Indian Ocean Tuna Commission
Commission des Thons de l'Océan Indien
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Report of the IOTC CPUE Workshop

San Sebastian, Spain, 21–22 October, 2013

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ACRONYMS

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

Executive Summary

A Workshop developing assessing CPUE trends and techniques used by IOTC RFMO was held in AZTI Tecnalia in San Sebastian (Spain), from 21 to 22 October 2013. The following were the key issues and recommendations identified at the meeting:

1. Use of newer standardization techniques (GLMM, GEOSTATISTICAL APPROACHES and CORE AREA APPROACHES) using operational data to assess divergence in CPUE's across fleets.

   1.1. While standard approaches worked well in most cases, the CPUE WG recommended that newer approaches should be tested. The results of the workshop conducted over the two day period, indicated that the GLMM models tend to capture the trends better. In addition incorporating more vessel specifics and using geostatistical techniques is another approach to pursue over time. Finally, the use of core-area approaches may be informative for by-catch species. Moreover, the majority feeling of the group was that during CPUE standardization the use of operational data when they are available is recommended as it will allow to capture the covariates that are important during the standardization process.

   1.2. The strongest recommendation that came out of the workshop was that in areas where CPUE's diverged the CPC's were encouraged to meet inter-sessionally to resolve the differences. In addition, the major CPC's were encouraged to develop a combined CPUE from multiple fleets so it may capture the true abundance better. Approaches to possibly pursue are the following: i) Assess filtering approaches on data and whether they have an effect, ii) examine spatial resolution on fleets operating and whether this is the primary reason for differences, and iii) examine fleet efficiencies by area, iv) use operational data for the standardization, and v) have a meeting amongst all operational level data across all fleets to assess an approach where we may look at catch rates across the broad areas.

   1.3. Simulation studies could also be developed to assess which models work best (delta log-Normal, zero inflated versus standard GLM+constant, Tweedie).

   1.4. Operational level data is useful if we want to quantify fishing fleet efficiency using fleet dynamic covariates. More applications could be developed using the methods developed by Hoyle and Okamoto (2010), or Hoyle (2009), and preliminarily presented by Dr. Okamoto at the CPUE workshop.

   1.5. Assess how core area Standardization works along with out of core or boundary area effects.

   1.6. Environmental data would be useful to consider in relation to standardization approaches. However, the way it is usually performed in GLMs, where an environmental covariate is associated to each observation (in regular 1°, 5° or even 10° grids) , may not be the most pertinent as it does not allow to identify the ecological processes which may affect CPUE. Alternatively, GLMs could be performed in sub-areas where the variability pattern of the environmental signature is well identified (using spatial EOFs to delineate those sub-areas). In such sub-areas, GLMs could be designed with and without environmental covariates to understand the potential effect of the environment. Environmental covariates should be in limited numbers (the lesser the better) and selected in order to test hypothesis on the ecological processes at stake.

2. Develop robust CPUE series for other species and Working Parties.

   2.1. The Working Group recommended to also focus the efforts in other species such as Temperate Tuna. In addition the WG recommended, developing better CPUE data for Neritic Tuna, and also improving the data and standardization on marlins and sharks.

   2.2. Develop a reference manual for use in performing a CPUE standardization for any fleet in any working party (e.g. neritic tuna WP or temperate tuna WP). Criteria for inclusion of the data in a stock assessment should also be developed (possibly using ICCAT techniques as a baseline).

3. With regard to Purse Seine data the following were recommended:

   3.1. Approaches being pursued by EU scientist have some promise, and more work should be put in the development of an index of abundance for the PS fleet on Skipjack Tuna, Yellowfin Tuna and Bigeye Tuna.

3.2. The availability of Vessel Monitoring System (VMS) data is a major requirement for the purse seine fishing fleet as it enables to spatialize the nominal effort (i.e. fishing or searching time), which is key to appreciate the temporal changes in the spatial extent of the prospected areas. VMS data may also be used to analyze PS trajectories with the aim to discriminate sets on FADs equipped with buoys from free school sets, log sets and foreign FADs sets (see after)

3.3. Purse seiners currently fish during the same trip on a combination of free-swimming and drifting FAD-associated schools. In addition, fishing on FADs results from both the detection of vessel-owned FADs through GPS geolocation systems as well as from the finding of 'foreign' FADs through bird detection for instance. Future analyses should focus on the separation of fishing time between searching and running towards FADs. Classification methods based on indicators describing spatial behaviour of vessels could enable to define typical fishing strategies and categorize trip components into such categories.

3.4. Data available on FAD activities collection have improved recently. Future analyses should focus on the definition of a fishing effort for purse seiners using FADs by (i) looking at the influence of the number of FADs owned by a vessel on individual CPUEs, (ii) by investigating the CPUEs in areas characterized by strong contrasts in FAD density. The influence of supply vessels on catch rates (e.g. the number of sets per day) and on the overall fishing capacity of the PS fleet should also be investigated at the vessel level through the information available from supply logbooks.

3.5. Analyses of temporal changes in individual and overall fleet catchability from CPUEs should be conducted to estimate fishing power creep and investigate how such changes are related with some major technological changes known for the PS fleet (e.g. bird radar). Including vessel effects into GLMs can reveal useful insights on vessel efficiency for such analyses. Attention should be paid also for change over time of fishery indicators which are part of the CPUE (e.g., number of set by day, % of successful set, catch size of the set).

4. The CPUE Workshop participants recommended that a thorough analysis of the history of the fishery would be useful for references for each species. In addition, the Group agreed that a central body (the Secretariat) should undertake additional activities in key areas (Neritic tunas where they can develop/collate the existing data on catch and effort and analyse this for some key species (eg. Longtail and Kawakawa)).

5. The CPUE Standardization Working Group agreed that a reference document that IOTC could use in what criteria should be used in utilizing a dataset for CPUE Standardization for all WP would incorporate the specifics of the temporal and spatial coverage of the data, and useful covariates that could quantify the fishing activity and the environment in which the fish lived.

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1. OPENING OF THE MEETING AND ADOPTION OF THE AGENDA

1. A Workshop developing assessing CPUE trends and techniques used by IOTC RFMO was held in AZTI Tecnalia in San Sebastian (Spain), from 21 to 22 October 2013. The meeting was opened on 21st of October 2013 by the coordinator Dr. Rishi Sharma (IOTC Secretariat) who welcomed 24 participants from 15 CPC's to the meeting.
2. The organization of this workshop was recommended by many WP reports since 2003, and was finally a key recommendation identified by the SC in 2012. It is the first workshop of this kind being held dealing only with CPUE issues in the Indian Ocean.
3. The participants of the meeting are listed in Appendix I and the agenda for the Meeting was adopted as presented in Appendix II.
4. Dr. Sharma informed the meeting about the scope of the meeting and the expected outcomes from the workshop. The agenda was adopted (Appendix II); and the participants were introduced.
5. The list of presentations at the meeting is given in Appendix III.

2. CURRENT STATUS AND STATISTICAL APPROACHES FOR STANDARDIZATION

2.1 Current Status of CPUE Standardizations and datasets in IOTC Areas

6. An overview of the changes in effort for the main longline fleets in the Indian Ocean was presented. Spatial and temporal changes were covered for the Indian Ocean regions for the main tropical and temperate tuna species. Issues relevant to targeting were identified as well as issues on contradicting indices of abundance need to be resolved for most tropical and temperate tuna species. Purse seine CPUE indices are lacking in coverage and usage, and while this is not unique to the Indian Ocean, more focus needs to be made in developing these indices. Finally, some techniques exploring bycatch species like billfish and sharks were also being developed, but more time needs to be spent on this subject. Finally, the neritic tuna species are become a larger percentage of the overall catch in the IOTC area (~33% in 2012), and more attention needs to be paid to developing some indices of abundances for these species, primarily in Iran, Indonesia and India.
7. A number of issues were raised relating to "weighting of contradictory signals", "advantage of use of operational data", "use of core area", and "impact of changes in selectivity to the standardization of CPUE", etc.
8. As far as contradictory CPUE signals were concerned, the issue needs to be resolved as to why there are differences, instead of developing a weighted index which does not address the issue. This would involve a more thorough examination of the operational data and may need different fleets to assemble the data in a grand experiment, and would also entail possible change in area strata, and looking at fleets concurrently. Issues of fishery selectivity also need to be addressed as to which component of the fleet is actually being targeted, and issues of hyperstability in purse seine versus rapid depletion in LL fleets also need to be addressed.

2.2 Statistical Approaches for deriving Indices of Abundance from CPUE data

9. Dr. Andy Cooper, an invited expert from Simon Fraser University, provided a broad overview of statistical approaches for deriving indices of abundance from CPUE data
10. When attempting to standardize CPUE estimates, researchers face a number of statistical issues, and the choice of statistical modeling approach will depend on the importance of these issues for their particular dataset. In particular, the choice of statistical approach will depend on whether catch is in numbers or weight, the importance of non-linear relationships, the prevalence of interactions, the hierarchical nature of the data, and the processes that generated the zeros in the data. Generalized linear models (GLMs) are one of the most common CPUE standardization approaches; however, it has problems handling many of these statistical issues. Zero-inflated models (typically Poisson and negative binomial) are well suited for when the data contain more zeros than one might expect and the process generating those zeros is uncertain. If the source of the zeros is fairly certain (e.g., habitat quality), then delta methods (e.g., delta-lognormal) are recommended. Generalized additive models (GAMs) are powerful when dealing with non-linearities, however they do not handle interactions well. Mixed-effects models are designed specifically for repeated-measures data (e.g., multiple observations of the same skipper) and are more flexible in handling variance and correlation structures than the standard GLMs. Regression trees perform well when there are many variables with many high-order interactions and non-linearities. Random

Forests (an extension of regression trees) are extremely well-suited for prediction modeling in the face of high-order interactions and non-linearities.

11. A number of important issues were raised during his talk and the question-and-answer session that followed, especially merits of using mixed-effect models and ways for handling the situation when zero catch occurs despite effort being present (e.g. a conventional lognormal with a constant adjustment, delta-lognormal, zero-inflated models and Tweedie distribution).

12. In discussion about the merits of mixed-effect models (incl. random-effects for the intercept and other covariates), the workshop acknowledged that the mixed-effect models might be able to deal with estimation of parameters for non-primary interaction terms and higher order ones, which are typically not well estimated due to poor information or over-parameterization. The models can also bring a concept of "borrowing strength" for better estimation by reflecting available sample/information. For instance, random effects might enable to account for collaborations between tuna vessels which is common practice and can result in spatio-temporal correlations in catch rates. However, these models do require careful examination of assumptions and should not be applied without careful study and consideration.

13. A query was raised if the third parameter controlling the distributional assumption in Tweedie model could be affected by some covariates. This could quite likely be the case and may warrant more advanced hierarchical modeling because the typical Tweedie distribution models won't allow such complexity. It may be worth examining if this really happens; and if the impact is important, it should be investigated how to extract the yearly CPUE trends from the result in that case.

14. In addition to the above, 1) the different terminologies used in different software were also of concern (e.g., Least Square Means from SAS versus the output from R and attempts to estimate the marginal means). The group suggested that some comparisons between SAS and R functions on a simple case-study would allow to address this issue; 2) ways of assessing the uncertainty is worth visiting although the issue depends on how the results are used.

2.3 Major IOTC CPC's Overview and Approaches

2.3.1 Japan longline CPUE Overview and Approaches

15. Dr. Okamoto presented an overview of Japanese data collection system. The owners of distant water fishing vessels are required to submit the log sheet on their operations every ten days. In the log sheet of longline, set by set data on catch number and weight in each species, and other information data such as fishing date and location, fishing effort (the number of hooks used and the number of hooks between float), water temperature are included. Additionally, information on the cruise, vessel, number of crew and the configurations of the fishing gear are asked to fill on the top part of the sheet by each cruise. Submitted logsheets are processed into electronic data files. Various error checks are conducted before these data are finalized. Because the coverage rate of logsheet is not 100% for longline fishery, it is necessary to raise the sample values to represent 100 %. Since 2008, VMS (vessel monitoring system) information is utilized to raise the log sheet data. Catch in weight in logsheet data is given in processed weight, so that conversion factors by species are used to convert processed weight to whole weight. Some items which are included in the logsheet but was not inputted into file, have recently been additionally inputted for assessment use.

16. In discussion, a question was raised if the observer system implemented in the Japanese fishery (ca 5%) would have been contributing to understanding the CPUE, especially if the calibration of CPUE from commercial vessels is possible or not. Dr. Okamoto responded that it would be possible but it is a future work given a consideration on manpower.

17. Dr. Matsumoto gave overview of approaches used in the standardization of Japanese CPUE. Standardization of CPUE for three tuna species in the Indian Ocean by Japanese longline fishery has been conducted based on GLM lognormal or negative binomial error structure. Effects of season (month or quarter), fishing ground (subarea or 5 degree latitude longitude blocks), fishing gear (number of hooks between floats, main and branch line materials), and environmental data (sea surface temperature and others) were incorporated for standardization. As for catch and effort data, aggregated data by 5 degree latitude longitude and month were mainly used, and aggregated data

by 1 degree latitude longitude and month or operational data were partly used. Little differences of standardized CPUE were observed among the resolution of catch and effort data used, error structures, or with or without sea surface temperature.

18. The workshop raised several issues with the analysis that requires further work. A question was raised for the authors' conclusion that the environmental data was not effective, and it was suggested that the environmental covariates (e.g. SST) be modeled with some nonlinear models to capture their nature or used as categorical values so that the interaction terms are easily incorporated. It was also suggested that the analysis be conducted using integrative environmental indices such as the Indian Ocean Dipole, depth of the thermocline, sea level anomalies or SST anomalies.

19. A comparison of three STD CPUE series estimated by 5-degree cells, by 1-degree ones and by operational data under same covariates revealed interesting results. The group noted that showing uncertainty (e.g. confidence intervals) would enable to appreciate how much the operational data would contribute to the improvement of estimation precision. The group also noted that the comparison was conducted using the same covariates while a major interest of using operational data is to include ancillary information on vessels characteristics (e.g. size) in the CPUE estimation process which can refine the CPUE standardization outputs.

2.3.2 Taiwan,China longline CPUE Overview and Approaches

20. Dr. Yeh presented an overview of Taiwanese data collection system. The presentation mainly reviewed the reformation of Taiwan,China statistics system after 2000 and focused on data collection related to CPUE standardization. The main framework of Taiwan,China Tuna Longline Logbook was introduced. The historical recovery rates of logbooks were reviewed. It is noted that the recovery rate of logbooks has rapidly ascended since 2003 due to some mandatory monitoring that was introduced for catches of BET, SBT and SWO prior to their export to foreign countries. In addition, with VMS and e-logbook, an increase in the amount of fishing vessels had also re-flagged to Taiwan,China could also explain the increase. The source of size data is from the logbook records. The sample numbers by year and the proportion of size samples to total catch numbers by vessel by set were investigated. The number of size samples by 2005 is the highest in the period between 1981-2012. This situation can be attributed to the rather high recovery rate of logbooks, high catch, and more vessel numbers in 2005.

21. Some questions were asked about a big change over years in the proportion of sample size for size data. In discussion, the workshop identified several possible reasons including a change in the target size in its fishery and that in sampling protocol. It also noted that a comparison between the Taiwanese and Japanese size data would partially contribute to interpretation on this effect.

22. CPUE standardization for Taiwanese data overview was also presented. The presentation focused on the procedures used in CPUE standardization for Taiwanese data. In the first place, original logbook data is explored thoroughly. Then some data exclusion principle is carried out to eliminate outliers to avoid the noise. Operational data aggregated by 5x5 grid spatial resolution is used in CPUE standardization. GLM with lognormal error structure is adopted. The main factors included are year, season, area, and target proxy. Considering the data availability, species composition is used as a target proxy in GLM. R^2 and AIC is used as criteria to model selection. The distribution of residuals and qqplot is used for Normality test. Besides, the residual against year effect is plotted to check the heterogeneity of residual's variance. Some sensitivity analysis was applied to understand the performance of different target proxies (species composition vs. NHBF) and different spatial resolution (5x5 grid vs. 1x1 grid) for shorter series from 1995. No significant difference shown in standardized CPUE trends for various scenarios. SAS procedures are used to do the related analysis.

23. It was suggested that allowing for vessel effects might help account for the fact that the inefficient vessels are the ones no longer targeting the species. If not taken into account, the analysis would result in a bias in the year effect. For this sort of analysis, a mixed-effect model might work well, but further investigation must be required.

2.3.3 Korea longline CPUE Overview and Approaches

24. Dr. Lee presented overviews of data collection system and analysis for standardization for Korean CPUE data.

25. Data collection and reporting system in Korea has been in place since 1970s. In the past the logbook had been required to be submitted to the Korean government, National Fisheries Research and Development Institute (NFRDI) within 30 days (home-based) or 60 days (foreign-based) after completion of their operations. Following this practice, it was impossible not only to meet the timely submission of data but also to have a chance to review and check the status of data collection undergoing onboard fishing vessels. To remedy that practices the data collection and reporting system has been improved. Now fishermen, in accordance with enforcement ordinance, are requested to submit monthly the logbook in electronic format, including the information on ecologically related species (ERS or bycatch) and biological measurement, etc. which has allowed to increase the coverage to almost 100%.

26. CPUE (catch per unit effort) standardization of Korean longline fisheries in the Indian Ocean has been conducted by Generalized Linear Model (GLM) using operational data and aggregated data (1977-2012). The data used for GLM are catch (in number), effort (number of hooks) and number of hooks between floats (HBF) by year, month and area. In addition, we explored the core area where Korean tuna longline vessels have been mainly fishing for tropical tuna, especially bigeye tuna. At this time, bigeye tuna CPUE was standardized for the whole area and the core area using operational data and aggregated data.

27. In the CPUE analysis, a core area was defined because the spatial coverage of the Korean long-line operations was poor for some areas and might not be representative of the whole population abundance. However, a concern was raised if the defined core area is appropriate or not in terms of ecological habitat of the species, and therefore the workshop suggested continued work for developing some objective ways for the definition of the core area.

2.3.4 EU Purse Seine CPUE Overview and Approaches

28. Dr. Chassot presented an overview of the data collection system for the European purse seine fleet. The European and associated flags fishing fleet was composed of 37 vessels in 2012. The vessel size and capacity increased over time and major technological changes occurred for different gears and attributes, which resulted in substantial improvements for both school detection and school catchability. The data collection system has been consistent since the early 1980s and it is based on comprehensive collection of logbooks, sales records, and well plans. VMS data are used for validating the geographic location of the sets. About 1,400 samples of 500 fishes are conducted annually at unloading to (i) correct the species composition (biased due to misidentification of small bigeye) and (ii) to estimate the size-frequency of the catch. Searching time is generally considered as a good nominal fishing effort for fishing on free-swimming schools but it is affected by fishing power creep and the development of fishing on schools associated with fish aggregating devices (FADs) that are equipped with GPS (see Figure 1). Data collection on FADs has improved in the recent years through (i) the provision of the numbers of FADs deployed at-sea on a quarterly basis following IOTC resolution 10/02, (ii) the collection of supply vessel logbooks which play a major role in FAD effort, and (iii) more recently the collection of buoy positions for a component of the PS fleet. Logbooks have recently been extended to include information on FAD deployment, buoy transfer, etc.

29. It was noted that a new IOTC Resolution (2013/08) specifies the mandatory implementation of drifting FAD logbooks for the purse seine fleet.

30. Dr. Soto presented an analysis of the standardization process for yellowfin and bigeye juveniles and skipjack caught on FADs which might provide insights into recruitment variability. Three abundance indices were estimated, two for the juveniles of yellowfin (≤10Kg) and bigeye (≤10Kg) and one for skipjack caught by the European purse seine fishery in the Indian ocean between 1981 and 2011 using generalized linear models. Catch and effort data come from detailed daily logbooks. Catch rates are modeled using the delta lognormal model. The method estimates a combined CPUE of the three species from aggregated catches, and the proportion of catches for each species, so the final individual abundance indices are calculated multiplying both estimators for each

species. Explanatory factors used in the analysis are: year, zone, quarter, holding capacity, country, and starting date of the vessel. Year is the factor that explains the largest component of the variability in CPUE and, depending on the species; the fishing area and the quarter are significant. Vessel characteristics have a significant explanatory effect in observed aggregated catch rates.

31. The Workshop suggested that the use of a multinomial model instead of 3 separate models for each species might be useful to account for the compositional nature of the data. It was noted that the temporal changes for yellowfin and bigeye are consistent with the recruitment time series estimated from the stock assessment models.

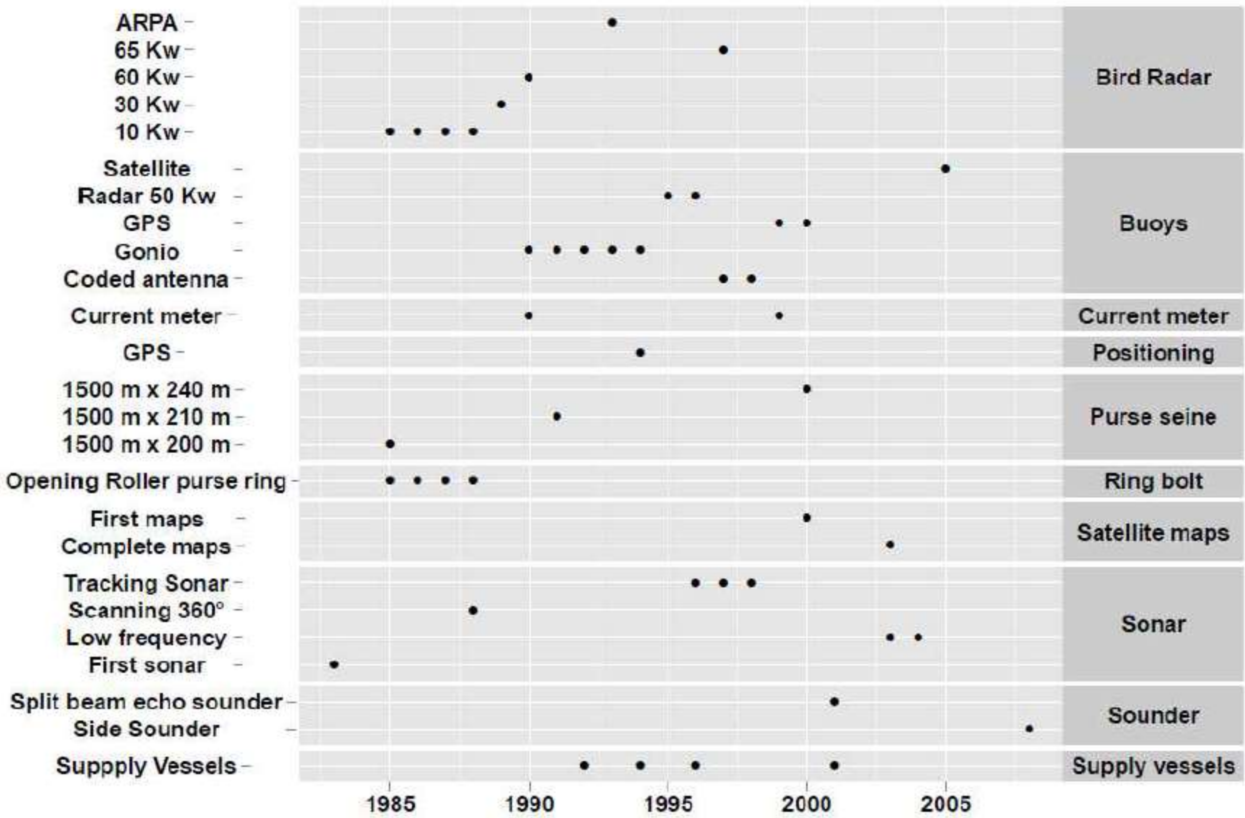

Fig. 1. Technological changes in PS fleet that shows technological change over time.

2.3.5 Maldives Pole and Line CPUE Overview and Approaches

32. Dr. Adam presented an overview of data collection for PL CPUE data. The time series of catch and effort data in the Maldives starts from 1970. The data collection system is based on total enumeration requiring use of conversation factors to estimate total weight. The unit of effort is the days fished. The data is reported to island offices where it is compiled into monthly summaries. From 2004 vessel specific monthly summaries were compiled. The system has worked well in the past, but with socioeconomic improvements and increasing vessel mobility, the quality of the data has been deteriorating. In order to address this growing problem a logbook system of reporting was introduced starting from 2010. Reporting from island offices also remains in place until logbook data coverage is complete. With this new recording system a new compilation system is also being developed. The web-enabled Fishery Information System (FIS) database includes modules for recording logbook data, fish purchase data and modules for keeping track of vessel registry and vessel licensing. Data for the CPUE standardization include vessel characteristics (LoA and HP), data on anchored FAD and livebait logbook data. Some of these data are already being used for the standardization of the Maldives CPUE. Once FIS database becomes online, a more complete vessel specific catch data will become available allowing improvements in the CPUE standardization work of the pole-and-line fishery.

33. Some queries were made on how catches from different gears on a single trip were separated. In response, it was noted that the information is recorded in revised logbooks, and the fishermen are to indicate the gear used on the day of fishing and the catch by species on that day.

34. Dr. Sharma presented a qualitative description and GLM-based standardization of the Maldivian skipjack pole and line fishery catch rate data for the period 2004-2011. The raw data consists of around 124000 records of catch (numbers) and effort (fishing days) by month, atoll and vessel; vessel characteristics were added to the CPUE dataset based on information from the registry of vessels. A subset of 56,698 records were extracted from the dataset, identified as records of fishing activity targeting skipjack. In the process, the paper discusses several data quality issues with the CPUE dataset, notably records with zero skipjack catch with a measured effort for PL fishery and which were eventually discounted from the final analysis. FAD data was also incorporated into the analysis using the number of active FADS associated with the nearest atoll that the landing data is collected from. In order to do this, the distribution of FADs was split into three regions incorporating the North Atolls, Middle Atoll and South Atolls. Vessel specific data including hull-type effects, length of the boat (as a vessel size class) and horse power was also used in the analysis. GLM based models using a log response on CPUE were examined. The final model presented estimated log (CPUE) from independent variables Year, Month, Area (N, S, or M), number of FADs used in the area, and Length of vessel, and interaction effects between the last 3 categories. The data was analysed at a monthly resolution before it was collapsed into quarterly signals for 2004-2011. Finally, using vessel length as a continuous covariate, the CPUE data was estimated for historic periods till 1985.

35. A question was raised on the possibility that the substantial decrease in SKJ CPUE might be due to changes in the spatial range of fishing activities, e.g. selection of on anchored FADs closer to the ports in relation with economic constraints associated with increased fuel price. No information is however available on the location of fishing activities at a fine scale.

36. It was suggested that the time series of standardized CPUE from Maldivian pole and line could be compared with the trends in SKJ abundance derived from PS CPUE (See point 31).

2.3.6 Other fleets Overview and Approaches

37. Mr. Jayasooria presented an overview of the CPUE data collection for Sri Lankan tuna fishery. The fisheries are mainly artisanal, livelihood dependent and multi gears. The CPUE is calculated for catch per trip for each boat types irrespective of gears. Trip length depends on fish harvest and the type of boats/gear combinations. Lack of past accurate scientific information for analysis/sharing and poor coverage due to the north and east conflict situation of the country during past years affected the historic time series of data. The newly initiated survey generates enough information to standardize the CPUE in tuna fisheries.

38. In discussion, the Workshop identified that the Standardization of CPUE is a sensitive issue in developing countries like Sri Lanka (coastal estates) due to non-availability of reliable data and nature of fisheries statistics systems. Therefore, it is needed to strengthen the methodologies for data collection by considering the status of artisanal fishery that required information for tuna fishery resource management. Moreover, it was highlighted that the need of expert assistance is needed to identify the possibilities, make recommendations and standardize the CPUE using the available data.

39. Mr. Wudianto presented an overview of the data collection on Indonesian tuna fishery. There are four main landing sites for Indian Ocean tuna industrial fleet, Benoa Fishing Port (Bali), Muara Baru fishing Port (Jakarta), Pelabuhanratu fishing port (West Java) and Cilacap fishing Port (Central Java). Three main gears that contribute significant catch of the total catch of tuna are tuna long line, purse seine, and hand line. Catch of tuna is mostly from the longline fishery in Indian Ocean. There are three types of long line operated by fishermen in the Indian Ocean which are surface long line, middle long line and deep long line. The catch compositions of three types of tuna longline are significantly different. Surface longline caught dominantly yellowfin tuna. Middle longline mostly caught albacore, whereas deep long line mainly caught bigeye tuna. Observation by using mini logger indicated the species of tuna have a preference on the certain water temperature. That phenomena should be considered for calculating effective instead of nominal CPUE for tuna long line.

40. Regarding the data collection conducted in Indonesia on principal market tunas, it was asked whether information was available for computing CPUE time series for neritic tunas for which very little information is currently available. Some information is available and could be gathered and made available for future working groups on neritic tunas.

2.3.7 Other projects to conduct CPUE Standardization (CECOFAD)

41. Dr. Gaertner presented the ongoing EU (DG Mare) research project " Catch, Effort, and eCOsystem impacts of FAD-fishing" (CECOFAD) in which scientists from IRD, IEO, AZTI and tuna owner companies as Orthongel, Anabac and Opagac will be involved. The main objectives of this 18-months project which will focus on the UE purse seiners operating in the three oceans are: (1) to define a unit of fishing effort for purse-seiners using FADs that accounts for different factors influencing catchability, (2) to standardize catch-per-unit-effort series of the EU purse seine fleet, for juveniles and adults of the three tropical tuna species and (3) to provide information on catch composition around FADs and estimate impacts on other marine organisms (e.g. by-catch of sharks, rays, turtles). To reach these objectives CECOFAD has been structured around 4 work packages. The tuna RFMOs will be associated to the project as observers and the main results of this study will be regularly presented to the Tropical Tuna Working groups or ad-hoc Working groups on standardization methods. Although the project was considered ambitious due to its relative short duration, the participants to the CPUEs workshop agreed about the relevance on FAD-CPUEs studies in purse seine fisheries.

3. Issues and Improvements in CPUE Standardizations

3.1 Fishery Changes over time (including targeting and technological creep)

3.1.1 Preliminary analysis of vessel effect using Japanese_longline_operational data and vessel ID

42. Dr. Okamoto presented results from preliminary analyses of longline catchability for bigeye tuna in the Indian Ocean estimated applying operational catch and effort data with vessel identification (call sign) into a GLM. Data of the core area of longline bigeye catch in Indian Ocean from 10N-20S from 1979 to 2011 was used. Estimated Vessel effect indicates that the fishing power of Japanese longline fishery in Indian Ocean have gradually increased during analyzed period. Vessel effect is useful tool to estimate change in the gross fishing power in long range of years without necessity to have information of items which affect catchability. As the effect of Vessel ID was calculated to be constant throughout the existence of the vessel during the analyzed period, change of catchability is grasped as the change in average Vessel ID effects caused by entering and leaving of each vessel which has its own Vessel ID effect. Therefore, Vessel effect is not sensitive to the quick change of issue which would affect catchability, such as change of fishing master.

43. The group thought this was a very creative and interesting approach to look at the fishing power. In this case it seems to indicate that fishing power has increased gradually over the past 30 years. This increase could be due to technology change, spatial changes, and replacement of older vessels with new, more modern vessels. The increases in the average fishing power in the final years may be driven by losing the vessels with less efficiency from the fleet. It was commented on including an area factor in the models, but the author explained if the areas are separately analysed, the continuity of vessel ID would be decreased and become further fragmented. Therefore it would be necessary to consider how the area effect is incorporated.. It was also commented on the possibility of detecting change in catchability more flexibly by using detailed information such as change in gear, operation, fishing master, etc. The author explained that many factors maybe related to the change in catchability and it might be difficult to know how much each factor may account for it, and that type of detailed information was not available for the past which would make the analysis difficult to conduct.

3.1.2 Blue shark and shortfin mako standardization for Portuguese longline fleet: Accounting for targeting effects

44. Dr. Coelho presented the methodology used by EU-Portugal for standardizing CPUE indexes of major shark species from the longline fishery in the Indian Ocean, focusing mainly on how the target effects were used and tested in the models. Portuguese longliners targeting swordfish and operating in the Indian Ocean regularly capture elasmobranch fishes as bycatch, and of those, the blue shark (BSH, Prionace glauca) and shortfin mako (SMA, Isurus oxyrinchus) constitute the two main species. Nominal CPUEs for these two species were calculated as kg/1000 hooks and standardized with Generalized Linear Models (GLM). Several different modeling techniques were tested and compared depending on the specific proportion of zeros in the catch data. The explanatory variables tested and used were year, quarter, area and the ratio of SWO/SWO+BSH catches to account for targeting effects. A sensitivity analysis was carried out for the ratio factor, comparing a base model using ratios categorized into 10 categories, ratios categorized into 4 categories, and removing the ratio factor from the models. In the case of BSH, where the ratio factor was contributing for a large amount of the deviance, removing the ratios was significantly affecting the estimation of the model parameters and the final CPUE standardized trend. On the contrary, for the SMA where the ratios were significant but explaining less of the

deviance, removing this factor was not affecting significantly the estimation of the model parameters and the final standardized CPUE trend. There seems to be a relation between the sensitivity of the ratio factor and the type of species modeled, usually with this variable having a higher importance for target species and a lower importance for the by-catch. However, this needs to be evaluated case by case, as an example is also presented for swordfish in the North Atlantic, in a model that was also not sensitive to the use of the ratio factor even though it was modeling the main target species of the fishery.

45. While the group found the results interesting, caution was advised on using those ratios as there is a tradeoff between catch and species abundance, and those ratios may be capturing more the effects of catchability and therefore biasing the index of relative abundance. The group agreed that using operational data (e.g. hooks between float, hook depth, hook style, bait type, gangion material, etc) is probably more adequate to account for targeting effects, but that type of more detailed data is usually not available from the earlier years of the fisheries and/or in logbook data. When no other options are available, using ratios with sensitivity analysis is probably better than not accounting for targeting effects at all.

3.2 Spatial Structure Changes

3.2.1 Area stratification based on Tree model

46. Dr. Matsumoto presented a work on area stratifications based on a tree model. Factor of "sub-area", which represents spatial similarity of catch and effort, is usually applied in CPUE standardization process in order to remove spatial effect from true population dynamics in a statistical manner. The sub-area for Japanese longline standardization has been manually specified and is usually species-specific, considered as no change during its analysis period. However Japanese longline had changed target species from albacore to bigeye during the late 1960s. Spatial distribution of catch and effort (sub-area) and target species are mutually related. We introduced concept of "potential target species (PTS)", which is a combination of factors (year, month, latitude, longitude and NHBF) indicate only one potential target species. PTS is interpreted as the species that fishermen expect to catch with a high probability. We applied the concept to north Pacific albacore and the result is preliminary. We determined criteria for PTS of four species (albacore, bigeye, yellowfin and swordfish) using tree-model. Only we used "dominated catch" data in operational level. "Dominated catch" is defined that for single species proportion of catch in number is more than 90% in a set. Tree decision model (by year) is applied as follows; Dominated species name = month + latitude + longitude + NHBF. Proportions of catch number in total catch number by species when PTS is ALB results in large differences between ALB (78% in average and other species around 30%). This result indicates that performance for extracting ALB dominated set using factors (longitude, latitude, month and NHBF) is good. The distribution of PTS for ALB is different among year, month, latitude, longitude and NHBF, which indicates adaptable stratification in consideration not only for traditional lat-long sub-area but also factors for year, month and NHBF.

47. The group found this novel approach quite interesting. This study used classification trees to estimate area stratifications, but it was suggested to also account for the biology and ecology of the species, especially if those area stratifications are used to establish core areas. Most of the study was carried out in the Pacific, but should also be useful for the IO. This type of classification can be very sensitive to the balance between species in the original data, so it might be useful to try to subset the data so that it becomes more balanced between the species it is trying to predict, in this case ALB and YFT. There was also discussion about examining the sensitivity of the results to changing the 90% cut-off for defining the dominated catch. As it is, though, the model appears to perform quite well in predicting locations where ALB is the potential target species.

3.2.2 Spatial GLM Approaches to use incorporating spatial auto-correlation or Geo-statistical approaches

48. Dr. Nishida presented work on GLM approach for incorporating spatial auto-correlation. Catch-per-unit-effort (CPUE) data have often been used to represent the approximate abundance indices of fish stocks. As the observed CPUE include various uncertainties, numerous statistical methods have been applied to standardize the data. The statistical theory behind these methods assumed that the observed CPUE data are independent. This is obviously invalid for fish population since it is common sense that fish move together, and the closer the observed fish abundance measurements, the more similar the measurements are. To solve this spatial autocorrelation problem in the CPUE standardization, we proposed a spatial approach to extend the standard general linear model (GLM) by incorporating the spatial autocorrelation. We applied this spatial approach to the yellowfin tuna CPUE data of the Japanese longline fisheries in the Indian Ocean as a case study. Including the habitat based model (HBM), we compared four types of GLM approaches as the standard GLM to spatial GLM with/without HBM. In conducting

the spatial GLM approaches, we examined four distance models (Gaussian, Exponential, Linear and Spherical) for spatial autocorrelation. Then, we evaluated the results of the CPUE standardization by AIC, r^2 and also graphical analyses. We found the spatial GLM approaches always produced the best fits to the data, while their variances were higher than those by the standard GLM. This occurred because the spatial GLM included the spatial autocorrelation and produced more realistic variances. We also found that HBM-based GLM approaches always produced better fits than those without the HBM option. In four distance models, the Gaussian model was the best. Finally, we graphically compared the abundance indices derived from the standardized CPUE. We found that trends of point estimates were slightly different between two methods, while 95% confidence intervals of the spatial GLM were larger than those with the standard GLM. The results suggest that the spatial GLM produces more practical and robust standardized CPUE and abundance indices, especially when the nominal CPUE include large spatial autocorrelations.

49. The group agreed that this approach seems very useful and encouraged its further use and exploration in future IOTC CPUE standardization processes. The group expressed concern at the estimated correlation distance of approximately 2000 km. The models presented were using 5*5 area resolutions, but the group mentioned the degree of correlation is likely dependent upon the spatial aggregation of the data and that for this type of analysis a finer spatial resolution (1*1 or individual sets) would be interesting to test. Another suggestion was to explore the proximity between sets as a possible explanatory variable in the models. Incorporating the correlation structure did not have major impacts upon the point estimates of the indices; however, it did significantly increase the uncertainty about those estimates.

3.2.3 Use of core areas as an approach for estimating CPUE's- Striped and Blue Marlin for Japan

50. We attempted to standardize CPUE (STD_CPUE) of blue marlin (*Makaira mazara*) and striped marlin (*Tetrapturus audax*) stocks in the Indian Ocean. We applied the Core Area Approach (CAA) in order to find representative areas of their abundances. We used Japanese tuna longline data for 41 years (1971-2011). As both species are by-catch, CAA is considered to produce more robust standardized (STD) CPUE. For CAA we selected positive (non-zero catch) sets and classified into 3 categories (high, medium and low frequency of positive sets) by quarter (Q). Then we further screened out a few common CAAs among 4 quarters, so that we can apply the interaction terms for Q in GLM. As a result, we could obtain more robust and stable STD_CPUE trends than in the past when we used the normal large area in GLM. In addition we could reduce number of 0 catch significantly as we use only positive sets. This also demonstrates the robustness of estimated STD_CPUE..

51. The group commented that a contraction in range of a species is usually considered as an indicator of the population status, and that by using the core area approach this issue is ignored, as the models are only modeling what is happening in the areas with higher catches along the time series. The core areas were defined based on the entire time series, but it might be useful to estimate the core areas on an annual basis and explore if changes have occurred through time. The group noted that it would also be useful to try to integrate some biological knowledge in the definition of the core areas.

3.3 Other Issues in CPUE Standardizations

3.3.1 Incorporating environmental factors in STD_CPUE, useful or useless

52. We reviewed and examined the usefulness of including ENV factors in STD_CPUE. This is because in recent years, more scientists tend not to use ENV data. The major reason is that majority of ENV factors produced significances in GLM because there is so much data. Thus, it is difficult to evaluate real ENV effects in the GLM process. In order to mitigate this problem, we attempted Lat*long (such as 1ox1o and 5ox5o) effects instead of ENV data as we thought that they may be able to handle ENV changes. But we still need to evaluate effectiveness of lat*long factor if they improve the problem. In addition, time-lag ENV effects have been recognized, which can be added easily to GLM. But we will still face the above mentioned problem in GLM. Until we clear out this outstanding problem or until we develop more effective way to incorporate the ENV data in STD_CPUE by GLM (or other methods), we suggest not to use ENV data.

53. The group had numerous comments about this thought-provoking presentation. Including the latitude and longitude in a model will only account for the average effect of that location. On the other hand, including environmental data assumes that their effects are constant across all areas. Exploring the deviations from the average environmental signal may relax both these assumptions and improve explanatory power. It was suggested

that rather than using a grid of cells for stratifications and then examining the environmental variables, the environmental variables and ecological processes themselves could be used to define the stratification.

3.3.2 Examining alternative approaches for CPUE Analysis: Generalized Linear Mixed effects Models for swordfish

54. Dr. Coelho presented a work focused on the use of alternative approaches for CPUE analysis, specifically in the use of Generalized Linear Mixed effects Models (GLMM) with an application to the swordfish (SWO) in the North Atlantic. The dataset was analyzed between 1997-2012, with the main effects in the models including year, area, quarter, a gear variable to account for different longline configurations (monofilament and multifilament) and a target variable to account for trips where sharks were predominant in the catch or potentially also targeted. Possible interactions were tested with likelihood ratio tests and AIC, and the significant interactions to be used in the final models included both interactions with and without the year variable. A demonstration is provided on the difficulty of using year interactions as fixed effects in a generalized linear model, given the number of the parameters that would have to be estimated and the need to average several annual trends for calculating the final standardized CPUE trend. As an alternative approach, the year interactions were modeled as random effects in a GLMM, resulting in a model with less parameters and that was still accounting for the variability associated with the year interactions.
55. The group commented that the approach was interesting, and that in addition to the random variables used, it would also be useful to test the inclusion of a random vessel effect in the models. The group commented that including random effects for year usually does not produce large changes in the final CPUE indices (unless the data are highly unbalanced) but it can increase the uncertainly which will result in wider confidence intervals for the parameters and in the final CPUE index.

3.3.3 Accounting for 0's in your data: Using delta-lognormal, tweedie, or adding constants to lognormal and gamma models - some cases examined

56. Dr. Coelho presented a work focusing the methodology used by EU-Portugal for standardizing CPUE indexes of swordfish and major shark species from the longline fishery in the Indian Ocean, focusing mainly on how different modeling approaches were considered and compared depending on the quantity of zeros in each dataset of each species. Portuguese longliners operating in the Indian Ocean target mainly swordfish but also capture regularly elasmobranch fishes as bycatch, especially blue shark (BSH) and shortfin mako (SMA). Nominal CPUEs for these species were calculated as kg/1000 hooks and standardized with Generalized Linear Models (GLM). The explanatory variables tested and used included year, quarter, area and the ratio of SWO/SWO+BSH catches to account for targeting effects. Several different modeling techniques were tested and compared to account for the zeros, namely tweedie (to model CPUEs in biomass directly), gamma and lognormal (adding a constant to the CPUEs) and a 2 part delta-lognormal. The 3 tested species had different scenarios in terms of numbers of 0's, specifically with BSH and SWO having a low percentage of zeros (<5%) and SMA a much larger percentage (~40%). In terms of models for the SWO and BSH, both the tweedie, the gamma and lognormal produced acceptable and similar results, while the delta-lognormal approach had problems to fit the binomial model component, mainly due to lack of contrasts (counts of 0 and positive sets) in some of the levels of some of the categorical variables. On the other hand, for the SMA the delta-lognormal and tweedie models were producing acceptable and similar results, while the gamma and lognormal were excluded because of the bias introduced when adding a constant to a dataset with a large percentage of zeros. Other models that could be explored to account for 0's in the data include models for count data (e.g. Poisson and Negative Binomial, in this case using the effort as an offset variable), zero inflated models, and simplification to a binomial model in which case we would be modeling the expected probability of capturing at least 1 specimen for a given species, an approach that may be useful for rare species such as for example incidental catches of sea turtles in longline fisheries.
57. The group commented that this was a very interesting and useful case study. It was surprising how little difference the choice of approaches had on the final CPUE index, but some of that may have been due to the fact that great care was taken to only apply reasonable approaches to each scenario (e.g., not using the add-a-constant approach when the percentage of zeros was high). The presentation highlighted the importance of matching the modeling approach to the specifics of the dataset while still testing the sensitivity of the results to the modeling approach.

4. BIAS IN CPUE AND MANAGEMENT IMPLICATIONS

4.1. Which tuna longline standardized CPUE are useful for stock assessments (SA) Japan, Korea or Taiwan,China?

58. In the past decade, we have been recognizing similarities or dis-similarities of STD_CPUE of different species exploited by Asian tuna longline fisheries (Japan, Taiwan,China and Korea). In general, STD_CPUE between Japan and Korea are similar as they used NHBF (number of hooks between float) consistently for the target proxy. However similarity of STD_CPUE between Japan and Taiwan,China are different among species. As for yellowfin tuna (YFT) and bigeye tuna (BET), they are totally different. As Japan STD_CPUE likely represents its real trend, it has been used for stock assessments (SA). As for albacore (ALB), they are also different, but the one by Taiwan,China likely presents realistic signals because Taiwan,China targets ALB in much larger areas than in Japan and Korea which do not target ALB. Thus ALB STD_CPUE by Taiwan,China has been used in SA. As for blue+striped marlin and swordfish, they are similar, thus both STD_CPUE have been used for SA. Major reasons of discrepancies may be the different data processing methods by different scientists in Taiwan,China or fundamental differences in nominal catch between 2 fleets. We need to elucidate real causes of discrepancies, so that we may be able to utilize all STD_CPUEs in the future. .

59. Dr. Nishida discussed the application of CPUE indices in a range of stock assessments and highlighted a number of species for which the CPUE indices may differ between fleets. It was considered that these differences may relate to differences in species-specific targeting and/or spatial differences in CPUE trends. There may also be issues relating to different analytical approaches implemented by different analysts that may result in different CPUE indices for the same fleet. It was recommended that where significant differences arose between CPUE indices that the national analysts should collaborate to attempt to reconcile these differences. An initial starting point in a comparative analysis could include undertaking parallel analyses based on a core area of the fishery.

4.2. Standards used in other RFMO's: ICCAT's approach to assess useful CPUE's and bias

60. Dr. Scott summarised the approach used within ICCAT to objectively review a range of separate and sometimes conflicting CPUE indices from different fisheries. However, it was noted that the scores are somewhat subjective and to date the process has not provided definitive criteria for the selection of a specific set of indices. Nonetheless, it was considered useful to adopt a similar approach for IOTC assessments. Other organisations are also developing similar criteria to review CPUE analyses such as the WCPFC.

61. In 2012, after many debates about the positive and negative attributes for using different catch rate time series in stock assessment models, ICCAT's Stock Assessment Working Group (WGSAM 2012) developed a detailed set of instructions for authors that describe the information and some of the analyses required for the appropriate construction, documentation and evaluation of CPUE series. These include a range of diagnostics that authors of CPUE standardization analyses should provide in their documents (such as, Ortiz and Arocha 2004; Kell et al. 2010, 2011). WGSAM also developed two tools: the first, a flowchart that is intended to guide the appropriate use of CPUE series in stock assessment models used by ICCAT given the assumptions of those models (Figure 2) and the second, a table intended to evaluate the sufficiency of CPUE series, and inform decisions regarding their inclusion in stock assessment models (Table 1). Several species groups have applied the approach to focus discussions on the appropriateness of various CPUE series for different stock assessment models. The utility of these tools for improving the efficiency to conduct the stock assessments and focus species group debates about CPUE series can only be evaluated after several iterations of their use. The IOTC might consider similar criterion or those developed by other stock assessment groups in support of decisions for adoption of different time series of CPUE into assessment procedures.

Table 1. Elements to evaluate the efficiency of CPUE series

ELEMENT	*DESCRIPTION*	*SUFFICIENCY SCORE (1 is poor, 5 is best)*				
		1	*2*	*3*	*4*	*5*
1	Diagnostics	No diagnostics or assumptions clearly violated				Full diagnostics and assumptions fully met.
2	Appropriateness of data exclusions and classifications (e.g., to identify targeted trips).	Not appropriate				Fully appropriate
3	Geographical coverage	Small localized fishery/survey				Represents geographic range of population
4	Catch fraction	Small				Large
5	Length of time series relative to the history of exploitation.	Short				Long
6	Are other indices available for the same time period?	Many				It is the only available index
7	Does the index standardization account for known factors that influence catchability/selectivity?	No				Fully
8	Are there conflicts between the catch history and the CPUE response?	Yes				No
9	Is the interannual variability outside biologically plausible bounds (e.g., SCRS/2012/039)	Frequently				Seldom
10	Are biologically implausible interannual deviations severe? (e.g., SCRS/2012/039)	Very severe				Minimal
11	Assessment of data quality and adequacy of data for standardization purposes (e.g., sampling design, sample size, factors considered)	Low				High
12	Is this CPUE time series continuous?	Very discontinuous				Completely

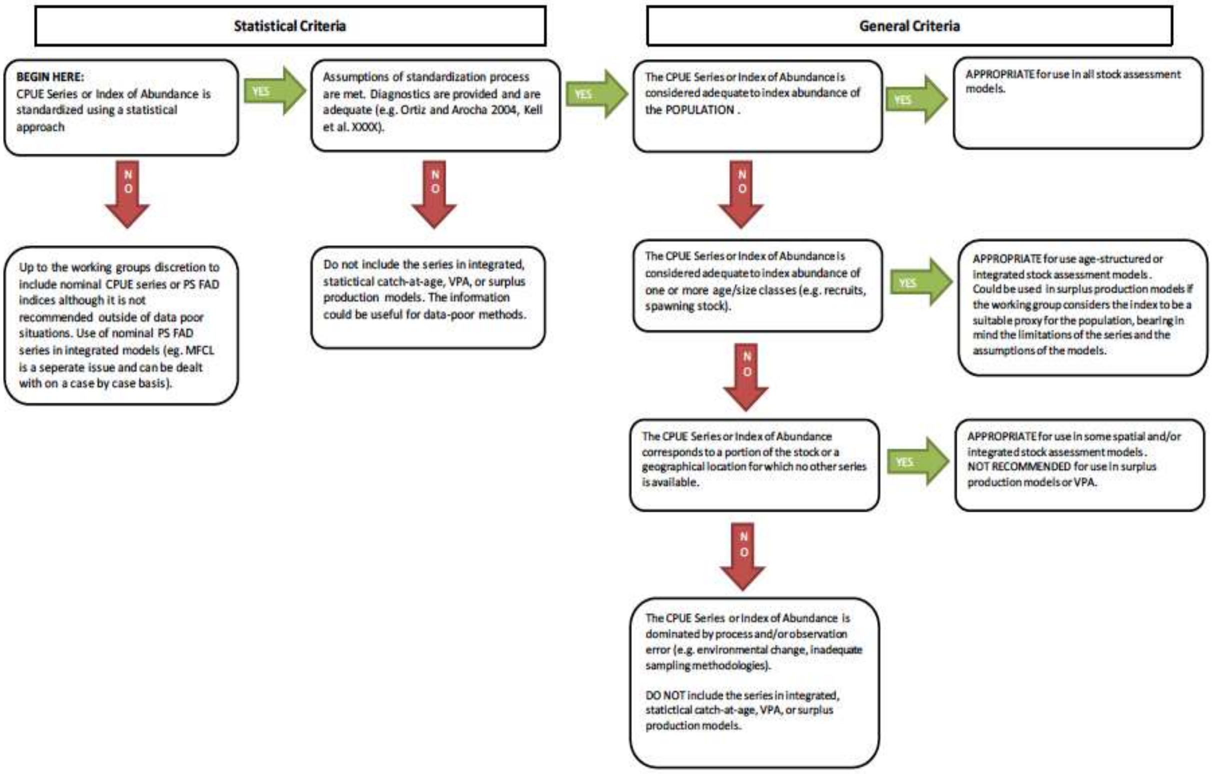

Fig. 2. A flow chart to facilitate the appropriate application of CPUE series to stock assessment models used by ICCAT (from WGSAM 2012)

CPUE WORKSHOP RECOMMENDATIONS AND WORKPLAN

5.1 Major recommendations of the IOTC CPUE Workshop

5.1.1 Use of newer standardization techniques (GLMM, GEOSTATISTICAL APPROACHES and CORE AREA APPROACHES)

62. While standard approaches worked well in most cases, the WG recommended that newer approaches should be tested. The results of the workshop conducted over the two day period, and the presentations covered by Dr. Coelho indicated that the GLMM models tend to capture the trends better than the standard approaches. In addition incorporating more vessel specifics and using geostatistical techniques is another approach to pursue over time. Finally, the use of core-area approaches may be informative for by-catch species. Moreover, the majority feeling of the group was that during CPUE standardization the use of operational data when they are available is recommended as it will allow capturing the covariates that are important during the standardization process.

63. *STRONG RECOMMENDATION: In areas where CPUE's diverged the CPC's were encouraged to meet inter-sessionally to resolve the differences. In addition, the major CPC's were encouraged to develop a combined CPUE from multiple fleets so it may capture the true abundance better. Approaches to possibly pursue are the following: i) Assess filtering approaches on data and whether they have an effect, ii) examine spatial resolution on fleets operating and whether this is the primary reason for differences, and iii) examine fleet efficiencies by area, iv) use operational data for the standardization, and v) have a meeting amongst all operational level data across all fleets to assess an approach where we may look at catch rates across the broad areas.*

64. Simulation studies could also be developed to assess which models work best (delta log-Normal, zero inflated versus standard GLM+constant, Tweedie).

65. Operational level data is useful if we want to quantify fishing fleet efficiency using fleet dynamic covariates. More applications could be developed using the methods developed by Hoyle and Okamoto (2010), or Hoyle (2009), and preliminarily results presented by Dr. Okamoto at the CPUE workshop.

66. Assess how core area Standardization works along with out of core or boundary area effects.

67. Environmental data would be useful to consider in relation to standardization approaches. However, the way it is usually performed in GLMs, where an environmental covariate is associated to each observation (in regular 1°, 5° or even 10° grids) , may not be the most pertinent as it does not allow to identify the ecological processes which may affect CPUE. Alternatively, GLMs could be performed in sub-areas where the variability pattern of the environmental signature is well identified (using spatial EOFs to delineate those sub-areas). In such sub-areas, GLMs could be designed with and without environmental covariates to understand the potential effect of the environment. Environmental covariates should be in limited numbers (the lesser the better) and selected in order to test hypothesis on the ecological processes at stake.

Recommend

- ***Develop models that account for overdispersion/underdispersion***
- ***Encourage using Regression Tree, Random forests for high-order and stratification purposes***
- ***Encourage using Spatial GAMs, and GLMM based techniques***
- ***Provide more detailed vessel specific covariates for model fitting.***
- ***Examine alternative hypothesis of spatial and temporal variation by fleets (Campbell Fish. Res. Draft Paper)***
- ***CPC's to initiate capacity building, but with responsibilities and capacity development carried out at a decentralized level (from IOTC secretariat on data programs and analytical approaches to use)***
- ***Major CPC's to meet inter-sessionally to resolve differences and possibly combine multiple sources of data in a grand CPUE standardization across fleets and areas. This could be coordinated by the IOTC if needed.***
- ***Develop operational data models to assess fleet effects and catchability changes over time.***
- ***Develop spatial GLM models on operational level data to assess accuracy of the current indices with and without spatial auto-correlation processes.***
- ***Assess Environmental data along with area (lat-long 1 by 1 degree grid) analysis.***
- ***Assess core area approaches along with boundary effects accounting for species densities.***

5.1.2 Develop a workplan for improving CPUE in IOTC area

68. The IOTC has focused development which contributes to improve the CPUE mostly for Tropical Tunas. However, limited work has been done on the other species, and is slowly improving on Temperate Tuna and Billfish. The Working Group recommended to also focus the efforts in other species such as Temperate Tuna. In addition the WG recommended, developing better CPUE data for Neritic Tuna, and also improving the data and standardization on marlins and sharks.

<u>Recommend: In order of priority the following should be conducted:</u>

- ***Improving the Temperate Tuna CPUE process by doing the following:***
  - ***a) Spatial structure could be revised for analysis.***
  - ***b) Try and have a sensitivity analysis using core areas so as to avoid fluctuations in CPUE by encompassing broader areas.***
  - ***c) The CPUE Index should account for targeting issues over time.***
  - ***d) Incorporate finer scale data, operational data at 1*1 degree spatial grid. Identify areas with homogenous effort distribution.***
  - ***e) Incorporate analysis by sub-region as maybe different components of the population.***
  - ***f) Explicitly model the zero catches-delta lognormal or Tweedie approaches.***
  - ***g) Alternative fleets gave a different signal and it may be useful to combine fleets and look at a core area CPUE across JPN, TWN,CHN and KOR. Use of TWN,CHN is probably recommended given it has the largest catch on Temperate Tuna.***
- ***If survey data exists to develop and assess the series for certain areas in the Arabian Sea, Bay of Bengal and Andaman Sea.***
- ***Missions to Indonesia, Iran and India need to be undertaken to assist those CPCs in developing catch and effort series from their historical data' and where missing, determine if estimation procedures could be developed that would produce a reliable historical series for Neritic Tuna***
- ***Develop indices for Marlins and Sharks with improved techniques and adding better covariates (if possible)***
- ***Develop objective criteria for utilizing one CPUE if contradictory signal are derived from different fleets.***
- ***Develop some indices for Skipjack using the PS Series.***
- ***For Tropical Tuna***
  - ***a) Account for targeting effects for BET and YFT Tuna***
  - ***b) If auxiliary information exists (e.g. economic data), to use that data in the standardization process***
  - ***c) Account for divergence in the trends between TWN,CHN and Japan for both BET and YFT.***
  - ***d) For YFT use some spatially explicit GAMS to derive indices that maybe more robust***
  - ***e) Account for low effort in 2009, 2010 and 2011 in areas affected by piracy.***

5.1.3 Develop a reference document for CPUE standardization and inclusion of an index in an assessment

69. Develop a reference manual for use in performing CPUE standardization for any fleet. Criteria for inclusion of the data in a stock assessment should also be developed (possibly using ICCAT techniques as a baseline).

<u>Recommend</u>

- ***Fine tune ICCAT, WCPFC and IATTC protocols for using an index.***
- ***Develop objective criteria and a reference manual for use in IOTC.***

5.1.4 Develop a robust index of abundance for the Purse Seine fleets operating in the Indian Ocean

70. Approaches being pursued by EU scientist have some promise, and more work should be put in the development of an index of abundance for the PS fleet on skipjack tuna, yellowfin tuna and bigeye tuna.

71. The availability of Vessel Monitoring System (VMS) data is a major requirement for the purse seine fishing fleet as it enables to spatialize the nominal effort (i.e. fishing or searching time), which is key to appreciate the temporal changes in the spatial extent of the prospected areas. VMS data may also be used to analyze PS trajectories with the aim to discriminate sets on FADs equipped with buoys from free school sets, log sets and foreign FADs sets (see after)

72. Purse seiners currently fish during the same trip on a combination of free-swimming and drifting FAD-associated schools. In addition, fishing on FADs results from both the detection of vessel-owned FADs through GPS geolocation systems as well as from the finding of 'foreign' FADs through bird detection for instance. Future analyses should focus on the separation of fishing time between searching and running towards FADs. Classification methods based on indicators describing spatial behaviour of vessels could enable to define typical fishing strategies and categorize trip components into such categories.

73. Data available on FAD activities collection have improved recently. Future analyses should focus on the definition of a fishing effort for purse seiners using FADs by (i) looking at the influence of the number of FADs owned by a vessel on individual CPUEs, (ii) by investigating the CPUEs in areas characterized by strong contrasts in FAD density. The influence of supply vessels on catch rates (e.g. the number of sets per day) and on the overall fishing capacity of the PS fleet should also be investigated at the vessel level through the information available from supply logbooks.

74. Analyses of temporal changes in individual and overall fleet catchability from CPUEs should be conducted to estimate fishing power creep and investigate how such changes are related with some major technological changes known for the PS fleet (e.g. bird radar). Including vessel effects into GLMs can reveal useful insights on vessel efficiency for such analyses. Attention should be paid also for change over time of fishery indicators which are part of the CPUE (e.g., number of set by day, % of successful set, catch size of the set).

Recommend

- ***Develop an index of abundance for the PS fleet***
- ***Account for fishery changes of the fleet in this index, and quantify vessel effects over time***
- ***Account for FAD effects and hyper-stability of the FAD index and compare these with free school and LL fisheries in areas where all fleets operate.***

5.1.5 Develop Capacity in Developing Coastal CPC's to Collect Data on Catch and Effort.

75. A long discussion occurred on the range and existence of data programs in the region. The CPUE Workshop participants recommended that a thorough analysis of the history of the fishery would be useful for references for each species. In addition, the Group agreed that a central body (the Secretariat) should undertake additional activities in key areas (Neritic tunas where they can develop/collate the existing data on catch and effort and analyze this for some key species (e.g. Longtail and Kawakawa)).

Recommend

- ***Focus capacity building initiatives for data collection programs for catch and effort data that may vary by time and space, especially for neritic tuna, sailfish and black marlin in the coastal CPCs.***
- ***Develop some series on Gillnet CPUE's over time and assess if these are useful for Neritic tuna, billfish and sharks***
- ***Focus capacity building initiatives for data analyzing programs for catch and effort data that may vary by time and space, especially for neritic tuna, sailfish and black marlin in the coastal CPCs.***

5.2 Produce a set of criteria for CPUE Assessment

76. The CPUE Standardization Working Group agreed that a reference document that IOTC could use in what criteria should be used in utilizing a dataset for CPUE Standardization for all WP would incorporate the specifics of the temporal and spatial coverage of the data, and useful covariates that could quantify the fishing activity and the environment in which the fish lived.
77. While one could not discount existing programs for collecting inaccurate data, improvements could be made in the future and then applied to correct archived data.

ADOPTION OF THE REPORT

78. The Report of the 1st CPUE Workshop conducted by IOTC was adopted on 4th November, 2013.

6. References

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APPENDIX I
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APPENDIX II: Agenda for IOTC CPUE Standardisation workshop.

October 21st, 2013

Registration — **8:30 AM**

1) Overview of approaches to use in standardization: Dr. Cooper: — 9 AM- 10 AM
2) Data overview by fleets currently operating in the IO (See Survey attached) — 10 AM-11 AM
    a. Data collection procedures
        i. Longline Fleets (LL) : Japan, Korea, Taiwan,China
        ii. Purse Seine Fleet: EU, Other
        iii. Bait Boat Fleet: Maldives
        iv. Others:
    b. Operational data resolution
        i. Longline Fleets (LL) : Japan, Korea, Taiwan,China
        ii. Purse Seine Fleet: EU, Other
        iii. Bait Boat Fleet: Maldives
        iv. Others:
3) Current procedures used for Standardization (See Survey attached) — 11 AM-1PM
        i. Longline Fleets (LL) : Japan, Korea, Taiwan,China
        ii. Purse Seine Fleet: EU
        iii. Bait Boat Fleet: Maldives
        iv. Others:
4) Issues for Improvement of standardization Procedures — 2 PM- 4 PM
    a. Fishery changes over time (including targeting and technological creep):
        i. Longline Fleets: Japan, Taiwan,China China
        ii. Purse Seine Fleets: EU
        iii. Baitboat Fleets
        iv. Other Fleets
    b. Spatial structure changes:
        i. Longline Fleets: Japan, Taiwan,China
        ii. Purse Seine Fleets: EU
        iii. Baitboat Fleets
        iv. Other Fleets
    c. Data Problems and gaps
        i. Longline Fleets: Japan, Taiwan,China
        ii. Purse Seine Fleets: EU
        iii. Baitboat Fleets
        iv. Other Fleets
    d. Discussion — 4PM-5PM

October 22nd, 2013

5) Combining CPUE series for stock assessment and Management Implications:
    a. Using A4A to assess impacts of biased CPUE on Assessments: — 9AM-10:30 AM
    b. Alternative CPUE Indices: How to incorporate them in an assessment — 10:30 AM-12 PM
6) Common guidelines for CPUE standardization to be used in Stock Assessment: Draft document for discussion. — 2PM- 4PM

Recommendations (Secretariat) — 4PM-5PM

APPENDIX III
LIST OF PRESENTATIONS

Presenter	Title
Topic 1: Current status and overview of approaches used for CPUE standardizations	
R. Sharma and M. Herrera	*A review of current CPUE Indices used for the Indian Ocean Tuna Commission*
A. Cooper	*Statistical Approaches for deriving indices of abundance from CPUE data.*
Topic 2: Data overview of fleets currently operating in the Indian Ocean	
H. Okamoto	*Overview of Japanese longline statistics*
Y. Yeh	*Overview of Taiwan,China longline statistics*
E.Chassot	*Overview of EU Purse Seine statistics*
S. Adam	*Overview of Maldivian Pole and Line statistics*
Topic 3a: CPUE Standardization Approaches currently used	
T. Matsumoto:	*Procedures used for standardization for Japanese longline CPUE.*
Y.Yeh	*Procedures used for standardization for Taiwan,China longline CPUE.*
E. Chassot	*Purse Seine CPUE standardization process and issues*
M. Soto	*Purse Seine CPUE's for juveniles*
R. Sharma	*Maldivian PL CPUE Standardization procedures and issues.*
Topic 3b: Other CPUE Standardization projects	
Mr. Jayasooriya:	*An overview of Sri Lankan Fisheries*
Mr. Wudianto	*An overview of Indonesian Fisheries*
Dr. Gaertner	Catch, Effort, and eCOsystem impacts of FAD-fishing" (CECOFAD)
Topic 4: Improvements in current CPUE standardizations	
Fishery changes over time (including targeting and technological creep)	
H. Okamoto	*Analyses of operational data based on Vessel ID.*
R. Coelho	*Blue Shark and ShortfinMako Standardization for Portuguese LL fleet: Accounting for targeting effects*
Spatial Structure changes	
K. Satoh (T.Matsumoto)	*Area stratification based on Tree model.*
T. Nishida	*Spatial GLM Approaches to use incorporating spatial auto-correlation or Geo-statistical approaches*
T. Nishida	*Use of core areas as an approach for estimating CPUE's- Striped and Blue Marlin for Japan*
Other CPUE issues to examine	

Presenter	Title
T. Nishida	*Incorporating environmental factors in STD_CPUE, useful or useless*
R. Coelho	*Examining alternative approaches for CPUE Analysis-Non-Linear Mixed effects Models for Swordfish.*
R. Coelho	*Accounting for 0's in your data: Using zero-inflated, delta-lognormal, tweedie or gamma models- Some cases examined.*
Topic 5: Bias in CPUE and Management Implications	
T. Nisihda	*Which tuna LL STD_CPUE are useful, Japan, Korea or Taiwan,China*
I. Mosquera (??)	*Assessing bias in CPUE's and the effect on assessments*
A. Cooper	*Simulating CPUE's using a simple 5 area model with varying temporal and spatial CPUE processes: Does a Non-linear Mixed effects model capture these changes?*
Topic 6: Common Guidelines and Recommendations	
H. Murua	*Generic Methods for combining and standardizing multiple CPUE's (ICCAT) and protocols for including a CPUE in an assessment*
R. Sharma	*Recommendations*

APPENDIX IV: INFORMATION AVAILABLE FOR THE CPUE STANDARDIZATION

1) Japanese longline fishery

	Field	Examples	Notes
	Fleet	LL	
Descriptive	Data Source	Logbooks for commercial vessels	
Temporal	Temporal Resolution	Set by set /Monthly	
Spatial	Spatial Resolution	Operational/1 degree/5 degree	
	Fleet Resolution	By Boat/Aggregated sets of boats	
Fishery	Effort Unit	Number of Hooks	
Operational	Species directed measures		
Environment	Exogenous/Environmental variables	SST recorded in logbooks (usually not used for analyses)	
	Vessel variables	None	
	Captain experience	None	
	Boat size	Gross tonnage	
	Crew etc.	Number of crew	
Vessel	Technology improvements		
Other	Missing Data/ 0 issues etc		
CPUE Standardization Related			
Technique Used	Log_Normal, Regression Trees, Delta_log Normal, etc	Lognormal and negative binomial	
Data Issues		Aggregated or operational level	
Resolution at which Conducted	Temporal/Spatial	1*1 or 5*5 degree month and operational	
Improvements Required		None	

2) Basic Survey for Taiwanese longline fishery

	Field	Examples	Notes
Descriptive	Fleet	LL	
	Data Source	Logbooks for commercial vessels	
Temporal	Temporal resolution	Set by set / Weekly	
Spatial	Spatial resolution	Operational / 1 degree from 1995 5 degree from 1979	
Fishery	Fleet Resolution	By Boat/Aggregated weekly sets by boat	
	Effort Unit	Number of Hooks	
Operational	Species directed measures		
Environment	Exogenous/Environmental variables	SST	
Vessel	Vessel variables	None	
	Captain experience	None	
	Boat size	Gross tonnage	
	Crew etc.	Number of crew	
	Technology improvements	None	
Other			
CPUE Standardization Related			
Technique Used	Log_Normal, Regression Trees, Delta_log Normal, etc	GLM with Lognormal error structure	
Data Issues		Target Proxy	
Resolution at which Conducted	Temporal/Spatial	Operational data with 5*5 degree spatial resolution	
Improvements Required		More technique could be tried	

3) Korea longline fishery

	Field	Examples	Notes
Descriptive	Fleet	LL	
	Data Source	Other	Logbook
Temporal	Temporal Resolution	Daily	Set by set
Spatial	Spatial Resolution	1 degree	
Fishery	Fleet Resolution	By Boat	
	Effort Unit	Number of Hooks Per Basket	
Operational	Species directed measures	Retained Catch (in weight and number) / discards by species, length	
Environment	Exogenous/Environmental variables	SST	
Vessel	Vessel variables	Call sign	
	Captain experience	Name of captain	
	Boat size	Tonnage	
	Crew etc.	Number of crews	
	Technology improvements		
Other	Missing Data/ 0 issues etc		
CPUE Standardization Related			
Technique Used	Log_Normal, Regression Trees, Delta_log Normal, etc	Log normal	
Data Issues			
Resolution at which Conducted	Temporal/Spatial	Temporal/Spatial (Added core area)	Combined into large areas/ seasons
Improvements Required			

4) EU fishery

	Field	Examples	Notes
	Fleet	EU PS	
Descriptive	Data Source	Logbooks	
Temporal	Temporal Resolution	Daily	
Spatial	Spatial Resolution	1 degree	
	Fleet Resolution	By Boat	
Fishery	Effort Unit	Fishing time, Number of set Per day	
Operational	Species directed measures	YFT,SKJ, BET	
Environment	Exogenous/Environmental variables		
	Vessel variables	Harvest capacity (m^3), starting date of the vessel, fleet (Spanish-French)	
	Captain experience		
	Boat size		
	Crew etc.		
Vessel	Technology improvements		
Other	Missing Data/ 0 issues etc		
CPUE Standardization Related			
Technique Used	Log_Normal, Regression Trees, Delta_log Normal, etc	Delta_log Normal	
Data Issues		Aggregated by vessel	
Resolution at which Conducted	Temporal/Spatial	Month/ET area	
Improvements Required			

5) Maldives PL fishery

	Field	Examples	Notes
Descriptive	Fleet:	Maldivian pole-and-line and handline tuna fleet	
	Data Source	Data reported by fishermen and compiled by island/atoll office staff aggregated over month. The data is supplemented by the fish collection (commercial purchase) data by exporters	This form of data collection will be stopped once logbooks coverage become acceptable <currently both logbook and collection by island/atoll offices takes place>
Temporal	Temporal resolution	Monthly	
Spatial	Spatial resolution	Geographic atoll; expected to be 1 x 1 from 2013 onwards	Logbook data will be 1 x 1 degree resolution.
Fishery	Fleet Resolution	By vessel aggregated over month	
	Effort Unit	Number of days	
Operational	Species directed measures	None	
Environment	Exogenous/Environ mental variables	None	
Vessel	Vessel variables	LoA, HP	
	Captain experience	None	
	Boat size	Gross tonnage	
	Crew etc.	Number of crew	
	Technology improvements	Use of anchored FADs	
Other		Livebait Logbook data (type of bait, location, and amount of catch, time of catch), does not cover the full fleet, need to computerize the data	
CPUE Standardization Related			
Technique Used	Log_Normal, Regression Trees, Delta_log Normal, etc	GLM with Lognormal error structure	
Data Issues			
Resolution at which Conducted	Temporal/Spatial	By region (North, South and Central)	
Improvements Required		Need to include livebait data	