# REPORT OF THE INTERNATIONAL WORKING GROUP ON TUNA PURSE SEINE AND BAITBOAT CATCH SPECIES COMPOSITION DERIVED FROM OBSERVER AND PORT SAMPLER DATA


## SUMMARY

Obtaining accurate estimates of species and size composition of tuna catches is essential in order to carry out consistent management of tuna resources. Experience has shown that this requires designated sampling programs, particularly when species are difficult to identify except by a trained individual. Such sampling programs exist in all tuna purse-seine fisheries in all oceans, however, they differ in the stage at which they sample the catch and their sampling protocols, as well as in subsequent data processing and estimation procedures. In spite of this, many logistic problems associated with the collection of representative samples are common to all programs. Moreover, these sampling programs and data processing procedures are often poorly documented in the scientific literature, making it difficult to learn from and improve upon sampling procedures in one fishery based on experience of programs in other oceans. In the interest of promoting discussion of sampling and data processing issues, the IRD organized an international working group of tuna purse-seine scientists to discuss sampling procedures and data processing for their respective fisheries, and to make recommendations for improvement to existing methodologies.

Presentations and discussions at the meeting touched on the following general topics: methods used to collect species and size composition data for catches in each fishery, including comparisons of the use of at-sea sampling by observers *versus* in-port sampling; data processing and extrapolation techniques used in each fishery, including length-to-weight conversion; and, procedures for handling strata with catch but few or no sample data.

Collection of species and size composition data for tuna catches in most purse-seine fisheries is done in port at the time of vessel unloading. Owing to logistic constraints, sampling is typically opportunistic. In-port sampling involves a multi-step process. First, wells of vessels are selected to be sampled, depending on whether the catch in the well all came from the same strata. Strata are typically defined by area and time of fishing, and type of purse-seine set. Fish within a selected well are then sampled for length and species identification. The sample of fish taken is based on numbers of individuals. The sampling of fish within a well is often designed to extend the sampling over as much of the unloading of the well as is logistically reasonable, although the procedure for doing this differs by sampling program and in general only a part of the unloading is sampled. Sampling differs among programs as to whether the same fish are sampled for both length and species identification or independently for length and species identification. Discussion of in-port sampling focused on the extent to which the requirement for well selection (catch from a single strata) may result in sampled catches that are not representative of the fishery as a whole, and on logistical problems that prevent the random selection of fish from within a well (with respect to both species and size).

One program collects species and size composition data at sea using observers. This sampling method involves collection of a representative sample of fish as the catch is loaded aboard the vessel. The current procedure is for observers to select a fixed number of fish from each brail. However, this procedure is believed to lead to biased samples of species composition and a study is underway to evaluate improvements to this method that may remove observer-imposed bias in sample selection. In general, sampler-imposed bias could exist in any sampling program, and has been documented in a few cases for in-port sampling. Thus, sampling methods developed to mitigate or minimize this problem may be useful for sampling both in-port and at-sea. In general, the presence and use of at-sea observers differs considerably among programs. In the Atlantic and Indian Oceans, observers are only sent to sea for estimating discards and bycatch. In the Eastern Pacific Ocean observers collect catch, bycatch and fishing operations data, but these data are not used to estimate the species or size composition of the total catch. In the Western and Central Pacific Ocean, observers are sent to sea to collect species and size composition data on the catch, as well as data on discards and bycatch.

The goals of data processing and estimation are similar for all programs: to estimate the species and size composition of the total catch by strata. Data sources, in addition to the species and size composition data, that are used in the estimation of total catch are largely similar among programs, except for certain fleets in the Western and Central Pacific, and include logbook, landing, cannery information, and where available, observer data. In the WCPO, landing and cannery

information are not usually available for certain fleets; therefore, only logbooks and observer sampling data are used. Well map data that are available in the Atlantic and Indian Oceans are not routinely available for all vessel trips in the Eastern Pacific Ocean or the Western Pacific. The data processing of species and size composition data typically involves the conversion from length to weight, and a raising procedure to raise these data to either the total well catch (EPO) or the total set catch (WCPO, AO and IO). Thus, the data unit of analysis differs among programs. Discussion focused on the extent to which unwanted variability may be added into the estimation procedure by using the species and size composition data to estimate individual-set catch composition, as opposed to using the data to estimate the catch composition of the well. The adequacy of the existing length-to-weight conversions were discussed in terms of the limited ranges of sizes covered by those data compared to the sizes of fish in the catch (possibly contributing to biases in the species composition estimates), and in terms of the possibility of systematic changes in the length-weight relationships spatially and seasonally. The need for sound analytical procedures for the treatment of catch from strata with no species and size composition data was also discussed.

Based on the material covered in the presentations and the group discussions, the following major recommendations were put forward. A detailed list of all recommendations can be found in Section 12.

- For in-port sampling programs the possible effects of the vertical stratification of the fish in the well in terms of both sizes and species should be studied further.
- For all sampling programs the consequences of departures from purely random selection of samples be evaluated with respect its impact on the outcome of stock assessments, and that whenever possible, these departures be minimized.
- For all sampling programs, weight data should be collected directly (when possible) or improvements to existing length-weight relationships should be made by collecting additional length-weight data that span the full range of fish lengths in the catch. In addition, potential improvements to existing length-weight relationships that might be realized by accounting for factors such as seasonality should be explored.
- For programs that use the set as the data unit for data processing and analysis, the feasibility of using the well (instead of the set) in as the data unit should be explored. In addition, for these programs it was recommended that the well map data should be better incorporated into the data processing procedures (*e.g.* to validate and if necessary to correct the logbook information).
- An evaluation of alternate (possibly simplified) time-area stratifications should be conducted for all oceans in order to determine if the time-area strata currently in use may be unnecessarily complex.
- As feasible, data from at-sea sampling should be collected and compared to in-port sampling in all oceans, realizing that the priorities of observer programs can be different in different oceans, depending on the particular conservation measures in existence for catch and bycatch species.

**Background**

Purse-seining (PS) is a dominant mode of fishing for tropical tunas that currently produces a global annual catch of about 2.5 million t (all species), including a large percentage of small-sized tunas. The large catches of small bigeye (BET), skipjack (SKJ), and yellowfin (YFT) tunas are of key importance as their inclusion in stock assessment models can strongly affect the estimates of MSY and consequently the scientific advice on the stock status. A good knowledge of the catch-at-size and age taken by the PS fishery is therefore essential in order to carry out consistent stock assessment for these resources.

Since the mid-1970's, it has been noted by scientists and Tuna Regional Fisheries Management Organizations (TRFMOs) that the species composition of landings must be estimated from data collected by designated sampling programs. Sampling programs have been developed worldwide for many PS fleets, but quite independently for each fleet and ocean, and at different time periods: since 1980 in the Atlantic Ocean (AO), 1983 in the Indian Ocean (IO), 1988 in the Western Central Pacific Ocean (WCPO) and 2000 in the Eastern Pacific Ocean (EPO). Nonetheless, there is a general recognition that the sampling issues and statistical uncertainties associated with the estimation of species and size composition of the catch are similar worldwide. The paradox is that these sampling schemes and associated data processing methods are often poorly described in the scientific literature making it difficult to share technical experience among organizations that might lead to improved methodology. Furthermore, it appears that these major issues have never been discussed by international groups of experts such as the FAO Coordinating Working Party on statistics.

Promoting exchange of technical information on sampling design and estimation procedures among all TRFMOs may lead to more efficient and timely development of improved methodology and therefore more consistent stock assessments for all tuna species. This is particularly important given that time series of estimated catches used in most tuna stock assessments extend over decades, and uncertainties in species composition and catch-at-size arising from sampling issues may be difficult to differentiate from changes in the fishery through time. For example, there has been an increase in the percentage of bigeye tuna in the catch since the mid-1990's. It is possible that changes in sampling procedures in the last two decades could have imparted temporal trends in species composition estimates. However, over this same time period the use of fish aggregating devices (FADs) by purse-seiners has increased dramatically, and this fishing method now produces more than 50% of the world tuna catch by purse-seiners. Thus, changes in the percentage of bigeye tuna in the catch, a species that is typically caught in association with FADs, and can be difficult to distinguish from other species as juveniles, could be due either to improvements in species identification or to changes in the fishery.

In such a context, the IRD took the initiative to organize an international working group on tuna purse-seine and baitboat catch species composition derived from observer and port sampler data. The main objective of this Working Group was to examine the various sampling schemes used to estimate catch species composition and catch-at-size of tropical purse seiner landings worldwide. Its basic goals were to: (i) examine the functioning of the various species sampling schemes developed for surface fisheries in the world oceans, (ii) discuss their statistical validity and potential problems, and (iii) make recommendations to the various scientific Committees of TRFMOs to improve the functioning of these sampling schemes and on the subsequent data processing necessary to estimate tuna catch-at-size.

## 1. Opening, adoption of Agenda and meeting arrangements

Dr. Nicolas Bez, vice Director of the Center, welcomed participants and wished an efficient meeting. Dr. Emmanuel Chassot, Coordinator of the meeting, welcomed Working Group participants and reviewed the objectives of the meeting. The meeting was chaired by Dr. Pilar Pallarés (ICCAT). The agenda (**Appendix 1**) was adopted after adding two new items. The List of Participants is attached as **Appendix 2**. The opinions expressed by individual presenters do not necessarily reflect the views of the group as a whole.

The following participants served as rapporteurs for various sections of the report:

| **Section** | **Rapporteurs** |
|---|---|
| 1,12,13 | P. Pallarés (PP) |
| 2,3 | R. Pianet (RP) |
| 4 | A. Fonteneau (AF) |
| 5 | E. Chassot (EC) |
| 6 | T. Lawson, C. Lennert-Cody (TL, CLC) |
| 7 | S. Ortega (SO) |
| 8 | A. Laurec (AL) |
| 9 | C. Lennert-Cody, T. Lawson |
| 10 | C. Brown (CB) |
| 11 | M. Herrera (MH) |

## 2. Detailed review of the sampling methods historically and currently in use in the various oceans to assess the size distributions & species composition of purse seiners and bait boats landings in the IO, AO (EU vessels, Ghana fleets), EPO, WCPO

It was first outlined that the main objective of this work is to get the best catch and size composition by species in order to make the assessments for the 3 tropical species; this objective may require different methodologies according to the size of fishes and type of fisheries (mainly less/more than 10 kg).

### *2.1. Atlantic Ocean (AO) & Indian Ocean (IO)*

A multispecies sampling has been implemented since 1980 (Cayré 1984) and 1982 (Pianet et al. 1999) in the AO and IO, respectively. For the AO, an ad-hoc procedure was used to correct the species composition for the period 1969-1979 (Cayré 1984). The sampling is made during the unloading of the purse seiners at fishing ports and consists in a 2-step approach: (i) the wells are selected from among those containing homogeneous strata and (ii) fishes are then intended to be randomly collected, within size category, from the wells and counted and/or measured. It is a simultaneous sampling to estimate both size and species composition. The sampling characteristics (sample size, strata, etc.) have changed through time and the current methodology is mostly based on the European project "Analysis of the tropical tuna multispecies sampling scheme" (Pallarés and Hallier 1997, Pallarés and Petit 1998, Pianet et al. 2000). The sampling is currently based on strata defined by large spatial areas, quarters and fishing mode (free school and log-school). The minimum and target sample sizes per stratum are 15 and 25, respectively. The sampling is made in 2 rounds separated from a few hours and supposed to be a simple random sampling within each selected well. The number of fishes counted and measured depends both on the fish size category within the well and on the fish species. To estimate the species composition the sample in number is converted into weight using the length-weight relationship.

#### *1.1.1 Sample selection. Discussion point*

Most of the discussion dealt with the sample size and how they are selected within a well, more especially as they are finally pooled in quite large strata; increasing the size of the sample is not meaningful if the selection procedure is biased. The difficulties to obtain a real random sampling within the strata (and especially when there is a mix of large and small fishes) due to the work condition was presented and its consequences discussed. The conclusion was that all possibilities to be as close as possible of a simple random or systematic sampling within strata must be studied and tried. One of the major points is that sampling have to be done before any sorting (see section 4).

#### *1.1.2 Choice of the well. Discussion point*

The second point discussed was about the selection of sampled wells based on "homogeneity" criteria, i.e. the different sets included in a well come from a similar fishing mode, and were made close enough in distance (<300 nm) and time (>15 d). 2 opposite opinions were expressed on the consequences of this rule: 1) it is justified as this is a stratified sample with the fishing mode as the main factor, which is later applied to the total catch of each time area strata each set according to its fishing mode; 2) a true single random sampling balanced coverage of the catches would also require "mixed" wells to be sampled. No agreement was made upon this point, except it was agreed that an estimate of the importance of these mixed wells should be made and the validity of this assumption should be at least checked based on some available samplings of such "mixed wells". Another option could be in the exhaustive sampling of all wells during the unloading of some boats.

#### *1.1.3 Sampling unit. Discussion point*

Another point raised was raised about the advantages and disadvantages of using the set as sampling unit. This assumption implies that – even if the sample was done on a well – it could later be assumed to be representative of the set(s) present in this well. It is this link well-set which necessitates the sampling of "homogeneous" wells (see section 3). There was considerable discussion on the point that, if the well was considered as the sampling unit rather than the set, many of the estimation complexities and pitfalls in obtaining representative samples may be avoided. It was recommended that this approach be considered.

#### *1.1.4 Selection of the fishes to measure*

For small fishes, the random selection can be difficult to implement as several wells can be unloaded at the same time; however, the process seems reasonably convenient.

### 2.2. *Eastern Pacific Ocean (EPO)*

*2.2.1 Historical and current situation*

The sampling method currently used to collect data for estimation of the species and size composition of the catch was briefly described. This method has been in use since 2000 and is described in detail by Suter (2008). Sampling methods used prior to 2000 were not presented but are described by Tomlinson *et al*. (1992) and references in Suter (2008).

The species and size composition data are collected from selected vessel wells during the unloading process in port. This port sampling program is based on a stratified 2-stage sampling design, with vessel wells as the primary sampling unit and fish within a well as the secondary sampling unit. At each stage the sampling is opportunistic, but assumed to be simple random sampling in the analysis of the data. Wells are only sampled if all sets of the well belong to the same stratum. For the purse-seine fishery, strata are defined by 13 areas, 12 months, large (> 363 mt fish-carrying capacity) and small vessels, and purse-seine set type (floating object, unassociated, dolphin). The number of wells sampled per stratum is variable.

There are two types of unloading procedures encountered by the port-sampling program, the most common of which is to unload the fish without express consideration for species or weight category. The other is to sort the fish during the unloading by species and weight category ('sorted' unloadings). The sorted unloadings are therefore sampled for length, but not for species composition.

Unloadings that are not sorted are sampled in the following manner. For each well to be sampled, samples of fish are collected separately for length and for species composition. In total, approximately 50 fish are measured for length for each species (fork length to the nearest mm). For species composition, in total, at least 100 fish are counted and identified to species. The exact details of the collection of lengths and counts depend on the anticipated catch composition of the well, which is determined in advance from logbook or observer records. In general, the procedure is that first 25 to 50 fish are measured, followed by 50 or more fish counted, followed again by measurements of more fish and then additional counts. The alternation between collection of measurements and collection of counts serves to extend the sampling over more of the unloading of the well. Further measurements and counts may be obtained if a new species is encountered during the sampling.

For sorted unloadings, the sampling procedure consists of measuring 25 fish of every weight category for each species. Weight categories are established at the time of unloading by the vessel crew or cannery staff. Sampling instructions given to port-samplers for both types of unloadings are provided in the Appendix of Suter (2008).

*2.2.2 Discussion points*

The procedure used is basically similar to the one presented for the AO and IO, with a stratification on the fishing mode (three purse-seine set types), area and month. However, an important difference is that the sampling of size and species composition are separate; *i.e*., fish measured for length are not included in the sample of fish for species composition and *vice versa*.

### 2.3. *Ghana*

*Multispecies sampling of Ghanaian purse seiners. Discussion points*

The procedure followed in Tema is a multi-species sampling, based in that used by the European fleets, established in the mid-1980's. Similar methods have been applied to sample the Ghanaian catch unloaded in Abidjan. Nevertheless, the sampling of transshipments to cargos is rare because the difficulty to access to these catches.

In addition, since 1996, this fishery (25-30 baitboats and 8-10 purse seiners) fishes mainly on FADs, and is characterized by a frequent cooperation and sharing of catches between both gears, often making it difficult to later separate the catches. Few logbooks are available, and in some cases a sorting process occurs, leaving large YFT and BET to transship to cargos and transshipping small fish to the BB. Consequently, it is often difficult to attribute a sample to an area or a fishing gear. So, the multispecies sampling at port considers 3 gear strata (BB, PS and Mixed), only one spatial stratum and by month. Overall, the system is considered as potentially fulfilling the assessment needs if properly implemented.

However, most of the available information, including sampling data, is not available in electronic format and therefore it is not used in the data processing. Consequently the annual catch by species (ICCAT-Task I) is obtained from the annual catch by boat provided by the fishing companies and an overall estimate of the species composition obtained from port sampling. The Ghanaian catch currently (average 2005-2007) represents more than 50% of all species catches in the eastern Atlantic.

## *2.4. Western Central Pacific Ocean (WCPO)*

### *2.4.1 Historical and current situation*

Purse-seine fleets have fished in the WCPO since 1967, when the Japanese fleet began operations. Other major fleets (and the year they began fishing) are from the United States (1976), Korea (1980), Chinese Taipei (1983), Papua New Guinea (1994) and Vanuatu (1994). Minor fleets are from Solomon Islands (1980), Federated States of Micronesia (1991), Spain (1999), Marshall Islands (2000) and China (2001). All fleets have operated under access agreements with the coastal states in the region, which are also members of the Secretariat of the Pacific Community (SPC). The provision of catch and effort logsheets is a condition of licensing and so the coverage of logsheet data provided to SPC by its members is high. Landings data are not generally available; thus, logsheets have been the primary data used to estimate the species composition.

A port sampling program covering the United States fleet was established in Pago Pago, American Samoa in 1988, under the treaty between the United States and member countries of the Forum Fisheries Agency. Port sampling programs covering other fleets were established in the early 1990's; however, coverage of the non-United States fleets by port sampling data has been low because the fleets move among a large number of unloading ports in the region and therefore the port sampling programs in the region do not operate on a regular basis.

Wells are selected by port samplers based on the homogeneity of geographic area, time period and school association, with the result that large sets are over-represented and small sets are under-represented. The sampling protocol for the non-United States vessels is for the port sampler to grab 5 fish from each net as the fish are lifted out of the well during unloading. Port sampling takes place during transshipment and is subject to a high degree of well mixing, which results in severely biased data. The non-United States port sampling data have, therefore, not been used to estimate the species composition of catches.

An observer program covering the United States fleet was also established in 1988 under the US Treaty. Observer programs covering the non-United States fleets have been established by SPC members since the early 1990's; however, coverage has been low. Most of the observer coverage in the region has been from the programs covering United States vessels and, more recently, vessels operating the FSM Agreement. Both of these programs are managed by the Forum Fisheries Agency. The national observer program of Papua New Guinea has also resulted in good coverage in recent years.

Observers take grab samples from each set during a trip. The sampling protocol is to grab 5 fish from each brail during the brailing process. Grab samples collected by observers have been subject to selectivity bias, such that the proportion of skipjack is under-estimated and the proportion of yellowfin is over-estimated. Nevertheless, the observer data have still been used to estimate the proportions of yellowfin and bigeye in the catches reported on logsheets as mixed yellowfin and bigeye. The proportion of skipjack reported on logsheets has not been adjusted with either port sampling or observer data, and so skipjack catches are over-estimated in the operational data, while yellowfin and bigeye are under-estimated.

Trials of a new observer sampling protocol began in 2008 on purse seiners fishing on anchored FADs in Papua New Guinea. In "spill samples", instead of the observer grabbing 5 fish per brail, a portion of a brail, usually 200 to 400 fish, is spilt into a container on the deck. The observer then records the species and length of each fish in the container. Usually 1 brail per set is chosen for the spill sample, although for large sets, more than 1 brail can be chosen. During the trials, grab samples were also collected. Analyses of the paired spill and grab samples indicate that (a) the species compositions determined from spill samples are accurate (unbiased) and reliable (low variance) and (b) the grab samples are subject to size selectivity bias. The selectivity bias of grab samples has been estimated and used to correct historical grab sample data. Paired samples will continue to be collected over the next few years and, in the near future, the observer programs of the SPC members will transition from grab samples to spill samples. The measurement of fish weights by observers, with motion-compensated scales, instead of or in addition to lengths, will also be explored as a means of avoiding errors in estimates of species compositions introduced through the conversion of lengths to weights with a length-weight relationship (see section 11).

*2.4.2 Discussion points*

The procedures for port sampling of the non-US vessels are quite similar to those described in AO, IO and EPO, with well as the sampling unit, while the sampling unit for port sampling of the US vessels is the landing category of species and size within a well. Observers in the WCPO sample the catch for species composition and size, whereas observers in the EPO report only visual estimates of the catch by species, rather than conduct sampling. Observers are not currently used in the AO nor IO.

It was noted that species compositions determined from port sampling result in a larger proportion of skipjack than from observer data, and that both are lower than in the proportion determined from logbooks. The reasons of such differences were discussed. The main problems with port sampling are the sorting of fish onboard (which is not usually known by the samplers) and bias resulting from the selection of the wells that contain large sets. (Stratification by species and size in wells was not found to be a problem.) The problems of sorting and the selection of large sets are overcome by observers sampling at sea, but grab samples taken by observers are subject to selectivity bias. Spill samples taken by observers appear to be promising because they overcome the problems of port sampling and selectivity bias.

## 3. Data processing and extrapolation of samples method used in each ocean: links between logbooks, landing and sampling data, & stratification used in the raising process

### *3.1. Atlantic Ocean (AO) & Indian Ocean (IO)*

*3.1.1 Historical and current situation*

The data processing aims to (i) correct for both the magnitude and species composition and (ii) estimate the size composition of the catch. It is based on 4 data sources: the logbook data and well maps available from skipper and refrigerator engineer, the landing data and the sample data (fish size and counts). Some characteristics in the sampling design and processing have been modified through time and the current methodology has been used since 1998 and applied to reprocess the data back to 1991 in both oceans.

The first step of the process consists in the harmonization of raw size data (dorsal length to fish length for large fishes) available at the well level and estimate of size frequency histograms by species at the scale of the set. For each size sample, raising factors based on weight categories (< 10kg and > 10kg) are computed to raise size histograms to the set level. In a second step, the species composition is corrected for each set based on the species composition estimated after aggregation of size samples within each stratum. The correction is based on 3 weight categories (<10kg, 10-30kg and >30kg). A hierarchical substitution scheme has been defined in order to progressively add samples when required so as to increase sample size and reach a minimum sample size value. An adjustment of the magnitude of catch is then made by estimating a raising factor between logbook catch and landings at the scale of the fishing trip. Some extrapolations can also be made to account for missing vessels and/or fishing trips when necessary. In a last step, the size frequency histograms are extrapolated at the scale of the squares of 5° of latitude and 5° of longitude based on the stratum {quarter*ET area*fishing mode} information for each square. Some final computations are made at different spatial scales (Exclusive Economic Zones, 1° by 1° squares, etc.) to provide datasets to TRFMOs and administrations.

*3.1.2 Discussion points*

The methodology used to raise the samples to the total catch was described. One of the delicate points discussed was the case of the sampled wells containing several sets or fractions of large ones. Even if the principle to raise the results at the level of individual sets was considered as useful, it was stressed that it may introduce noise in the process of estimating the final result i.e., the catch-at-size by species and stratum. The difficulty comes at least partially from the assumed link between well and set(s). It was considered that the importance of this noise should be at least estimated.

It was noted that some of the conversion formulas currently available, for converting between types of lengths or from length to weight, may be poorly estimated. It was recommended that such formulas should be improved, either by utilizing available or collecting new data if necessary (see section 11). It was further noted that, even when the conversion formulas are well estimated, some errors and potential biases might be introduced when applying the conversion. These problems may be overcome through on-board observer or port sampling by weighing directly the species in the sample, but it also implies some other difficulties. Some comparative studies from combined port/observer samples were suggested. The problem of the influence of the set size on the species composition is not taken in account and will be looked at in section 7. Finally, the basic hypothesis (which was initially tested) of the method is the homogeneity of the strata, and the link between well and set(s); is it justified, or is it only introducing noise in the final estimates? Some participants agreed with this point, and considered that it will probably be better to stay at the wells level to estimate the species composition and to build the final catch-at-size by stratum. It would also be useful to work on the well level like one does for the logbooks.

## 3.2. *Eastern Pacific Ocean (EPO)*

### *3.2.1 Historical and current situation*

The data collected by the port-sampling program are used to estimate the total catch in weight (and in numbers) for each species, and the total catch in weight (and in numbers) by 1 cm length interval for each species. The estimation procedures used since 2000 are briefly described below, and are presented in detail in Tomlinson (2002; 2004). The current estimation procedures are dependent on four data sources: port-sampling data of lengths and species composition, observer or logbook data on total catch by strata, and cannery information on total fishery catch. Estimation procedures used for pre-2000 sampling designs are described in Tomlinson *et al*. (1992).

For the purposes of analysis, the data unit is taken to be the well (not the set) and the individual length and count information is summarized for each sampled well. Length measurements of each species are converted to weight based on length-weight relationships as shown in Suter (2008, and references therein). Length samples (by species) from sorted unloadings are pre-processed to approximate samples of lengths from unsorted unloadings, using information on the well tonnage of each weight category. All well sample data are then further processed to obtain estimates for each well sample of the fraction, in numbers, that belong to each of the three tuna species (yellowfin, skipjack, bigeye), and of the average weights of each species. Further details on data processing will be available in Pérez (in prep.).

Estimates of total catch by species and total catch by species for each length interval, in numbers and weight, are obtained based on ratio-type estimators (Tomlinson, 2002; 2004). Fishery-wide estimates are based on the sum of estimates computed separately for each of several strata. Strata are defined by area (13 areas; *e.g*., Suter, 2008), month, purse-seine set type (dolphin, floating object, unassociated) and two vessel size categories (greater than 364mt fish-carrying capacity, less than or equal to 364 mt fish-carrying capacity). The estimation procedures require knowledge of the total catch weight of all species in each sampled well and the total catch weight of all species in each stratum. The total weight of all species in each sampled well is obtained from observer data or logbooks. The total catch weight of all species in each stratum is estimated by prorating the total fishery catch, obtained primarily from cannery records, to strata using the fraction of total observer or logbook catch that occurred in each stratum (Tomlinson, 1992). Strata with catch but no sample data are combined with nearby strata with samples. The estimated total catch quantities for each species are used in the stock assessments as described in IATTC (2009).

### *3.2.2 Discussion points*

Compared to the AO and IO, well map data are not routinely available in the EPO for trips of all vessels, which prevents a well-set link for some well samples. The methodology used is quite similar in several respects to the precedent (stratification, well selection, etc.), with the exception that for analysis of the EPO port-sampling data, the well is considered to be the data unit, not the set. IATTC is currently reviewing the EPO sampling design for collection of port-sampling data, and is exploring possible modifications to the spatial strata used to post-stratify the port-sampling data

### 3.3. *Western Central Pacific Ocean (WCPO)*

SPC processes large quantities of data on behalf of its small island member countries and territories. 6 full-time data entry staff process logsheet catch and effort data, port sampling data and observer data. The data are utilised by SPC for statistical monitoring, stock assessments and other purposes, and the processed data are provided back to the SPC members for incorporation into their national tuna fisheries database systems, for which technical support is provided by SPC. Data management services are also provided by SPC to the Western and Central Pacific Fisheries Commission (WCPFC), and this entails management of catch and effort data, and size data, provided by both SPC members and non-SPC members of the Commission.

Operational catch and effort data held by SPC are aggregated by 1° latitude, 1° longitude and month, and raised, based on coverage rates, to represent the total catch and effort. The proportions of yellowfin and bigeye in the combined catch of yellowfin and bigeye that are reported on logsheets are estimated using a GLM fitted to observer data. The model has year and school association as categorical variables, and latitude and longitude are modeled with cubic splines.

The data aggregated by 1x1 and month are further aggregated by year, quarter, MULTIFAN-CL area and school association for use in stock assessments. In addition to unadjusted input data, a second set of input data that has been adjusted with species compositions determined from observer data corrected for selectivity bias has recently been produced. The observer data cover 1996–2008. For strata of year, quarter, area and association in 1996–2008 for which observer data are missing or insufficient, the species composition is estimated from a linear categorical model with year, quarter, area and association, and most of their interactions. For 1967–1995, for which observer data are not available, the species compositions are estimated from a model with quarter, area and association, and all interactions, but not year.

The MULTIFAN-CL assessments use length and weight data directly; thus, SPC does not compile catch-at-size data for assessment purposes.

## 4. Review in each ocean and country of the potential problems due to sorting of tuna during or just after the fishing operations, mixing tunas from various sets in distinct wells

One of the main assumptions in port sampling programs of tuna catch landings is that each set has been stored in a given (or several wells), but without any subsequent change done by the crew of their storage location. This rule has been widely confirmed in the AO, IO and EPO for all fleets, from interviews with skippers and from observer data, especially in the EPO, an area with 100% of observers showing a very low mixing of fished tunas. The peculiar case of the last set during a trip when the boats are already full was noticed as a infrequent event, and this information tends to be well recorded in the logbooks, it does not introduce a significant problem in the port sampling.

For the most part, tuna catches can be well sampled well by well, and with a potential link to the sets, in the AO, IO, and EPO, with a few exceptions such as the Ghanaian fishery (see section 2.3). In the AO, the only remarkable exception is the Tema-based Ghanaian fleet, for which a wide range of tuna movements have been permanently observed before the landings: inside each vessel, between purse seiners and baitboats, between fishing vessels and freezers. Similar uncontrolled movements of tunas inside/between boats have been also identified for the Iranian and Thai purse seiners.

In addition, in the Ghana catches and many of the purse seine fleets active in the WCPO there has often been catch sorting and mixing between wells, before the landing. These movements and sorting introduce a serious complexity and uncertainty in the port sampling. However, even in this context of “tuna mixing” there is still a potential of doing an efficient port sampling of the sizes and species composition of the landed catches, but losing the information on fishing mode and sometimes gear (Ghana), and on the exact time and area strata. This type of port sampling has been for instance conducted on the Ghana fleet in the AO. Their results may not be ideal, but at least they may allow to correctly estimating the yearly catch at sizes of a sensitive species such as bigeye.

It was noticed that sampling programs done by observers can be an alternate sampling method used for purse seiners fleets that are doing these types of “tuna mixing”. It was noticed that these frequent and active manipulation of the tuna catches was linked to the building of the Asian types of PS and to their freezing process, and also to their very large crews. It was also noticed that the freezing and storage processes used in these vessels tend to increase the uncertainties in the species identification of small tunas when they are frozen. It was recommended that all of the Western pacific fleets that are doing this type of tuna mixing before their port landings be identified.

Such sampling by observers done during the fishing operations have been done during many years in the WCPO; these methods, their potential biases and results will be analysed in section 9 of this report.

## 5. Comparison in species composition between logbook (well map), observer and port sampler data for the purse seine fisheries in all oceans

### *5.1. Logbook and well maps*

Species composition of the purse seine catch in the IO and AO has been derived from port sampling data based on logbook and well map data. For the French purse seiners, some discrepancies can generally be found between logbook data recorded by the skipper and well map forms filled by the refrigerating engineer that are generally considered more accurate in terms of weight categories by species. For this reason, some adjustments of logbook data have been sometimes made in the IO by IRD port samplers to provide a better description of composition in weight categories of the wells and sets. No well map is used in the EPO. Well maps should be collected and used whenever possible.

### *5.2. Comparison between methods for estimating species composition*

No observer data have been collected in the IO and AO for estimating the species composition. In the WCPO, significant differences in species composition of purse seine catch during 1995-2006 determined from port sampling and observer data have been shown (Lawson 2008). For instance, the proportion of YFT was estimated close to 30% and 23% of the catch based on observer data and port sampling data, respectively. Since each method can be subject to several different biases, it is difficult to draw conclusions about the best method. Lawson (2008) proposed to consider the estimates as potential lower and upper boundaries for the species composition. Recent experiments conducted in the WCPO on anchored FADs suggest that spill sampling could lead to less biased species composition compared to current grab samples by eliminating the size selection bias by observers identified to occur during grab sampling (Lawson 2009; see section 6).

### *5.3. Species composition in tuna free schools in the Indian and Atlantic Oceans*

Fonteneau et al. (draft) analyzed the problems and uncertainties faced by the estimation of species composition and sizes caught by purse seiners on free schools in the IO and AO. Free schools catches tend to be dominated in both oceans by large tunas (large yellowfin (YFT), but also large bigeye (BET) and albacore (ALB)) therefore their species composition should be well recorded in most or all the logbooks. However the comparative analysis of the logbooks and sampling data shows that there are small but frequent biases in the logbook data, with a tendency to underestimate the frequently observed small catches of large BET and ALB when they are mixed with large YFT. For instance when 1 t of large BET (or large ALB) is mixed in a 50 t school of large YFT, these BET have been seldom recorded in the logbooks.

Furthermore, the analysis of the present data processing and extrapolation of the sampling and logbook data shows that these small quantities of large BET and of large ALB tend to be underestimated. Other analytical potential biases are also identified in the present data processing, often leading to an overestimation of BET catches. As these catches of large tunas are well identified by species in the well maps and also by the results of the multispecies sampling, these 2 datasets should be better used in future data processing to fully identify these quantities.

The same document also indicates that in the method used, the estimated weight of these large tunas predominantly caught in free schools sets are sensitive to the quality of the relationship (i) between predorsal and fork length and (ii) between length and weight. It appears that these relationships are often quite weak for large BET and ALB. It was then recommended by the WG that equations describing these basic relationships should be improved, primarily targeting an increasing of sampled tunas at large sizes (see section 11).

It was considered by the WG that these potential errors and biases in the free schools species composition should be better analyzed and corrected by the concerned scientists. These subsequent corrections of the species and size composition should be applied for both past and future data, in the AO and IO, using a corrected software and the new improved biological relationships.

### *5.4. Time series of catches of bigeye tuna, by ocean*

Different sources of data, collection and processing methods are currently used to estimate the catch species composition of tuna in the world oceans. In addition, sampling designs and methods have changed through time within each ocean in relation to the evolution of the fisheries, scientific issues and advances. Despite these strong differences, some general patterns can be deduced from the time series of percentage of BET in the purse seiner catch worldwide (Figs. 1-4). In the recent years and despite the numerous uncertainties associated with estimates within each ocean, the levels of BET in the catch are rather similar and comprised within a range of 5-12%.

There seems to be a general pattern of increasing proportion of BET estimated in the purse seine catch in all world oceans. This increase could be mainly due to a combination of the increase in FAD fishing since the mid-1990's and an improvement in species identification and correction of the species composition. On a global scale, the historical percentages of BET in the catch before the 1980's should be considered with great care and are possibly underestimated in the absence of multispecies sampling.

In the EPO, the percentage of BET in the catch has increased from less than 2% in the mid-1980's to more than 10% in the recent years (Fig. 1). Since 2000, the estimate of catch composition is based on port sampling data.

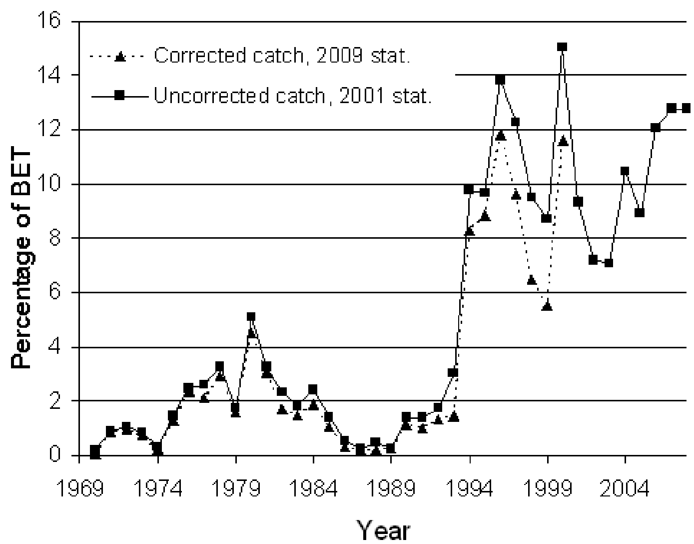



Fig. 1. Eastern Pacific Ocean (EPO): percentage of bigeye in the catches of purse seiners as currently estimated and as they were estimated in 2000 based on logbook & observer data).

In the WCPO, the time series of percentage of BET in the catch greatly differs between fishing fleets and data sources (Fig. 2). For instance, the percentage of BET was almost null from 1980 to the mid-1990's for the US purse seiners and increased drastically thereafter to around 3-4% in the 2000's, suggesting changes in the fishery and/or in data collection and processing.

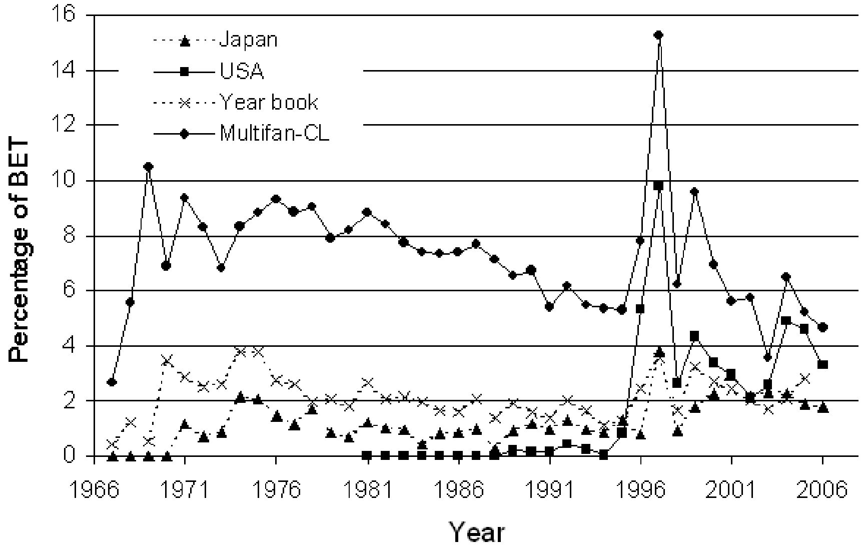



Fig. 2. Western Central Pacific Ocean (WCPO): percentage of bigeye in the catches of Japanese and USA purse seiners, average levels of BET catches estimated by recent SPC sampling and derived from the MULTIFAN-CL stock assessment model.

In the AO and IO, the correction in species composition shows an increase in the proportion of BET in the catch from about 2-3% to 4-7% (Figs 3-4). In both oceans, there has been a steady increase in the proportion of BET after 1990 corresponding to the development of FAD-fishing.

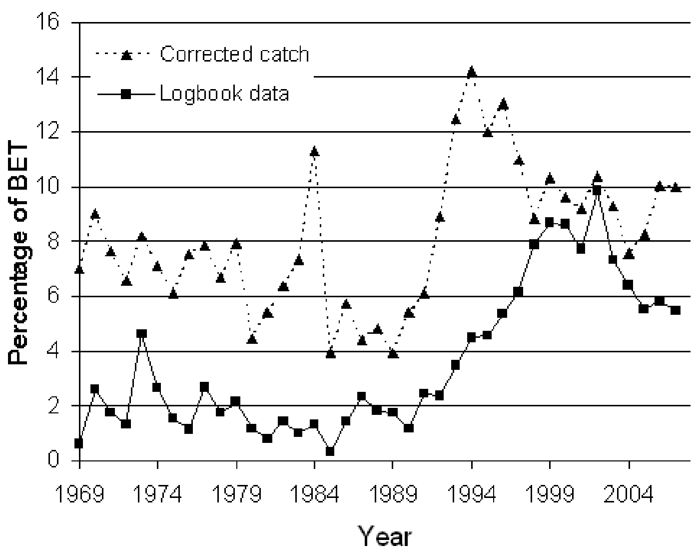



Fig. 3. Atlantic Ocean (AO): percentage of bigeye in the catches of purse seiners as currently estimated and as they were estimated by skippers in the logbooks (ICCAT data including correction for the Spanish purse seiners during 1980-1985)

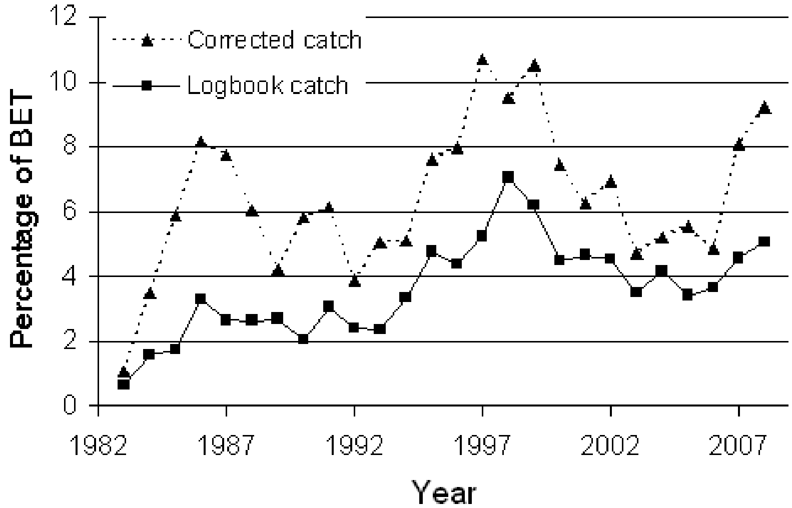



Fig. 4. Indian Ocean (IO): percentage of bigeye in the catches of purse seiners currently estimated and estimated by skippers in the logbooks

## 6. Spill sampling: present results and potential constraints, problems and potential use

### *6.1. SPC presentation*

In the WCPO, observers have routinely collected species composition data by grabbing 5 fish per brail during the brailing process. However, the species compositions determined from grab samples suggest that the data are subject to size selectivity bias. SPC therefore developed a new sampling protocol wherein fish are spilt into a container on the deck during brailing, rather than being individually selected by the observer. Experiments with spill samples were first conducted onboard a purse seiner fishing anchored FADs in the waters of Papua New Guinea in March 2008. For each of the sets during the trip, a portion of every tenth brail was spilt into a bin (Fig. 5). The first brail in each set to be sampled was varied among sets in order to reduce potential effects of layering in the set. The species and length of each fish in the spill sample is recorded by the observer using a digital voice recorder.

Fig. 5. Sampling tuna onboard a purse seiner after spilling fish from the brail into a bin

Further trials with spill samples were conducted during 3 trips in Papua New Guinea fishing anchored FADs during June-August 2008. The species compositions per trip for the 4 trips (Fig. 6) are almost identical, which suggests that spill samples result in estimates of the species composition that are accurate (unbiased) and reliable (low variance).

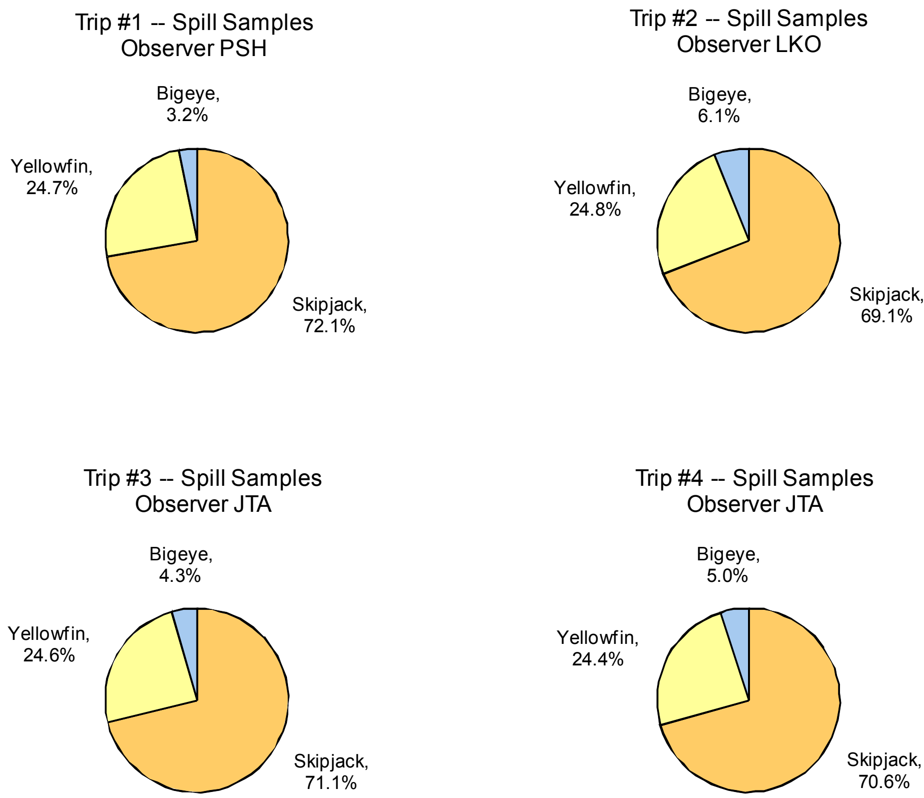



Fig. 6. Estimates of purse-seine species composition determined from spill samples collected during four trips in Papua New Guinea in 2008

The species compositions shown above were determined from spill samples taken from each set made during the trip; there were 7, 30, 15 and 13 sets made during trips #1 to #4 respectively. It is of interest to note that the species compositions varied considerably among sets during a trip; the standard deviations of the proportion of skipjack, yellowfin and bigeye were about 22.1%, 18.5% and 9.4% respectively.

### *6.2. Discussion of subsection 6.1*

Sampling bias in the presence of large fish was discussed. Concern was raised about the size of the spill sample container imposing a limitation on the size of the largest fish that might be sampled. In the absence of large fish, the probability of sampling a kilogram of fish does not depend on fish size. If each kilo of fish in a set is equally likely to be present in the spill sample, regardless of the size of the fish, then the estimates will not be biased. However, if there are large fish in the brail, they could fall outside of the container, depending on where they are in the brail, and therefore there may be a bias because the container is too small for the largest fish. Relying on the observer to notice that the largest fish did not end up in the container may be problematic.

A comment was made on the extension of the spill sampling method to direct collection of weight data. The current spill sample protocol is to measure the length of each fish in the sample; however, trials will be conducted during which the weights of fish will be recorded, either instead of or possibly in addition to the lengths. Using the weights of fish in the sample to estimate the species composition will avoid potential biases introduced by converting lengths to weights with a length-weight relationship.

Suggestions were made regarding the evaluation of the spill sampling method. It was noted that the paired aspect of the grab and spill samples could possibly be improved by first spilling the fish into the container, then collecting a grab sample and subsequently replacing these fish so that they would be included in the spill sample. While comparisons of the estimates of species compositions determined from spill sampling and grab samples indicate that spill samples result in estimates that are less biased, and of lower variance, the estimates from the spill samples should also be compared to the well map data and the landing information, when such data are available.

The necessary size of the sample collection container relative to purse-seine set type was discussed. The spill samples taken from sets on anchored FADs in Papua New Guinea in 2008 contain fish up to about 116 cm; however, considerably larger fish may sometimes be present in unassociated schools. It may be necessary to use larger containers when taking spill samples from unassociated sets and SPC will consider this in due course.

It was further noted that an important part of evaluation of the spill sample method would be to perform a comparison of between-spill and between-brail variability in species composition. Variability in species composition among the four trips was much less than the variation in species composition among sets within a trip, but the relevance of this depends on the spill sample not being a biased sample of the brail. With this in mind, it was suggested that the selection of the brail chosen for spill sampling be randomized.

There was further discussion as to how to select brails for spill sampling. It was commented that the procedure thus far has been to collect one spill sample per every 10 brails loaded aboard the vessel (2 spill samples may be collected for large sets). To avoid a sampling bias introduced by any layering of fish within the net, the first brail that is sampled may be varied from set to set. Concern was expressed that small sets may present problems with the selection of the brail for spill sampling; however, SPC commented that observers are trained to judge such situations accordingly. It was suggested that if the number of brails in the set is known in advance, it would be preferable to randomly select the brails for spill sampling; however, in practice the number of brails is not known at the start of brailing.

It was noted that the stability in species composition among trips fishing in a similar area and time period has been observed in other fisheries. The clear similarity between species composition of the four trail trips indicates that there are negative correlations in species composition among sets, and that this should be investigated. Anchored FADs -- the floating object type of the 4 trial sets -- may attract a stable population of fish, and this may result in a negative correlation in the species composition among sets. Stable species catch composition has also been observed at sea mounts. Even though there is a lot of variability from set to set, the species composition among trips can be similar because the same local population is fished.

It was indicated by the SPC that the collection of paired spill and grab samples for other fishing modes is planned in order to further evaluate the method.

The question was raised as to what step in the spill process discards are identified. Concern was expressed that if discards are sampled in the container, then raising the sample to the set weight may be problematic unless the observer data or the logbook data contain the discard amount of the set. Concern was also expressed that observers may not be able to both record discards and conduct species composition sampling of a set; however, SPC reported that both are routinely done by observers in the WCPO.

It was noted that if grab samples taken by observers at sea are subject to size selection bias, then grab samples taken by port samplers may also be subject to a similar selectivity bias, to a degree that may depend on the port sampling protocol. In this regard, it was noted that the port sampling protocol should be such that the non-random selection of fish by the port sampler is minimised.

There was discussion about the practicality of spill sampling. It was noted that spill samples can be conducted by a single observer, but assistance of the vessel crew is essential since the brail selected for the spill sample must be positioned near to the container for spilling. Crew assistance may also be necessary for the handling of very large fish. On the other hand, since only one brail from all but the largest sets is selected for a spill sample, the interference caused by spill samplers is much less than that caused by grab samplers, who take 5 fish from each and every brail. SPC noted that the placement of observers is a condition of licensing in the WCPO, and so the cooperation of the vessel crew with spill samples should not be problematic; however, where the placement of observers is not a condition of licensing, the goodwill of the crew will be required. There may be logistical problems with the placement of a large container on the deck of a small purse seiner.

It was noted by the SPC that 2 types of observers are currently being employed in the WCPO: fully-trained observers undergo three to 4 weeks of training and collect a range of scientific data, while “cadets” undergo only one week of training and collect primarily compliance-rated data. It was suggested that, if necessary, observers be given a priority on the types of data to be collected. In this way, if the observer can not complete all requested sampling tasks, he/she may focus on the most important tasks; otherwise, it is possible that the quality of observer data may suffer.

Given that the results from the spill sample trials in the WCPO are encouraging, it was suggested that experimental spill sample programs be considered for the other ocean areas for comparison to the data collected by existing port-sampling programs. A secondary objective would be to collect data to evaluate the relationship between the species composition and the set weight.

## 7. Assessment of some aspects of EPO port sampling design and of the sampling bias due to the effects of set weight on species composition in the IO and AO

### *7.1. Evaluation of aspects of the current IATTC port sampling design and estimation procedures for tuna catches*

A recent report presented at the IATTC stock assessment review meeting was presented (Lennert-Cody and Tomlinson, in press). The goals of this work were to explore the following questions: i) Are the purse-seine sets of wells sampled by the port-sampling program typical of the entire fishery? ii) Are the purse-seine port-sampling data more variable within wells or among wells? To evaluate the first point, observer data collected onboard large purse-seine vessels in 2000-2007 were used. Sets were grouped into 2 categories: ‘sampled’ and ‘unsampled’ sets. Sampled sets were those sets that were loaded into vessel wells later sampled as part of the port-sampling program. Unsampled sets were sets loaded into wells not later sampled by the port-sampling program. Two quantities were studied: the sum of yellowfin, bigeye and skipjack tuna in the catch (‘tuna catch’) of each of the 3 types of purse-seine sets, and the percentage of bigeye tuna in the catch of floating object sets. For each of these quantities, the differences between sampled and unsampled sets were tested using a randomization test, by set type and year. On average, the tuna catch of sampled sets was significantly greater than that in unsampled sets. The percentage of bigeye tuna in the catch of sampled sets was sometimes significantly different from that in the catch of unsampled sets, but results were not consistent across years nor test statistics. Significant differences were small and mostly positive. For the percentage of bigeye tuna, additional analyses will be undertaken to explore other test statistics, taking into account individual vessels, and to compare observer estimates of species composition to those from the port sampling data.

To address the second question, the port sampling data of unsorted unloadings of large vessels were used. The purpose of the analysis was to try to compare variability of average fish length within wells to variability among wells. Length data were analyzed for yellowfin tuna in dolphin sets and unassociated sets, and for bigeye tuna in floating object sets, assuming the data represent a random sample of fish from each well. To simulate replicate samples within a well, individual fish lengths were resampled with replacement from the data of each well. A mixed-effects model was then fitted to the average length data (plus ‘replicates’) of each year. The model included a stratum effect (fixed effect), a well effect (random effect) and an error term. To compare within-resample variability to among well variability, the approximate 95% confidence interval bounds for the well effect and the error were computed and compared. Variability among resamples was found to be much less than variability among wells. This suggests that variability within wells may be less than variability among wells. If this were true, with a fixed sampling budget, extra sampling effort would be better allocated to sampling more wells rather than more fish within a well. However, a previous study (Wild, 1994) found that the unloading of fish from the well was not random with respect to size. Preliminary comparisons suggest that even with possible unloader-imposed selectivity, within-well variability is likely less than among-well variability.

Nonetheless, future research is being planned to address this issue which will include a review of exhaustive well sample data from previous studies, and possibly a new special sampling study (including exhaustive sampling).

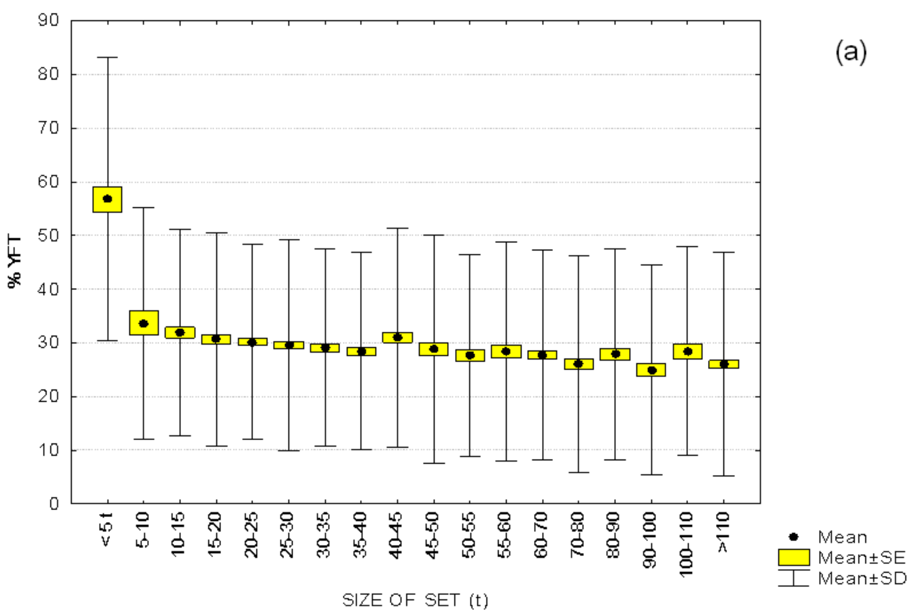
7.2 Discussion of subsection 7.1

It was commented that if the sample of lengths and species identifications from a vessel well do not represent a random sample, then the within-well variance may be underestimated. This would inflate the among-well variance. IATTC noted that they are currently looking into this possibility using historical data on near-exhaustive well samples.

### *7.2. Species composition in relation to set size in the Atlantic and Indian Oceans*

It has been assumed in the multispecies sampling schemes of the AO and IO that the species composition in a given stratum (area*quarter*fishing mode) does not depend on set size. A preliminary analysis was presented during the WG and showed some patterns in species composition in relation to set size for floating objects in both oceans; the percentage of yellowfin and skipjack tuna decreasing and increasing with set size, respectively. On the other hand, the percentage of bigeye did not show any significant change with set size. A comparison between areas and quarters was also shown, similar trends being observed.

The results of the preliminary analysis also indicated a large change in species composition between the smallest set size category and the larger set sizes (Fig. 7).



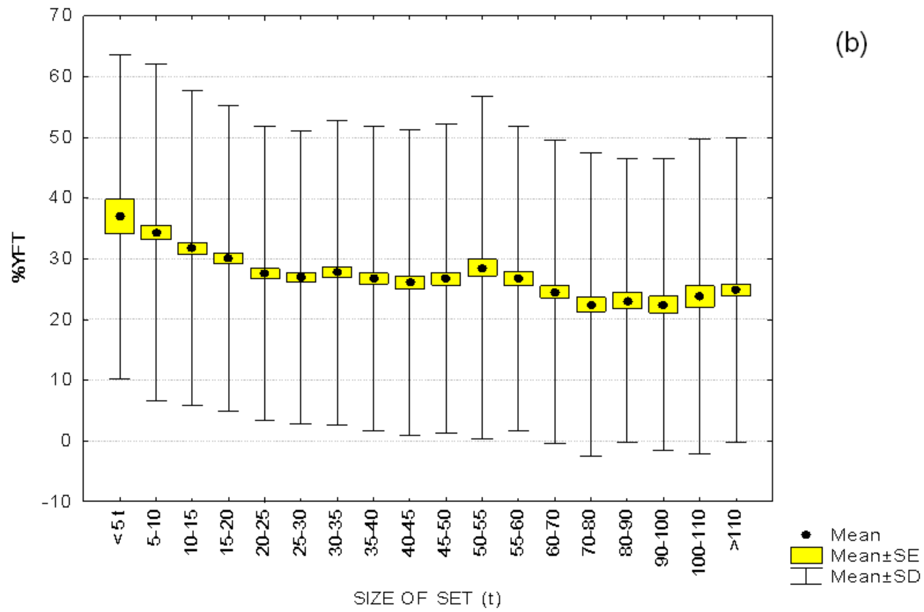



Fig. 7. Percentage variability of yellowfin tuna in relation to the size of the set for floating objects sets in (a) Indian Ocean and (b) Atlantic Ocean.

Some discussion points were raised after the presentation. It was noted that the data used for this preliminary analysis utilized wells in which set sizes varied. It was recommended that restricting the data to wells with homogeneous set sizes would provide a better estimate of the species composition across set size. For the WCPO the relationship between set size and the species composition was examined using both observer data and port sampling data (Lawson 2008). For associated schools, a relationship with set weight was found in species compositions determined from both types of data. However, the relationship determined from port sampling data was less clear than the relationship determined from observer data. It was considered that the use of port sampling data resulted in the introduction of noise in the relationship because the unit of sampling in port is the well rather than the set.

## 8. Analysis of sampling bias based on several 'supersampling' operations conducted in the Indian and Atlantic Oceans

In the Indian and Atlantic Oceans the sampling of a well is usually performed following a 2 “rounds” protocol, 2 groups (sub-samples) of fish being successively drawn from the well at different moments during the unloading process. Whenever possible the first group is taken during the first half of the unloading operation and the second one during the second half. This should make it possible to compare length and species compositions from the 2 corresponding datasets. In some cases extended (super) sampling operations were conducted, which should make it possible to compare more than 2 subsamples from a single well.

It has not been possible however to conduct detailed analysis of this existing data before or during the meeting, due to difficulties for extracting early enough the proper material from the database.

### *8.1. Vertical stratification effects*

It was commonly agreed among participants that in a well fish species and fish lengths tend not to be evenly distributed from the surface down to the bottom of a well (and similar phenomena are likely to affect other “containers” such as brills). Such a layering effect may be due to (at least) 2 phenomena:

– Physical causes which may generate a vertical sorting, on the basis of length and species,

– Accumulation in a single well of fish coming from different sets, which may differ in terms of species composition and/or length distribution.

In order to avoid this layering effect, in the AO and IO the sample is taken in two steps at different time during the unloading process. Nevertheless, for logistical reasons it is almost impossible to ensure that the sample taken from a well in order to measure fish or identify species is really a pure Simple Random Sampling or a strict Systematic Sampling (see below) with respect to depth within the well. Several sampling protocols labeled up to now as random ones are largely opportunistic, and it would be preferable to mention it and to avoid misuse of the phrase random sampling.

In order to assess the importance of this problem it was recommended in the Atlantic and Indian Oceans:

– to extract relevant data from the (super or not) sampling operations from existing databases, and to analyze possible if not likely discrepancies between "subsamples" from the same well, if possible taking into account the time at which each of the "subsample" was taken during the unloading process,

– to conduct further dedicated super sampling operations, if the analysis from existing data suggests it would be appropriate.

A discussion took place, which focused on 2 issues: i) some vertical stratification effects in wells and ii) samples are generally taken in an at least partly opportunistic way, instead of rigorously following a statistically safe and well known protocol. As regards IATTC new plans to review the current port-sampling design, including a possible special sampling project were announced, as well as revisiting of the previously collected data. In both cases, results should be distributed among participants as soon as possible, as well as possible results from similar research in other areas.

Lawson (2008) examined stratification of the species composition and the size of fish in sets at sea and wells in port in the WCPO by comparing the species compositions determined from 10% intervals in the sequential order of sampling. The sampling protocol for both observers and port samplers in the WCPO is to grab five fish from each brail during the brailing of a set and each net during the unloading of a well. The species compositions from 6,262 sets sampled by observers indicate that, on average, there is no stratification by species composition, but that stratification by size of fish occurs, with smaller fish towards the end of sampling of a set. The species composition determined from 321 wells sampled in port indicated that neither stratification by species composition nor by size of fish occurred on average.

It was suggested that for the purpose of examining stratification in the other ocean areas, fish should be continuously selected throughout the unloading of wells and that such data should be collected for a large number of wells. It was noted that examining the stratification in a small number of wells that had been subject to super-sampling would not result in estimates of the average level of stratification, whereas the objective of the analysis should be to determine the extent to which the average level of stratification affects estimates of the species composition for a stratum of time period, geographic area and school association. While stratification of the species composition may occur for certain wells in a stratum, Lawson (2008) found no stratification in wells, on average, which suggests that the effects of stratification among wells may cancel out.

### *8.2. Consequences of applying at least partially opportunistic sampling protocols*

It was agreed among participants that due to logistical constraints it is not possible to completely fulfill the conditions required by a statistically safe sampling protocol, be it simple Random Sampling or Systematic Sampling. This is an almost common problem in all fisheries (ubiquitous?), even if situations differ between fisheries and landing harbors, and often between large and small fish. The impossibility to use a pure random sampling protocol may result in:

– Biases in the estimates of the species compositions and/or lengths distributions, if fish from different vertical strata in the well do not have equal probability to appear in the sample, while a non negligible vertical stratification related to lengths and/or species takes place, or if fish are taken according to the judgment of the individual samplers (see section 9).

– Underestimation of the "within well variances", if fish from a sample tend to be more similar than fish from the whole well (this may for instance occur if the sample is taken from a single layer in the well), but also overestimation if the sampling protocol is close to Systematic Sampling while variance are calculated using formulas related to Simple random Sampling.

It was strongly suggested to analyze the consequences of departures from the key hypotheses on the estimation/assessment process, and to develop such analyses up to the end products of the stock assessment process in order to assess their real impact, instead of analyses limited to the consequences on estimated quantities related to individual wells.

It was also recommend to take full advantage of all possibilities which could make it possible to bring sampling protocols closer to fully statistically safe ones, in particular in relation to systematic sampling. Efforts develop for instance in the AO, IO and EPO in order to spread the gathering of the sampled fish in the sample over the duration of the unloading of the well is a step in this direction, and the possibility of further steps should be analyzed.

**9. Grab sample bias and size selection bias for observers and port sampling: an analysis of sampling data and of simulated datasets**

9.1 SPC presentation

The study entitled "Selectivity bias in grab samples and other factors affecting the analysis of species composition data collected by observers on purse seiners in the Western and Central Pacific Ocean" was presented (Lawson 2009). Paired grab and spill samples collected by observers during 4 purse-seine trips in Papua New Guinea in 2008 were used to estimate the selectivity bias in grab samples. The availability of fish in a set to be selected by a grab sampler was estimated and it was found that the availability of very small and very large fish was less than that of mid-sized fish. Availability can be affected by both physical characteristics of sampling and the behavior of the samplers, including selectivity bias; see Lawson (2009) for a definition of availability.

Historical grab samples in the WCPO were corrected for availability and estimates of the species composition determined from the corrected observer data were found to be consistent with those determined from port samples of species and size categories delivered to canneries in American Samoa by the United States purse-seine fleet. The proportion of skipjack is considerably less, and the proportion of yellowfin greater, than in the species composition determined from operational (logsheet) catch and effort data. SPC will conduct stock assessments using both (a) operational catch and effort data adjusted for the proportions of yellowfin and bigeye in the combined catch of "yellowfin plus bigeye" reported on logsheets and (b) catch and effort data adjusted with observer data corrected for availability.

The results in the study are based on paired grab and spill samples taken during only four trips and while the methodology appears to be sound, the correction of the observer data is only preliminary. Paired grab and spill samples will continue to be collected over the coming years and the data used to further refine estimates of availability and to correct the historical observer data.

9.2 Discussion of subsection 9.1

It was noted that if the availability of fish depends on the size of the fish, then the model may produce biased estimates when applied to samples with fish of different sizes than those in the data used to build the model.

Concern was expressed that if the spill sampling method is not implemented by all observer programs at the same time, then continued collection of paired grab and spill samples may be necessary in order to monitor potential changes in availability. Changes in the size distribution of the population, as well as other factors, through time, may result in changes in availability. There is also the potential that availability could change as a result of observers modifying their behavior because they are aware that their sampling technique is being evaluated.

It was suggested that sufficient numbers of paired samples be collected to evaluate model performance using data that have not been used to fit the model. In this way, a more realistic evaluation of model performance can be obtained.

**10. A model-based approach to predicting species composition for strata with missing data**

***10.1. SPC presentation***

A model-based approach to predicting the species composition for strata with missing data was developed in Lawson (2009). Observer data covering 1996–2007 were stratified by year, quarter, area (as defined for use in MULTIFAN-CL) and school association (FAD/free), and three linear categorical models of the species composition -- one model each for the proportions of skipjack, yellowfin and bigeye -- were fitted to the estimates of the species compositions for each stratum. The models contained the same variables, including year, quarter, area and association, and all interactions except year-area (which caused a rank deficiency). The data were weighted by the number of sets used to determine the species composition in each stratum.

When the species composition for strata with missing data were predicted by the three models, it was found that the predicted proportions of skipjack, yellowfin and bigeye for a given stratum always summed to unity, which was recognized as being a very convenient property. During the meeting, the outline of a proof of this property was provided based on linear regression equations. The prediction errors were found to be relatively small, whereas the standard deviations were large.

The predicted species compositions were used to adjust those strata of the input data for the MULTIFAN-CL assessments conducted by SPC for 1996–2007 that were missing observer data. To predict the species compositions for strata in the period 1967–1995, for which no observer data are available, models considering only the factors of quarter, area and association, and their interactions (i.e. ignoring year) were fit to the observer data covering 1996–2007. While the species compositions predicted from models that do not contain a year effect are highly unreliable, their use was considered better than leaving the MULTIFAN-CL input data unadjusted. The amount of the catch in the MULTIFAN-CL input data for which the species composition was predicted by the models was less than 10% and so it is not expected that the assessments will be greatly affected by the unreliable predictions.

### *10.2. Discussion points*

It was suggested that a multinomial regression could be used to model the proportions of all three species simultaneously, and that this option should be explored.

Concern was expressed regarding the inclusion of interactions with the year effect; however, the models are being used to predict the species compositions for each stratum, and not to estimate a time series of year effects. Therefore such interactions with year are not a concern but instead are appropriate and should improve the accuracy and precision of the estimates.

It was suggested that the residuals should be examined for lack of fit, but, at the same time, it was noted that transformations of the data to improve the fit would result in the predicted species compositions no longer summing to unity. It was also noted that the implicit assumption of an underlying Gaussian error distribution, if violated, would result in underestimates of the variance of the estimates. Examination of the residual may also be useful on this point.

This modeling approach utilizes all observer data to fit the models, but final species composition estimates do not directly utilize observer data for strata with less than 20 observations, using instead the model predictions. A hybrid approach was considered in order to retain direct representation from the available observations. In this approach, both the predicted species composition for a given stratum and the species composition determined from the observer data for that stratum could be averaged with an appropriate weighting based on the number of sets observed. However, given the relatively low amount of the catch in the MULTIFAN-CL input data for which the species composition is predicted (<10%), the development of complex procedures may not be justified.

The usual approach to strata with missing data is to substitute the species composition for neighboring strata. It was noted that this approach was analogous to the use of models that had only interaction terms. Substitutions have not been used in the WCPO and so the predicted species compositions were not compared to them. However, if linear categorical models are used to predict species compositions for the other ocean areas, where substitutions have been used routinely, the two sets of species compositions should be compared. The relative amount of catch in the other ocean areas for which the species composition has been determined from substitutions was not readily available; therefore estimates of the potential impact of the different approaches were not made.

It was noted that the stratification of port sampling by geographic area in the EPO, IO and AO introduces a high level of complexity, both to the selection of wells for sampling and in the analysis of the data, including the need for substitutions. When the procedure for selecting wells to sample is based on a stratified sampling design, a process which excludes wells which straddle strata, the samples may no longer be representative of the fishery as a whole. It may be useful to conduct simulations to examine whether the improvement in the variance of the estimates of species compositions justifies the use of sampling stratified by area. It may be found that simple random selection of wells for sampling, together with a system of post-stratification for the analysis of the data, may be as statistically efficient and more cost effective than selecting wells on the basis of area.

## 11. Sensitivity of the results to length-weight and dorsal length-fork length relationships

No individual presentation for this section. The WG briefly discussed the negative effects that the use of inadequate equations for the conversion of non-standard measurements into standard measurements, i.e. fork length and round weight, might have in deriving catch by species and catch-at-size from the samples available for surface fisheries. The WG noted that the regression equations that are used for tropical tuna species caught by surface fisheries may not be appropriate, in particular in the case of bigeye and skipjack tuna. The WG identified several issues concerning this subject and recommended some actions to overcome them that are presented in the following sections.

### *11.1. Insufficient information available*

Most of the equations currently used for the estimation of standard weights or lengths are poorly documented and the sampling data that were used for such studies are rarely available, making it difficult to validate the estimates. The WG agreed on the need for the scientists conducting such studies to document the sampling procedures appropriately. In addition, the WG encouraged scientists to report the results of these studies to the TRFMOs concerned, including the raw data that was used for deriving these equations. The WG also recommended that the TRFMO create catalogs containing the type of information available and make this available through its web sites or by other means.

### *11.2. Poor sampling design*

#### *11.2.1 Heterogeneity in sampling methods*

The heterogeneity in sampling methods includes boh the use of different sampling tools (e.g. calipers, boards, tape recorders) and the collection of samples of fresh or frozen specimens indistinctly, depending on the type of sample. The WG agreed on the need to harmonize data collection methods and procedures, recommending that the TRFMOs work jointly in the preparation of guidelines for the collection of this type of information and make this available through their web sites or by other means.

#### *11.2.2 Insufficient sampling coverage*

The equations used for converting from non-standard into standard measurements are often based on insufficient numbers of observations, in particular with regards to:

- sampling size: the number of specimens measured is generally too low. In addition, the majority of the samples available do not contain an adequate representation of specimens over the whole range of sizes caught by the fisheries. This is especially the case for specimens of large size, as it is the case with the bigeye tuna, albacore and yellowfin tuna,
- time-area and fishing mode: the samples available refer usually to specific areas and/or seasons, not adequately covering the entire year or fishing area. Samples are not collected routinely, making it impossible to assess if the relationship between length and weight changes significantly over time and/or depending on the area fished.

The WG agreed on the need to implement sampling for the conversion of non-standard to standard measurements as a routine activity, in particular length-weight sampling. The WG suggested that the following activities be explored/developed:

- Routine collection of samples at the canning factories, in particular for yellowfin tuna and skipjack tuna,
- Routine collection of samples from baitboat fisheries, in particular for skipjack tuna and small yellowfin tuna and bigeye tuna,
- Routine collection of samples from longline and hand line fisheries, in particular for large specimens of yellowfin tuna and bigeye tuna

In addition, the WG agreed on the need to assess how the length-weight relationship changes over time and/or space, recommending that the data available be used to conduct such studies, if possible.

### *11.3. Inadequate data processing*

*11.3.1 Estimation of sampled weights by using the available lengths*

The WG noted that sample weights are usually estimated from the available lengths, by using the existing length-weight equations. It was noted that this involves the use of two equations for large yellowfin tuna and bigeye tuna specimens, as such specimens are usually measured from the tip of the snout to the base of the first dorsal fin (LD1) and the existing LD1-weight equations are not used at present. As a consequence, LD1 lengths must first be converted to fork lengths, from which weight is then estimated. This process tends to introduce additional uncertainty.

*11.3.2 Use of deterministic methods for the estimation of weights from the available lengths instead of length-weight keys*

The WG noted that in some cases, the parameters of the length-weight have been estimated through a linear regression of log(L) vs. log(W). The consequence of the logarithmic transformation is to increase the weight of the smallest observation at the expense of the larger values and, therefore, the parameters are somewhat biased (IOTC Technical Report 02/01). The WG agreed that a more appropriate approach is to convert a distribution of lengths into a distribution of weights, i.e. assigning each given length a distribution of possible weights using length-weight keys, instead of a single weight. The WG recommended that this approach be used to convert from non-standard measurements into standard measurements, including conversions from LD1 to fork length.

The WG noted that the use of [non-standard length]-fork length-round weight equations for the estimation of sampled weights by species may add uncertainty to the estimates of species composition for surface fleets. It was agreed that, whenever it is possible, sampling schemes should consider weighing the fish sampled.

## 12. Recommendations

- The group discussed the possible effect of the vertical stratification of the fish in the well in both sizes and species composition. Although the information available did not show major effects, the group recommended that, for the Atlantic and Indian oceans, the two subsamples currently obtained from the same well, as well as data obtained by super sampling should be analyzed to evaluate this preliminary assumption. Similar analyses should be conducted for the EPO using available historical information as well as any new data obtained for these purposes.

- The group recognized the difficulty to perfectly implement randomness in the selection of the sample, in particular when small and large fish are mixed. Therefore, it was recommended to analyze the consequences of the departures from pure randomness on the conclusions in terms of stock assessment and to reduce, whenever possible, such departures.

- To avoid the possible bias in the species composition due to conversions (dorsal length to fork length and/or length to weight) applied in the estimation process, the group recommended either to collect weight data (when possible) or to improve the current relationships by collecting a larger number of measurement and to investigate potential improvements such as accounting for factors such as seasonality. In addition, sensitivity analyses should be conducted to assess the impact of parameter values of these relationships on the species composition and eventually on the catch per species both at the stratum and basin-scale level. Considering that the basic data used to obtain this kind of relationship are not confidential, the group recommended that these original data be made available to all? scientists.

- The group considered that the use of GLM Linear categorical models and perhaps other General Linear Models is a useful approach to estimate the species composition when sampling data do not exist or are insufficient. These models could be applied either at the strata level in poorly sampled strata or to fill gaps in the historical series. Alternative models should be investigated, in particular, the use of multinomial count models for multi-species sampling, as well as the possibility of incorporating year interactions.

- Due to the impact of the correction of species composition in the resulting catch by species, in particular in the bigeye catches, the group considered that it would be necessary to have detailed description of the past and present procedures applied in the different oceans, including data processing, to estimate these bigeye catches. These descriptions would for instance be of major importance to better understand changes in the bigeye catches in the past.

- The group discussed the data processing of the different oceans and recommended the revision of the raising process of samples in the Atlantic and Indian Ocean procedure, including in particular exploring the possibility of replacing the set by the well as the sampling unit. The group also pointed out that the information obtained from the well map data should be better incorporated into the data processing (e.g. to validate and if necessary to correct the logbook information). In addition, the current time and area stratification used in the Atlantic, Indian and Eastern Pacific data processing should be reanalyzed using recent data and potentially revised.

- The group discussed the new spill sampling protocol recently developed for use by observers in the WCPO and took note of its positive preliminary results. It was noted that such spill sampling could be considered in other oceans on a trial basis to compare to the species composition estimates obtained from port-sampling procedures. In addition, the group recommended maintaining and/or establishing port sampling programs to conduct comparative analyses. The group also noticed that the priorities of the observer programs can be different in each area depending on the particular requirements. For instance, in the EPO and in the AO and IO the observer programs are mainly focused in collecting basic information on bycatch and fishing operations only available on board, while in the WCPO the observer program is focused on sampling. Therefore the group considered that the feasibility of applying similar methods to port sampling and/or other areas should be investigated.

**13. Other matters**

As a general introduction to the meeting, a presentation of ongoing work financed by the Pelagic Fisheries Research Program (PFRP) and conducted by Julien Trolet (IRD) was made about the development of a worldwide database of catch and effort data aggregating the different databases managed by each TRFMO. Dr. Olivier Maury (IRD) then presented the general objectives, principles, and organisation of CLIOTOP, a regional project implemented under the international research program GLOBEC, devoted to the study of oceanic top predators within their ecosystems and based on a worldwide comparative approach.

**14. Report adoption and closure**

The report was adopted. The Chair thanked participants for their hard work and declared the meeting closed.

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**Appendix 1**
**Agenda**

1. Opening, adoption of the Agenda and meeting arrangements.
2. Detailed review of the methods historically and currently in use in the various oceans to assess the size distributions & species composition of purse seiners and bait boats landings in the IO, AO (EU vessels, Ghana fleets), EPO, WCPO.
3. Data processing and extrapolation of samples method used in each ocean: links between log books, landing and sampling data, & stratification used in the raising process.
4. Review in each ocean and country of the potential problems due to sorting of tuna during or just after the fishing operations, mixing tunas from various sets in distinct wells.
5. Comparison in species composition between logbook (well map), observer and port sampler data for the purse seine fisheries in all oceans.
6. Spill sampling: present results and potential constraints, problems and potential use.
7. Assessment of the sampling bias due to the effects of set weight on species composition in the IO and AO.
8. Analysis of sampling bias based on several 'supersampling' operations conducted in the Indian and Atlantic Oceans.
9. Grab sample bias and size selection bias for observers and port sampling: an analysis of sampling data and of simulated datasets.
10. A model-based approach to predicting species composition for strata with missing data.
11. Sensitivity of the results to length-weight and dorsal length-fork length relationships.
12. Recommendations
13. Other matters
14. Report adoption and closure

**Appendix 2**

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