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# Methods of Studying Fishery Interaction

(Paper Prepared by the Secretariat)

## Introduction

1. Existing and potential interaction among fisheries is an important concern wherever two or more interest groups are exploiting a common population of fish. In the western Pacific Ocean, these interest groups may be distant water fishing nations employing pole-and-line, purse seine and longline gear, individual Pacific Island countries employing one or more of those gear types in their own locally-based industrial tuna fisheries and artisanal/subsistence fishermen in many Pacific Island countries who rely to some extent on tuna for income and/or food.

2. Fonteneau (1986) recognised three classes of fishery interaction: (i) between generation interaction; (ii) within-generation interaction between fisheries that exploit a species at different stages of its life history; and (iii) within-generation interaction between fisheries exploiting a so-called common stock. Interaction between generations could arise, for example, when the activities of a fishery exploiting adult fish reduce the reproductive potential of the population to such an extent that recruit overfishing occurs, thus affecting other fisheries (and itself) exploiting the next generation of the population. Such a situation raises other more far reaching issues than simply the effect of one fishery on another; clearly the biological viability of the entire population is threatened in such an eventuality. Fortunately, this situation has rarely been observed in tuna fisheries, and certainly never in tropical tunas (some evidence for recruitment decline in Atlantic bluefin tuna has been presented). The second and third classes of interaction are within-generation interactions, i.e. they refer to the effects of one fishery on another in relation to the existing population. In fact, class (iii) is really a special case of the more general class (ii), i.e. within-generation interaction where the stock (that portion of the population available to the fisheries) is assumed to be simultaneously available to both fisheries.

3. The methods used for studying fishery interaction fall into three general categories that relate mainly to the types of data that they employ. The simplest are descriptive methods using basic fisheries statistics. An example of this type of method would be the correlation of catch rate trends in a longline fishery (the affected fishery) with total catch taken from the same population at some earlier stage by a purse seine fishery (the affecting fishery). When the age or size composition of the catch of each fishery is available, it is often possible to estimate age- or size-dependent fishing mortality rates for the fisheries (using cohort analysis) and then apply a multi-fishery yield-per-recruit analysis to estimate interaction between the fisheries. The third class of method employs tag recovery data, generally with catch and effort data from the recovery fisheries, to provide an estimate of fishery interaction.

4. In this paper, a number of methods for estimating fishery interaction that fall into these categories are reviewed and their applicability to various interaction problems regarding western Pacific tuna fisheries discussed.

## Descriptive fishery statistics

5. Some indication of fishery interaction can often be obtained from the basic statistics that are usually collected from the fisheries. Interaction has been implied from comparisons of catch and catch rate trends and correlations of average size and catch rate observations within discrete area-time strata.

### *Catch and catch rate trends*

6. Such trends have often been used as indicators of interaction between surface and longline fisheries for yellowfin in the eastern Pacific (Kume and Joseph 1969; Shingu et al. 1974; Miyabe and Bayliff 1987), western Pacific (SPC 1985; Suzuki 1986) and eastern Atlantic (Fonteneau 1986). Typically, these analyses take the form of comparing trends in longline fishery catch rates in areas of high and low purse seine catches. This type of comparison involves an assumption that fish are not mixing rapidly between the areas under consideration, i.e. that local depletion in an area due to intensive purse seining will be maintained and be reflected in reduced longline catch rates at some later stage (purse seiners generally catch somewhat smaller fish than longliners).

7. The main problem limiting the effectiveness of this method is that the variance of longline catch rate resulting from environmental fluctuations and changing fishing techniques may be too high to enable detection of the effect of purse seine fishing. For this reason, fairly long time series of longline catch rates are necessary, which may tend to violate the assumption of non-mixing. In one study (SPC 1985), this problem was addressed by using a general linear model that specified longline catch rates in discrete area-time strata (dependent variable) as a function

of year, quarter, latitude, longitude, current purse seine catch, cumulative purse seine catch and current purse seine catch rate (independent variables). Applying this model to yellowfin data in the western Pacific, no significant effects on longline catch rates of any of the purse seine catch or catch rate variables could be detected. However, this should be interpreted with some caution as all independent variables were assumed to be measured without error; this assumption was certainly violated for the purse seine fishery variables.

### *Correlations of average size and catch rate observations*

8. Correlations of this type have often been carried out to detect fishery interaction. In fact, any population measurement that showed substantial variation could be used for this purpose; average size and abundance (as indicated by catch rate) are two of the more common measurements taken. The correlations are in effect testing for commonality of stocks fished by the two gears in small area-time strata. For example, commonality would be indicated by a strong positive correlation in average size of fish caught by the two gears. Kume and Joseph (1969) found such a correlation between purse seine and longline caught yellowfin in the eastern Pacific, however their results were not supported by a later study of Miyabe and Bayliff (1987). Similarly, positive correlations in average size of skipjack and yellowfin were found in samples from pole-and-line and purse seine catches in the Solomon Islands (SPC/Fisheries 20/WP.4). On the other hand, no significant correlation in yellowfin catch rates of purse seiners and longliners fishing in the same area-time strata in the western Pacific could be detected (SPC 1985). This is not too surprising given the differences in size of fish exploited by these fisheries.

## Age- or size-structured models

9. Age- or size-structured models have been developed to describe fishery interaction in a number of tuna fisheries, e.g. Lenarz and Zweifel (1979) for Atlantic and eastern Pacific yellowfin, Suzuki (1986) and Suzuki and Koido (1987) for western Pacific yellowfin and Hampton (1988a) for southern bluefin tuna. In these studies, fishing mortality rates by age or size class are calculated for each gear type and input to a multi-fishery yield-per-recruit model. A measure of interaction is then obtained by observing the change in yield-per-recruit of one fishery in response to changes in fishing effort in the other fishery. The effects of changing the age or size at entry to the fisheries can also be investigated in this way.

10. The age- or size-specific fishing mortalities are usually calculated using some form of cohort analysis. In order to partition fishing mortalities between the fisheries, it is necessary to assume something about population structure. If the population is assumed to be available to both fisheries, fishing mortality is easily partitioned on the basis of the ratio of catches by the fisheries in each age (size) class. If availability is unequal, then some hypothesis regarding the proportion of the population available to one fishery that is, was or will be available to the other

is necessary. For example, Lenarz and Zweifel (1979) tested hypotheses that 100%, 50% and 0% of the eastern Atlantic yellowfin population available to longlining was also available to purse seining. In the case of southern bluefin tuna (Hampton 1988a), the hypothesis was more straight forward because the older fish, particularly in the age class where the cohort analysis is initiated, are exploited only by the longline fishery. Further, the geographic extent of the longline fishery would imply that the entire population of older fish is available to longlining, therefore, it is reasonable to assume in this case that all of the population available to surface fishing will eventually become available to the longline fishery. Whether or not some portion of the total population is recruited directly into the longline fishery is largely irrelevant as long as fishing mortality is interpreted as a parameter representing the total population for all age classes.

11. The alternative to assuming a particular stock structure is to incorporate migration between the fisheries as explicit parameters of the age- or size- structured model, such as has been done by Hilborn (1985) and Kleiber and Baker (1987). While such parameters are difficult to estimate and require extensive tagging data to do so, these models are more realistic and allow different hypotheses to be easily tested.

### Interaction models based on tagging experiments

12. Several models have been developed in recent years to describe fishery interaction that require tagging data as their primary input. These range in complexity from simple, direct estimates of interaction based on observed recaptures in one fishery from releases in another, to sophisticated models explicitly incorporating the dynamics of the tagged population and fishery.

#### *Majkowski and Hearn (1985) model*

13. The simplest model is that described by Majkowski and Hearn (1985), who measured interaction between two fisheries exploiting a population at different points along its migration path. (This model could also be applied in situations where the two fisheries were size selective, with little overlap between the two.) The model requires tagged fish to be released in the "upstream" fishery (fishery 1) and recaptured in the "downstream" fishery (fishery 2). Basically, interaction is measured by comparing the weight of fish released (usually as calculated from a weight-length relationship) in fishery 1 (corrected for recaptures in fishery 1) with the weight of fish recaptured in fishery 2. If the releases are representative of the total catch in fishery 1, the weight of fish recaptured in fishery 2 may be multiplied by the ratio of total fishery 1 catch to weight of releases to obtain a direct estimate of the effect of fishery 1 on fishery 2. Standard corrections for tag shedding, tagging mortality and non-reporting must be applied to obtain unbiased estimates.

14. The main advantage of the method is that it provides a direct estimate of interaction: no explicit solution for mortality or migration parameters is required, therefore the use of complex statistical estimation techniques is avoided. There is, however, a price to pay for this simplicity. The results can only ever refer to the situation that existed in the fisheries and fish population at the time of the experiment, i.e. there is little potential for extrapolation.

### *Kleiber et al. (1984) model*

15. This model provides an estimate of the potential for interaction expressed as the proportion of total biomass units to a receiver stock (throughput) resulting from migration from a donor stock. It can be shown that the coefficient of interaction (I) can be specified as

$$I_{d \rightarrow r} = \frac{RA_d P_d}{\alpha_d \beta_r N_0 C_r} \qquad (1)$$

where R is the total number of tagged fish recovered from the receiver stock, $A_d$ is the total attrition rate in the donor stock, $P_d$ is the donor standing stock, $\alpha_d$ is the proportion of tagged fish surviving type I tag losses, $\beta_r$ is a factor taking account of non-detection, non-return and inaccurate reporting of recovered tags, $N_0$ is the number of tagged fish released into the donor stock and $C_r$ is the catch rate (biomass per unit time) from the receiver stock. I can then be evaluated using known values of R and $N_0$, an average value of $C_r$ from catch statistics from the receiver stock and estimates of $A_d$ and $P_d$ from the tag returns from the donor stock (Kleiber et al. 1983). Values of $\alpha_d$ and $\beta_d$ are also required, but are not usually known with great certainty. The sensitivity of I over possible ranges of both these parameters should be checked.

16. The interaction coefficient is more a measure of interaction between stocks than between fisheries, but as such is an appealing concept. Its value lies in that it is a useful indicator of the potential for interaction, and in theory is insensitive to the state of the fisheries when the experiment was carried out. In other words, the interaction coefficient should remain a valid measure of stock connectedness regardless of how the fisheries alter over time. Its main drawback is that the effect of increasing catch or effort in one fishery upon the catch of another is not readily available. It also assumes constant attrition and catch rates, which may not be realistic in some cases.

***Sibert (1984) model***

17. This is a two-fishery model that provides a representation of the rate of return of four categories of tags from releases in the two fisheries. The four categories consist of returns from the fishery of release and returns from the alternate fishery for each of the release sets. An important feature of the model is the partitioning of tag attrition and accretion into components due to natural mortality, fishing mortality, emigration and immigration.

18. Returns in the four categories are specified as

$$\begin{gathered}
r_{11}(t)=\frac{\beta_1 F_1}{1+ab}\left\{a\left[\frac{bN_{11}(t\text{-}\Delta t)+N_{12}(t\text{-}\Delta t)}{u}\right]\left(1\text{-}e^{-u\Delta t}\right)+\left[\frac{N_{11}(t\text{-}\Delta t)\text{-}aN_{12}(t\text{-}\Delta t)}{v}\right]\left(1\text{-}e^{-v\Delta t}\right)\right\} \\
r_{12}(t)=\frac{\beta_2 F_2}{1+ab}\left\{\left[\frac{bN_{11}(t\text{-}\Delta t)+N_{12}(t\text{-}\Delta t)}{u}\right]\left(1\text{-}e^{-u\Delta t}\right)+b\left[\frac{N_{11}(t\text{-}\Delta t)\text{-}aN_{12}(t\text{-}\Delta t)}{v}\right]\left(1\text{-}e^{-v\Delta t}\right)\right\} \\
r_{21}(t)=\frac{\beta_1 F_1}{1+ab}\left\{a\left[\frac{bN_{22}(t\text{-}\Delta t)+N_{21}(t\text{-}\Delta t)}{u}\right]\left(1\text{-}e^{-u\Delta t}\right)+\left[\frac{N_{21}(t\text{-}\Delta t)\text{-}aN_{22}(t\text{-}\Delta t)}{v}\right]\left(1\text{-}e^{-v\Delta t}\right)\right\} \\
r_{22}(t)=\frac{\beta_2 F_2}{1+ab}\left\{\left[\frac{bN_{22}(t\text{-}\Delta t)+N_{21}(t\text{-}\Delta t)}{u}\right]\left(1\text{-}e^{-u\Delta t}\right)+b\left[\frac{N_{21}(t\text{-}\Delta t)\text{-}aN_{22}(t\text{-}\Delta t)}{v}\right]\left(1\text{-}e^{-v\Delta t}\right)\right\}
\end{gathered} \tag{2}$$

where $r_{11}(t)$ is the number of returns from fish released in fishery 1 and recovered in fishery 1 between time t-$\Delta$t and time t; $r_{12}(t)$ is the number of returns from fish released in fishery 1 and recovered in fishery 2 between time t-$\Delta$t and time t; $r_{21}(t)$ is the number of returns from fish released in fishery 2 and recovered in fishery 1 between time t-$\Delta$t and time t; $r_{22}(t)$ is the number of returns from fish released in fishery 2 and recovered in fishery 2 between time t-$\Delta$t and time t; $N_{11}(t\text{-}\Delta t)$ is the number of tagged fish released in fishery 1 and alive in fishery 1 at time t-$\Delta$t; $N_{12}(t\text{-}\Delta t)$ is the number of tagged fish released in fishery 1 and alive in fishery 2 at time t-$\Delta$t; $N_{21}(t\text{-}\Delta t)$ is the number of tagged fish released in fishery 2 and alive in fishery 1 at time t-$\Delta$t; $N_{22}(t\text{-}\Delta t)$ is the number of tagged fish released in fishery 2 and alive in fishery 2 at time t-$\Delta$t; $F_1(t)$ is the instantaneous rate of fishing mortality in fishery 1 between time t-$\Delta$t and time t; and $F_2(t)$ is the instantaneous rate of fishing mortality in fishery 2 between time t-$\Delta$t and time t.

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## METHODS OF STUDYING FISHERY INTERACTION

(Paper Prepared by the Secretariat)

## ERRATUM

Page 10, para. 28, 3rd line —— "(SPC/Fisheries 20/Information Paper 6)" should read "(SPC/Fisheries 20/WP. 17)"

19. The variables a and b are the positive roots of the following two quadratic equations:

$$\begin{aligned} T_{12}a^2 - (A_2-A_1)a - T_{21} &= 0 \\ T_{21}b^2 - (A_2-A_1)b - T_{12} &= 0 \end{aligned} \qquad (3)$$

where $A_1=M_1+F_1+T_{12}$ and $A_2=M_2+F_2+T_{21}$ ($T_{12}$ being the transfer rate from fishery 1 to fishery 2 and $T_{21}$ being the transfer rate from fishery 2 to fishery 1). The remaining variables v and u are given by

$$\begin{aligned} v &= \frac{A_1+bT_{21}+abA_2+aT_{12}}{1+ab} \\ u &= \frac{A_2-aT_{12}+abA_1-bT_{21}}{1+ab} \end{aligned} \qquad (4)$$

20. If $N_1$ and $N_2$ are the numbers originally released, at time t=0, $N_{11}(t)=\alpha_1N_1$, $N_{12}(t)=0$, $N_{21}(t)=0$ and $N_{22}(t)=\alpha_2N_2$. At subsequent times, the numbers alive in the four categories are given by

$$\begin{aligned} N_{11}(t) &= \frac{1}{1+ab}\left\{a\left[bN_{11}(t-\Delta t)+N_{12}(t-\Delta t)\right]e^{-u\Delta t}+\left[N_{11}(t-\Delta t)-aN_{12}(t-\Delta t)\right]e^{-v\Delta t}\right\} \\ N_{12}(t) &= \frac{1}{1+ab}\left\{\left[bN_{11}(t-\Delta t)+N_{12}(t-\Delta t)\right]e^{-u\Delta t}-b\left[N_{11}(t-\Delta t)-aN_{12}(t-\Delta t)\right]e^{-v\Delta t}\right\} \\ N_{21}(t) &= \frac{1}{1+ab}\left\{a\left[N_{22}(t-\Delta t)+bN_{21}(t-\Delta t)\right]e^{-u\Delta t}+\left[N_{21}(t-\Delta t)-aN_{22}(t-\Delta t)\right]e^{-v\Delta t}\right\} \\ N_{22}(t) &= \frac{1}{1+ab}\left\{\left[N_{22}(t-\Delta t)+bN_{21}(t-\Delta t)\right]e^{-u\Delta t}-b\left[N_{21}(t-\Delta t)-aN_{22}(t-\Delta t)\right]e^{-v\Delta t}\right\} \end{aligned} \qquad (5)$$

21. To reduce the number of parameters, $F_1(t)$ and $F_2(t)$ are specified in terms of either catch (biomass) or effort per unit time, thus

$$\begin{aligned} F_{1k} &= Q_1 E_{1k} = \frac{C_{1k}}{P_1} \qquad k=1,2, \ldots, n \\ F_{2k} &= Q_2 E_{2k} = \frac{C_{2k}}{P_2} \qquad k=1,2, \ldots, n \end{aligned} \tag{6}$$

where $Q_1$ and $Q_2$ are catchability coefficients for fishery 1 and 2, $P_1$ and $P_2$ are the average population sizes in fishery 1 and 2, n is the number of time periods considered, $C_{1k}$ and $C_{2k}$ are the catches of fishery 1 and 2 in period k, and $E_{1k}$ and $E_{2k}$ are the efforts in fishery 1 and 2 in period k.

22. Sibert (1984) used a least squares technique to obtain estimates of the various parameters, and employed a square root transformation as a weighting scheme for observations within the four tag recovery categories. Several methods of weighting the four individual sums of squares were also tested. Difficulties can arise in choosing the most appropriate weighting schemes, both for observations within and between return categories. These problems can be partially avoided by using a maximum likelihood technique based on multinomial probabilities. Here, a likelihood function can be constructed for each fishery of tag release, e.g. for releases into fishery 1,

$$f_1\left(\{r_{11}(k), r_{12}(k)\}\right) = \frac{N_{11}(0)\left(1-Pr_1\right)^{N_{11}(0)-R_1} \prod_{k=1}^{n}\left\{p_{11}(k)^{r_{11}(k)}\ p_{12}(k)^{r_{12}(k)}\right\}}{\left\{\prod_{k=1}^{n} r_{11}(k)!\ r_{12}(k)!\right\}\left(N_{11}(0)-R_1\right)} \tag{7}$$

where $R_1$ is the total number of returns from fishery 1 releases up to and including period n, $p_{11}(k)$ is the probability of recovery in fishery 1 during period k ($=r_{11}(k)/N_{11}(0)$), $p_{12}(k)$ is the probability of recovery in fishery 2 during period k ($=r_{12}(k)/N_{11}(0)$) and

$$Pr_1 = \sum_{k=1}^{n} p_{11}(k)+p_{12}(k).$$

23. An equivalent function, $f_2(\{r_{21}(k), r_{22}(k)\})$ can be written for releases into fishery 2. Estimates of parameters may then be found by minimising

$$L = -\log_e \left[ f_1(\{r_{11}(k), r_{12}(k)\}). \, f_2(\{r_{21}(k), r_{22}(k)\}) \right]. \qquad (8)$$

Simulation trials (Hampton 1988b) have shown that unbiased results are obtained using the maximum likelihood technique, whereas the degree of bias with the least squares approach depends on the weighting scheme used.

24. Hilborn (1986a) has developed an extension of the Sibert (1984) model that simultaneously estimates interaction among more than two fisheries using a maximum likelihood technique based on the Poisson distribution. This method could be potentially useful, however it is still under development and requires further validation.

### *Other interaction models based on tagging experiments*

25. The models of Sibert (1984) and Hilborn (1986a) incorporate specific parameters describing movement between fisheries or areas. When interaction between geographically separated fisheries is being considered, models of tag dynamics that include a general movement sub-model may be appropriate. There are few applications of such models in the fisheries literature, however Hilborn (1986b) has done some preliminary work in applying random movement (diffusion) models to western Pacific skipjack data.

## Application of interaction models to western Pacific tuna stocks

26. Each of the models discussed above has potential application to western Pacific skipjack stocks, and in fact several have already been applied. In this section, some of the important fishery interaction questions in the western Pacific are reviewed and the applicability of the above models discussed.

### *Interaction between large-scale purse seine and longline fisheries for yellowfin*

27. Yellowfin purse seine - longline interaction has been an important issue in a number of areas apart from the western Pacific, namely in the eastern Pacific, the eastern Atlantic and the Indian Oceans. In the western Pacific, the purse seine fishery is largely confined to the area between 5°N - 5°S and 130°E - 170°E. The longline fishery includes this area, but also extends further to the east, north and south. Unlike the eastern Pacific and eastern Atlantic fisheries, the sizes of yellowfin exploited using the two gears is quite distinct in the western Pacific, with purse seiners generally taking smaller fish than longliners (Suzuki 1986). This is because

yellowfin are mostly caught in log sets in the western Pacific (log schools generally consist of mainly small yellowfin, whereas free-swimming schools are generally comprised of much larger fish).

28. The use of descriptive fishery statistics to detect a purse seine - longline interaction has been a routine activity of the Tuna and Billfish Assessment Programme (TBAP). While the possibility of interaction has been demonstrated (SPC/Fisheries 20/Information Paper 6), more conclusive findings have not been possible to date mainly through a lack of data. In particular, complete data on the geographic and temporal distribution of total purse seine catch of yellowfin is necessary for a definitive study. Also, at least a substantial representative sample of longline catch and effort data is necessary to calculate accurate CPUE estimates. The TBAP is continually working to improve data coverage; this will receive a major boost in the near future when data provided by US purse seiners under the Multilateral Treaty on Fisheries become available.

29. The use of age- and size- structured models to describe purse seine - longline interaction, as has been done in the eastern Pacific and eastern Atlantic, is dependent upon the availability of catch size composition estimates from both fisheries, as well as the gross catch and effort data. A comprehensive length-frequency sampling programme is about to begin for US purse seiners fishing in the western Pacific under the terms of the Multilateral Treaty. These data will be made available to the TBAP through the Forum Fisheries Agency. In addition, the Japan Far Seas Fisheries Research Laboratory has collected yellowfin length-frequency data from the catches of Japanese purse seiners and longliners for some years, and it is possible that Korean and Taiwanese authorities make similar collections. A collaborative analysis of all western Pacific yellowfin data would be a major step forward.

30. There are presently no tagging data available that would enable the application of the tag models described above to yellowfin purse seine - longline interaction. When such data are available from the upcoming Regional Tuna Tagging Project (SPC/Fisheries 20/WP.5), several of these models could provide valuable information. In particular, the application of Sibert's (1984) model (modified for releases in the purse seine fishery only) and the development of a general quantitative description of yellowfin movement would be appropriate areas of investigation. It must be emphasised that these models also require comprehensive fishery statistics for any realistic application.

### *Interaction between large-scale purse seine fisheries and industrial fisheries of Pacific Island countries*

31. Several Pacific Island countries have developing tuna fisheries, the largest of which is that in Solomon Islands, where in excess of 30,000 tonnes of tuna have been taken each year since

1983. Other countries having significant industrial tuna fisheries include Kiribati and Fiji, and there are prospects of several others beginning in the near future. Of obvious concern to these countries is how the large purse seine catches by Japanese, US, Korean and other distant water vessels might affect their own fisheries. In the case of Solomon Islands, this question might be addressed using the Sibert (1984) approach, however the other national fisheries are unlikely to generate the number of tag returns required for meaningful estimates of transfer rates to be obtained. In these cases, the application of a generalised movement model may be appropriate.

32. These questions will be investigated by the new Regional Tuna Tagging Project, however, in the case of skipjack, there already exists a substantial body of tag return data (acquired during the Skipjack Survey and Assessment Programme) from which a generalised description of movement could be formulated if the detailed catch and effort data (particularly from the Japanese pole-and-line and purse seine fisheries) were available. Collaborative research between SPC and distant water fishing nations is required if further progress is to be made in this area.

### *Interaction between industrial fisheries and artisanal/subsistence fisheries*

33. In many countries of the SPC region, small-scale tuna fishing by island inhabitants is very important to their economic, social and nutritional well being. Therefore, questions regarding the possible effects of industrial fisheries on artisanal and subsistence fisheries are frequently raised.

34. Because artisanal and subsistence catches are relatively small, it is likely that significant interaction would only occur where there are industrial fisheries operating in the same general area. In these cases, interaction can be investigated directly by tagging in the general area of the industrial fishery and observing recaptures in the nearby artisanal and subsistence fisheries. This will be an important component of the new Regional Tuna Tagging Project. Whether or not it would be appropriate to fit one of the models described above to such data would depend on the number of recoveries and the availability of catch and effort statistics from both the industrial and artisanal/subsistence fisheries.

### *Interaction among fisheries of all types operating in different EEZs*

35. The fact that tuna have been traditionally been classified as highly migratory, has led most people, including biologists, lawyers and economists, to assume *a priori* that there will be a strong interaction between tuna fisheries in different countries. The results of the Skipjack Survey and Assessment Programme suggested that, at the time, interaction between countries was minor compared to other sources of loss from the population. However, there is always the possibility of significant interaction between adjacent countries, particularly if the fisheries are intense. This type of interaction question is probably best addressed using a general movement

model, but as discussed above, a definitive analysis of existing and future tag data will depend on the availability of necessary catch and effort statistics.

## Summary

36. The geographic and temporal distribution of catches and CPUE can provide indications of fishery interaction if detailed, and fairly complete, catch and effort data from the fisheries are available. In these cases, a sound approach would be to develop a linear model that attempts to explain the variation in CPUE of a fishery that is suspected of being affected by another.

37. Strong positive correlations between gears of some measurement of the fish population, e.g. average size or abundance, can indicate that the gears are fishing a common stock.

38. Age- or size-structured models can be used to assess interaction between fisheries if the appropriate age- or size-frequency data are available. This method has some potential for addressing the question of yellowfin purse seine - longline interaction in the western Pacific; this would require substantial collaboration between organisations having access to appropriate data.

39. Several models for analysing tagging experiments for the purpose of assessing interaction were reviewed. Different models are appropriate for addressing the different interaction questions that exist in the western Pacific. Models that specify transfer and mortality rates for specific interacting fisheries (e.g. Sibert 1984) would be appropriate for assessing interaction between fairly closely located, relatively intense fisheries. In other cases, the use of a general model of tuna movement may be more reasonable.

40. All the methods for studying fishery interaction have one common requirement - detailed, and as complete as possible, catch and effort statistics for the interacting fisheries. For the large-scale problems, e.g. yellowfin purse seine - longline interaction and between country interaction, collaboration between organisations collecting the data will be essential.

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