INTER-AMERICAN TROPICAL TUNA COMMISSION

WORKSHOP ON DEVELOPING INDICES OF ABUNDANCE FROM PURSE-SEINE CATCH AND EFFORT DATA

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REPORT

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*presenter different from first author

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1. Introduction

Robin Allen, Director of the IATTC, gave a brief introduction to the meeting after which Mark Maunder, the meeting chairman, gave a few additional comments. The IATTC holds an annual technical workshop on a topic that is of significant importance to the stock assessment of tunas and billfishes in the eastern Pacific Ocean (EPO). The topic of the meeting of November 2004 arose from research needs identified at the annual review of the staff's stock assessments held in May 2004.

Indices of abundance developed from catch and effort data are one of the most common types of information about biomass trends used in fisheries stock assessment. This is particularly true for tunas and billfishes, for which fisheries-independent surveys are not available. Tagging studies provide information about abundance, but comprehensive tagging studies are generally not available for these species, and none have been carried out in the EPO.

Indices of abundance are used in the stock assessment models to provide information to estimate the model parameters, which, in turn, are used to estimate the quantities for management advice (*e.g.* maximum sustainable yield). The current method used for stock assessments of tunas in the EPO (A-SCALA), uses catch and effort information from a number of fisheries to provide information on abundance. Each of these fisheries harvests a somewhat different subset of ages, so information from multiple fisheries is desirable for obtaining information on all ages of fish. The catch and effort data from the purse-seine fisheries currently used in A-SCALA is simply catch per day of fishing.

Recent focus has been on the development of indices of abundance from Japanese longline catch and effort data. In general this relates to the larger individuals of the population. The methods used include habitat-based standardization (HBS), statistical habitat standardization (statHBS), regression trees, and neural networks. These methods have been developed mainly to incorporate the increased depth of the longline over time as they have changed to increase the catches of bigeye tuna. Habitat-based models and the neural network approach match the depth of the longline with the environmental conditions and the habitat preference of the species.

Recent assessments for bigeye tuna in the EPO have shown weak recruitment and high fishing mortality for the younger individuals. Since purse-seine fisheries catch small bigeye, indices of abundance from purse-seine catch and effort data may improve the bigeye tuna assessment. Such indices of abundance may also improve the skipjack and yellowfin assessments, since longline indices of abundance are not available for skipjack, and longline catch comprises only a small portion of the catch of yellowfin tuna. There are three types of purse-seine sets in the EPO 1) sets on unassociated schools, 2) sets on tuna associated with floating objects, and 3) sets on tunas associated with dolphins. Each of these types may pose unique problems and require different approaches.

Historical indices of abundance developed from purse-seine catch and effort data for tunas in the EPO have included simple catch rates compared to a standard vessel class and linear modeling that measure effort in either days of fishing or hours of searching. However, there has been a large amount of technological development, and the introduction of fish-aggregating devices (FADs) with locator beacons has transformed the nature of searching time in the floating-object fishery. Therefore, novel approaches to the development of abundance indices are needed, particularly for the FAD fisheries. This workshop was organized to facilitate the development of methods to produce indices of abundance from purse-seine catch and effort data.

To focus the discussions, six questions were posed at the start of the meeting.

1. What is the basis for expecting that catch per unit of effort (CPUE) provides information on abundance in a) dolphin-associated, b) unassociated, and c) floating-object purse-seine fisheries?

2. Is there an appropriate measure of effort for a) dolphin-associated, b) unassociated, and c) floating-object purse-seine CPUE?

3. Has the development in technology in a) dolphin-associated, b) unassociated, and c) floating-object purse-seine fisheries increased catchability?
4. Are our current techniques able to estimate increases in catchability for purse-seine fisheries?
5. What data should be collected to develop indices of abundance from purse-seine catch and effort data?
6. What are the most promising methods to develop indices of abundance from purse-seine catch and effort data?

The Commission, at its 72nd Meeting, provided additional guidance to the during its discussion of Document IATTC-72-13, *Marking of Fish-Aggregating Devices,* which outlines a staff proposal for a system for marking FADs. The proposal was made within the context of measures to better understand and manage the use of FADs, and the marking of this type of gear is supported by FAO and other international agreements. The Commission discussed this topic and agreed to send it to the Working Group on Stock Assessment for consideration, as it falls under the data collection category. Some participants felt that the proposal was more appropriate for anchored FADs and that more research was needed on other gears as well, such as longlines, while others supported it because it would improve research on FADs, which could reduce the catch of small bigeye tuna.

2. The EPO fisheries and data

2.1. Summary of the fisheries (E. Everett)

Ed Everett gave an overview of the purse-seine fisheries in the EPO. During the early years of the fishery most of the catches were taken by pole-and-line gear, but by the mid-1960s most of these boats had been converted to purse seiners. At that time most of the catch was taken by US-flag vessels. The catch of tunas increased, peaking in the late 1970s, declining in the early 1980s, and increasing substantially starting in the mid-1990s due to an apparent increase in the abundance of yellowfin tuna and the expansion of the FAD fishery. By this time the fleet was multinational, and there were essentially no US-flag vessels left in the fishery. There have been substantial changes over time in the sizes of the vessels and the technology used.

As mentioned previously, there are three types of purse-seine sets in the EPO, sets on unassociated schools, sets on tunas associated with floating objects, and sets on tunas associated with dolphins. In general, vessels concentrate on either floating-object (mostly FAD) sets or dolphin-associated sets and set on unassociated schools when they are encountered.

2.2. The EPO fisheries, from a fishing captain's perspective (R. Stephenson)

Captain Dick Stephenson presented information on the operational aspects of fishing on tunas associated with FADs and tunas associated with dolphins. He described the methods used to search for tuna and set the net, and how these have changed over time and differ among vessels. These descriptions included, among others, the use of helicopters, speedboats, bird radar, powerblocks, de-ringers, the backdown procedure to release dolphins, problems that occur, such as net collapses, and the process of brailing.

Notable comments include:

a. The increased efficiency of brailing reduces the handling time and increases the amount of fish that can be caught in a single set. Brailing was originally carried out using the skiff, but now a boom attached to the vessel is used. Brails have evolved from those that can handle about 1.5 tons to those that can handle about 5 tons.

b. FADs have progressed from highly-detectable radio buoys, to cell-call buoys, to stealth global positioning systems (GPS) and echo-sounder buoys.

c. Individual skippers have their own systems. For example, Captain Stephenson uses colored lights (green, red, white, and blue) on FADs to attract tuna. Red and white lights are thought to attract skipjack, and blue and red lights are thought to attract bigeye tuna.

d. Tuna species for large individuals can be identified by the echo-sounder signal and the behavior of the school. The boat-based echo-sounder can be used to determine if the fish are small or large, how densely packed the school is, and position relative to the FAD. It is difficult to distinguish small bigeye from skipjack, but large bigeye have a different signature.

e. The behavior of the tuna depends on the time of day. In the morning the tuna are in a tightly-packed ball around the FAD. By noon the tuna are spread out at the surface.

f. Bigeye behavior varies with moon phase. More bigeye are near the surface three days before and after a full moon.

g. Captain Stephenson generally has 30 FADs in the water and 8 on the boat. Larger boats may have 200 FADs. If a FAD is found with large amounts of tuna, the FADs on the boat are deployed in that area. The FADs are generally set 15 miles apart and 4 to a 'block.' They are set perpendicular to the current so that their paths do not overlap. Often the FADs are deployed on the way to port so that they are available for the next trip. FADs are deployed in areas away from the strong currents, and they tend to travel about 4.5 to 8 miles per day. He tends to leave them 30 days before checking them.

h. The area 4°S-4°N has a huge number of FADs and many vessels, Captain Stephenson generally does not fish there because his FADs, which are the beacon type, have a high rate of loss due to other vessels. In general, 2 or 3 FADs of 30 are lost per trip in the northern area, but 20 may be lost per trip around the equator.

i. Radio beacons can be found by bird radar and scanning devices, and GPS buoys can be found by locating the birds above the FAD. 'Beeper radar' can locate a FAD 15-20 miles away on a calm night.

j. The large fish usually go to the bottom of the purse seine and dominate that area.

2.3. The FAD fishery, from an observer's perspective (M. Román)

Marlon Román presented a summary of the FAD fishery in the EPO, based on his experience aboard vessels as an observer from 1989 to 1998, with additional updated information from current IATTC observers. The construction of FADs has varied over time and between vessels, but the current construction is fairly uniform. The FAD consists of a bamboo frame covered in netting with floats for buoyancy. Netting about 25m in length and weighted at the bottom is hung below the FAD. A bait bucket may be added to the FAD. FADs have been modified over time to reduce their detection by other vessels.

A locator beacon is attached to the FAD to aid in location. The types of location beacons have changed over time from simple radio buoys to GPS buoys. Radio buoys and GPS buoys are sometimes used together. The GPS buoys are used to find the general area of a group of FADs, and radio buoys to find the individual FADs. If flotsam is found, a locator beacon is often attached. Dead animals (*e.g.* whales) may be taken on board, wrapped in netting, and released elsewhere.

FAD sets generally occur shortly before or after sunrise. This is presumably because the tuna are tightly grouped around the FAD at this time and thus easier to capture.

The details of two trips were shown highlighting the wide variety of behaviors that occur in the FAD fishery. These behaviors included, setting on the FADs of other vessels, attaching radio beacons to flotsam, using dead marine mammals as FADs, deploying FADs, setting on FADs deployed on a previous trip, repeatedly deploying FADs in a good area and setting on them, and then moving them back to the initial deployment position.

2.4. Summary of the fishery data (J. Suter)

Jenny Suter gave an overview of the data available for the purse-seine fisheries in the EPO. The logbooks contain trip information, such as dates of departure and arrival, ports of departure and arrival, *etc*, along with some general vessel characteristics. The logbooks also contain the dates and times of vessel events, such as those for each set made, and the amount of catch by species taken in each set.

In addition to logbooks, catch estimates are available from observer records, unloading records provided by the canneries, and from a species-composition sampling program (done in conjunction with length-frequency sampling) that has been carried out since 2000, which provides independent estimates of the composition of the landed catches.

Effort data, such as number of days fished, searching time (length of day minus time spent setting and retrieving the net and landing the catch aboard the vessel), or number of sets made, is available from vessel logbooks and observer records.

The catch or effort data can be stratified by month, area, set type, *etc.,* by using the logbook or observer data. Total catch data are obtained from the cannery records, supplemented by observer or logbook data for trips for which cannery data are not provided. Total effort can be estimated by summing up the observer or logbook data and raising it to the total number of trips made during the time period in question.

Results of species composition sampling suggest that bigeye catches are underestimated by observers, and that canneries underestimate bigeye catches more than do the observers. Other summaries of the data were presented, including temporal trends in numbers of vessels, fish-carrying capacity, catch by species, spatial patterns, and lengths of sets.

Issues discussed included position validation via inferred speed; disparities in species-composition estimates among methods, and the way that the introduction of the AIDCP Tuna Tracking System in 2000 has affected the independence of logbook and observer records.

2.5. Summary of observer data (N. Vogel)

Nick Vogel summarized the history of the IATTC observer program, and collaboration of the IATTC with national observer programs. This was followed by a brief description of the data collected, editing procedures and amount of data collected through 2003. Information on equipment changes over the years, including net length and depth and use of helicopters, echo sounder and bird radar, was presented. The presentation closed with a description of the current *Flotsam Information Record* (FIR), used for collecting data on floating objects, a description of its limitations, and an introduction to the new form which will replace it in 2005.

Issues discussed included the equipment specification information available in the IATTC database; observer duty levels (95-99% of fishing time); and the introduction of the AIDCP Tuna Tracking System .

2.6. Summary of fish behavior and data (K. Schaefer and D. Fuller)

Simon Hoyle, on behalf of Kurt Schaefer and Dan Fuller, presented research on the behavior, vulnerability and acoustic discrimination of tunas. Archival tags have been deployed on 265 bigeye, 102 yellowfin, and 33 skipjack tuna. Archival tag recoveries to date are from 104 bigeye, 43 yellowfin, and 3 skipjack. Bigeye show regional fidelity to the EPO. They spend about 20% of their time in the equatorial EPO associated with floating objects, with a mean duration of 3 consecutive days per event. Yellowfin show seasonal movements in conjunction with latitudinal shifts of the 20°C surface isotherm. Yellowfin are not restricted in depth to the mixed layer, but spend considerable time in offshore areas off northern Mexico, 'bounce diving' throughout the day to depths of about 250 m, which appears to be a foraging strategy targeting prey organisms of the deep scattering layer (DSL). Skipjack tuna also exhibit bounce-diving behavior to depths of 250-350 m during the day in the equatorial EPO, also apparently targeting prey organisms of the DSL.

A comparative study of bigeye and skipjack behavior was carried out using ultrasonic telemetry, sonar, echosounders, and underwater video. Aggregations were observed upcurrent of moored buoys and downcurrent of drifting objects. When associated with an anchored moored buoy, bigeye were deeper than skipjack during both day and night. However, when associated with a drifting object, bigeye depth distributions were shallower than those of skipjack during both day and night. At night the aggregations were more diffuse, and the fish were feeding on organisms in the DSL near the surface. Skipjack schools associated with drifting FADs have been observed at dawn to separate from aggregations.

It is possible to discriminate bigeye, yellowfin, and skipjack tuna with commercial echo-sounders. The swimbladder can account for a majority of the acoustic target strength. Skipjack lack swim bladders, and bigeye swim bladders are larger than those of yellowfin. IATTC tagging cruises have verified the ability to discriminate among the species using echo-sounders and behavior. In addition, sonar provides estimates of the sizes of aggregations.

In addition to providing information useful for developing indices of abundance, these results may be useful in for management considerations in avoiding the capture of bigeye tuna associated with FADs.

3. Overview of the analysis of CPUE data

3.1. Traditional CPUE approaches (M. Maunder)

Mark Maunder described the traditional analyses used to develop indices of abundance from catch and effort data. He referred to the recent special issue of Fisheries Research (volume 70 issues 2-3) for reviews and applications.

The standard approach is to use a general linear model (GLM) with CPUE as the dependent variable. This is generally referred to as CPUE standardization. A multiplicative model with lognormal error structure is developed by log-transforming the CPUE. Year is included as a categorical variable, and used to represent the relative index of abundance. Multiple explanatory variables are tested for inclusion in the model (*e.g.* area or latitude/longitude, month/season, vessel or vessel characteristics). If there are significant zeros the delta-lognormal distribution is used. Interactions with the year effect are ignored.

The necessary considerations required to standardize CPUE data include 1) deciding on a method (*e.g.* GLM, general additive model (GAM), regression tree, neural network, general linear mixed model (GLMM), HBS, statHBS, integrated), 2) choosing explanatory variables (which ones, categorical or continuous, interactions, polynomials, transformations), 3) deciding on the dependent variable (CPUE, catch, grouping data, subset of data, which measure of effort: include multiple measures of effort as explanatory variables), 4) choosing an error structure (*e.g.* least squares, log-normal, Poisson, negative binomial, delta methods to cope with zeros), 5) choosing a model selection technique (using r^2, F test, AIC, cross validation, score, stepwise regression) 6) selecting diagnostics (are the assumptions met, outliers), and 7) determining how to include the CPUE-based index in the stock assessment model.

Two major problems with standardizing CPUE data are dealing with large numbers of zero catches and interactions with the year effect. Large numbers of zeros can occur with non-target or rare species, or species that aggregate. Methods to deal with zeros include adding a constant, using zero-inflated distributions, or using the delta distribution to model the probability of a positive outcome and the distribution of positive outcomes. Interactions between area and year are very common. These can be dealt with by using a habitat-weighted average of the indices for each area, using a spatially-structured population dynamics model, or using a mixed-effect analysis of the CPUE data.

3.2. Past IATTC uses of CPUE data (S. Hoyle)

Simon Hoyle described the historical use of catch and effort data as indices of abundance. CPUE data have been used by the IATTC in population models since the early 1950s. As emphasis moved from surplus production to cohort models, CPUE received less attention, but the introduction of integrated analysis using an age-structured statistical catch-at-length analysis (ASCALA) has raised its profile once again. Early *ad-hoc* standardization was by vessel class, with catch rates compared to a standard vessel class. Linear modeling was introduced in the late 1960s. Analyses that separated search time and handling time were developed from the mid-1970s to the mid-1980s. These aspects of fishing effort are affected by different components of abundance (distance between 'fishable' schools and school size, respectively) and vessel characteristics. However, these CPUE standardization methods were used only for comparison with the 'raw' catch rates that are currently used in the ASCALA models.

3.3. Using catch and effort data in A-SCALA and model sensitivity (M. Maunder)

Mark Maunder described how purse seine catch and effort data are currently used in the IATTC tuna stock assessments. A-SCALA is used to assess the tuna stocks in the EPO. The stock assessment model fits to catch data conditioned on effort, and this extracts the information about abundance from the catch and effort data.

Only catch by set is available, separated into the three purse-seine fishing methods. However, catch per set is not an appropriate measure of stock size, it is probably more related to school size and school size is not necessarily related to stock size. Therefore, the number of days fished is regressed against the three set types to determine the number of days attributed to each of the set types (the coefficients in the regression). This is then used to convert catch per set by method into catch per day fished by method.

Sensitivity analyses were carried out to determine the influence of the purse-seine catch and effort data on the yellowfin and bigeye tuna stock assessments. First the assessments were run with the emphasis on the purse-seine catch and effort data at a low level (the standard deviation for the effort deviate penalty was set to 2); then the emphasis on each of the purse-seine set types was increased (the standard deviation for the effort deviate penalty was set to 0.2). Additional analyses were carried out for bigeye tuna with 1) the catch-at-length sample size divided by 10 to give more emphasis to the CPUE data, 2) a 2% per year increase in purse-seine catchability, and 3) hyperstability incorporated into the CPUE of the floating-object fishery. The results showed that for bigeye tuna the floating-object CPUE had very little influence on the results unless the length-frequency sample size was greatly reduced, and in this case the confidence intervals were very wide and the difference was not significant. The CPUE for the dolphin-associated fishery was more influential for yellowfin, and determining an index of abundance from this fishery for yellowfin tuna shows the most promise for improving the assessment. No analysis was carried out for skipjack tuna; it is possible that purse-seine CPUE is more important for skipjack because the assessment does not include data from the longline fisheries.

The trends in catchability from the assessments when the catch and effort data for the purse-seine fisheries were de-emphasized were described. The floating-object fisheries for bigeye tuna showed a general increase since the fishery expanded in 1993, but there were also periods of sharp decline. No remarkable trends were seen in the purse-seine fisheries for yellowfin tuna, except for some gradual declines.

4. Research

4.1. Incorporating oceanographic data (A. Langley)

Adam Langley presented results of an analysis highlighting the effect of oceanographic conditions on the purse-seine fishery. Data from oceanographic models and remote sensing are readily available, and can be easily incorporated in to the analysis of CPUE data from purse-seine fisheries. Two examples were presented from the purse-seine fishery of the western and central Pacific Ocean (WCPO). A qualitative analysis of purse-seine CPUE data from the Papua New Guinea anchored-FAD fishery revealed skipjack catches are strongly influenced by the prevailing current flows in the preceding month. A separate analysis used a clustering approach to define areas of intensive purse-seine fishing activity on unassociated fish. A GLM approach was then applied to investigate the influence of oceanographic features on the amount of skipjack taken from these monthly "clusters.” The oceanographic data explained a significant proportion of the variation in catch. Catch rates were influenced by the temperature at depth, chlorophyll-a concentration, meridional and zonal current flow, and the degree of convergence of currents. The model was applied to explain recent trends in the performances of several different fleets operating in the fishery. The inclusion of oceanographic data is likely to be informative in the development of a CPUE model to predict catch rates from the drifting FAD fishery.

4.2. Modeling abundance of tuna at anchored floating objects in the tropical eastern Pacific Ocean (S. Harley and M. Maunder*)

Mark Maunder presented a framework for modeling the tuna dynamics around floating objects. The population of tuna around a FAD increases due to immigration and decreases due to natural mortality, fishing mortality, and emigration. These processes can be represented by mathematical equations, and the catch taken from the FAD predicted and compared to the observed catch to estimate the model parameters. The basic underlying concept is that the accumulation rate of fish at a FAD is indicative of the local abundance of tuna. This will be moderated by FAD density, local fishing effort, and other factors.

To carry out this type of analysis the catch must be associated with a FAD. At present this is possible only with 1) the anchored TAO buoys, by matching GPS coordinates of the catch with TAO buoy coordinates or 2) within a trip if the observer can uniquely identify the FAD after the first set on that FAD or if the FAD was deployed on that trip. However, if drifting FADs had identification numbers the catch from any vessel could be associated with a FAD.

Modifications to the simple model described above could include

a. Information on when a FAD is checked but not set on

b. Effects of neighboring FADs

c. Effects of fishing in the local area

d. Inclusion of information from conventional and archival tagging data

e. FAD movement that accumulates fish

f. FAD age to accumulate the fish community

g. Random effects to integrate multiple FADs into a single analysis

4.3. FADs as attractors (M. Maunder)

Mark Maunder described how FADs could be modeled as attractors, while allowing for fish movement and habitat effects. This description was based on the presentation "Modeling Animal Movement, Resource Selection, and Home Range Simultaneously" by Dale Zimmerman, Department of Statistics and Actuarial Science, University of Iowa, Aaron Christ and Jay Ver Hoef, Alaska Department of Fish and Game, presented at the fifth Winemiller Symposium (see Christ, A., Ver Hoef, J.M., and Zimmerman, D. 2004. An Animal Movement Model Incorporating Resource Selection and Home Range. Proceedings of the American Statistical Association, Section on Statistics and the Environment [CDROM] Alexandria, VA: American Statistical Association: in press.). The calculations are simplified by assuming normal distributions for the FAD attraction and the movement of fish. However, a more complex estimation method similar to that used by the Pelagic Fisheries Research Program of the University of Hawaii at Manoa group would probably be needed for application to FADs and tuna. The method could be applied to archival tag data for tunas in the EPO.

4.4. Counting FADs (S. Hoyle, C. Lennert-Cody, and M. Maunder)

Simon Hoyle described methods that could be used to estimate the number of FADs in an area. Information about the distribution of FADs in space and time is needed to help determine the relationships between tuna population dynamics and purse-seine catch rates. He outlined a framework for modeling FAD population dynamics, taking into account issues such as type, ownership, detectability, movement, deployment, removal, and stealing of FADs. He considered the types of data currently collected in the EPO, and presented maps (1990-2002) of 1) average distance traveled between floating object visits, and 2) average number of unique floating-object visits per vessel.

He considered the utility of collecting additional data. Currently planned observer data collection on FAD deployment and removal is essential, and a mark-recapture experiment has potential benefits.

4.5. Effects of communication among fishermen on CPUE as an index of abundance (M. Dreyfus)

Michel Dreyfus described an individual-based neural network model of decisions by fishermen to allocate fishing effort employing a spatial model, considering the fact that fishermen cooperate in the tuna fishery, forming code-groups. It is shown in the simulations that this characteristic of the fishery generates an overestimation of abundance with CPUE or hyperstability. An option to adjust CPUE is considered that seems to correct this problem: calculation of CPUE is based only on vessels fishing in different areas.

4.6. Abundance of bycatch derived from "known" bigeye tuna abundance. (M. Newman, R. Olson, and M. Maunder*)

Mark Maunder presented a method to develop indices of abundance for bycatch species based on the ratio of the catch of bycatch species to the catch of bigeye tuna in a FAD set, under the assumption that the total bigeye tuna abundance is known. The bigeye tuna abundance is taken from the stock assessment for bigeye tuna. If the behavior of the bycatch species is similar to that of bigeye tuna then the ratio of the bycatch to the bigeye catch rates may not be influenced by the many unknown factors, such as FAD density or FAD age. Additional explanatory variables such as area or month can be added in a GLM context to remove additional variability not related to total abundance. The model parameters are estimated by fitting the predicted catch to the observed catch for the bycatch species. This approach may be useful for developing abundance indices for skipjack tuna from the catch and effort data for the FAD fishery.

4.7. Japanese purse-seine fisheries in the north Pacific Ocean: considerations for bluefin tuna assessment (H. Yamada)

Harumi Yamada reported on the Japanese purse-seine fishery in the Pacific north of 20° N, which is quite different from the fisheries in the tropical oceans, and discussed the estimation of abundance indices for Pacific bluefin tuna (PBF). The Japanese purse-seine fishery in the North Pacific operates in groups containing one fishing vessel (80-135 gross registered tons), one or two scouting boats, and two carrying boats. The fishing vessel has no fish wells. The fishing vessels target unassociated schools, regardless of target species, and sometimes set on schools associated with flotsam, but never use FADs. The scouting boats play an important role in finding the fish schools.

The Japanese purse seiners operate on two fishing grounds. One is the Pacific Ocean east of Japan, where the catch of PBF larger than 10 kg is observed in summer. The other is the western Sea of Japan to the Tsushima Strait, where the catch of PBF smaller than 10 kg is observed in the Strait through the year.

Purse seines are a major fishing gear catching PBF accounting for half the catch. Therefore, information on the purse seine fisheries should provide the most reliable abundance indices of PBF. The vessels usually target more abundant skipjack in the Pacific Ocean or small pelagic fishes in the western Sea of Japan, although they try to catch PBF if they are available.

The study estimated abundance indices, using catch and effort data. Records with no PBF catch were excluded. It was suggested that all effort should be considered directed toward PBF in the PBF area, as they are targeted if observed, and that operation data for scouting boats, in addition to the fishing vessel's data, should be collected.

4.8. Statistical habitat based model for standardizing longline CPUE (M. Maunder and M. Hinton)

Mark Maunder described the statistical habitat-based method (statHBS) that is used to develop abundance indices from longline catch and effort data. This method is an extension of the HBS method (IATTC Bull. 21(4)). The HBS model matches the depth of hooks with oceanographic data to determine the habitat where each hook is located. The effort is then calculated by summing the habitat preference related to the habitat of each hook to determine the effective effort for the entire longline. The habitat preference has traditionally been obtained from the time spent in each habitat, estimated from archival tag data. However, statistical tests applied to predicted catch from nominal and HBS standardized effort have produced results indicating that the habitat preference data may not be appropriate. The statHBS method extends these statistical tests to estimate the habitat preference by fitting the HBS predicted catch to the observed catch.

The habitat preference data from archival tags may not be appropriate because they include time when the fish are not feeding. There is also a mismatch between the spatial and temporal scales of the archival tag data and the oceanographic data, the wrong habitat variable may be used, and the archival tag data are limited in their spatial and temporal coverage.

It might be possible to apply the statHBS method (*e.g.* some modification of its current application) to purse-seine catch and effort data, in order to take oceanographic information into consideration.

5. Discussion of methods to develop indices of abundance from purse-seine catch and effort data

To focus the discussions, six questions were posed at the start of the meeting. In addition, the Commission gave the stock assessment working group guidance to evaluate the need for marking FADs. The discussion relating to these are presented below.

5.1. What is the basis for expecting that CPUE data provide information on abundance in 1) dolphin-associated, 2) unassociated, and 3) floating-object purse-seine fisheries?

CPUE data will provide information on relative abundance only if a measure of effective effort is available (*i.e.* either there is a valid measure of effort, and catchability does not change, or effort can be standardized for changes in catchability). Currently, it should be possible to determine measures of effective effort for the dolphin-associated and unassociated fisheries by determining the searching time. Due to the presence of locator beacons on FADs, measures of effective effort are not available for the FAD fisheries. The measure of effective effort for the FAD fishery may be related to the time the FAD is in the water "searching" for fish.

Cohort analyses carried out by the IATTC staff for yellowfin tuna have produced similar trends to catch per day fished, except in El Niño years, suggesting that catch per day fished is a reasonable measure of abundance for yellowfin, but catch per hour searched, or some other search measurement, should be somewhat better. However, the large changes in the spatial coverage of the effort are a concern.

5.2. Is there an appropriate measure of effort for 1) dolphin-associated, 2) unassociated, and 3) floating-object purse-seine CPUE?

An appropriate measure of effort for the dolphin-associated fisheries and unassociated school fisheries is search time/distance/area, but more work needs to be done to consider factors such as code groups, spatial shifts, and the use of helicopters. Code groups may cause hyperstability in the CPUE. Due to difficulties in defining searching time by set type, it may be appropriate to use only vessels that make most of their sets by one method.

No measure of effective effort is currently identified for the FAD fisheries.

5.3. Has the development in technology in 1) dolphin-associated, 2) unassociated, and 3) floating-object purse-seine fisheries increased catchability?

A comprehensive analysis has not been performed to determine how changes in technology have influenced catchability in the EPO purse-seine fisheries. It is expected that the introduction of bird radar and helicopters, and possibly the increased height of the observation towers, have increased catchability for the dolphin-associated and unassociated school fisheries. Several factors are thought to affect catchability in the FAD fishery, including FAD types, technology of the FAD, learning how to use FADs and where to put them, and the numbers of FADs (high density may reduce catchability). Handling ability has improved, reducing handling time, increasing catch, and reducing discards. This should have improved the apparent catchability. Large differences in catchability are apparent between vessels, related to crew skills, vessel age, and technology level.

To determine if the development in technology has changed catchability, a GLM or other statistical method could be used with abundance from the stock assessment as an offset.

5.4. Are our current techniques able to estimate increases in catchability for purse-seine fisheries?

The A-SCALA stock assessment can estimate increases in catchability for bigeye and yellowfin tuna if the indices of abundance from the longline catch and effort data are proportional to abundance. However, to calculate the changes in catchability, an appropriate measure of effort is required for the purse-seine fisheries.

5.5. What data should be collected to develop indices of abundance from purse-seine catch and effort data?

In general, for all fisheries, information should be collected on the equipment used and fishing strategy for each vessel. This information could be collected from skipper interviews. Some information on equipment used already exists in the IATTC vessel characteristic data base. Additional information should be collected on the use of code groups.

The FAD fishery is currently the most problematic for determining indices of abundance, and several different types of data should be collected. The new FAD form will collect vital information on the number of FADs deployed and removed. In addition it is important to uniquely identify individual FADs by trip and by vessel (*e.g.* number them). If this is not possible, a mark-recapture experiment on FADs should be carried out. Other information on the behavior and abundance of fish around FADs, for example with the use of archival, sonic, and conventional tags, should also be collected. Access to information from echo-sounder FADs from commercial vessels or a specific survey using echo-sounder FADs may be informative.

5.6. What are the most promising methods to develop indices of abundance from purse-seine catch and effort data?

There are several methods that have been identified as possible sources of abundance indices for tunas in the EPO. The first most basic method is to use a standard GLM approach on dolphin-associated and unassociated fisheries with search time/distance as the dependent variable. This may involve identifying vessels that predominantly use a single method and using the data from these vessels. However, the limited spatial coverage of unassociated fisheries for yellowfin tuna is a concern.

A GLM or similar approach with biomass estimated from the stock assessment as an offset might be promising for estimating the effects of technology on catchability. This could be used for bigeye or yellowfin tuna, and then the changes in catchability used in an assessment of skipjack to standardize the CPUE data. Alternatively, the abundance of bigeye or yellowfin estimated in the stock assessments could be used in a change-in-ratio method for skipjack or bycatch species.

Due to the changing spatial distribution of effort, methods that model the spatial and temporal correlation (*e.g.* random effects type models) might be promising. Cluster analysis of vessels might be useful to identify code groups so that this can be taken into account in the analyses.

The alternative approach for estimating indices of abundance by modeling the dynamics of tuna around FADs rather than using CPUE data may be the best method for the FAD fisheries. This would also require the estimation of local FAD density by modeling FAD dynamics or the distance between FADs or number of unique FAD sightings.

An alternative to using CPUE data to develop indices of abundance is to carry out large-scale tagging programs for tunas.

5.7. Marking FADs

Placing unique marks on all FADS so they can be identified between trips and between vessels is necessary for much of the work suggested to develop indices of abundance from the FAD fisheries. FADs are the searching component of effort in this fishery and information about the searching component is necessary for developing indices of abundance. A FAD is equivalent to a fishing vessel, so it is necessary to know where it is and how much catch is taken in association with it. Local FAD density is also important, as it may influence the accumulation rate of fish at the FADs. Information on FADs may provide insight into factors other than tuna abundance. For example, FADs attract organisms other than tuna, and thus affect the entire pelagic ecosystem. Such information may provide insights into bycatch mitigation and whether there is a relationship between the number of FADs and the catchability of tunas.

At present there is almost no information on the number of FADs that are deployed in the ocean, their movement, life span, and ultimate fate. Some of this information will be available from the new *Flotsam Information Record*, but much of it will require assigning unique identification to FADs.

5.7.1. Mark characteristics

Marks should be unique permanent identifiers (ocean wide) and attached before the FAD is first put in water. The identifier should be easily identified by an observer while the FAD is still in the water. The marking should include flotsam turned into FADs. The FAD characteristics should be recorded and the FAD linked to the originating vessel and any vessels that own locator beacons attached to the FAD.

5.7.2. Considerations

Marking of FADs requires several considerations including:

a. Who attaches the marks?
b. Confidentiality e.g. should the identification numbers be randomized so the vessel can be identified only in the database and by persons associated with the vessel that deployed the FAD?
c. Should the mark be linked to object or beacon?
d. Dealing with vessels without observers fishing on FADs;
e. Type of mark e.g. number, barcode, or short-range radio system.

5.7.3. Alternatives

An alternative to marking of all FADs is a comprehensive plan that includes 1) mandatory completion of the new *Flotsam Information Record* , including when a FAD is deployed and when it is removed and 2) mark only a proportion of all FADs deployed and recording subsequent observations of them from all vessels (*i.e.* a mark-recapture study). Therefore, they would still require unique identifiers. Other methods, such as using colors, with variations including changing the colors each week, are possible, but would provide less information.