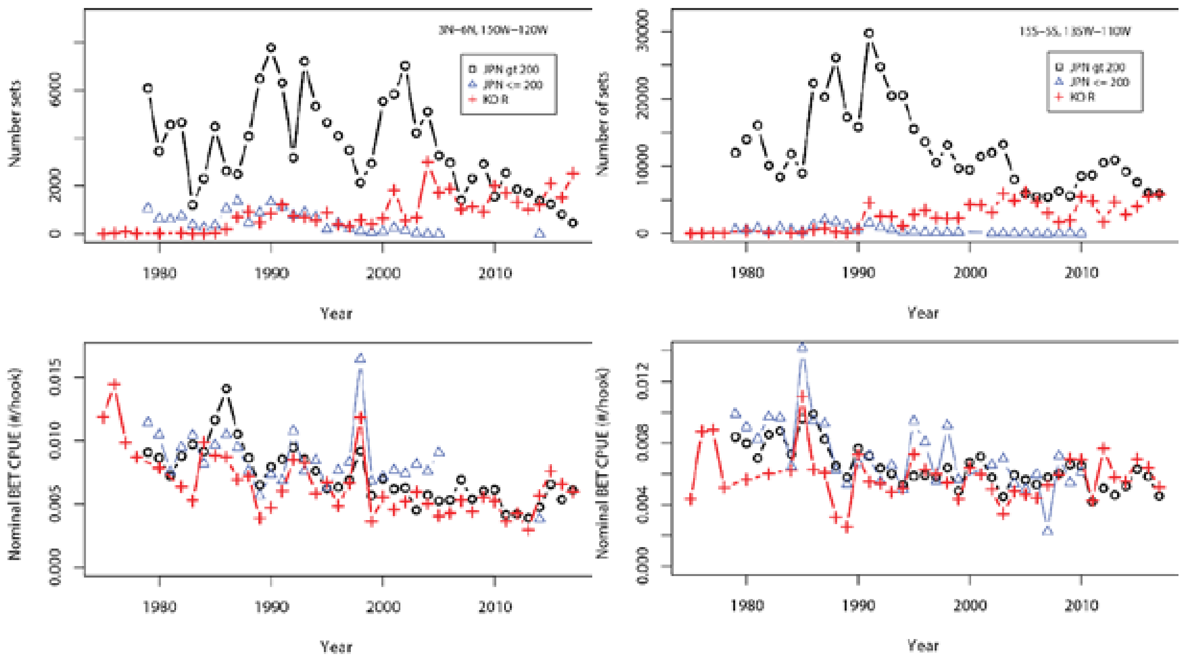


FIGURE 11. Nominal bigeye tuna CPUE for the Japanese fleet (large and small vessels) and for the Korean fleet.

5. LONGLINE REGULATIONS IN THE EPO

Guillermo Compean presented a review of international regulations in the Pacific Ocean for longline fisheries that may cause changes fish targets. A link to the presentation is here. The main points presented and discussed were:

- some changes in the fleet might be because of starting to target swordfish,
- albacore is increasing catch in EPO, IATTC needs to do an southern albacore assessment,there is an increased Albacore CPUE in many oceans, but Japense industry says it is not targeting albacore. Need to look at secondary tragetting,
- need to check if data from overlap management area between IATTC and WCPFC is being used in the IATTC assessments,
- shark catches by longline is also important,
- coastal based longliners are important,
- there are longliners that target sharks, both distant water and coastal, researchers need to be mindful of this when standardizing the data,
- The IATTC is requiring that transhipment information about sharks to be provided.

6. LEARNING FROM EXPERIENCES ON CPUE STANDARDIZATION IN OTHER T-RFMOS

6.1 IOTC AND ICCAT

Simon Hoyle presented "Collaborative work in IOTC and ICCAT, and lessons learnt ". Link to the presentation here. Experiences analysing operational distant water fleets tuna data include:

- 2008-2012: US provided data collected at Pago Pago canneries. Joint analyses of Southern albacore CPUE using data for Japan, Korea and Chinese Taipei, with cluster analysis for targeting.
- 2009: SPC-held operational data submitted by fleets fishing in Pacific EEZs. Japanese data was used for estimating the CPUE for bigeye and yellowfin tuna.
- From 2010: Japan permitted analyses of their operational data for WPCO for bigeye and yellowfin tuna by SPC.
- From 2015: Japan, Korea and Taiwan provided access to Indian Ocean data for collaborative work on bigeye, yellowfin and albacore CPUE. Seychelles joined in 2016 (see also Hoyle et al 2019b)
- From 2018: Japan, Korea, Chinese Taipei and the USA provided access to Atlantic Ocean data. The analyses are done typically during a one-week workshop (see also Hoyle et al 2019a).

The analysis process has the following workflow:

- load the data (import, clean, and create variables);
- characterise data (plot and summarize to identify unique characteristics of datasets, and any issues that should be addressed);
- cluster analysis, to separate fisheries by targeting strategy,
- standardize data, individually and jointly.

Some key lessons learnt in the IOTC and ICCAT experiences were:

- consistency in data formatting is crucial to optimize the use of time,
- the understanding the data and fisheries is more important than improving the standardization methods, data characterization papers should be produced for future reference,
- Indices may be affected by both lower sample sizes, and varying motives for data submission across the fleet, thus exploring data coverage and reasons for change will help understand the data,
- differences between trends in different fleets are useful indicators of potential problems in one dataset or the other,
- indices from operational data are better than indices based on aggregated data because analyses can take more factors into account and analysts can check the data for inconsistencies and errors,
- it is important to identify target changes, and either remove relevant effort or include a categorical variable (e.g. Chinese Taipei oilfish fishery in the Indian Ocean),
- one-week workshops are too short to explore many aspects, such as considering spatiotemporal interactions, but they provide the starting point for further exploration.

6.2 WCPFC

Laura Tremblay-Boyer presented the lessons' learnt in the Western and Central Pacific Ocean with collaborative work among different longline fleets to do CPUE standardization. Her presentation "Evolution in the CPUE standardization for WCPC assessments: From fleet-specific GLMs to spatio-temporal modelling of Pacific-wide operational data sets" is summarized next (see also Tremblay-Boyer et al 2017).

Timeline of the CPUE work:

- Pre-2009: the Pago Pago dataset was analysed in collaboration between the US (Keith Bigelow) and SPC (Simon Hoyle) for the South Pacific albacore tuna stock.
- 2009-2013: collaboration between Japan and SPC (Simon Hoyle) for in-situ data analysis.
- 2015: fleet-combined indices where developed in collaboration between SPC China, Chinese Taipei, Korea, Japan and the United States for CPUE analyses only for Pacific-wide bigeye assessment (and SP albacore for some countries), for that a workshop was carried out at SPC with country representatives and specific staff, the analyses are done on secure computer and the data is available until August of that year; the SPC scientific staff request the non-deletion of the data, (WCPFC-SC11-2015/SA WP-07) the request is accepted.
- 2017: combined indices were done for yellowfin and bigeye assessments using delta-GLM and spatiotemporal methods. The problems with this approach were:
    - Does not account for spatial correlation between neighbour cells
    - Challenging to included space-time interactions
    - Mix-bag of spatial effect: oceanography, fleet dynamics, etc.
    - Indices run individually by region
- 2018: combined index developed for the South Pacific albacore assessment using spatio-temporal models:
    - Cluster (targeting) and vessel effects included in the model
    - Analysis of what environmental variables should be included as catchability covariates and what to include as abundance covariates was done.
    - Some variables may influence local abundance and others regional abundance.
    - For yellowfin tuna, there are no differences in the indices that included local versus those that included regional covariates.
    - For SP albacore, spatiotemporal models estimated larger abundances at the start of the time series and smaller at the end of the series, when compared with GLM indices
    - Issues detected:
        - missing vessel ID introduces bias in stock-wide CPUE;
        - it is not clear how to extrapolate for regions that have partial coverage.

Discussion:

- Selectivity over different fleets: Artificial fleets use different selectivity for index length composition.
- Validation of spatio-temporal models: Spatio-temporal models allow extrapolation, models should be carefully validated.

7. OVERVIEW OF STATISTICAL METHODOLOGY FOR CPUE STANDARDIZATION

7.1. GLM/GAMMS

Simon Hoyle presented "The *Cpue.rfmo* library and the GLM/GAMM approach". Link to the presentation here. **Laura Tremblay-Boyer** and **Simon Hoyle** presented a tutoral on github and how to install the library (link to the tutorial here).

The main points about *Cpue.rfmo*:

- is a private R library available in Github developed by Simon Hoyle,
- open to collaboration by contacting the author,

- for standardizing RFMO tuna catch and effort data efficiently.
- tool for sharing methods among scientists and RFMOs
- includes scripts to handle the processes of importing and cleaning, characterizing, clustering and standardizing.
- allows national scientists to replicate the analyses and contribute with the code.
- allows for running many analyses in a fast, efficient and consistent way
- method currently implemented are the generalized linear models and generalized additive models
- CPUE is either modelled as lognormal (CPUE+ constant) or a delta-lognormal model (two components are modeled: the probability of zero CPUE and the log (CPUE) for sets with catch.
- HBF and hooks parameters are cubic splines, yrqtr, vessel, latlong5, and cluster are categorical variables.
- assessment regions are modelled independently, consistent with their treatment in the assessment.
- within a region, 5° cells are modelled as independent categorical variables, areas without effort need a special treatment.
- shifting effort introduces bias, which is addressed with a specific procedure.
- alternative model structures need to be explored
- diagnostics as center part of the approach (*e.g.* influence plot).
- Trends from models with and without vessel effects can be compared to investigate changes in catchability associated with changes in the fleet due to:
    - effort creep
    - changes in targeting.

Discussion:

- *Validation of spatio-temporal models*: Spatio-temporal models allow extrapolation, models should be carefully validated.
- *VAST versus GLM:*
    - The speed GLM in R might be useful
    - Did the GLM that included knots (as opposed to cells) have time area interaction?
    - There is a lot of data so why do we need to borrow information?
    - Is using covariates to fill in spaces more important than sharing information using spatio-temporal model?
- *Spatial correlation and edge effect*:
    - Spatial correlation may change over space:
        - temperate versus tropical,
        - coastal versus offshore.
    - A solution for changes in spatial correlation would be to estimate indices for different areas separately to check if they have different correlation structure.
    - Need to use cross validation for interpretation and edge effects.
- *Size composition:*
    - Selectivity in Multifan: an “artificial” fleet is used for index, which has a different selectivity for index length composition than the fishing fleets.
    - to represent the index size composition the CPUE-weighted size comps should be used

- for the catch fleets the size composition should be weighted by the catch.
- Did different target clusters have different selectivity?

- *Diagnostics*: what diagnostics to do for combining fleets?
  - a jackknife could be done by removing fleets, if have there are enough fleets.
  - do this for an area use area where all fleets operate.
  - look at vessel effects by country to see if there are patterns.
  - map residuals by fleet and cluster.
  - look at size data, but size data is questionable or limited in space and time for some countries.
- *Vessel, trip and set effects:*
  - Using a missing vessel variable as a parameter for each trip and estimate mean and variance for the distribution, gives better estimate of the overall variance, for those cases when vessel ID is not available.
  - No trip information is available, but the logbook ID is available, so that can use in the models. Some countries don't have vessel IDs, so the vessel effect has to be estimated for each set.
  - use fixed effects for vessel rather than random effect so to minimize the effect of a very disparate vessel effect,
  - When using random effects, the extreme value may influence the estimates of the other vessel effect.
  - vessel effect may change over time: interaction time * vessel effect may occur due to changes in technology or targeting, *etc*, over time

Recommendation: focus on what diagnostics to use

7.2 SPATIOTEMPORAL MODELS IN VAST

Haikun Xu presented "Introduction to the spatiotemporal model: VAST". The link to the presentation is here.

Spatiotemporal models are:

- Delta-generalized linear mixed models that assume a spatial grid of "knots" with which random effects (spatial and/or spatiotemporal) are associated.
- The use of "knot" is to decrease the number of parameters to be estimate.
- The spatial and spatiotemporal random effects are spatially correlated using simplification assumptions about the relationship among "knots"
- The position of each data point in relation to the "knots" of the user-defined grid determine its expected value.
- The approach is implemented in the R library VAST developed and maintained by Jim Thorson (Alaska Fisheries Science Center, NOAA, USA)

Discussion:

- Anisotropy
- *Covariates:* Can you use SST data to predict in areas where is no data?
  - VAST only include linear effects; no-linearity can be added using the variable squared (X^2).
  - Laura has added a spline to the VAST code.
  - If the environmental variable to be add is a density variable, values for this variable area

needed for all time steps and knots.
    - If the variable is a catchability variable, values are needed for all the data points
    - Sometimes the variable may be both a catchability and an abundance variable. An idea is to try cross validation: take time with good coverage and delete edges and see how well it predicts (try in all areas and in some years).
- *Seasonality*: Quarterly variation in the area fished is a problem. The is a seasonality feature in VAST but is undocumented so far.
- *Changes in correlation:* Spatial and/or temporal correlation may change over space and time. We need diagnostics to detect this. Could plot the spatial temporal structure of the residuals. There may be interaction between spatial-temporal variation and the time-varying correlation.
- *Data weighting:* the use of aggregated data may be needed to make model converge within a reasonable time span, some aggregations may have lots of data others not much. The inclusion of data weighting in VAST would be a solution to deal with this. A request should be made to the developers.

<u>General discussion using GLM/GAMMs and VAST:</u>

- How does subsampling effect the CV? Currently the CV is not used in the stock assessment, so the subsampling effect maybe not be so important. The CV does not account for catchability changing over time or autocorrelation.
- CV may change over time due to less effort, but in the current stock assessment, the CV is assumed to be the same for every year.
- Catchability may change over time for a vessel, vessel effect alone does not deal with this. There is need to have information on what gear they have and how it had evolved over time. For example, the introduction of bird radar had a significant benefit in pole and line.
- Might be useful to use skipper as a covariate. These data is currently unavailable to the staff.
- To develop the models a smaller data set (*e.g.* from specific companies) that contained the needed data could be used, to see what covariates maybe important.
- In areas that are not fished every year, what do you do? Just ignore it. But if the area not fished changes differently than the area fished, then the index will be biased in relation to the total population.
- a core fleet where we know that technology did not change could be chosen to do the index. Then other vessels from other fleets could be used to estimate catchability changes. But why not just use the core vessels for the index?
- Estimate the mean of the random effect over time as a diagnostic.
- Why not do subsampling by vessel? Because need vessel effect.
- Why use vessel as a fixed effect? Random effects assume a distribution, which is not the case because there are changes over time. Limited time. Random effects might have computational benefits. Often not see a big difference. Might need to look at interactions between cluster and vessel.
- Why not sharing among area and time?
- How do you fill in cells with no data?
- Data aggregation gives too much weight to cells with not much data?
- Do vessel effects have a big influence, are they needed?

Recommendation: get information on gear usage to use in standardization.

7.3 INDICES BY SIZE CLASS

Haikun Xu presented "Standardization including size composition data in VAST" when he explained the theory on including the size class composition as response variable vector in the VAST models. The link to the presentation is here. He illustrated the theory with an example of the standardization of the purse-seine CPUE of yellowfin tuna caught in set associated with dolphins in the EPO and of the Japanese longline data for BET for Area 1.

Discussion:

- Can you look at the correlation in index among size?
- How many size bins should be used? The choice of the number of bins was related to computational issues, there was no convergence for models with quarterly time step instead of annual time step, and finer bins with many length classes, as opposed to less classes
- Blocks in the covariance matrix might indicate stages where spatial move occurs.
- May do the intercept as a an AR1 over length to allow smaller bins. Perhaps intercept is on small length bin but spatial is on longer length bin. Haikun uses spatial factor for length with loadings for different lengths. Kai-san uses AR1 for length like AR1 for time with the cross product with area.
- Should we standardize length comp data? Perhaps, but need to designate what is catchability and what is density.

Recommendation: create a specific code to do length-frequency CPUE analysis

Keisuke Satoh presented preliminary results on the standardization of the Japanese longline data for BET for all the EPO[5]. The spatiotemporal modelling using size-specific catch rate observations is important because it: (i) provides size-specific index of abundance (CPUE + LF); (ii) estimate the spatiotemporal distribution for different life stages (e.g., juvenile vs. mature fish); (iii) evaluate the existence of spatial segregation by size.

Discussion:

- Size distributions change with El Niño and La Niña:
    - Are the differences among El Niño, normal and La Niña conditions due to spatial movement, discarding or purse seine catch?
    - Probably not purse seine because they are catch too small fish.
- Is the distribution of catch due to the distribution of fish or to the distribution of the effort?
- Did HPB have a different effect on length? Have not linked HPB information with length data yet.
- Some of the Japanese CPUE data associated with size, most of the CPUE has no size associate to it and there is size data by itself. How do we deal with this? If length composition data is not missing at random there might be a problem
- Why is large fish index different from other size classes indices?
    - There is a large number of fish caught so may not be sample size.
    - From 2015 on only observers measured fish, so observers may be more likely to measure large fish.

[5] The work has been published in https://doi.org/10.1016/j.fishres.2021.106065

Recommendations:

- Compare CPUE with and without size data and see if it is consistent.
- Collect data so operational variables are linked with CPUE.
- Link historic size composition data with the logbook data.
- Compare observer versus commercial length comp spatially standardized

Simon Hoyle did an analysis during the workshop comparing the length frequencies obtained by observers versus the length frequency obtained by commercial fishermen for Japan. The results we highly variable dependent on assumptions, but general conclusion is that no significant effect was found.

Influence of observer vs crew sampling

Yr + qtr + te(lat,lon)

	Estimate	Std. Error	t value	Pr(>|t|)
as.factor(source)3	-0.5253	0.8191	-0.641	0.52130

Yr + te(lat,lon) by qtr

1.as.factor(source) 3	-0.02	2.30	-0.01	0.992361
2. as.factor(source)3	10.2243	1.5842	6.454	1.10E-10
3.as.factor(source)3	1.1823	1.8578	0.636	0.524517
4.as.factor(source)3	7.913	3.452	2.292	0.021913

Yrqtr + te(lat,lon)

BET1

as.factor(source)3	-4.8717	1.0672	-4.565	5.00e-06

Discussion:

- Sometimes LF measurements by fishermen are improved after an observer has been on a trip because they show the fishermen how to fish.
- Information on vessel ID for the length frequency data is needed to check this
- Is there high grading in the Japanese fleet?

Simon Hoyle presented the experiences on corresponding size-composition data to the indices and catch in the Western and Central Pacific Ocean:

- They use the CPUE to weight the size compositions in some assessments, then they used just catch, then in latest ALB assessment, they used both.
- For YFT, there was a large changes in spatial distribution of where the length frequency samples came from. This is because the size composition data came from the training vessels and they did not necessarily fish where CPUE was high
- When using commercial data fishing is more likely to be areas with high CPUE.

Ricardo Oliveros-Ramos showed a work in progress on corresponding size-composition data to the indices and catch. A link to the presentation is here. The main ideas were:

- the size composition data should be weighted by the catch to represent the size composition of the catches

- the size composition data should be weighted weighted by the index of abundance (CPUE) to represent the population size composition.
- The spatial resolution of the data may influence the results, the best solution would be to use high spatial resolution data (i.e. CPUE from near-to-raw data).
- Ilustration with 5° latitude by 10° longitude length frequency data for the Japanese longline fleet for BET and YFT, weighted by the Japanese CPUE and the total catches in the same spatial scale.
- There were two sources of differences in the resulting length compositions:
    - spatial the variability in the CPUE versus the variability in catches
    - the spatial variability in the length compositions.
- The weighting will not be important if there is no variability in space of size composition or if the catch and CPUE have the same spatial variability.
- The weighting becomes important when effort is concentrated in some areas with high catch (high catch/high effort = average to low CPUE vs high catch / low effort = high CPUE).
- The resulting size composition for both BET and YFT for the population did not shown a strong increase in large sizes in the latest years as the length composition of the catches did.

Discussion:

- Operational data shows a different size pattern over time

Simon Hoyle presented results of his unpublished research “Spatial variation in tropical tuna life history”, focusing on the large tropical tunas (BET and YFT), using size composition data from different fleets over time. His main conclusions were:

- Strong spatial variation in size across the Pacific Ocean, and within the current assessment regions.
- Sex ratios also have distinct patterns that vary across the Pacific Ocean

Discussion:

- If time variation is not accounted, is spatial variation just as big?
    - Time is the main effect,
    - space can be big,
    - fleet effect is relatively small.
    - The time effect is probably fishing in different areas

- Is small fish due to growth, depletion, or movement?
    - Not depletion because consistent over long periods.
    - Could be both growth differences and movement.
    - Could be depth of gear, but no strong evidence yet. Need to link LF to operational data.

- SST appears to effect yellowfin
- Both bigeye and yellowfine tuna show an increase in average length from 1985 to 1995:
    - Adjusted for location and one fleet.
    - Could it be HPB.
    - Only 1x1 length data.

7.4. ASSESSING STANDARDIZATION METHODS

Nicholas Ducharme-Barth[6] presented the work in progress on using the SEAPODYM model to produce simulated data sets based on the skipjack population of the Western Pacific Ocean where presented. The goals were to test the ability of CPUE standardized using spatiotemporal methods to estimate the abundance of the population

Discussion:

- Need spatio-temporal to deal with changes in spatial distribution of fleet particularly contraction and expansion.
- Change in catchability in same direction as abundance, got bias, because it was confounded. If the scales or frequencies are different probably can.
- Vessel effect did not account for changes in catchability due to gear.
- Is preferential sampling related to CPUE or distance to port? Both.
- Preferential sampling with spatial shift causes issues in delta GLM but geostatistical models are better are addressing this issue.
- Vessel effects are confounded with catchability
- Why did the addition of SST not help much? SEAPODYM was used as simulation platform, which implements complex non-linear model for whole life history, movement, etc, depending on the temperature. In the estimation model, just a simple linear term was added, which perhaps was insufficient to capture the SST effects.

Recommendations:

- Perform more simulations to test spatial-temporal models.
- Use simulation studies to assess the effect of aggregating data (e.g. by spatial cell-time-vessel vs. spatial cell-time).

7.5. TARGETING AND VESSEL EFFECTS

Cleridy Lennert-Cody presented preliminary results on estimation of targeting effects in the EPO using different methods. Link to the presentation here:

- The Japanese data were used.
- The motivation for the work was the apparent decrease of some species in the catch of the Japanese fleet, such as albacore, and the increase of others, such as swordfish, at the same time that gear changes were detected (HBF increase).
- Four approaches were implemented to estimate targeting outside of the CPUE standardization model:
    - Cluster analysis of proportion of species catch (Hoyle et al. 2019a method);
    - Gaussian mixture analysis of relative BET CPUE residuals (Okamura et al. 2018 method);
    - Hybrid method (cluster analysis of relative CPUE residuals for multiple species),
    - Potential Target Species (PTS) method (Satoh and Matsumoto, 2017).
- Preliminary results for the PTS method were:
    - Classification and Regression Tree (CART) analyses and random forests analyses found limited relationship between the PTS values assigned to sets and covariates such as quarter of the year, 5° latitude and 5° longitude, which could complicate predicting the PTS for any set from spatial and temporal covariates commonly available in logbook data.

[6] This work has been published in https://doi.org/10.1016/j.fishres.2021.106169

- The preliminary results for the other three methods were:
  - There was little correspondence between the cluster assignments of these three methods.
  - BET may have always been a target in area A1 during 1979-2017.
  - Given the temporal changes in CPUE, this could indicate that changes in fishing strategies to catch other species (e.g., secondary targets) do not strongly impact the ability to catch BET.
  - The greatest contrast in proportion CPUE among clusters was seen for the Hoyle et al. (2019a) method and the least for Okamura et al. (2018) method.
- The next steps suggested for the work were:
  - Apply methods to other longline fleets and other assessment areas.
  - Run sensitivity analyses with respect to configuration of the two components of the Okamura et al. (2018) method (e.g., covariates and smoothing in GAM; covariates used in Gaussian mixture, etc).
  - Conduct simulations to further evaluate performance of the methods.
  - Investigate possible improvements to the hybrid method, such as:
    - Fitting a multivariate Gaussian mixture to multiple species residuals;
    - Developing an iterative fitting procedure to better separate targeting effects from density effects.

Discussion:

- Yellowfin has more CPUE in cluster 2 in the Hoyle methods and only 25% of the effort so should consider including a cluster covariate or just use cluster 2.
- Could consider doing the clustering with the species of interest because abundance will be confounded with cluster.
- Look at the index from each cluster and see if there is a difference, and if there is, look further at the residuals to find out why.

Simon Hoyle presented an overview for estimating targeting effects. The link to the presentation is here.

- Two ways to use the results of the cluster methods:
  - Drop a cluster from the final standardization analysis
  - Keep the cluster in the analysis as a covariate.
- The swordfish cluster still catch bigeye it is reasonable to keep it in as long as you can estimate a catchability difference.
- If there are different CPUE trend for the cluster, then find out why:
  - It might be that the area where that data is coming from should be a different substock.
  - Influence plots can be used to see if cluster has an influence or not.

Discussion:

Targeting:

- When to throw out data targeting another species?
- Can you use individual data, but use a targeting effect to the trip or vessel/moth vessel/month/cell, rather than aggregate?
- Does proportion in each cluster change over time? Cluster interacts with time, so it is important to determine if the proportion in each cluster changes over time.
- Targeting modeled as a random effect: vessel+year+month

Suggestion: repeat Cleridy's analyses for area 3. The index could be re-run without swordfish cluster.

Laura Tremblay-Boyer presented "Pacific-wide changes in tuna targeting *via* cluster analysis of all-fleet operational data sets". The link to the presentation here.

Discussion:

- All swordfish clusters filtered out
- When it was a bigeye or yellowfin tuna cluster, they were kept in analysis but used cluster as a covariate
- For regional weighting for albacore, only used albacore targeting clusters were used.
- Hard to differentiate between bigeye or yellowfin tuna clusters
- Plotted CPUE by cluster, if not difference then OK.
- Used *Kmeans* because it was faster and gave similar results to other methods
- Is spatial cluster, targeting or availability?

Cleridy Lennert-Cody presented preliminary results on estimation of targeting effects in the EPO using Hoyle's cluster method for Japan (Figures 12 -14) and Korea (Figures 16 and 17). The results showed that all clusters have about the same average CPUE for BET. For the Korean fleet in most or all areas, the marlin-dominated clusters have low BET, but very few sets.

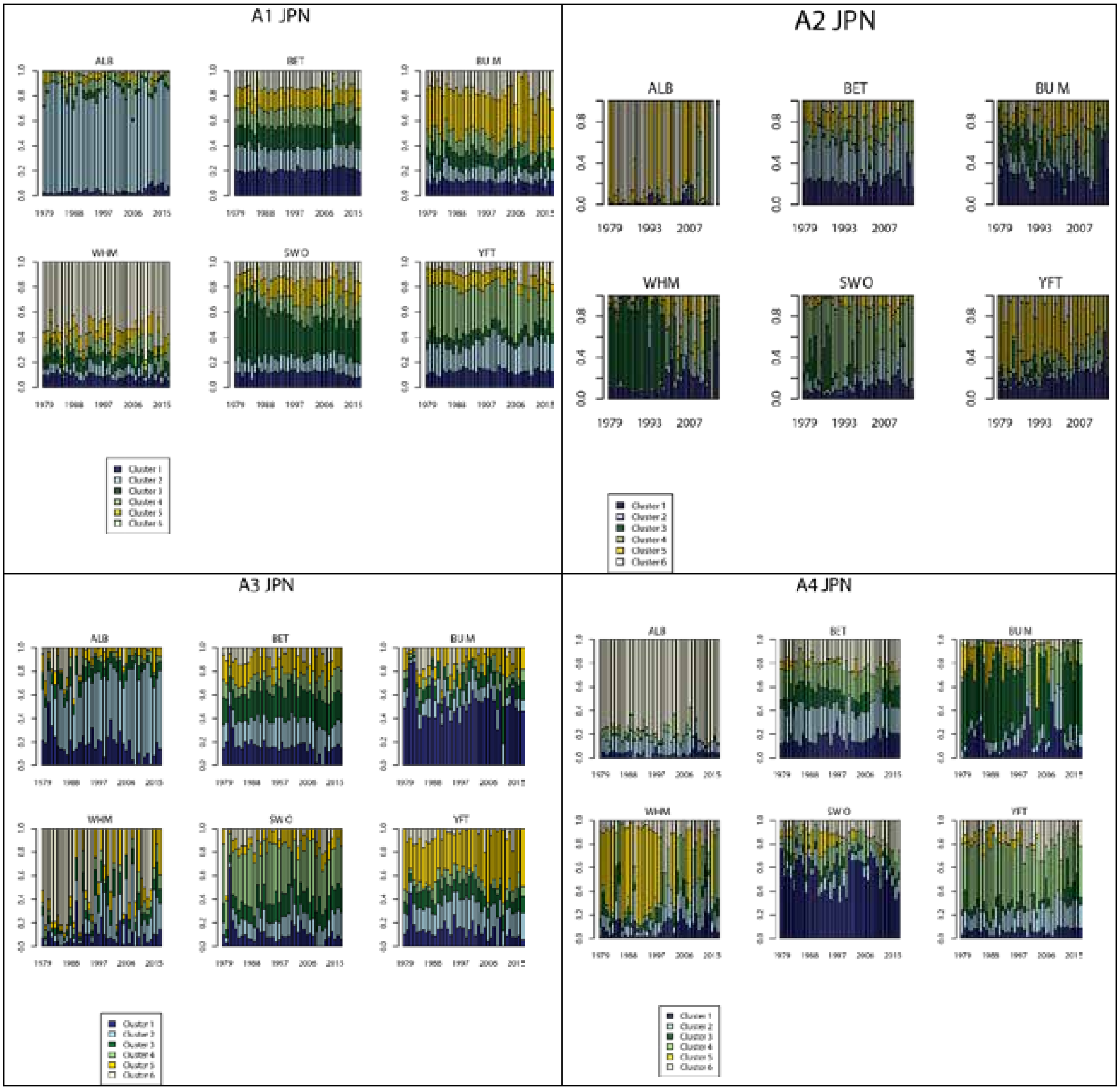


Figure 12. Average proportional CPUE for the six species for six clusters in four areas for the Japanese data.

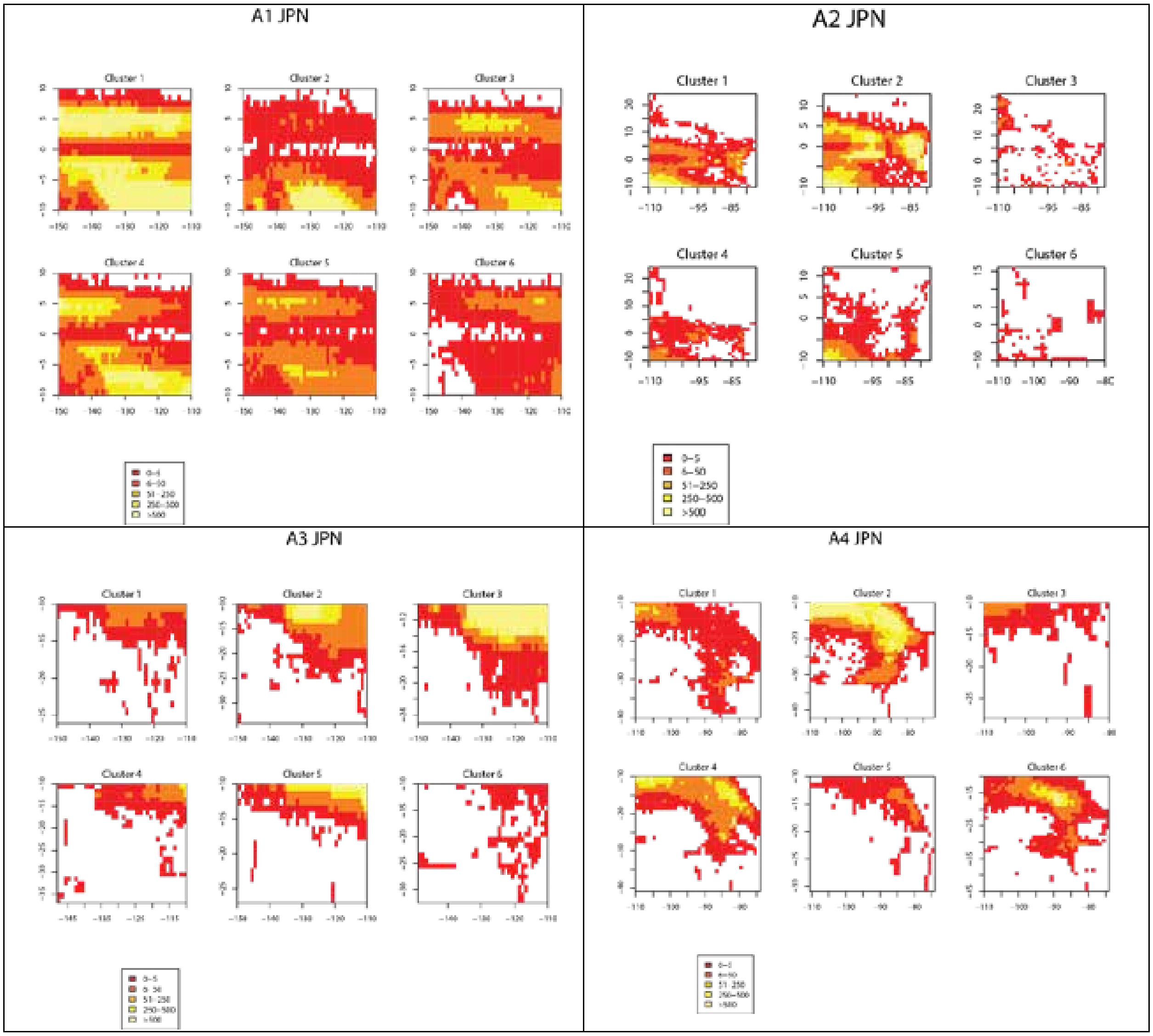


Figure 13. Spatial distribution of sets by cluster in four areas for the Japanese data.

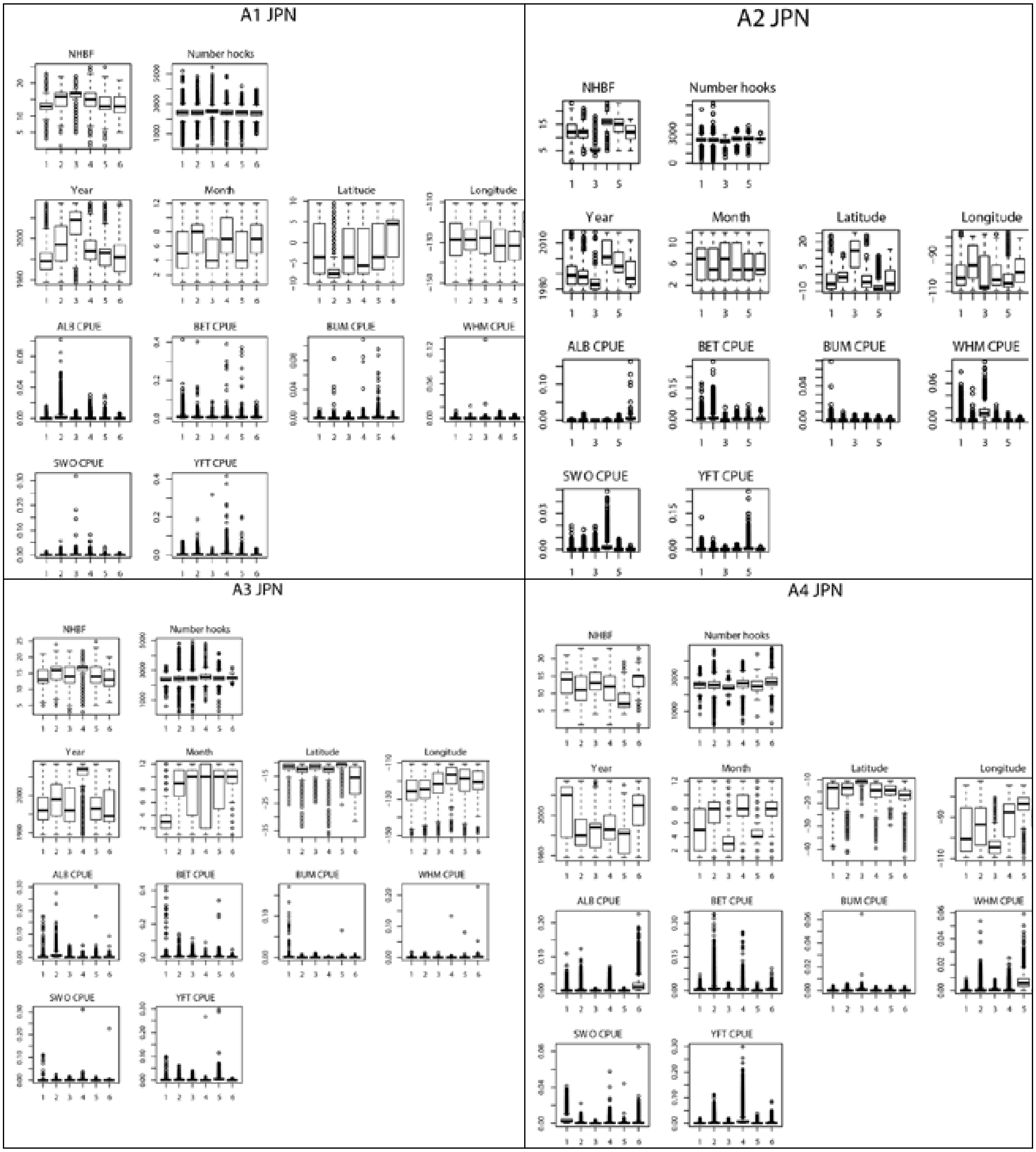


Figure 14. Box plot of the CPUE of six species and covariates by cluster in four areas for the Japanese data.

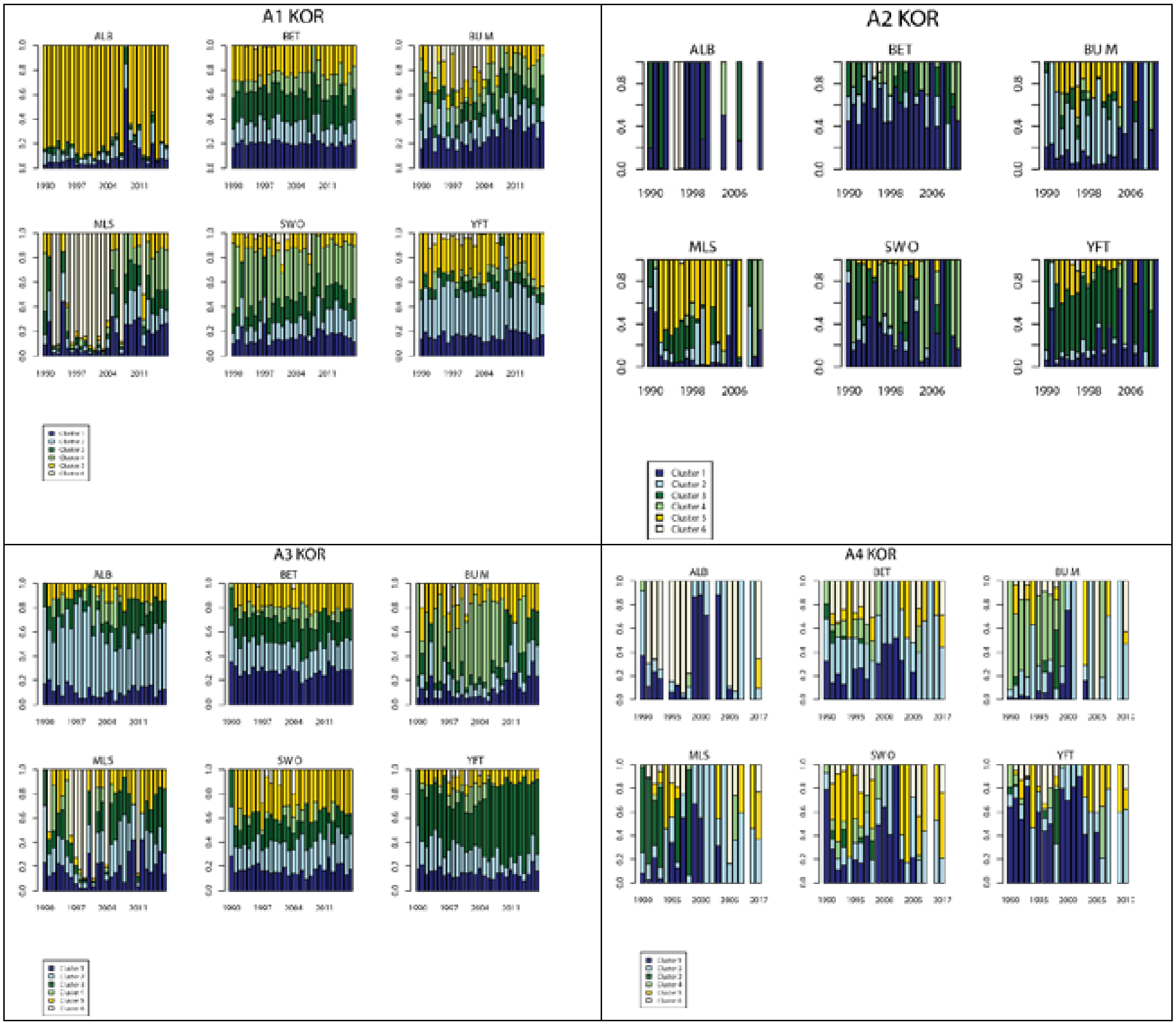


FIGURE 15. Average proportional CPUE for the six species for six clusters in four areas for the Japanese data.

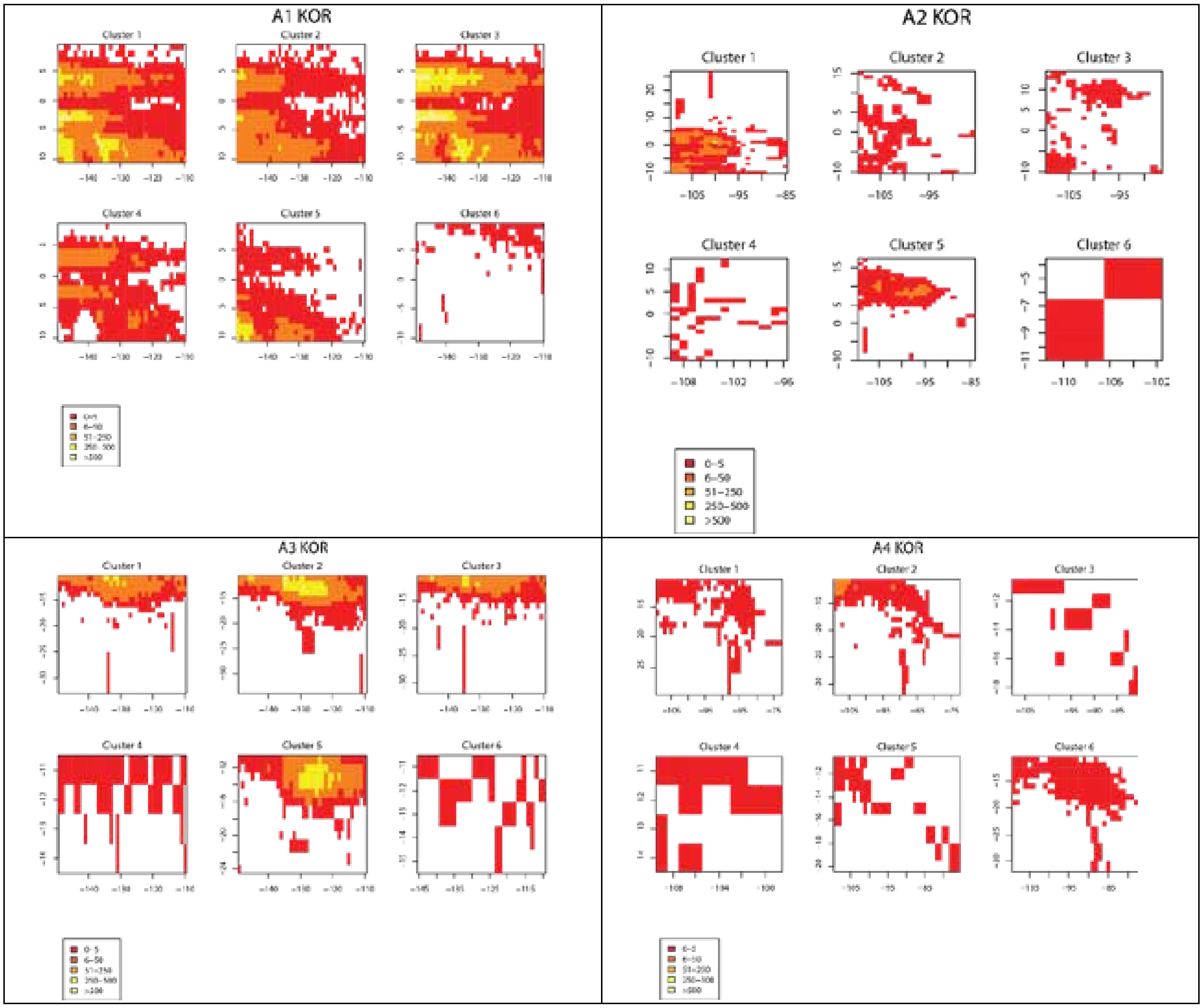


FIGURE 16. Spatial distribution of sets by cluster in four areas for the Korean data.

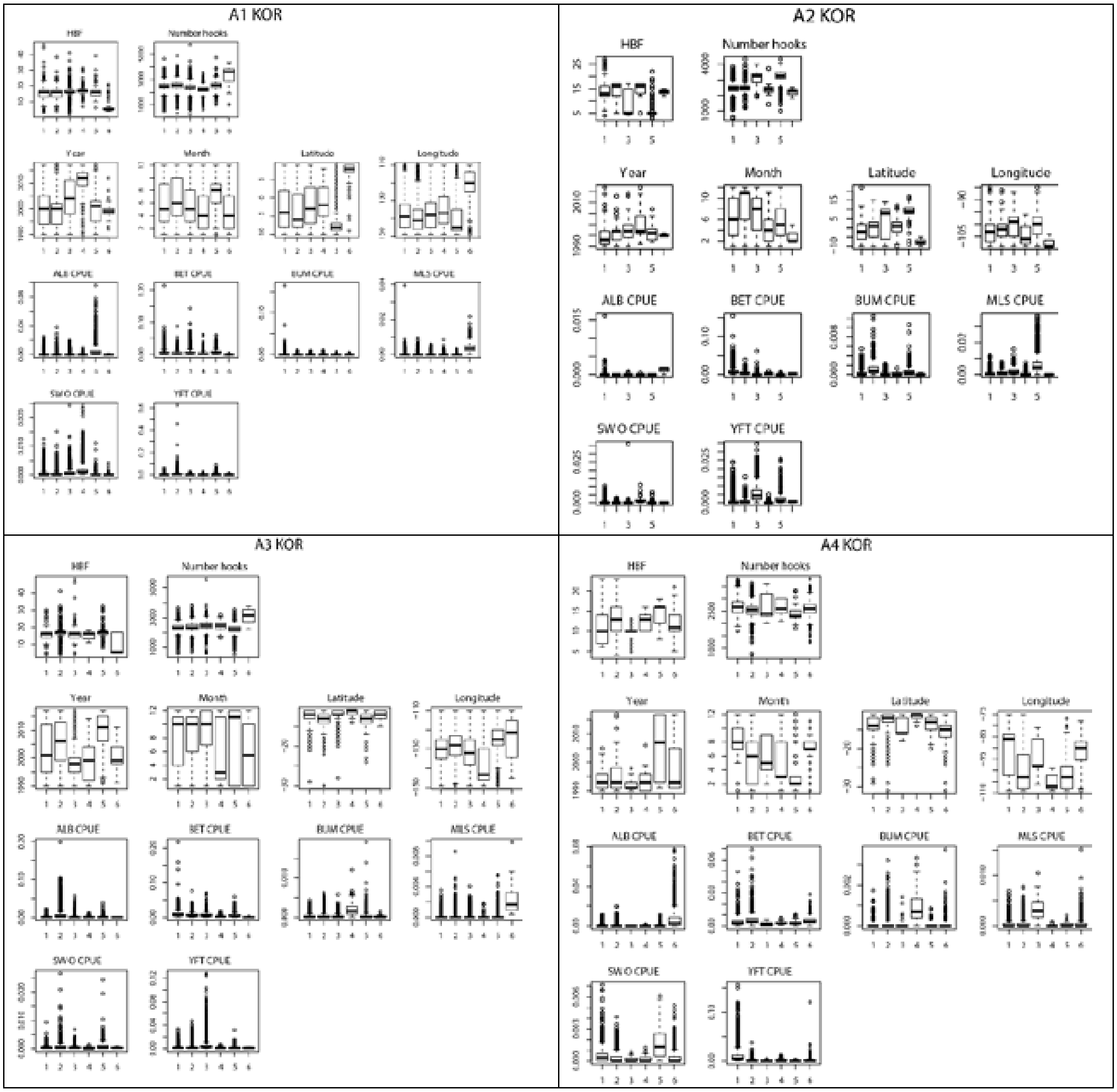


FIGURE 17. Box plot of the CPUE of six species and covariates by cluster in four areas for the Korean data.

Recommendation:

- Remove marlin clusters from Korean data when constructing indices of abundance.

Simon Hoyle and Cleridy Lennert-Cody presented an overview of strategies for estimating targeting and fishing strategies effects. First, the targeting should be identified using one of these three approaches:

- Fishing strategies / métiers:
    - Longline vs trawl;
    - Longline for oilfish vs albacore (Indian Ocean);
    - Longline for bigeye/yellowfin vs yellowfin/bigeye vs bigeye/swordfish.

- Gear-based or data-based indicators:
  - HBF, number of hooks, location, season, vessel,
  - Lightsticks, set time, bait type.
- Species composition (including bycatch species).
  - 1. Identify targeting first, then fit CPUE model:
    - Cluster analysis methods (He et al 1997, Hoyle et al 2019a,b)
    - PCA-based (Winker et al 2017)
  - 2.Fit CPUE model first, then identify targeting from residuals:
    - Gaussian mixture method (Okamura et al, 2018)
    - Hybrid method (Lennert and Maunder, unpublished)
  - 3.Estimate targeting and other covariates simultaneously
    - VAST (Thorson 2019)
    - Iterative hybrid method (Lennert-Cody et al unpublished).

The cluster analysis method was applied for the 1° by 1° by vessel and month data from Japan and Korean. The result suggests that there about the same CPUE for BET in all or most clusters in A1. This led to recommendation not to include targeting in model for A1, consistent with treatment of IO model for tropical areas.

<u>General discussion on targeting:</u>

- Does proportion in each cluster change over time? Cluster interacts with time, so it is important to determine if the proportion in each cluster changes over time
- Are targeting and vessel effect confounded?
- CPUE is correlated with El Niño Southern Oscillation. Is it catchability changes due to the change in thermocline or is it changes in the spatial distribution of the fish?

Recommendations:

- Targeting: Model targeting as random effect (vessel+year+month)
- Repeat the analyses for area 3.
- Rerun the index without swordfish cluster.
- Clustering - use Hoyle's method with the number of clusters equal to the number of species. Remove data from clusters with little BET and then use remaining data to do the VAST model estimating targeting internally. This is because Hoyle method looks at area targeting, gear targeting, and the interaction, but hybrid does not identify area targeting. Do sensitives to all data and to just using the discarded data. Correlation structure may be different between clusters. Perhaps don't use targeting in the tropics because targeting always seems to be for BET.
- Don't put spatial targeting because it is confounded with area effect and there is lots of data so other species don't provide much
- Review all the available information to determine if the correlation between longline CPUE and El Niño Southern Oscillation is related to catchability, changes in spatial distribution, or recruitment.

Haikun Xu presented the work "Vessel effects and targeting using Japanese operational data in spatial-temporal model (VAST)" (link to the presentation is <u>here</u>, results summarized in Figure 18) The data used were aggregated at the 1 by 1 scale.

- Four VAST model were built for Area 1:

- (1) base model (the domain was just area one, included spatial and spatiotemporal random effects),
- (2) as base but the spatial domain included area A2, results were summarized just for area 1,
- (3) as base, but the data was aggregated by 1 by 1 and vessel,
- (4) as (3) but vessel effects were estimated. Vessel effects are added as a random effect

- Similar models were done for area 2, which was data poor.
- Vessel effects should be included in the standardization procedure:
  - more pessimistic abundance trend with vessel effects than without.
  - A shift of vessels with low efficiency to vessels with high efficiency was detected in the mid-1990, as low efficiency vessels left the EPO during that period.
  - The true abundance trend maybe even more pessimistic because the catchability of a vessel is likely to increase over time.
- Combining data in adjacent areas primarily impacts the estimates of index of abundance and the associated CV for data-poor area and period.
- Targeting effects were explored for area 1by estimating random effects for each combination of year-lat-lon-vessel (“set”) and including the proportion of BET, SWO, YFT (decomposed in 3 factors) as catchability covariates in the delta portion of the VAST model (encounter probability)
  - No temporal pattern in targeting effect were found for BET, YFT, and SWO in A1.
  - Including targeting effects had a minor effect on the index of abundance when there is no trend in targeting effects over.
  - If there are trend over targeting, they are likely confounded with year effect.

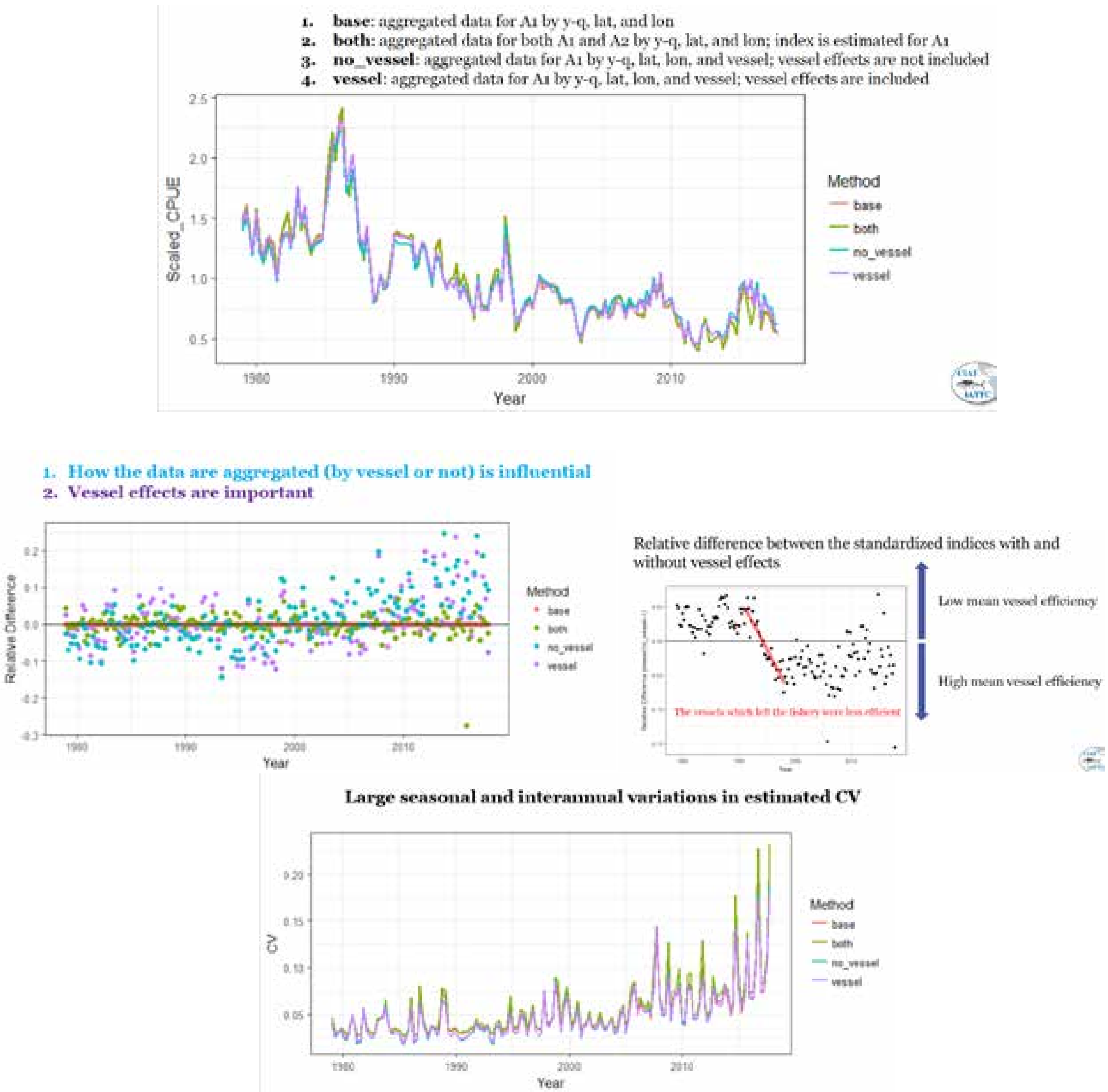


Figure 18. Estimated abundance indices for BET using spatiotemporal models for BET in areas 1, as well as vessel effects and estimated of uncertainty.

Previous analyses with Korean operational longline data also suggested that:

- The long-term trend in Bigeye abundance was minor
- Bigeye tuna was less depleted in recent years in comparison to that suggested by Japanese aggregated longline data: similar interannual variations but different long-term trends
- Hook-between-float has a minor effect on the standardized index
- There is a pronounced spatial pattern in the catch rate of bigeye tuna for the Korean fleet

Discussion:

- What is the overlap between Korea and Japan in area 1? Divergence may be fine scale spatial variation.

- Area 2 assumes that correlation in area 2 is the same as in area 1 or sharing density?
- One vessel effect is estimated for each vessel, while each set could have a different target and thus a targeting effect. If a model includes both vessel and target, then need to use random effects
- Did you include habitat effect? Habitat, year, lat, long, and vessel effects were included

Recommendations:

- Investigate the differences between Korea and Japan: for example, do an index using Korean and Japanese data simultaneously and do indices separated for each fleet, compare the indices and the residuals patterns
- Look at spatial overlap between Korean and Japanese data over time.
- What level of effort is considered as occupied cell? Pie maps %by fleet. Do average lat-long over time. Do Warens statistic and the d statistic.
- To see if targeting is confounded with year, do a model with year effect turned off and see if targeting changes.
- Plot targeting effects on the map. This may be challenging since the random effect is estimated for the combination of vessel/space/time rather than for a set. Maybe map the mean and standard deviations of random effects for targetting.
- Compare modelling target effect as vessel+space*time versus vessel*space*time in VAST
- Run a test with equal weighting for each cell.
- Run the Japanese data with only vessels that stayed in after the reduction in the 1990s.

8. COMPARISIONS OF DIFFERENT MODELS

Simon Hoyle completed the individual fleet and joint fleet analysis for the EPO using the GLM/GAM approach with cluster analyses (Appendix F, Figure 19). The results were compared for area 1 with the spatio-temporal model (with size aggregated) that included vessel effects (Figure 20). The Chinese Taipei series is the most variable and short. The Japanese and Korean indices present opposite trends. The index done using spatio-temporal model and the joint GLM have two marked differences: at the beginning of the period the spatio-temporal model estimated larger abundance than the GLM, at the end of the period the pattern reversed.

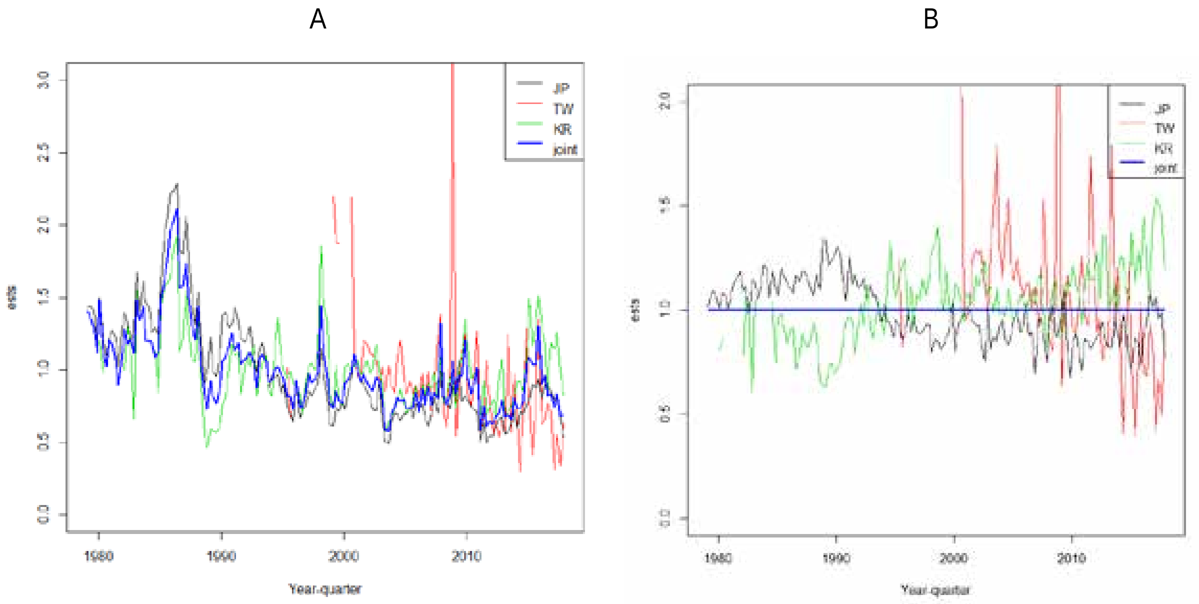


Figure 19. A. Indices from data for individual fleets and joint index using the GLM/GAM approach for area 1. B. Ratio of the individual indices and the joint index.

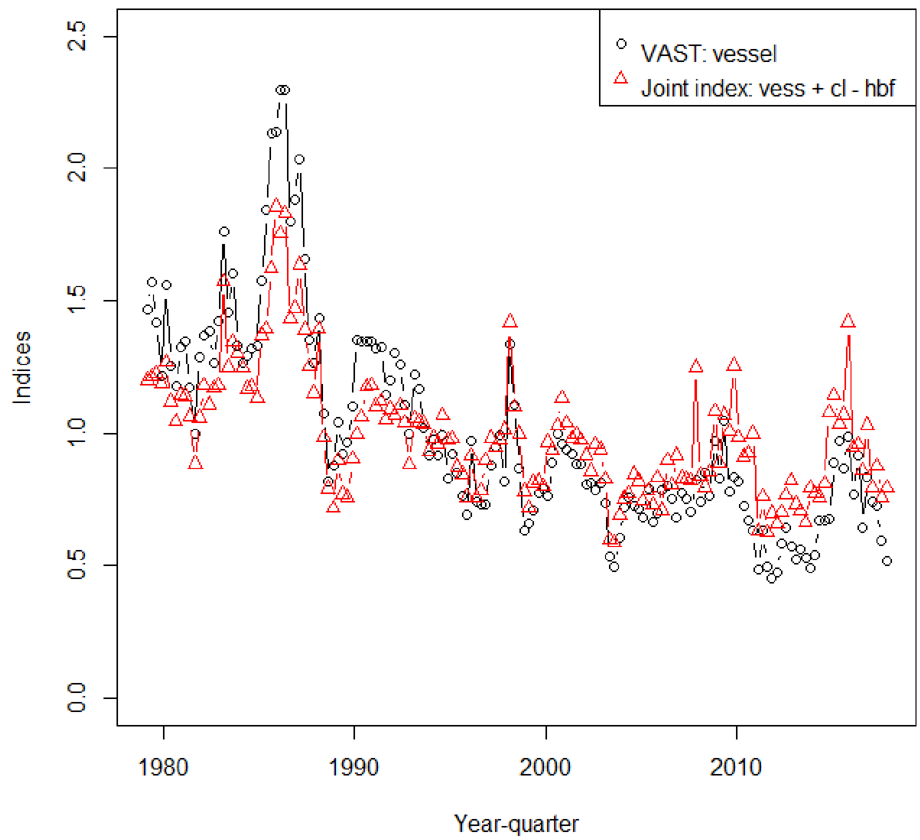


Figure 20. Comparison of the joint index of abundance done using the GLM/GAM approach including vessel effects and clusters to account for changes in targets (but without HBF effects), and the spatio-temporal index with vessel effects for area 1.

9. FUTURE WORK

Several model runs were suggested for continuation of the work (Table 3) :

Table 3. Model configurations suggested for the continuation of the collaborative work

Data sets	Areas	Effects	Priority
JPN + KOR (1990 on) [aggregated from Op. level in year, quarter, 1 by 1, vessel] compute median(hbf) as covariate	Tropical: 1 and 2	1.Space and time	High
		2. As(1) + hbf	High
		3. As (1 or 2) with Vessel effects	High
		4. As (1 or 2) with targeting	
		4.1 "targeting" estimated in VAST. When using the definition of "targeting" as vessel * cell* year, the results similar to model (1), it did not remove the increase in efficiency as expected.	No
		4.2 targeting as cluster effect	Low
		5. As (1 or 2) with vessel effects and targeting estimated outside VAST (clusters)	Low
JPN with "obvious" targets excluded (from cluster analysis)	Subtropical : 3 and 4	6. Space and time	High
		7. As (6) + hbf	High
		8. As (6 or 7) + Vessel effects	High
		9. As (6 or 7) + targeting	
		9.1 "targeting" estimated in VAST. When using the definition of "targeting" as vessel * cell* year, the results similar to model (1), it did not remove the increase in efficiency as expected.	No
		9.2 targeting as cluster effect	Medium
		10. As (6 or 7) with vessel effects and targeting estimated outside VAST (clusters)	High
JP CPUE with size data, 1986 on with 9 classes by year	Tropical: 1 and 2	11. Space and time	High
		12. As (11) + hbf	High
		13. As (11 or 12) with vessel effects	Not possible
		14. As (11 or 12) with targeting	
		14.1 "targeting" estimated in VAST	Might not converge
		14.2 targeting as cluster effect	Low
		15. as(11 or 12) with vessel effects and targeting estimated outside VAST (clusters)	Not possible

Other directions for future work suggested were:

- Assess the effect of temporal changes in spatial distribution of effort to understand whether data from different flags can be combined
- Repeat the analyses for yellowfin tuna to see if the same patterns seen for bigeye tuna arise
- Repeat the length composition analysis using data just obtained by the crew or just observer data

- Investigate the correlation of the CPUE of the different fleets with El Niño and La Niña
- Cluster analyses: Combining all regions may improve the results for interpolated areas.
- Continue investigating how to detect changes in targeting

A complete list of recommendations to be considered when collecting and treating longline CPUE data to produce indices of abundance in general and to the tropical tunas in the EPO was produced by the group (Appendix A).

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APPENDIX A. RECOMMENDATION FROM THE PARTICIPANTS

The participants drafted and approved a set of recommendations to be considered when collecting and treating longline CPUE data to produce indices of abundance, as follows.

A.1 Data availability

a. *Commend* Japan, Korea, China, and Chinese Taipei for making the operational-level data available to the IATTC staff for analysis while their scientists are present (Japan) or until the 10th meeting of the Scientific Advisory Committee (Korea, China, and Chinese Taipei).
b. *Commend* Japan and Korea for making the size-composition data with fine spatial resolution available to the IATTC staff for analysis until the 10th meeting of the Scientific Advisory Committee.
c. *Request* the IATTC staff to prepare a document stating the reasons why the operational-level data, and the corresponding fine scale size-composition data by sex, should be made available for research for longer periods of time.

A.2 Data collection

a. *Encourage* CPCs to continue collecting size-frequency data at levels of coverage adequate for computing indices of abundance by size class.
b. *Continue or start* interviews with fishers, to collect information on gear usage for use in CPUE standardizations and to better understand fishing strategies, including choices of secondary targets, and any changes in the gear (for example, changing the number of hooks between floats within a set, or adding light sticks in part of the set), and how they fill the "Target" field in the logbooks.
c. *Retrospectively match* operational data with length-composition data and ensure that they are linked for future data collection.
d. *Continue* retrieving unique identifiers for vessels in the Japanese database prior to 1979, and do so for other fleets where needed.
e. *Compile* information about technological changes to vessels in order to understand changes over time that can be used in the CPUE standardization.
f. *Encourage* CPCs to require the recording in vessel logbooks of the use of light sticks and the times of the end of the set/start of retrieving and end of retrieving (with indication of time zone used).
g. *Encourage* Chinese Taipei to provide all available logbook data to data analysts, representing the best and most complete information possible.

A.3 Analyses

a. *Continue* the collaborative work among the IATTC staff, external collaborators, and CPC scientists.
b. *Compare* the length-composition data for the Japanese fleet recorded by vessel crews and by on-board observers, to understand the recent tendency towards larger sizes, taking into account spatial effects.
c. *Examine* the reliability of logbook data by comparing with the observer data. For example, use the observer data to develop a model to predict what the catch-per-set rates should be in an area-year-quarter stratum, and compare to the logbook data to evaluate variations in the reporting.
d. *Examine* the "Target" field (tuna, swordfish, shark) reported in the Japanese logbook data and see what characteristics relate to the different targets.
e. *Analyze* observer data that include hook-by-hook information to evaluate whether gear setup changes within a set.
f. *Evaluate* the data to determine whether swordfish are caught in the same sets as bigeye tuna. Catches of swordfish appear to occur in areas where large numbers of hooks between floats are used, which

could indicate deeper sets.

g. *Review* observer data to identify secondary targeting and define, if necessary, new data fields to be added to logbooks.
h. *Conduct* cross-validation studies on fishery data from time periods with good spatial coverage or with survey data to evaluate biases caused by poor spatial coverage of the species' habitat, such as missing data at edges and in patches (*e.g.,* EEZs where fishing is restricted), and/or by preferential sampling. Investigate the use of environmental variables to impute CPUE in spatial cells with no data, and check the effect of excluding from the analysis and/or predictions cells that are deemed unsuitable habitat for the species.
i. *Use* length-compositions estimated with by VAST models and spatially weighted by catch to represent the length-compositions of the catches in the assessment, and spatially weighted by CPUE to represent the length-compositions corresponding to the indices of abundance. More efficient methods are needed to be able to implement VAST models with finer length-interval stratification. Investigate alternative methods to analyze the length-composition data in VAST.
j. *Review* all the available information related to the effect of El Niño and La Niña oceanographic conditions on CPUE and *evaluate* correlations between EPO and Central Pacific CPUE indices and the El Niño indices to determine if there are spatial changes in the distribution, recruitment, or catchability of the stock.
k. *Investigate* the seasonality feature in VAST.

A.3 Diagnostics

a. *Compare* vessel effects by flag.
b. *Define* a set of standard diagnostics that should be applied to the spatio-temporal modeling.
c. *Develop* diagnostics to identify when the correlation structure changes in space or time.
d. When using the results of clusters analyses in the model to standardize for targeting (e.g., the cluster ID is used as a factor in the CPUE standardization model), *examine* the year effect by cluster for differences.
e. *Compare* CPUE among flags in areas where their effort overlaps.
f. *Construct* influence plots and step plots.
g. *Continue* simulations to test spatial-temporal models. Use simulation studies to assess the effect of aggregating data (*e.g.* by spatial cell-time-vessel *vs*. spatial cell-time).

A.4 EPO abundance indices

a. Targeting by vessel/gear *versus* spatial targeting: *exclude* spatial targeting in VAST because this is a density effect and it is confounded with the spatial components of the model.
b. *Compute* indices of abundance for the four areas of the spatial assessment from Japanese data and from post-1990 Korean data (when the Korean fleet shifted away from targeting albacore in temperate areas and concentrated in the tropics).
c. *Exclude* the data associated with the clusters of the fleet-specific cluster analyses of catch composition that had a high proportion of CPUE for striped marlins, except for area 1 for the Japanese fleet (because of the high proportion of bigeye in the striped marlin clusters in that area). Clustering should be done using Hoyle's method. Use cluster as a catchability covariate factor. Include the eliminated cluster in a sensitivity analysis.
d. *Further investigate* targeting to determine how best to model targeting in VAST (*e.g.*, formulation of targeting effects, specify target at the vessel*cell*year level rather than set, set-by-set targeting is probably not happening, *etc*.).
e. *Further investigate* the size-based CPUE model.

APPENDIX B: LIST OF PARTICIPANTS AND GROUP PHOTO

List of participants of the IATTC Workshop to improve the longline indices of abundance of bigeye and yellowfin tunas in the eastern Pacific Ocean, 11-19 February 2019, La Jolla, CA, USA.

NAME	ORGANIZATION	EMAIL
Alexandre Aires-da-Silva	IATTC	alexdasilva@iattc.org
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Cleridy Lennert	IATTC	clennert@iattc.org
Doonam Kim	National Institute of Fisheries Science	doonam@korea.kr
Guillermo Compean	IATTC	gcompean@iattc.org
Haikun Xu	IATTC	hkxu@iattc.org
Hui-Hua Lee	NOAA	huihua.lee@noaa.gov
Jiangfeng Zhu	Shanghai Ocean University	jfzhu@shou.edu.cn
Jon Lopez	IATTC	jlopez@iattc.org
Juan Carlos Quiroz	TUNACONS	juan.quirozespinoza@utas.edu.au
Keisuke Satoh	Fisheries Research and Education Agency	kstu21@fra.affrc.go.jp
Laura Tremblay- Boyer	SPC	lauratb@spc.int
Mark Maunder	IATTC	mmaunder@iattc.org
Nicholas Ducharme-Barth	SPC	nicholasd@spc.int
Ricardo Oliveros	IATTC	roliveros@iattc.org
Shane Griffiths	IATTC	sgriffiths@iattc.org
Sheng-Ping Wang	National Taiwan Ocean University	wsp@mail.ntou.edu.tw
Simon Hoyle	Consultant	simon.hoyle@gmail.com
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Sung Il Lee	National Institute of Fisheries Science	k.sungillee@gmail.com
Takayuki Matsumoto	Fisheries Research and Education Agency	matumot@affrc.go.jp
Toshihide Kitakado	Tokyo University of Marine Science and Technology	kitakado@kaiyodai.ac.jp

Participants of the IATTC Workshop to improve the longline indices of abundance of bigeye and yellowfin tunas in the eastern Pacific Ocean, 11-19 February 2019, La Jolla, CA, USA. From left to right: Laura Tremblay- Boyer, Juan Carlos Quiroz, Shane Griffiths, Toshihide Kitakado, Steve Teo, back row: Nicholas Ducharme-Barth, Ricardo Oliveros-Ramos, Jiangfeng Zhu, Mark Maunder, Keisuke Satoh, Simon Hoyle, Takayuki Matsumoto, Alexandre Aires-da-Silva, Cleridy Lennert, Haikun Xu, Sheng-Ping Wang, front row: Jon Lopez, Sung Il Lee, Doonam Kim, Carolina Minte-Vera. Not in the picture: Guillermo Compean, Hui-Hua Lee.

APPENDIX C: AGENDA

INTER-AMERICAN TROPICAL TUNA COMMISSION
WORKSHOP TO IMPROVE THE LONGLINE INDICES OF ABUNDANCE OF BIGEYE AND YELLOWFIN TUNAS IN THE EASTERN PACIFIC OCEAN
La Jolla, California (USA)
11-15 February 2019

PROVISIONAL AGENDA

Monday 11 February

0900: Opening of the meeting and welcome (*Alexandre Aires-da-Silva*)

0915: Introductions, notifications, workshop goals and products (*Carolina Minte-Vera, Chair*)

1. Statement of theme and goals

0930: Keynote talk: CPUE standardization (*Mark Maunder*)

1000: Current indices of relative abundance for bigeye and yellowfin in the EPO from standardized longline data, and their potential problems (*Carolina Minte-Vera*)

1030: Coffee break

2. Review of operational-level CPUE data and national regulations for longline fisheries in the Pacific Ocean

1100: Japan (*Keisuke Satoh*)

1130: Korea (*Sung Il Lee*)

1200: Lunch

1300: China (*Jiangfeng Zhu*)

1330: Chinese Taipei (*Sheng-Ping Wang*)

1400: Comparison of all fleets in the main EPO stock assessment area (*Carolina Minte-Vera)*

1430: Discussion: similarities and differences among data sets and ways to combine them

1500: Announcement about the IATTC tagging program (*Kurt Schaefer*)

1510: Coffee break

3. Learning from recent experiences on CPUE standardization in t-RFMOs

1530: Collaborative work in IOTC and ICCAT, and lessons learnt (*Simon Hoyle)*

1600: Evolution in the CPUE standardization for WCPFC assessments: from fleet-specific GLMs to spatio-temporal modelling of Pacific-wide operational data sets

(*Laura Tremblay-Boyer*)

1630: Discussion

1700-1900: Social!

Tuesday 12 February

4. Overview of methods for CPUE standardization

0900: *Cpue.rfmo* library and the GLM/GAMM approach (*Simon Hoyle*)

0930: Spatial-temporal models (*Haikun Xu)*

5. Targeting effects

1000: Review of international regulations in the Pacific Ocean for longline fisheries that may cause changes in fish targets (*Guillermo Compean*)

1030: Coffee break

1100: Overview for estimating targeting effects (*Simon Hoyle*)

1125: Estimation of targeting effects in the EPO using different methods (*Cleridy Lennert-Cody*)

1150: Pacific-wide changes in tuna targeting via cluster analysis of all-fleet operational data sets (*Laura Tremblay-Boyer)*

1205: Discussion

1230: Lunch

6. Preliminary results of the CPUE standardization using operational-level data

1330: Results using Hoyle's approach: by fleet and combining the data (*Simon Hoyle*)

1400: Spatial-temporal models with the inclusion of vessel effects and targeting

(*Haikun Xu)*

1430: Discussion and recommendation for further CPUE analyses

1530: Coffee break

1600-1700: Analyses (*some participants*)

Completing the CPCs descriptive reports about the data (*other participants*)

Wednesday 13 February

7. Assessing standardization methods

0900: Simulation experiments (*Nicholas Ducharme-Barth*)

8. Inclusion of size-composition data

0930: Experiences on corresponding size-composition data to the indices and catch (*Simon Hoyle*)

1000: Corresponding size-composition data to the indices and catch

(*Ricardo Oliveros-Ramos)*

1030: Coffee break

9. Review of size-composition data from longline fisheries in the Pacific Ocean

1100: Japan (*Keisuke Satoh*)

1130: Korea (*Sung Il Lee)*

1200: Lunch

10. Standardization: including size-composition data

1300: Standardization including size composition data (*Haikun Xu*)

1330: Preliminary results of indices by size category (*Keisuke Satoh*)

1400: Discussion

1500: Coffee break

11. Results

1530: Results of analyses conducted during the workshop

1630: Discussion and further suggestions, review of next two days' agenda

The Thursday and Friday schedules will depend on the work done during the week, following suggestions from participants

Thursday 14 February

0900-1200: Analyses (*some participants*)

Github demonstration (*Laura Tremblay-Boyer* and *Simon Hoyle)*

1200: Lunch

1300: Presentation of new analyses

1400: Discussion

1430: Coffee break

1500-1700: Analyses (*some participants*)

Completing the CPC's descriptive reports about the data (*other participants*)

1800-2000: Dinner

Friday 15 February

0900: Results of new size-composition analyses

1000: Discussion

1030: Coffee break

1100: Presentation of new analyses for CPUE standardization

1200: Lunch

12. Final discussion and recommendations

1300: Discussion on future work for CPUE and size-composition data, recommendations from the group

1500 Coffee break

1530: Recommendations from the group (continued)

1630: Approval of recommendations

1700: Adjournment

LOCATION:

Embassy Suites Hotel, La Jolla

4550 La Jolla Village Drive

San Diego, CA 92122

USA

APPENDIX D: ANNOUNCEMENT ABOUT THE IATTC TAGGING PROGRAM

Kurt Schafer announced the new IATTC tagging program to the participants. The link to the presentation is here. Flyers will be translated to the national languages for local distribution. Suggestions for enhancing the probability of tag recoveries from bigeye and yellowfin tuna caught by longlines were requested.

APPENDIX E: REPORT BY FLEET

Suggested report outline:

- Fleet
- Authors
- National regulations (how is the catch limit allocated among vessels? E.g. transferable quota by vessel, non-transferable quota by vessel, quota by company – depending on "score" etc...) /treaties that may affect fishing strategies
- Time series of catch
- Any changes in fishing practices over time
- Description of data collection (operational CPUE data) and any changes over time
- Description variables in the file and (any particularities e.g. ZZ-NA for vessel_ID, etc, precision of latitude and longitude, how is coded [E or W] etc)
- Coverage over time (and method to compute it)
- Year start, year finish, spatial domain (lat range, long range)
- Histogram of number of species in the file (by 5-yrs period)
- Stacked plot of HBF
- Maps over time (5-yrs period): CPUE main species, effort, HBF

E1. KOREA

Korean longline fleet

Sung Il Lee and Doo Nam Kim

National Institute of Fisheries Science (NIFS)

1. [ASK for approval/managers] National regulations

(how is the catch limit allocated among vessels? E.g. transferable quota by vessel, non-transferable quota by vessel, quota by company – depending on "score" etc.) / treaties that may affect fishing strategies

[Add later]

2. Annual total catch

Since 1975 the total catch had increased, showed a peak in 1991, and then it was stable at the level of average 19,000 tons. However, it sharply decreased in 2006, showed the low level of below 10,000 tons until 2009, and increased to more than 10,000 tons thereafter.

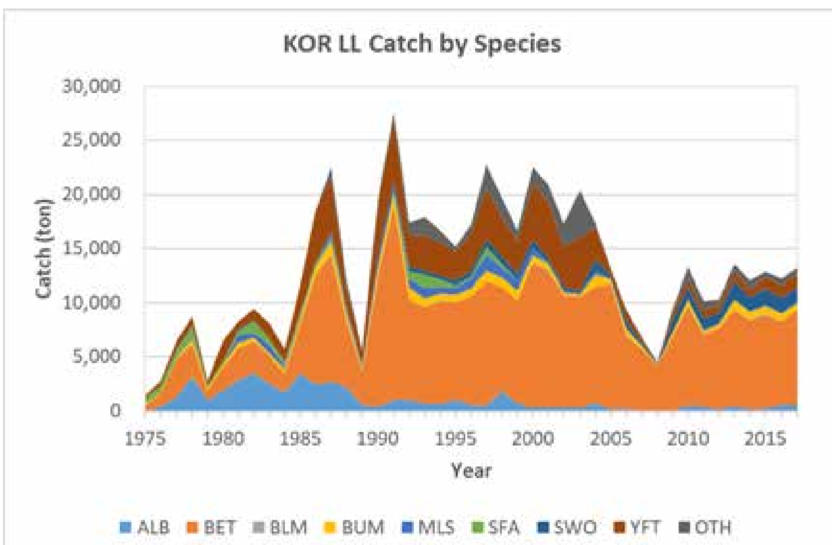


Fig. 1. Annual catch of major species by Korean longline fisheries in the EPO, 1975~2017.

3. Changes in fishing practices over time

As for the species composition, ALB in total catch was relatively higher from 1975 to 1990, and the proportion of BET and YFT accounted for 76% in average from 1990 to 2004. Since 2005 the proportions of BET and SWO increased, while the proportion of YFT decreased. In particular, BET accounted for about 70% of total catch.

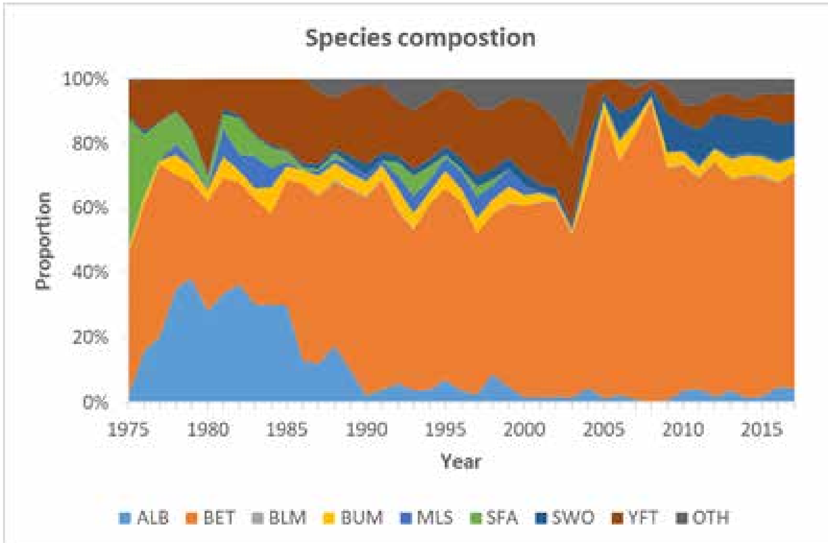


Fig. 2. Annual species composition of Korean longline fisheries in the EPO, 1975~2017.

4. Description of data collection and any changes over time

In Korea, the data reporting and management is legally based on the Distant Water Fisheries Development Act. Until Nov. 2012, fishermen used paper logbook to record their fishing information, and they submitted the logbook within 30 days (home-based) or within 60 days (foreign-based) after completion of their operations, and there was a problem in achieving 100% of data coverage. Hence, in Dec. 2012, we strengthened and revised the Act to oblige fishers to report every month using electronic format logbook (ex. excel format), and could achieve 100% in the coverage thereafter. In addition, we begun to collect information on discard/release according to tuna RFMOs data requirement, and added ecologically related species (ERS; sharks, sea birds, sea turtles) data reporting format. In Sep. 2015, we developed and changed the system to Electronic Reporting System. At present, fishermen report their fishing information every day, and the National Institute of Fisheries Science (NIFS) reviews the data in real time. And the information is cross-checked with data of VMS and CDS. Particularly, catch information is cross-checked prior to issuing the CDS.

5. Description of data used for CPUE standardization

The data set span from 1971 to 2017 and include the longline operations of the Korean distant water fleet in the Pacific Ocean. The data include the following fields:

- **Call sign:** In the data set, there are three types of call sign. Firstly, the call signs that consist of “alphabet and number” are real vessel IDs. Secondly, the call signs that start with "ZA” or ZB" are codes assigned by the NIFS staff based on the name of the vessel when no actual call sign information was available. If the codes are the same, they are the same vessel. Lastly, there is the code of “ZZ-NA” that has no vessel information.
- **Date:** date of the set in year-month-day
- **Year/Month:** year/month of the set
- **Lat01/Long01:** latitude/longitude of the set
- **"NS":** code 1 or “N” (north), 2 or “S” (south),
- **"EW":** code 1 or “E” (east), 2 or “W” (west)

- **"hooks":** Number of hooks used in the set
- **"floats":** Number of floats used in the set
- Number of fish caught in a set of **"ALB":** albacore tuna, **"BET":** bigeye tuna, **"BLM":** black marlin, **"BUM":** blue marlin, **"MLS":** striped marlin, **"OSH":** sharks, **"OTH":** other species, **"SFA":** sailfish, **"SKJ":** skipjack tuna, **"SWO":** swordfish, **"YFT":** yellowfin tuna, **"Total":** all species

6. Data coverage over time

The coverage of the operational level data for the Eastern Pacific Ocean (EPO) was calculated by dividing the BET catch (5 by 5 area) by the nominal BET catch held in the IATTC Secretariat. However, the data were revised for this collaborative work.

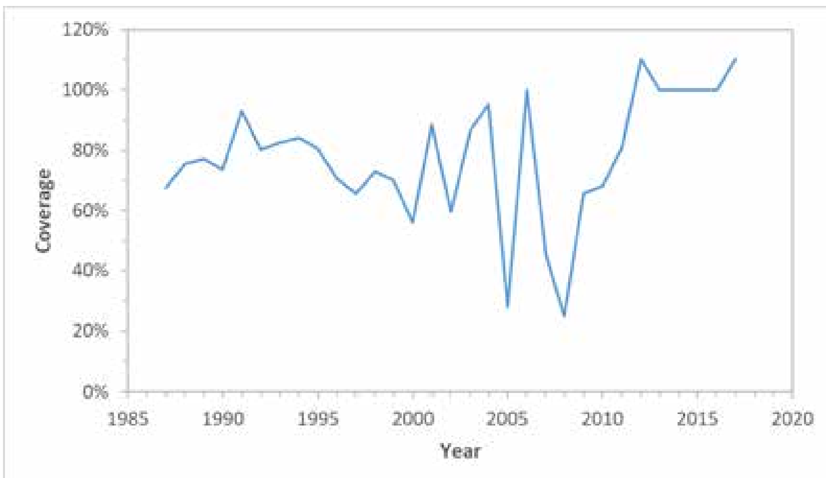


Fig. D1. 3. Coverage of Korean longline operational data for the EPO.

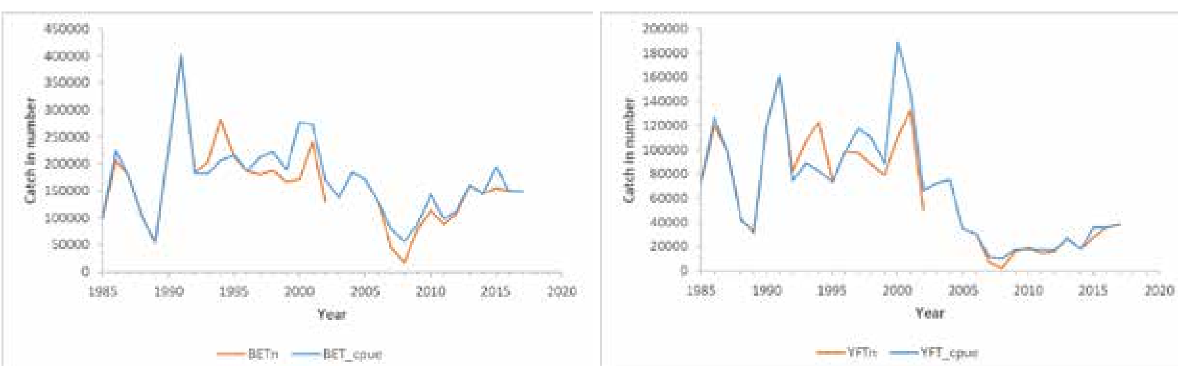


Fig. 4. Revised operational data of Korean longline fleet (red: old data, blue: revised data).

7. Fishing characteristics

The efforts of Korean longline fleet have mainly concentrated at the tropical area, targeting bigeye and yellowfin tunas.

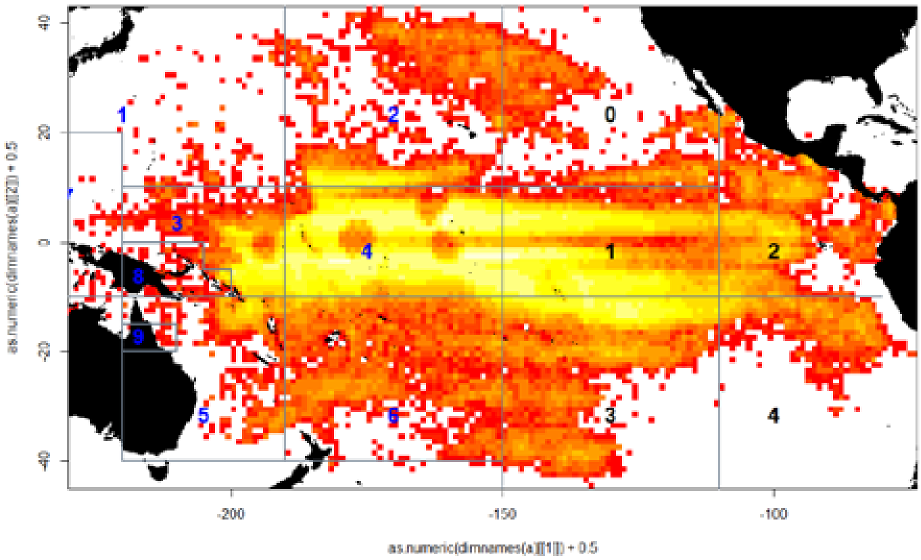


Fig. 5. Map showing fishing efforts of Korean longline fleet in the Pacific Ocean.

8. Frequency of number of species caught

Fig. 6 shows the frequency of number of species caught per set in the Korean longline fleet for the period of 1971~2017.

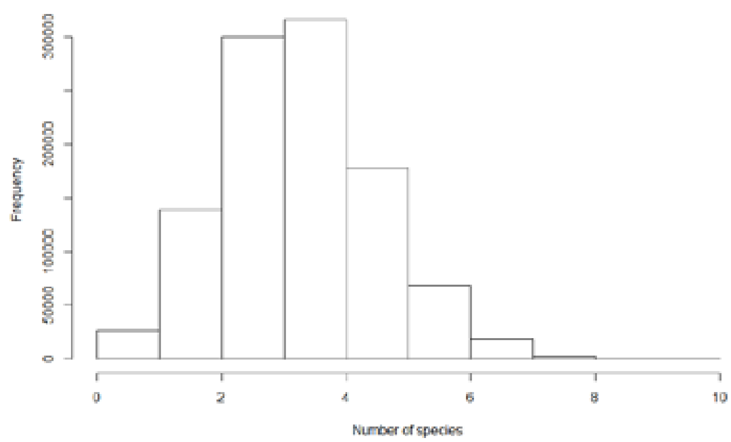


Fig. 6. Frequency of number of species caught per set.

9. Changes in HBF used over time

Until the end of 1980s, most of the Korean longline vessels in the EPO used lower number of hooks between floats (HBF) of below 9. In 1990s, fishing vessels used a wide range, from 9 to 20, and since 2010s they have used the HBF of above 16.

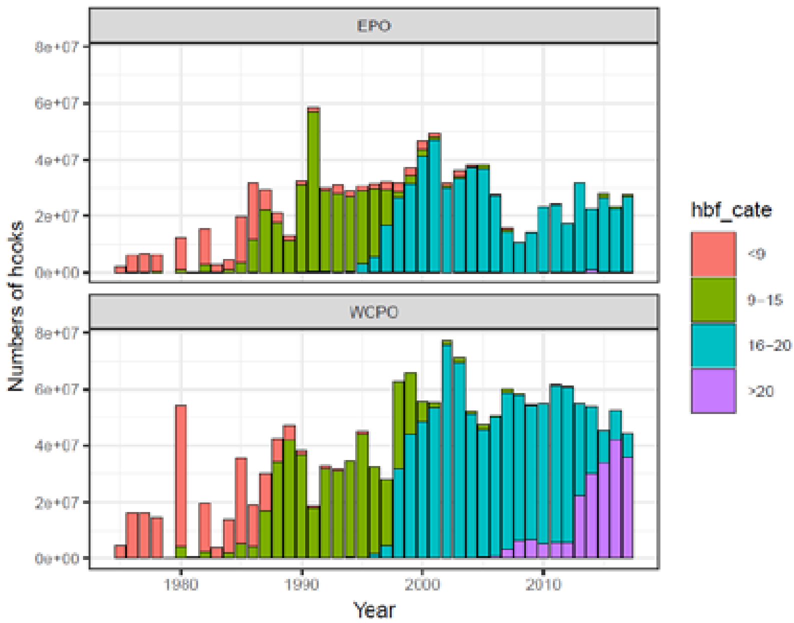
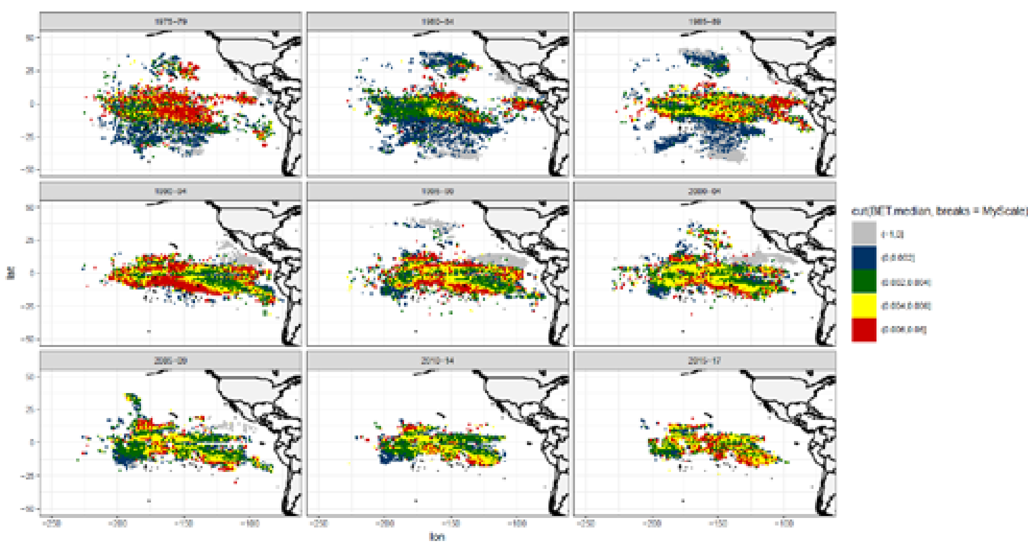


Fig. 7. Changes of the HBF used over time.

10. Maps of CPUE of main species, fishing effort and HBF by 5-yr period

Figs. 8, 9 and 10 represent maps showing CPUEs of bigeye, yellowfin and albacore tunas, fishing efforts and HBF by 5-year period, respectively.



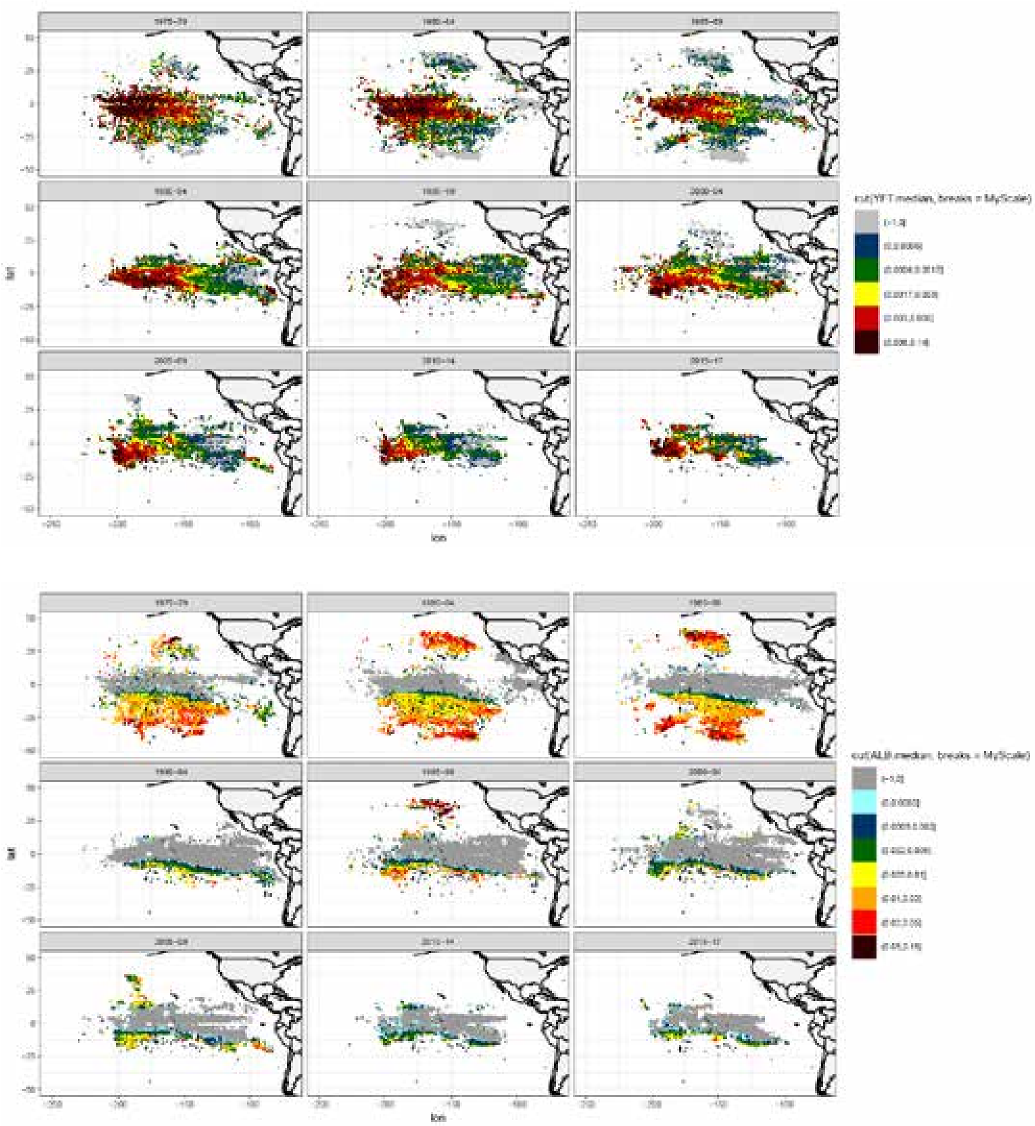


Fig. 8. Geographical distributions of CPUEs of bigeye (top), yellowfin (middle), albacore (bottom) tunas caught by Korean longline fleet in the Pacific Ocean.

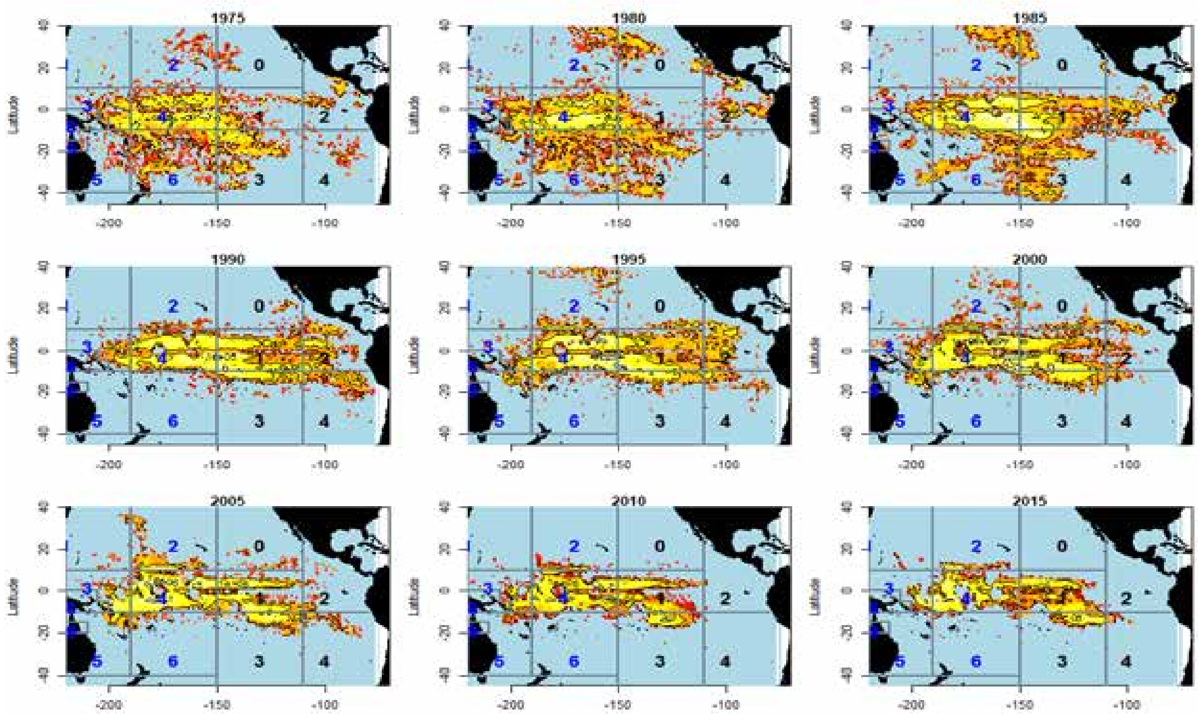


Fig. 9. Geographical distributions of fishing efforts by Korean longline fleet.

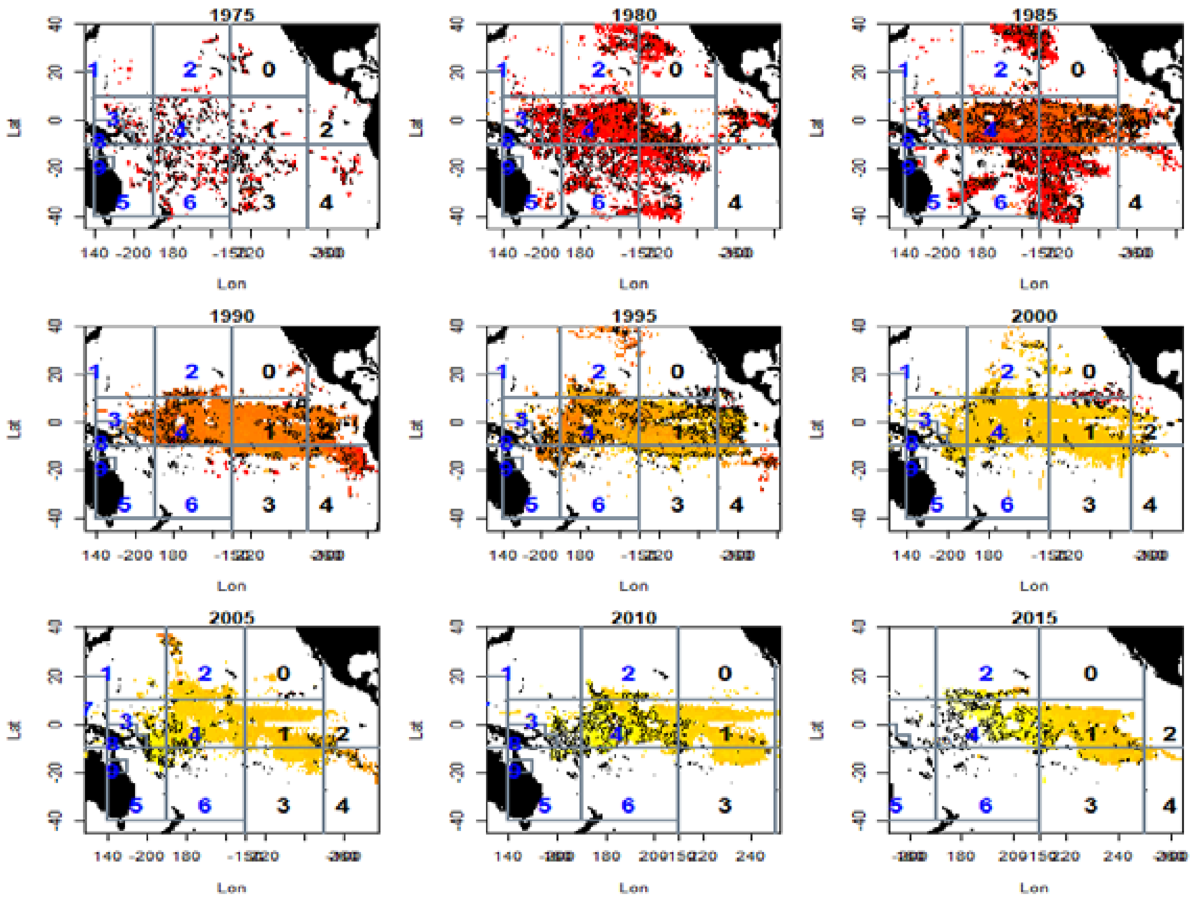


Fig. 10. Geographical distributions of HBF by Korean longline fleet.

E2. JAPAN

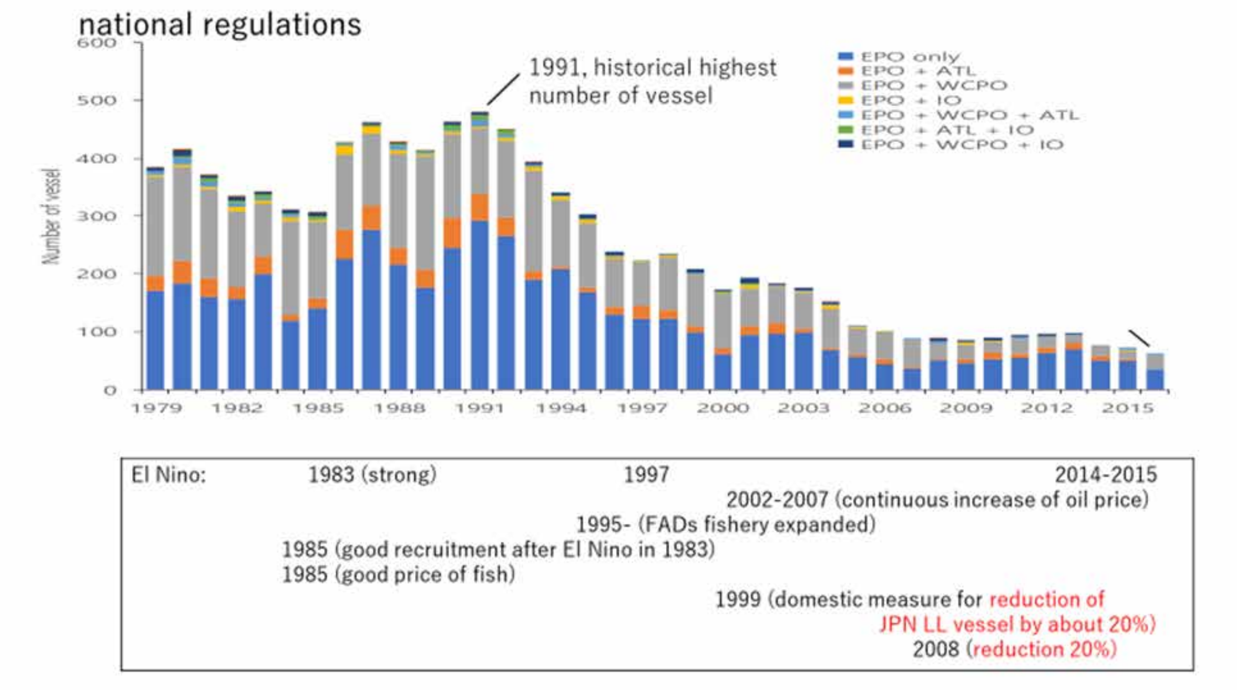


Figure D2.1 Number of Japanese vessels operating in the eastern Pacific Ocean

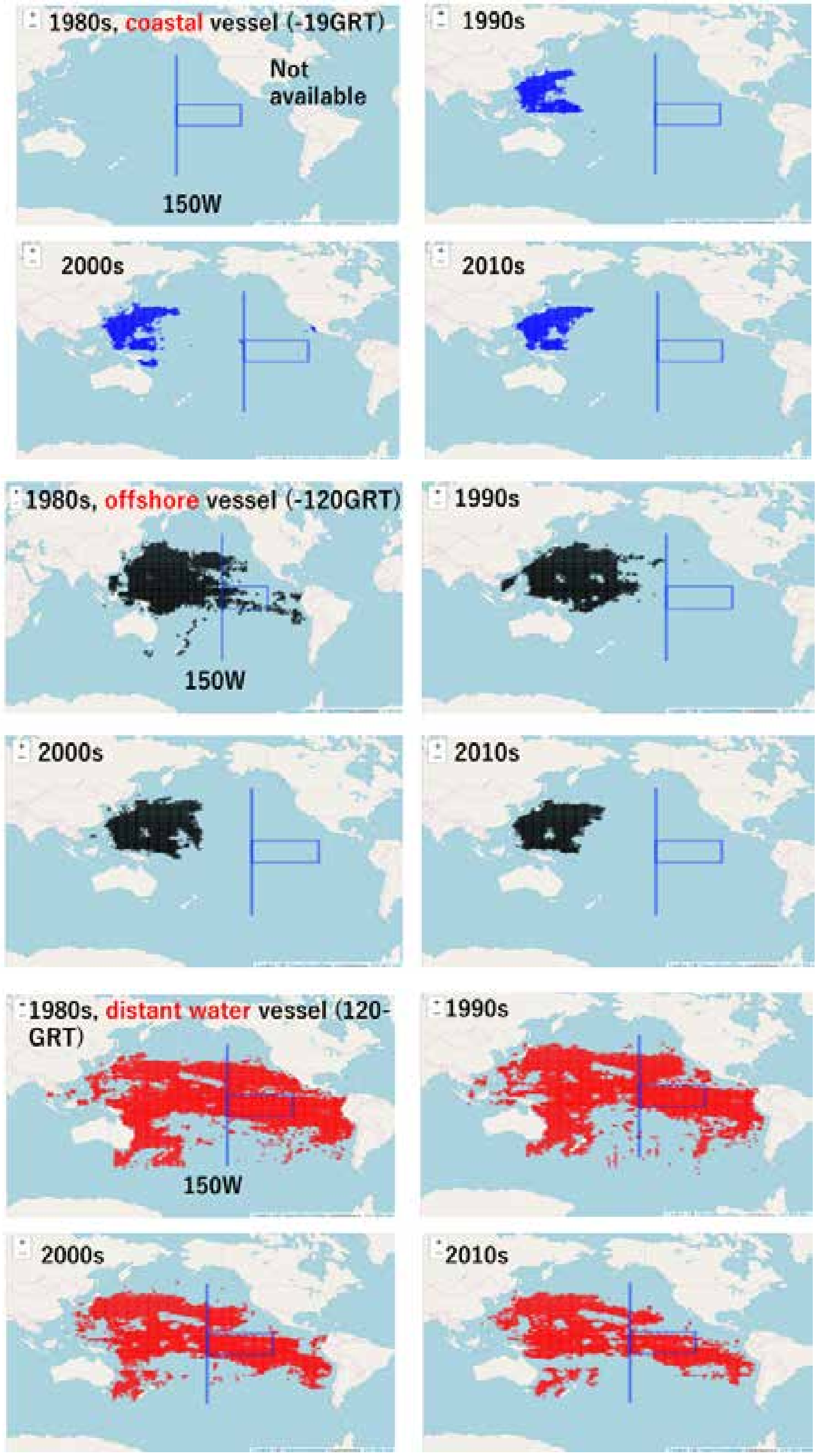


FIGURE D2.2. Areas of operation of the Japanese fleets in the Pacific Ocean: (top)coastal vessels; (middle) offshore vessels and (bottom) distant water vessels

E3. CHINESE TAIPEI

Author

Sheng-Ping Wan

National Taiwan Ocean University, Taiwan

Time series of catches

1964-2017

Change in fishing practice over time

Taiwanese tuna longliners operating in the EPO can be classified into two categories according to the gross registered tonnage (GRT), namely large scale tuna longliners (LTLL, larger than 100 GRT) and small scale tuna longliners (STLL, smaller than 100 GRT).

The LTLL fleet started fishing albacore for canning in early 1960s with tuna fishery development of Taiwan, and some fishing vessels changed targeting bigeye tuna for Japan sashimi market with shifting operation in equatorial areas of EPO in early 2000s. Now, there are one fleet operating in north hemisphere for north Pacific ALB, one in south hemisphere for south Pacific ALB and another one in equatorial areas (15°S-15°N) for tropical tuna.

For STLL fleet, they started fishing in the EPO in late 1990s for yellowfin tuna with some for sharks, and the fishing fleet shrunk in the middle of 2000s for less catch and higher operation cost. Now, most of them operate in south hemisphere of EPO for south Pacific ALB with few fish in equatorial areas for tropical tuna.

Description of data collection

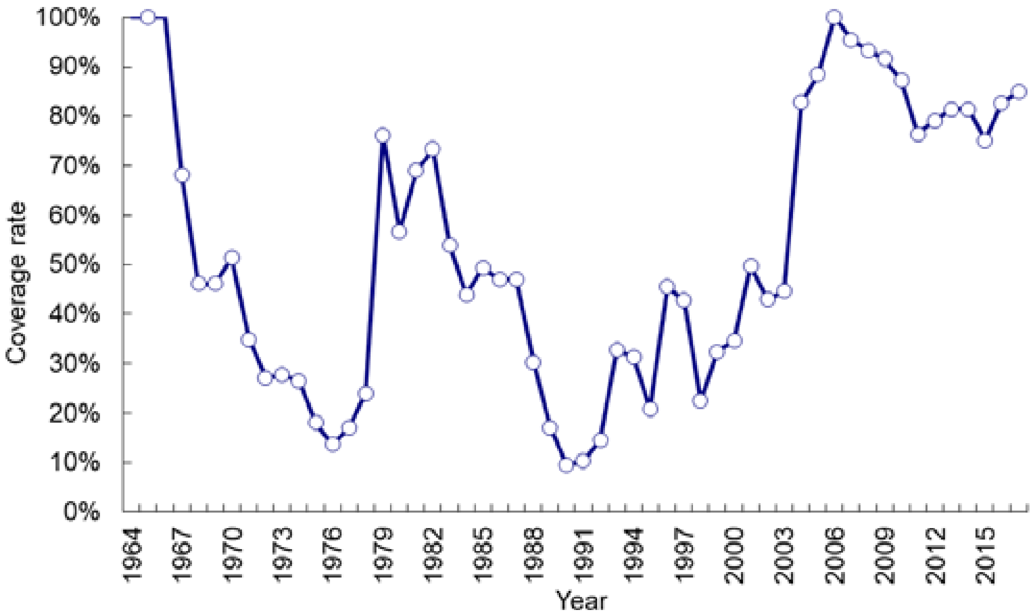
Logbooks are collected while fishing vessels calling port or transshipping catch. In order to collect fishery data in real time, Taiwan implemented electronic logbook reporting on LTLL and distant-water purse seiners (DWPS) fleets in 2014, and which was applied to STLL fleet in 2015. The logbook data is the main data source of catch and effort for all species. The size data of all species is mainly from the first 30 fish caught for each setting recorded on logbook. All fleets are required to submit catch reports periodically while fishing: fishing vessels of LTLL report weekly and the STLL fishing vessels operating outside of our EEZ report monthly. In addition, the fishing vessels and the fish traders have to report the trade and transshipment data. Market State data on LTLL are collected from the Organization for the Promotion of Responsible Tuna Fishery (OPRT) and from fish traders at foreign ports; as to the landing of STLL fishery in foreign ports, information on the fishing activities of the fishery was obtained from port States trading companies and such information together with available commercial trade data was used for the catch estimation.

Description of data file

The fields of logbook data contain vessel ID, fishing date (year, month and day), fishing location (longitude and latitude by 5 degree), hooks, number of hooks between float (after 1994), catch in number/weight by species*, fishing location (longitude and latitude by 1 degree, after 1994), and etc. Although bait, sea water temperature and hook depth are also listed in the logbook but there are large amounts of missing values for these fields.

* Species: albacore, bigeye tuna, yellowfin tuna, Pacific bluefin tuna, southern bluefin tuna, other tunas, swordfish, striped marlin, blue marlin, black marlin, other billfishes, skipjack, sharks, and other species.

Coverage over time

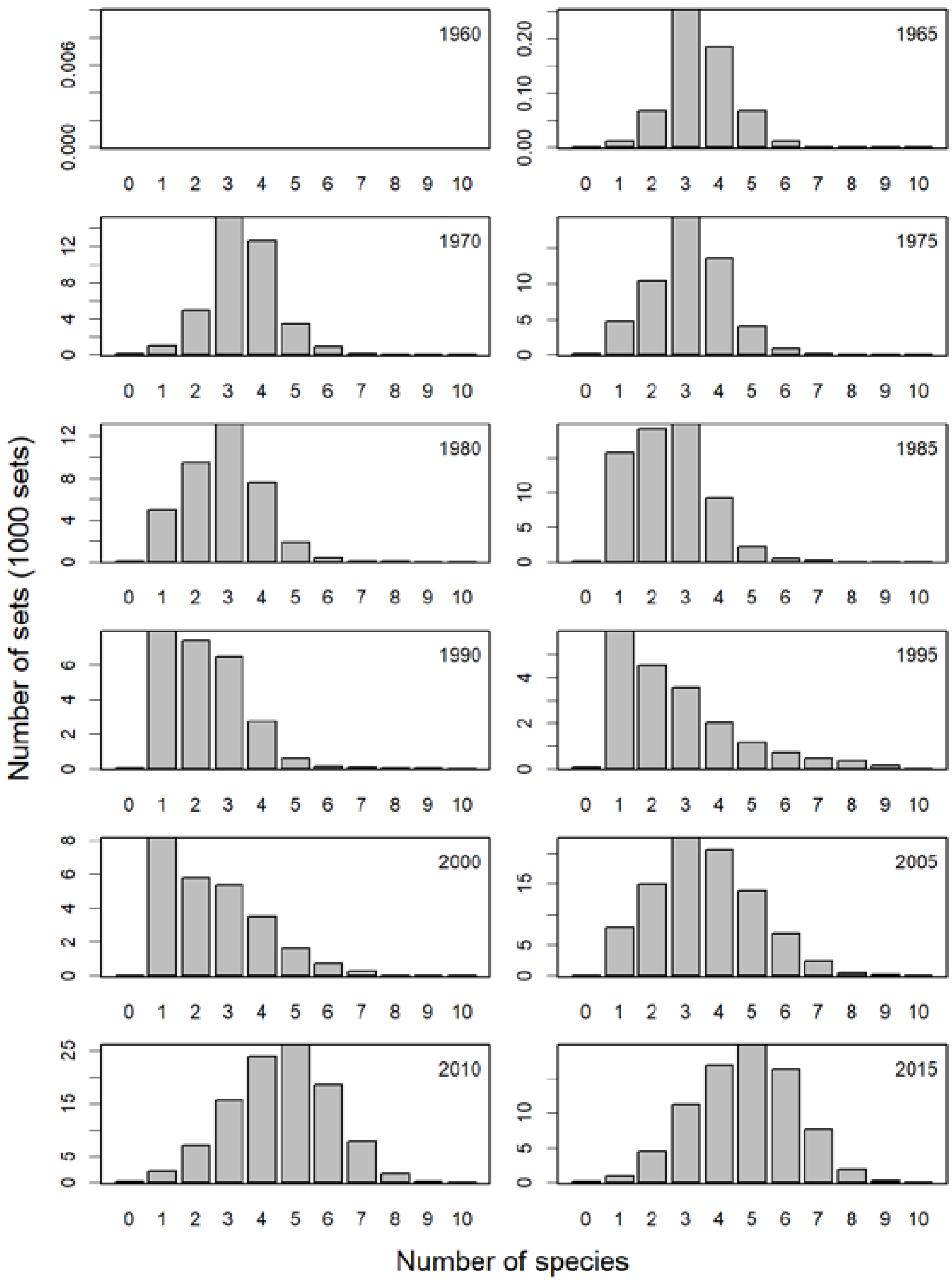


Year start, year finish, spatial dominate (lat & lon range)

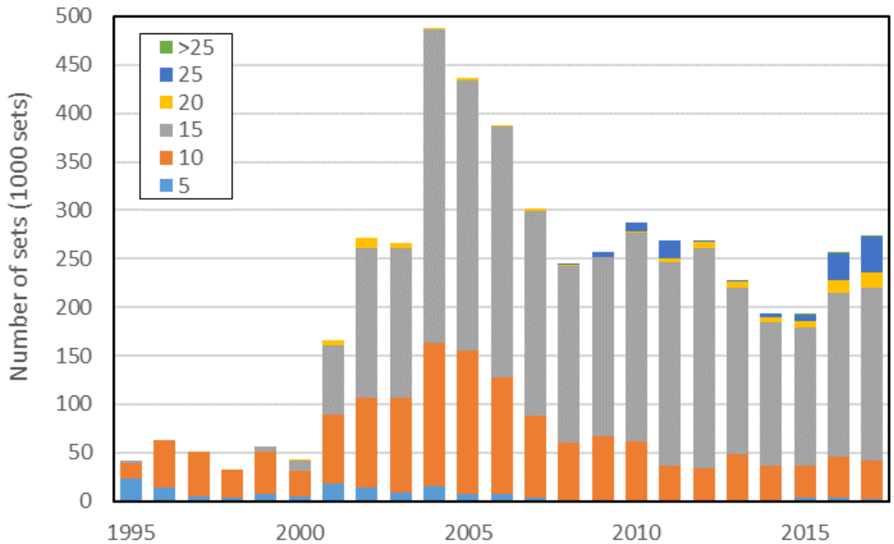
The LTLL fleet started fishing in the EPO in early 1960s, while the STLL fleet started fishing in the EPO in late 1990s. The latest data were updated up to 2017 for both of LTLL and STLL.

Most efforts concentrated in the south Pacific Ocean (5-40°S and west of 160°E - 130°W) before the middle of 1990s, and then gradually expanded northwardly and eastwardly in the entire Pacific Ocean. However, the fishing fleet shrunk in the middle of 2000s for less catch and higher operation cost.

Histogram of fish species (by 5 years)

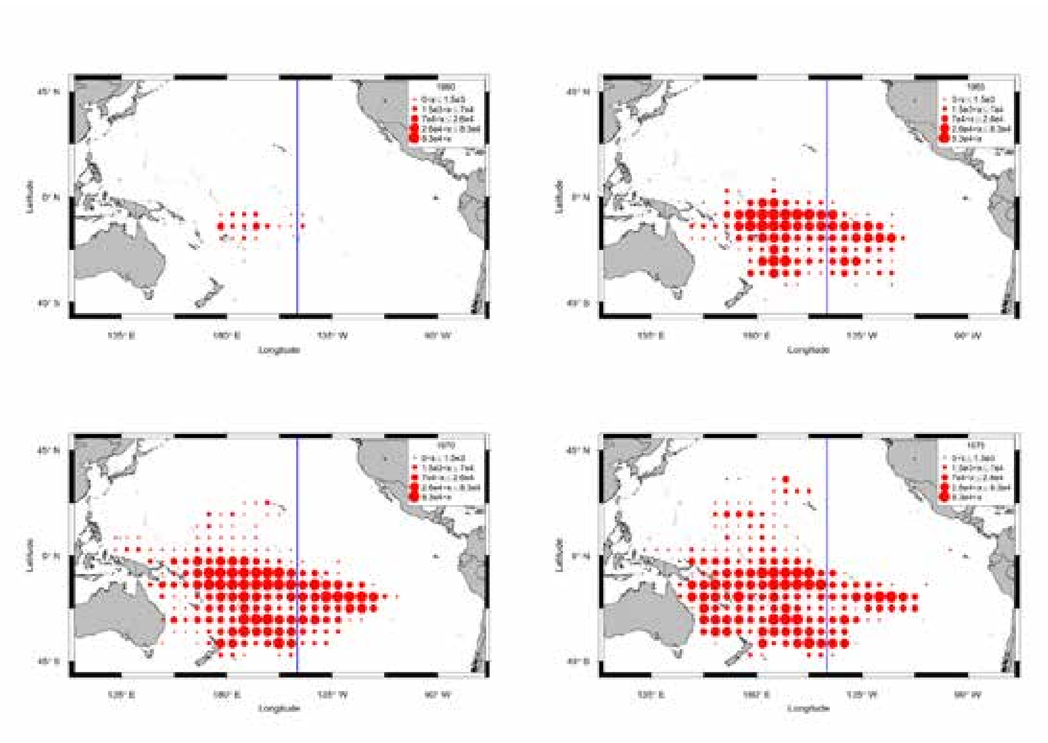


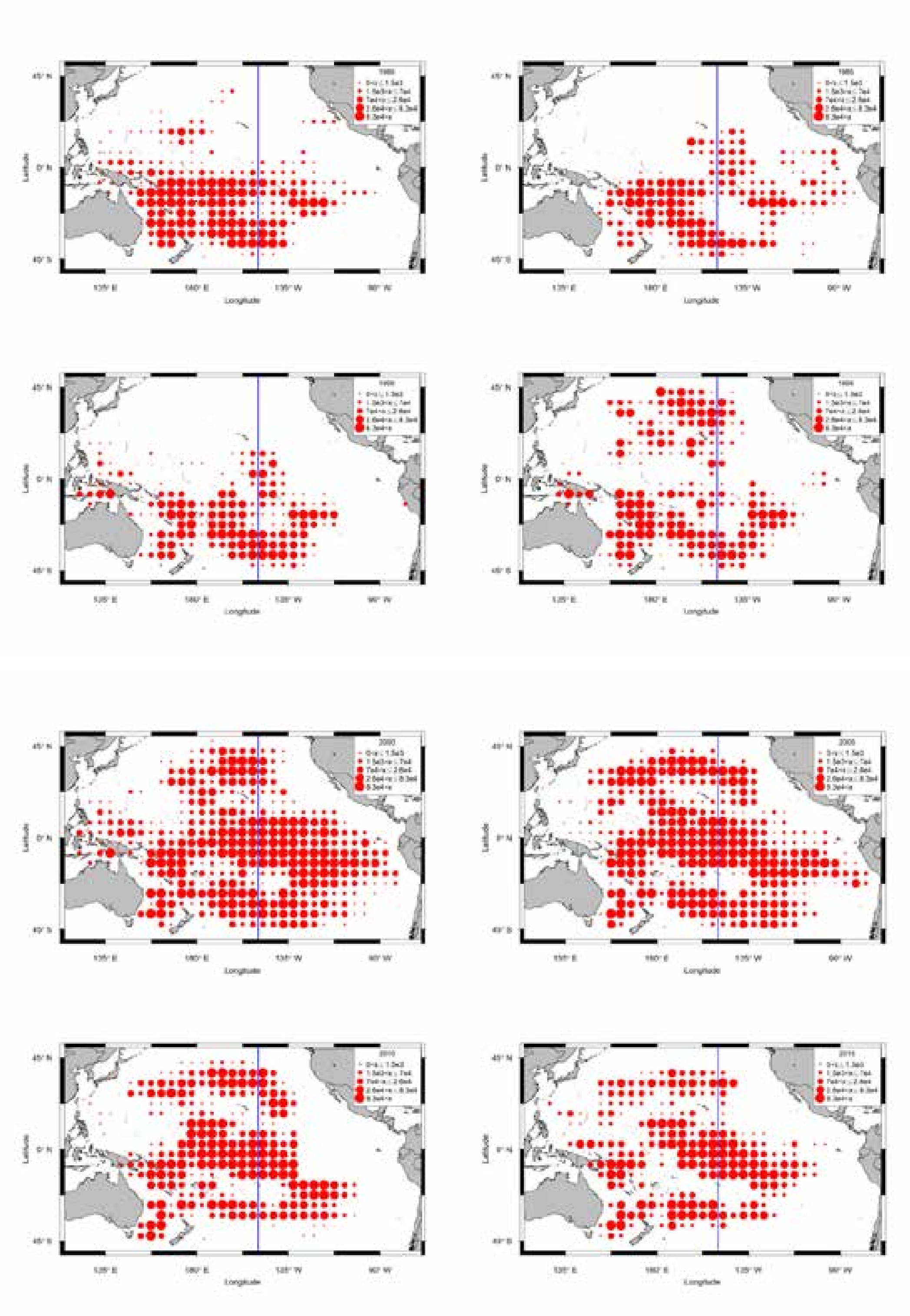
Stacked plot of HPB



Maps over time (5-years period): CPUE main species, effort, HPB

Effort (hooks):





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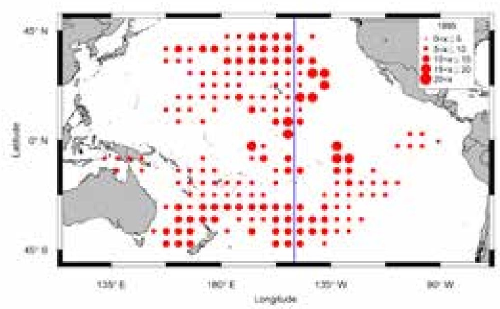
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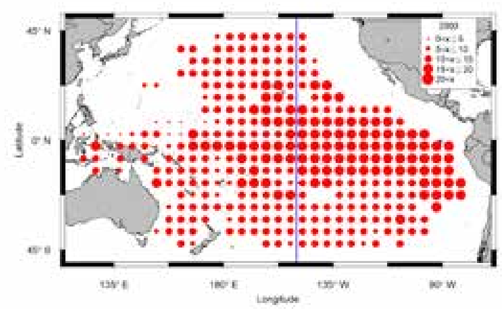
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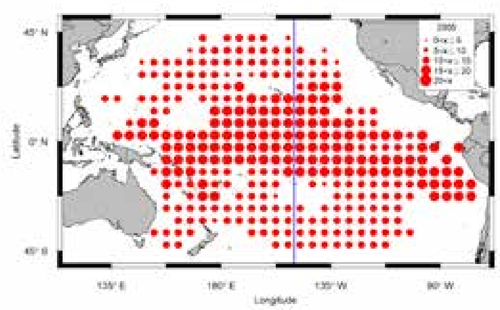
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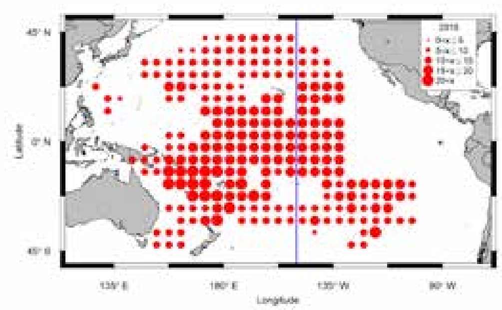
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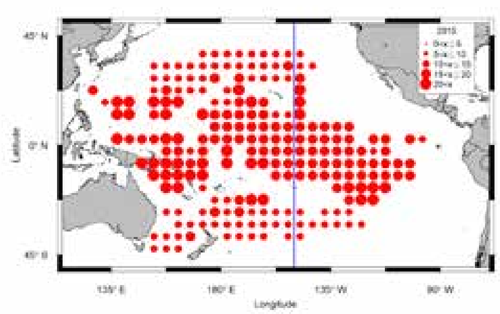
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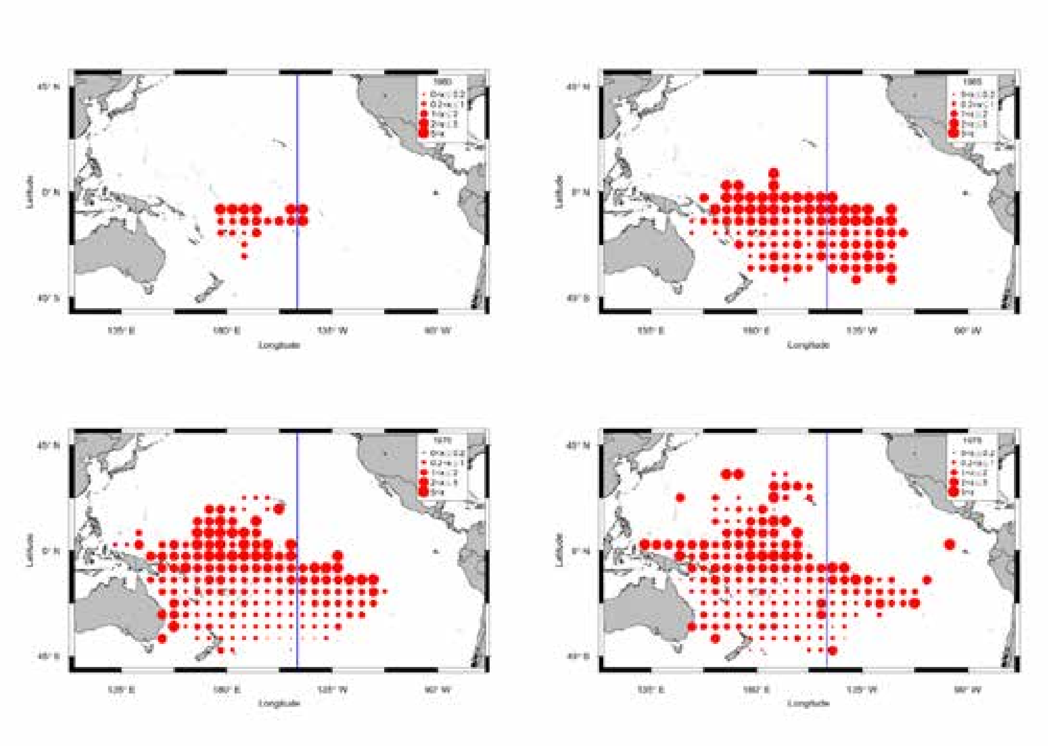

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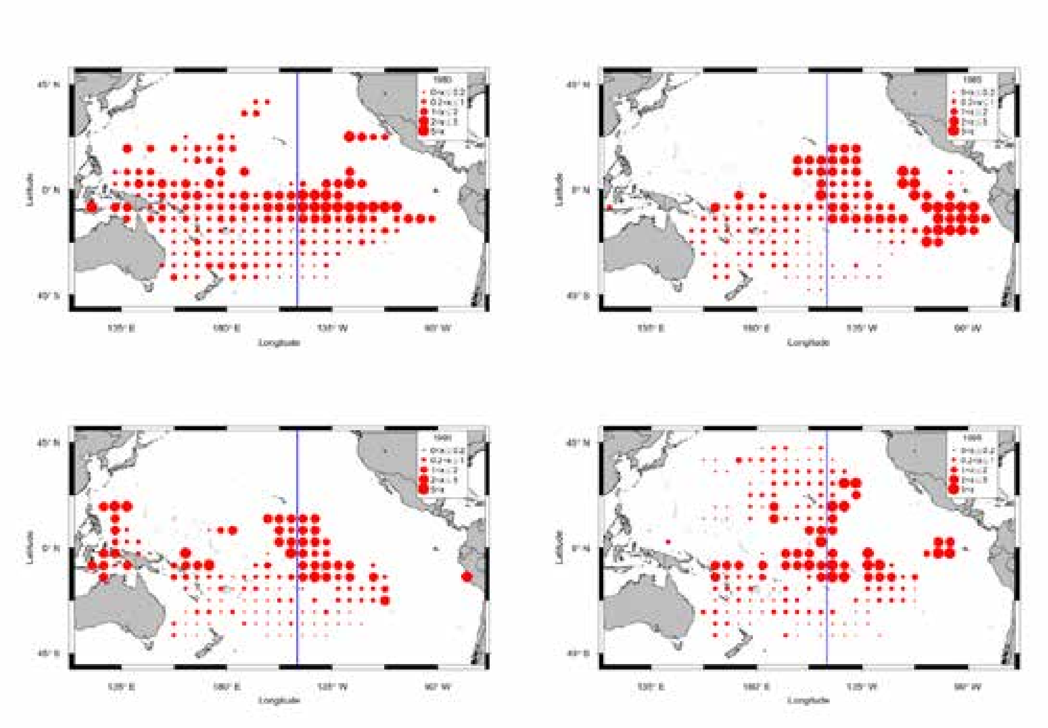

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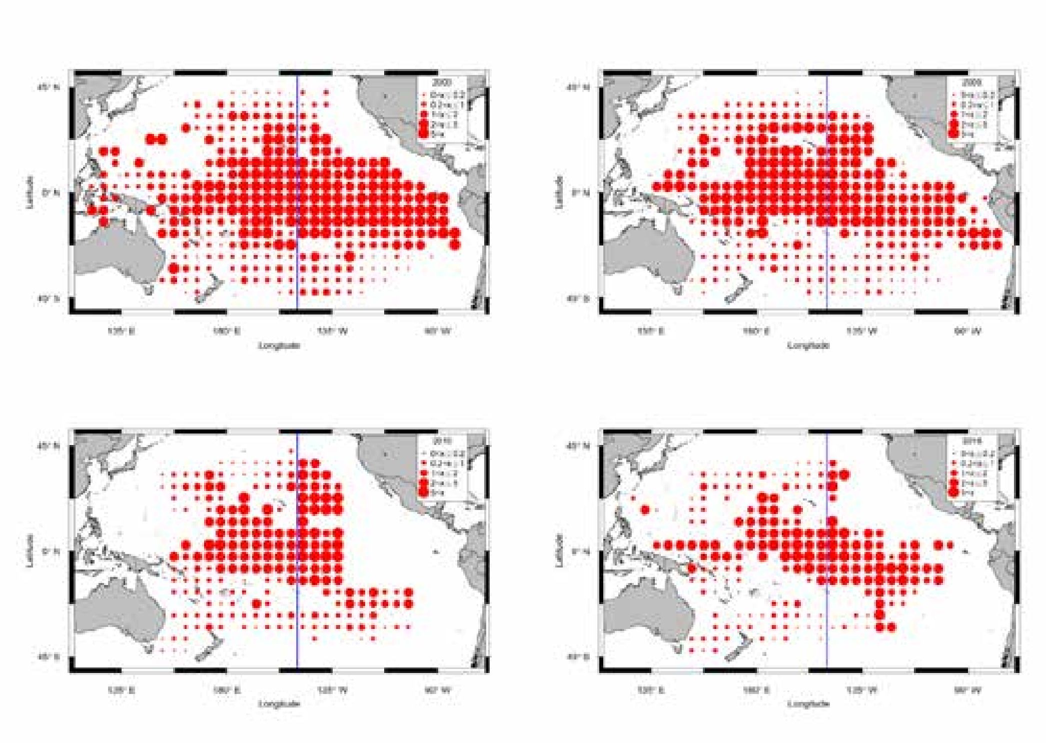

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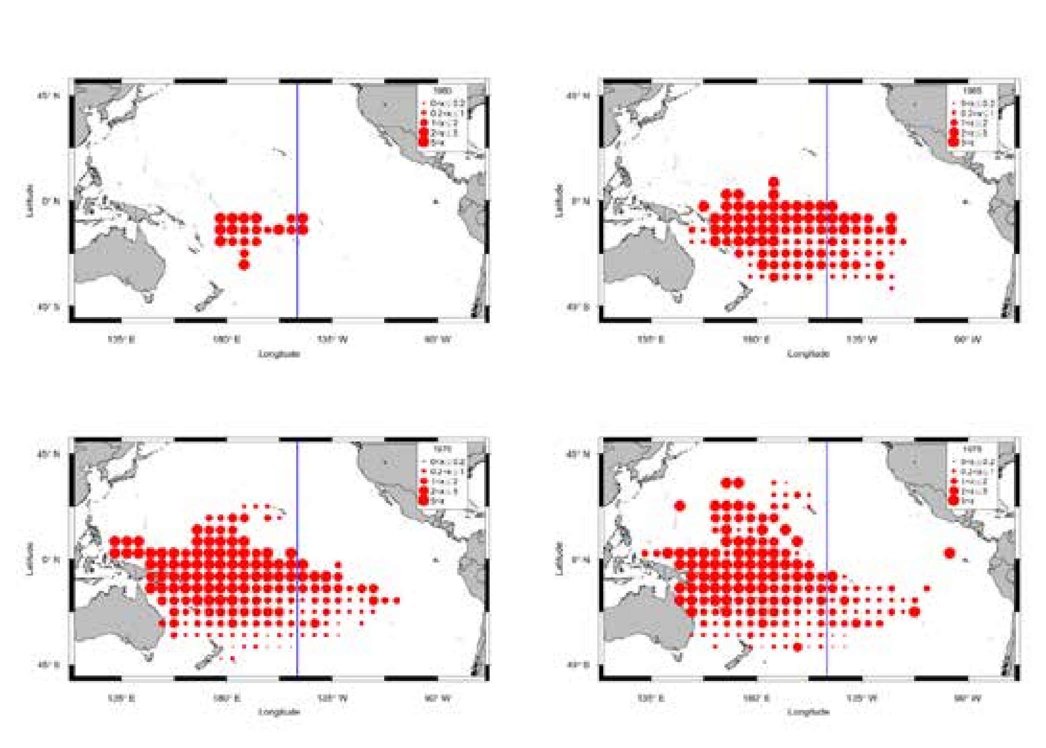

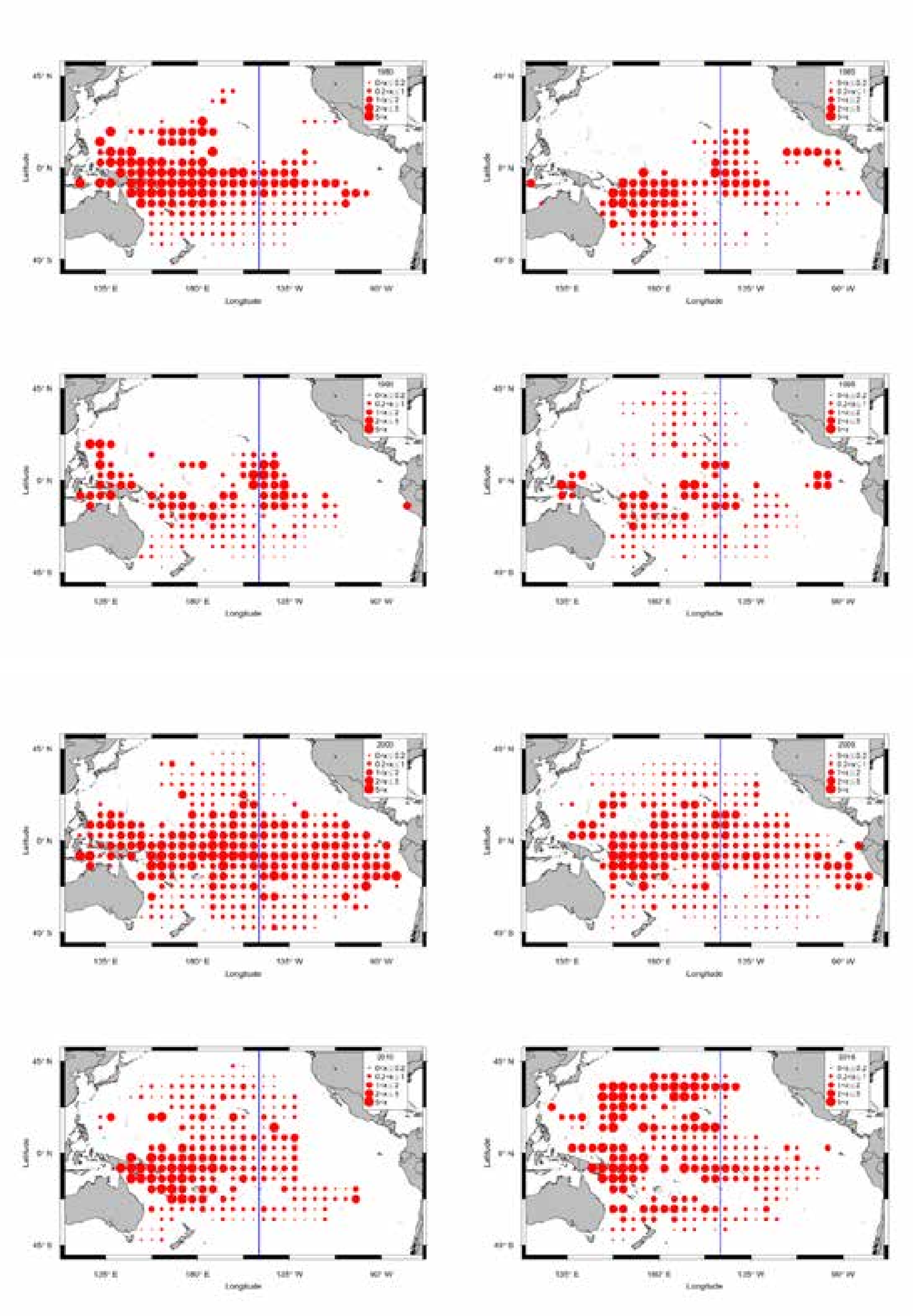

F4. CHINA

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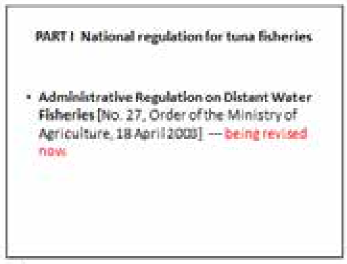

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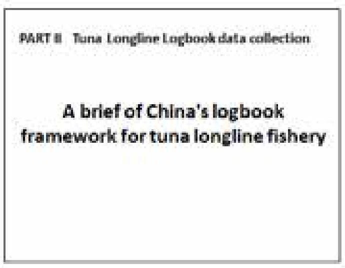

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Current logbook system

- Notification (for implementing Logbook) released by the Ministry of Agriculture on August 31, 2008
- Implementation started from Jan 1st, 2009 for fishing companies;
- Mandatory for every tuna longline vessel;
- Return by Mar 31 for the previous year, to the office of NCFC at SHOU

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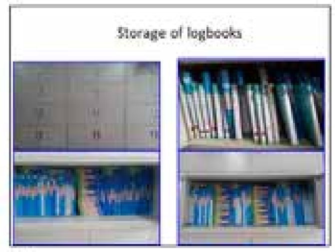

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Pros and cons of current version

Cons:

- Too much workload for fishermen onboard
- Long time needed to input into database
- Quality of some data was low

Pros:

- Record individual weight by (main) species

13

Data Quality

Main sources of low quality:

- Error in recording individual weight, and set position/date
- Not fill out forms in detail as required (e.g. tags, marine mammals interaction)
- Record as species group for some bycatch species

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Implementation of **new** logbook version

- Improve species identification instruction.
- Encourage return by Email with the new EXCEL sheets
- Record catch in weight and number by day/set;
- Follow the protocols and manuals used by WCPFC
- Since about 2015

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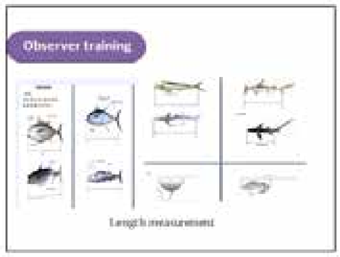

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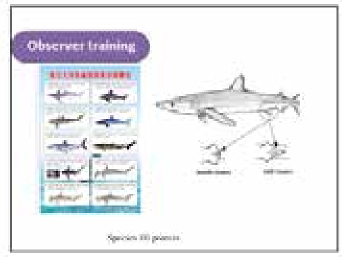

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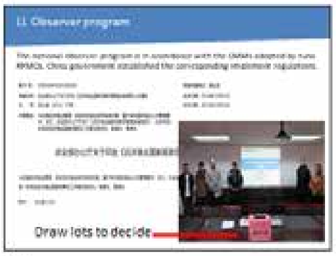

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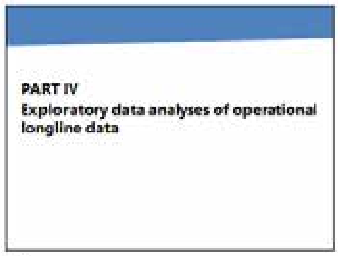

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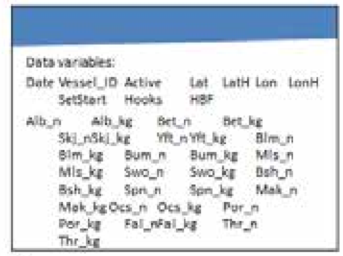

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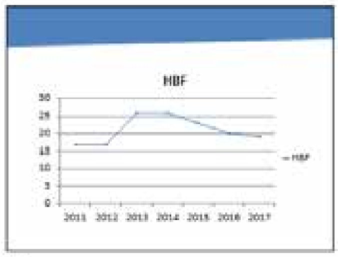

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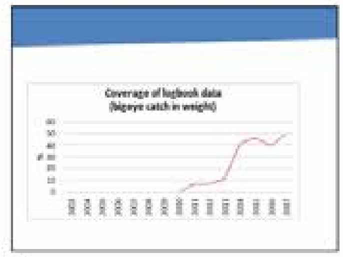

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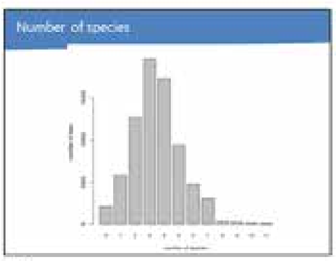

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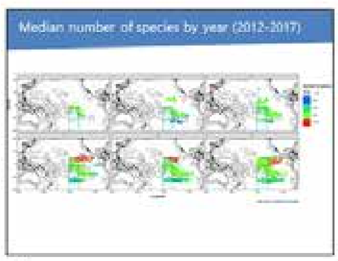

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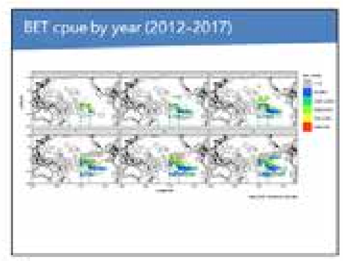

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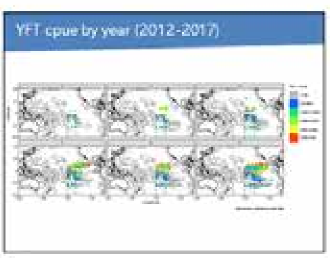

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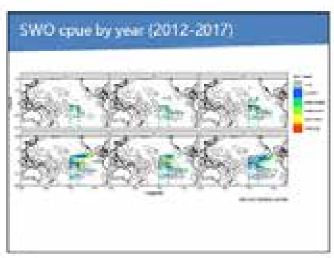

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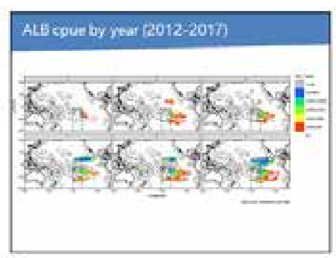

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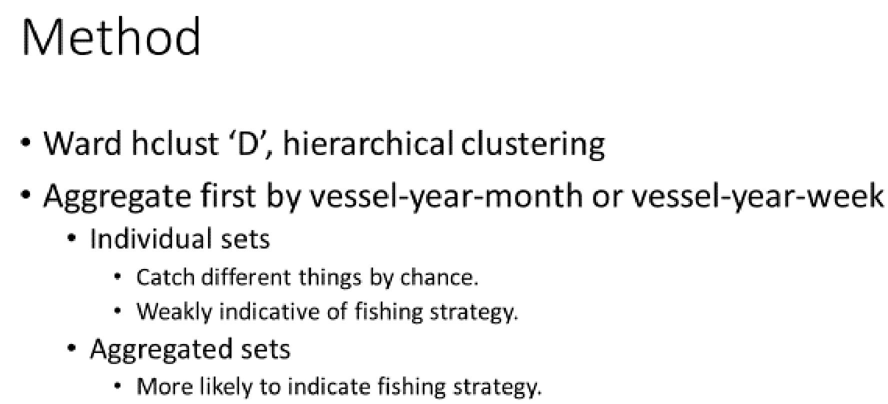
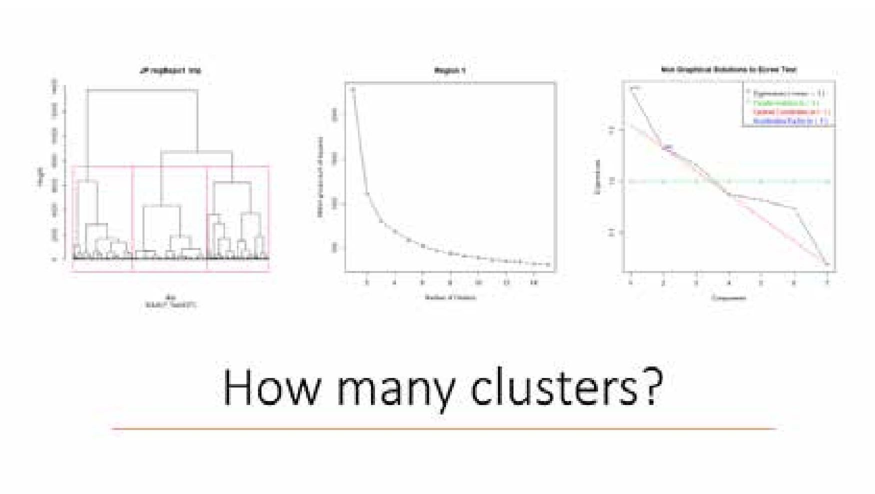
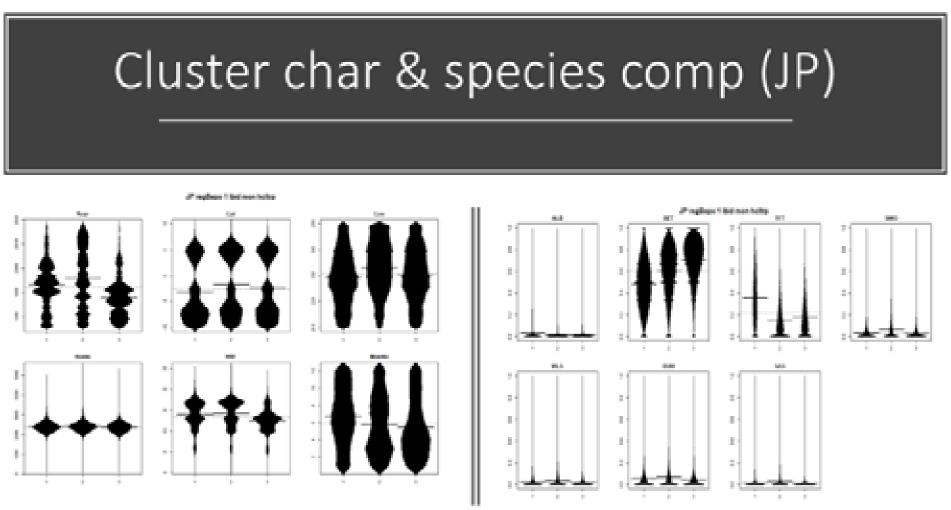
APPENDIX F: CLUSTER ANALYSIS AND JOINT INDICES USING GLM/GAMS

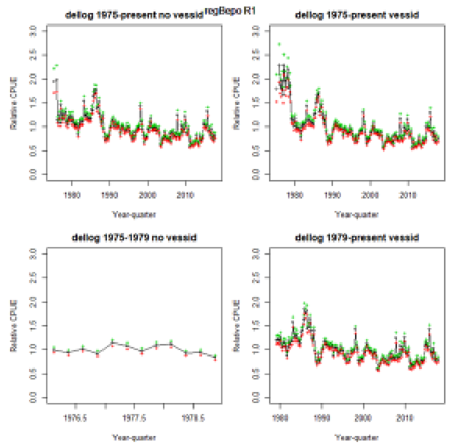
By Simon Hoyle

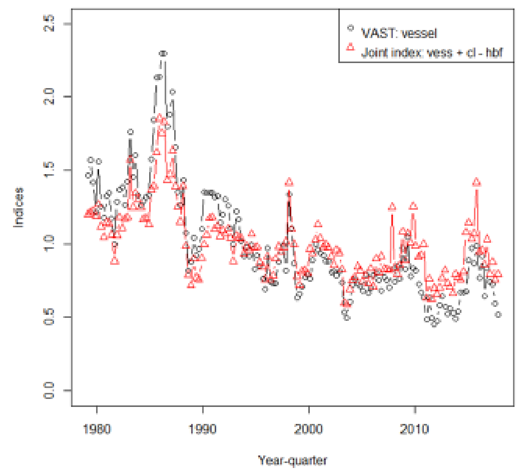




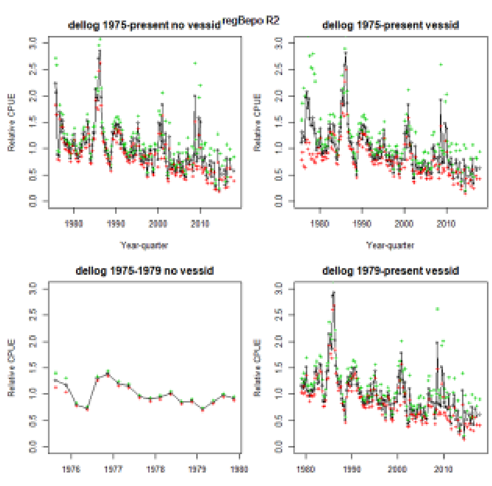


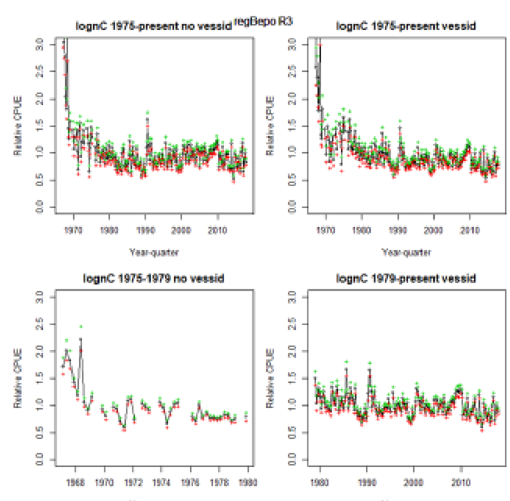
Joint indices, region 1

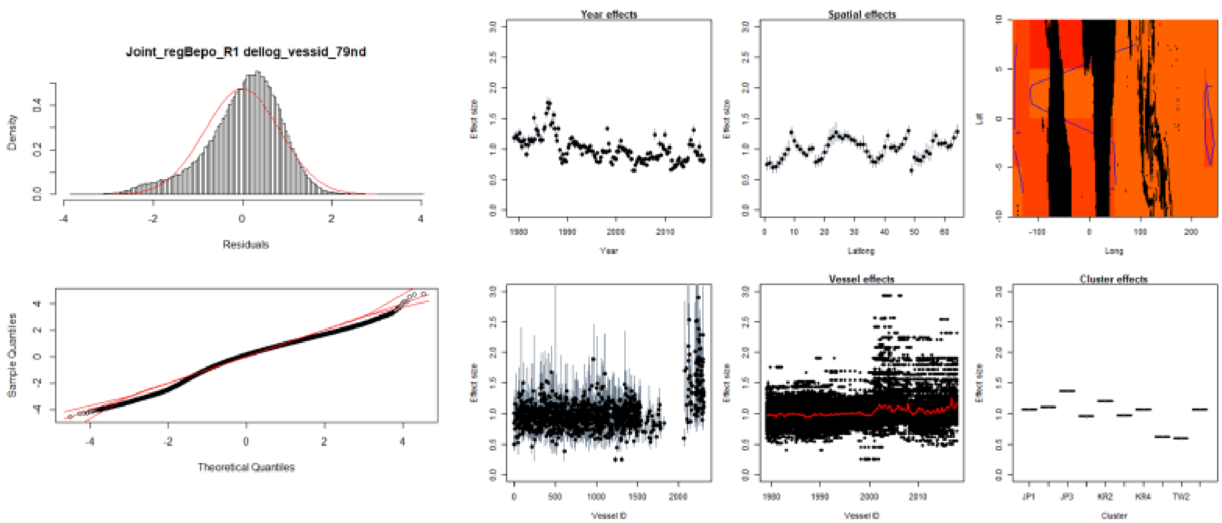




Region 2, 3



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Density
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Sample Quantiles
Theoretical Quantiles
Year effects
Effect size
Year
Spatial effects
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Lat
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Vessel effects
Vessel ID
Cluster effects
Cluster