REVIEW OF CATCH ESTIMATES FOR TAIWANESE DISTANT-WATER LONGLINERS

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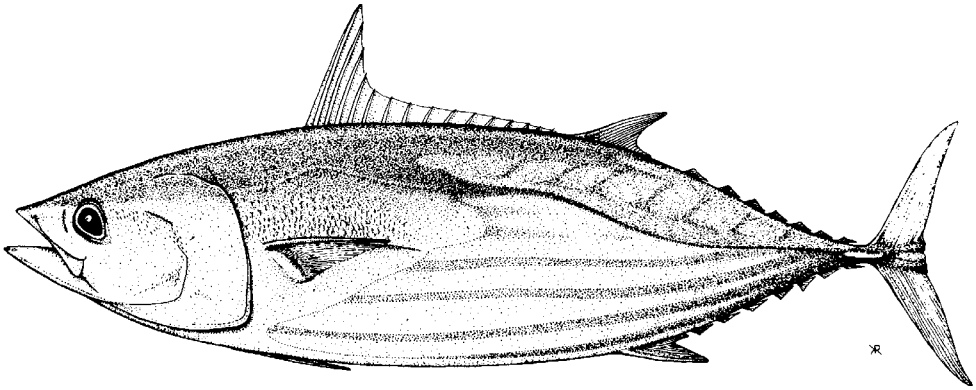

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INTRODUCTION

Estimates of catches and landings for Taiwanese distant-water longliners are available from several sources. Estimates of catches within time-area strata (5° latitude by 5° longitude and month) have been published by National Taiwan University (e.g. Tuna Research Center, 1974–1995; henceforth the "TRC bulletins"). National Taiwan University (NTU) has also published estimates of annual landings in the TRC bulletins. Estimates of annual catches of south Pacific albacore, based on landings, but different from those published in the TRC bulletins, have also been presented by NTU at meetings of the South Pacific Albacore Research (SPAR) group (South Pacific Commission 1996). The Taiwan Fisheries Bureau (TFB) has published albacore landings data (e.g. Taiwan Fisheries Bureau 1992–1994). Landings data are also compiled by the Taiwan Deep Sea Tuna Boatowners and Exporters Association (henceforth, the "Tuna Association").

The estimates of catches aggregated by 5° by 5°, published in the TRC bulletins, have been an important input to the assessment of south Pacific albacore, *Thunnus alalunga* (Fournier & Hampton 1996). They have also been used to produce estimates of annual catches by the Taiwanese distant-water longline fleet in the SPC statistical area, which have been published in the SPC Tuna Fishery Yearbook (Lawson 1996). It is therefore important that the reliability of the 5° by 5° data be established. Concern about the reliability of the 5° by 5° data has arisen at meetings of the SPAR group, primarily due to comparisons of annual catches determined from the 5° by 5° data to those based on landings data (Table 1). The methods used to derive the 5° by 5° data and the estimates of annual catches based on landings are examined below.

CATCH AND EFFORT DATA AGREGATED BY 5° X 5° BY MONTH

The 5° by 5° data for 1967–1979 and 1988–1993 represent logbook data that have been raised on the basis of an independent estimate of effort in the Pacific Ocean; the 5° by 5° data for 1980–1987 represent logbook data that have been raised on the basis of independent estimates of effort within each stratum of 5° by 5° and month. Table 2 presents the coverage of total effort by logbook data for Taiwanese distant-water longliners in the Pacific Ocean. Figures 1 and 2 show the time series of total effort, and coverage of total effort by logbook data, respectively. The following observations are of interest:

- For 1967–1977, catch totals determined from the 5° by 5° data are greater than those based on landings, and coverage by logbooks is low.
- For 1978–1987 (except for 1980), catch totals determined from the 5° by 5° data are less than those based on landings, and coverage by logbooks is relatively high.
- Coverage by logbooks dropped considerably in 1988, and remained low during 1989–1993.
- Total effort in 1980 and 1992 appear to be much greater than would be expected, given the magnitude of inter-annual changes in total effort for other years.
- For 1980, coverage by logbooks in terms of the number of sets was 90 per cent, while coverage in terms of the number of hooks was 53 per cent. In contrast, for all other years, coverage in sets and coverage in hooks are similar.

The methodology used to raise the logbook data depends strongly on the independent estimates of effort. For 1967–1969, the estimate of total effort in Table 1 was determined from the number of cruises in the Pacific Ocean covered by radio reports that each vessel was required to file with the Kaohsiung Fisheries Radio Station of the Kaohsiung Municipal Government. For 1970–1971, the estimate of total effort was based on the number of sets in the Pacific Ocean covered by the radio reports, while for 1972–1979, it was based on the number of hooks in the Pacific Ocean covered by the radio reports. For 1980–1987, the logbook data were raised on the basis of total effort for each stratum determined from the radio reports.

The data collected from radio reports consist of a code for the 5° by 5° grid where fishing was located, the total fishing effort in number of hooks, the catch in number of fish of the two most abundant species, and the catch of all species combined in number of fish. The reports refer to a single day fishing, and it was required that they be made by each vessel on a daily basis.

Coverage of total effort by radio reports was high during 1967–1987. However, with the lifting of martial law in 1988, coverage by radio reports declined considerably. Therefore, for 1988–1993, total effort has been estimated by multiplying the average numbers of hooks per vessel per month (determined from logbook data) by the number of vessels registered to fish in the Pacific Ocean for each month. The number of vessels registered to fish in the Pacific has been provided to NTU by the Kaohsiung Fisheries Administration of the Kaohsiung Municipal Government.

The ratio of the estimate of total effort to the effort covered by logbooks has been used as a raising factor in the following manner:

1. The number of fish caught in each stratum has been estimated by multiplying the catch in number of fish reported on logbooks for each stratum by the raising factor.

2. The effort in each stratum has been estimated by multiplying the number of hooks reported on logbooks for each stratum by the raising factor.

3. The catch in weight in each stratum has been estimated by multiplying the catch in number of fish by the average weight of fish caught in the stratum. The average weight of fish caught in the stratum has been determined from measurements of lengths of individual fish which are recorded on the logbooks, using a length-weight curve.

Table 3 compares catch estimates determined from the 5° by 5° data to landings data published in the TRC bulletins, for 1980–1993. It is of interest to note the following:

- For 1981–1991, the catch estimates determined from the 5° by 5° data are less than landings, while for 1980 and 1992, they are much greater than landings.

- For 1993, the albacore and bigeye catch estimates determined from the 5° by 5° data are equal to the landings, while the yellowfin catch estimate for 1993 is much less than landings.

The equality of the albacore and bigeye catch estimates determined from the 5° by 5° data and landings, for 1993, is due to the fact that, for these two species and this year, the 5° by 5° data were subject to a fourth step of processing, wherein the catch in weight for each stratum and for each of the two species was multiplied by a correction factor. The correction factors, one for albacore and one for bigeye, were the ratio of landings divided by the sum over all strata of the catch in weight determined from step 3 above.

CATCH ESTIMATES, BASED ON LANDINGS, PRESENTED TO SPAR

The catch estimates that have been presented to meetings of the SPAR group by National Taiwan University (Table 1) have been derived from landings data for the whole Pacific Ocean which, for 1967–1990, have been adjusted with the 5° by 5° data to represent the catch in the south Pacific Ocean. The method used to derive these estimates for 1967–1990 is presented in Table 4 (adapted from Wang, personal communication, April 1993). The following points are noteworthy:

- The landings data for 1967–1990 from Wang (personal communication, April 1993) were reported to have been provided by the Taiwan Fisheries Bureau. For 1971–1980, the landings data from Wang (personal communication, April 1993) are considerably different from those provided by TFB and reported in Wang (1993), while for 1981–1990, they are almost identical (Table 5).

- The estimates for 1991–1993 in Table 1 were reported as estimates of the catch in the "SPC area" (which may refer to the SPC statistical area, although the context would imply the south Pacific Ocean, i.e. the SPAR area) in Wang (1996). However, it is not clear how the estimates for 1991–1993 were obtained. There is no mention of the source of the estimates for 1991–1992 in Wang (1996). The estimate for 1993 was reported to be based on annual reports published by TFB and TRC (Wang 1996). But while the estimates for 1991–1993 are smaller than estimates of landings for the whole Pacific published by TFB and TRC, and compiled by the Tuna Association (Table 5), they are too small to represent the catch in the south Pacific determined by correcting the TFB, TRC or Tuna Association estimates of landings (Table 5) for the whole Pacific Ocean for the proportions of the catch in the south Pacific (which were 0.999, 0.943 and 0.958 for 1991–1993 respectively, according to the 5° by 5° data held at SPC).

- The estimates for 1994–1995 presented under 'SPAR6' in Table 1, and under 'Wang' in Table 5, represent estimates of landings in the Pacific Ocean obtained from the Taiwan Deep Sea Tuna Boatowners and Exporters Association (Wang, personal communication, September 1996).

- It would appear from Table 4 that the estimates of catch and effort in the south Pacific Ocean determined from the 5° by 5° data were obtained by summing the 5° by 5° catch and effort data for the north Pacific Ocean, and then subtracting these sums from totals for the whole Pacific Ocean, which have been published in a separate table in the TRC bulletins, rather than by summing the catch and effort for the south Pacific Ocean, and the whole Pacific Ocean, directly from the 5° by 5° data. This could result in two sources of error. First, the totals for the whole Pacific Ocean in the separate table might not correspond to the sum of the 5° by 5° data due to errors in summation. Second, the 5° by 5° data may have been updated since the totals in the separate tables were published. To address these questions, the analysis presented in Table 4 was repeated using the 5° by 5° data held at SPC. The proportion of the catch in the south Pacific was estimated by summing the catch in the whole Pacific Ocean and the south Pacific directly. Differences greater than 1,000 mt were found between the totals calculated in this manner and those presented in Wang (personal communication, April 1993) for 1975, 1978, 1986 and 1987. Nevertheless, the estimates of the proportion of the catch in the south Pacific determined from the two methods were similar. Estimates of the catch in the south Pacific differed, on average, by only 204 mt for 1967–1979 and by only 1 mt, on average, for 1980–1990; the largest difference was 882 mt for 1975. The fact that the largest differences were found for 1967–1979 suggests that the 5° by 5° data for these years may have been revised since the TRC bulletins were printed, or that the separate tables of catches for the whole Pacific were in error, or both.

- According to 5° by 5° data held at SPC for 1967–1993, on average, 99 per cent of the albacore caught by Taiwanese distant-water longliners is taken from the south Pacific; the proportion ranges from 94 per cent (1975) to 100 per cent (1973, 1984–1990).

DISCUSSION

The fact that the catch totals for 1967–1977 determined from the 5° by 5° data are all greater than those based on landings (Table 1), while the catch totals for 1978–1987 (except for 1980) determined from the 5° by 5° data are less than those based on landings, suggests that there is systematic bias in the 5° by 5° data, the landings data, or both, for those periods. However, while there is no obvious explanation for these trends, the trend for 1967–1977 is perhaps somehow related to the fact that the 5° by 5° data for this period were originally published in the TRC bulletins as unraised data. (In September 1992, SPC received a raised version of these data from NTU, which were used to produce Table 1.)

The systematic differences bertween the catch totals determined from the 5° by 5° data and those based on landings might also be related to the manner in which the average weights for each stratum, the $\hat{W}_i$, have been determined from the length measurements recorded on the logbooks. To avoid bias in the estimate of average weight, the length measurements should first be converted to weights, using a weight-length curve. However, if the average weight is estimated by first determining the average length, and then converting the average length, using a weight-length curve, then the estimate of the average weight will be biased, since the relationship between weight and length is nonlinear. The degree of bias in the estimate of the average weight will depend on the variability of the length measurements.

The 5° by 5° data for 1980 would appear to be particularly suspect, due to the unexplained discrepancy between coverage in terms of the number of sets and coverage in terms of number of hooks (Table 2); to the high value of total effort relative to neighbouring years (Table 2); and to the large differences between catches determined from the 5° by 5° data and landings (Table 3). It is perhaps relevant that 1980 was the first year for which the logbook data were raised on the basis of the total effort within each 5° by 5° stratum, rather than total effort in the Pacific Ocean.

The 5° by 5° data for 1992 would also appear to be suspect, due to the high value of total effort relative to neighbouring years, and to the large differences between catches determined from the 5° by 5° data and landings (Table 3). (It should be noted that while the estimate of total catch for the Pacific Ocean determined from the 5° by 5° data for 1992, 31,106 mt [Table 3], is similar to the estimate of albacore landings in the Pacific Ocean published by the Taiwan Fishery Bureau, 30,404 mt [Table 5], the latter estimate is believed to cover north Pacific driftnet catches of albacore unloaded at Pago Pago, American Samoa, in addition to longline catches.)

The method used to derive the 5° by 5° data depends strongly on independent estimates of total effort. For 1967–1987, estimates of total effort were determined from radio reports, while for 1988–1993, they were based on estimates of the number of vessels fishing in the Pacific, which in turn were determined from departure reports provided to the Kaohsiung Fisheries Administration.

While there is no independent information available to assess the reliability of the radio reports, the estimate of total effort for 1980 would appear to be too high. On the other hand, the reliability of the estimates of the number of vessels fishing in the Pacific based on departure reports is known to be

relatively low. The vessels must file their departure reports, which indicates the ocean in which they intend to fish, before leaving Kaohsiung. The reports are valid for twelve months, after which they can be extended for another six months. However, the vessels often change oceans during their time away from Kaohsiung, and these changes were not accounted for in the estimates of the number of vessels in the Pacific provided by the Kaohsiung Fisheries Administration to National Taiwan University. The high estimate of total effort for 1992 may be related to inaccurate estimates of the monthly numbers of vessels fishing in the Pacific.

The estimates of the catch in weight for each 5° by 5° stratum depends on the estimate of the average weight, which in turn depends on estimates of lengths of the fish recorded on the logbooks. Unfortunately, no information was available to assess the reliability of the method for determining the average weights.

The method used by NTU to derive the 5° by 5° data for 1967–1979 and 1988–1993, based on total effort in the Pacific Ocean, can be written as follows. Let e_i, n_i and $u_i = \frac{n_i}{e_i}$ be the effort, catch in number of fish, and catch rate in number of fish per hook, respectively, reported for the i[th] stratum on logbooks. Let E^* be the independent estimate of total effort in the Pacific Ocean based on radio reports or on the e_i and estimates of the number of vessels active. Let $\hat{E}_i$ be the estimate of effort within the i[th] stratum, $\hat{N}_i$ the estimate of the catch in number of fish, $\hat{W}_i$ the estimate of the average weight (based on length data in the i[th] stratum), and $\hat{C}_i$ the estimate of the catch in weight. We have:

$$\hat{E}_i = e_i \cdot \frac{E^*}{\sum_i e_i} \tag{1}$$

$$\hat{N}_i = n_i \cdot \frac{E^*}{\sum_i e_i} \tag{2}$$

$$= \hat{E}_i \cdot u_i \tag{3}$$

$$\hat{C}_i = \hat{N}_i \cdot \hat{W}_i . \tag{4}$$

Let K be the observed landings for the Pacific Ocean. The problem evident in Table 1 is that the sum of the 5° by 5° catch in weight data does not usually agree with the observed landings; that is, $\sum_i \hat{C}_i \neq K$. The exception is for albacore and bigeye for 1992 (Table 3). For these two species in 1992, we have:

$$\hat{C}'_i = \hat{C}_i \cdot \frac{K}{\sum_i \hat{C}_i} \tag{5}$$

Equation (5) can be re-written in two forms:

$$\hat{C}_i' = \hat{N}_i \cdot \hat{W}_i' \tag{6}$$

where $\hat{W}_i' = \hat{W}_i \cdot \frac{K}{\sum_i \hat{C}_i}$, and (7)

$$\hat{C}_i' = \hat{N}_i' \cdot \hat{W}_i \tag{8}$$

where $\hat{N}_i' = \hat{N}_i \cdot \frac{K}{\sum_i \hat{C}_i}$. (9)

That is, the adjustments of the estimates of catch in weight by landings can be interpreted as a correction to the average weight for each stratum, or as a correction to the number of fish caught in each stratum. If the estimates of catch in numbers have not been modified, which is presumably the case for albacore and bigeye for 1992, then the correction, in this case, has been to the average weights.

The problem that the sum of the 5° by 5° catch in weight data does not equal landings can be avoided by raising the logbook data on the basis of landings, rather than on the basis of an independent estimate of total effort. Let C^* be an independent estimate of the total catch in the Pacific Ocean, based on landings, such that $C^* = f(K)$, where the function f might represent raising due to incomplete coverage of the observed landings and/or the conversion from gilled-and-gutted weight to whole weight (although it should be noted that albacore are landed whole). Also, let $\hat{N}$ and $\hat{W}$ be estimates of the total catch in numbers of fish for the Pacific Ocean and the average weight of fish caught in the Pacific Ocean respectively. Preferably, $\hat{W}$ should be determined from port sampling or observer data, which should be stratified by time-area to give average weights for each stratum, $\hat{W}_i$, and which should be weighted according to the distribution of the catch, such that

$$\hat{W} = \frac{\sum_i \left(n_i \cdot \hat{W}_i\right)}{\sum_i n_i} \tag{10}$$

But logbook data, i.e. the n_i and c_i, treated in a similar manner, might suffice. First we obtain an estimate of the total number of fish caught in the Pacific Ocean:

$$\hat{N} = \frac{C^*}{\hat{W}} \tag{11}$$

Then we derive estimates of the catch and effort in each stratum:

$$\hat{N}_i = \hat{N} \cdot \frac{n_i}{\sum_i n_i} \tag{12}$$

$$\hat{C}_i = \hat{N}_i \cdot \hat{W}_i \tag{13}$$

$$\hat{E}_i = \frac{\hat{N}_i}{u_i} \tag{14}$$

Summing the $\hat{C}_i$ and solving with equations (10)–(13) shows that $\sum_i \hat{C}_i = f(K)$; that is, the sum of the 5° by 5° catch in weight data equals landings, as expected. It can also be shown that for the method based on an independent estimate of total effort and the method based on an estimate of total landings to give the same results, then the following relationship must hold:

$$\frac{E^*}{\sum_i e_i} = \frac{f(K)}{\sum_i \left(n_i \cdot \hat{W}_i\right)}. \tag{15}$$

That is, the ratio of total effort to the sum of effort recorded on logbooks must equal the ratio of landings to the sum of the product of the catch in number of fish recorded on logbooks and the average weights.

The above method is appropriate for a fishery in which a single species accounts for the majority of the catch. The catch in number for other species, for each stratum, can be estimated using the $\hat{E}_i$ and the catch rate for each species, for each stratum, determined from the logbook data. The catch in weight for other species can be estimated from the catch in number and the average weights determined from either the length data or the logbook data.

The question arises as to whether the method based on landings could be applied to the Taiwanese distant-water longline fishery in the Pacific Ocean. In fact, Taiwanese distant-water longliners have been sampled for lengths of albacore in Pago Pago, American Samoa, by the United States National Marine Fisheries Service, since 1964, and in Levuka, Fiji, by SPC, since 1992; these data are available stratified by 5° by 5° and month. Also, landings data are available from various sources (Table 5). Unfortunately, it appears that the logbook data held by National Taiwan University prior to 1981 are missing; they cannot at present be located in either electronic or hardcopy format. The logbook data for 1981 onwards are, however, held by both NTU and the Overseas Fisheries Development Council of the Republic of China (OFDC), which took over responsibility for tuna fisheries data from NTU in July 1996. The method based on landings could therefore be applied to the logbook data for 1981 onwards.

Unfortunately, the logbook data for 1981 onwards are not held by SPC. However, if we are willing to accept the average weights for each stratum in the 5° by 5° data, i.e. $\frac{\hat{C}_i}{\hat{N}_i}$, then it is possible to derive the 5° by 5° data based on landings, i.e. the estimates obtained from (12)–(14), from the estimate of landings, K, and the 5° by 5° data based on total effort, i.e. the estimates obtained from (1), (2) and (4). An estimate of the catch in weight and the catch in number, for each stratum, can be obtained from equations (5) and (9) respectively. Let $\hat{U}_i = \frac{\hat{N}_i}{\hat{E}_i}$ be the estimate of the catch rate in the ith stratum. Noting that

$$\hat{E}_i' = \frac{\hat{N}_i'}{\hat{U}_i} \tag{16}$$

and substituting equation (9), we obtain an adjusted estimate of effort:

$$\hat{E}_i' = \hat{E}_i \cdot \frac{K}{\sum_i \hat{C}_i} \tag{17}$$

It is of interest to note that the independent estimate of total effort, E^*, no longer figures in the 5° by 5° data. If $C^* = K$, then it can be shown that the estimate of the catch in number obtained from equation (9), i.e. the 5° by 5° data based on an independent estimate of total effort but corrected by landings, and that obtained from equation (12), i.e. the 5° by 5° data based on landings, both reduce to $n_i \cdot \frac{K}{\sum_i \left(n_i \cdot \hat{W}_i\right)}$. Similarly, the estimates of catch in weight obtained from equations (5) and (13) both reduce to $n_i \cdot \hat{W}_i \cdot \frac{K}{\sum_i \left(n_i \cdot \hat{W}_i\right)}$, and the estimate of effort obtained from equation (17) reduces to $e_i \cdot \frac{K}{\sum_i \left(n_i \cdot \hat{W}_i\right)}$.

CONCLUSION

The following conclusions can be drawn:

- There appears to be systematic positive bias in the 5° by 5° data for 1966–1977 and systematic negative bias for 1978–1987 (except for 1980); however, there is no obvious explanation for the bias.

- The 5° by 5° data for 1980 and 1992, which result in high values of annual catch and effort in the Pacific Ocean, are particularly suspect. The 1980 data were raised on the basis of the total number of hooks within each 5° by 5° stratum reported by radio. The large discrepancy between logbook coverage in terms of the number of hooks for 1980 (53 per cent), and coverage in terms of the number of sets (90 per cent), needs to be explained. The 1992 data were raised on the basis of an independent estimate of effort in the Pacific Ocean determined from estimates of the number of vessels active per month. The estimates of the number of vessels active per month are considered to be only rough estimates; for 1992 in particular, they may overestimate the number of vessels active.

- The differences between the two sets of landings statistics obtained from the Taiwan Fisheries Bureau reported in Wang (1993) and Wang (personal communication, April 1993), particularly for 1971–1980, need to be explained. The values and sources of landings statistics for 1991–1993 used to determine catch estimates for the “SPC area” reported in Wang (1996), and the method used to derive the catch estimates from landings (if the catch estimates are, in fact, different from landings), need to be identified.

- Differences in landings statistics from 1991 onwards published by the Taiwan Fisheries Bureau and the Tuna Research Center, and compiled by the Tuna Association, need to be resolved.

- The Overseas Fisheries Development Council should consider revising the 5° by 5° data, by raising the logbook data on the basis of landings, using the logbook data it holds for 1981 onwards and, in order to determine reliable average weights, the port sampling data held by SPC.

- SPC should convert the 5° by 5° data raised on the basis of effort to 5° by 5° data raised on the basis of landings using the method presented above. The converted 5° by 5° data should then be used in assessments of south Pacific albacore, and to estimate the total catch of albacore in the south Pacific Ocean (for the purposes of the SPAR group) and in the SPC statistical area (for the SPC Tuna Fishery Yearbook).

EPILOGUE

The Council of Agriculture, Executive Yuan, provided distant-water longline data covering 1994 to SPC in April 1997. The 1994 data, which were prepared by OFDC, were raised on the basis of landings, rather than effort.

The 5° by 5° data held at SPC for 1967–1993, raised on the basis of effort, were converted to 5° by 5° data raised on the basis of landings. Estimates of albacore landngs for 1967–1979 were taken from Wang (personal communication, April 1993), while estimates for 1980–1989 are TFB estimates from Wang (1993) and Taiwan Fisheries Bureau (1990). Estimates of landings for 1990–1994 were provided by the Council of Agriculture (Shieh, personal communication, April 1997).

The conversion procedure is equivalent to multiplying effort, the number of albacore caught, and the catch of albacore in metric tonnes, in each stratum, by the annual ratio of albacore landings to the albacore catch summed over all strata of the effort-based 5° by 5° data. The average weight and the catch rate for each stratum, both for albacore and the other species, remain the same. The catch of other species, in number of fish and in metric tonnes, for each stratum, is determined from the converted value of effort, the catch rate and the average weight.

Table 6 presents summary statistics for the whole Pacific Ocean for the effort-based data and the landings-based data. The annual conversion factor, i.e. the ratio of total albacore landings to the albacore catch in metric tonnes summed from the effort-based 5° by 5° data, is also shown. The conversion factor for 1994 is 1.0 because those data were already raised on the basis of landings by OFDC. Figures 3 and 4 compare the time-series of estimates of the albacore catch in metric tonnes and effort, respectively, determined from effort-based 5° by 5° data to estimates determined from landings-based 5° by 5° data.

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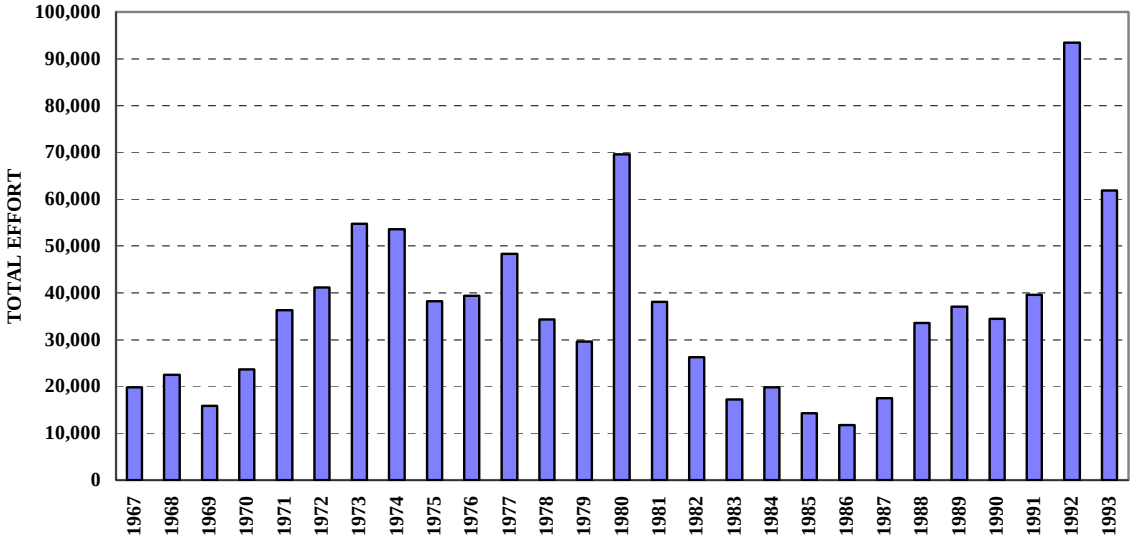

Figure 1. Total effort (thousand hooks) by Taiwanese distant-water longliners in the Pacific Ocean.
Source: TRC bulletins

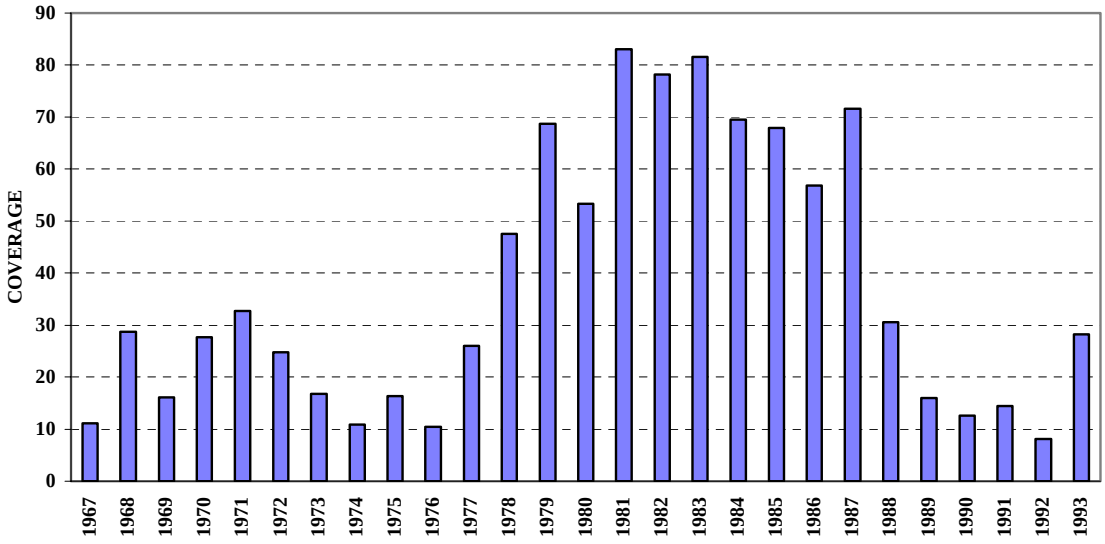

Figure 2. Coverage (percent) by logbook data of effort (number of hooks) by Taiwanese distant-water longliners in the Pacific Ocean.
Source: TRC bulletins

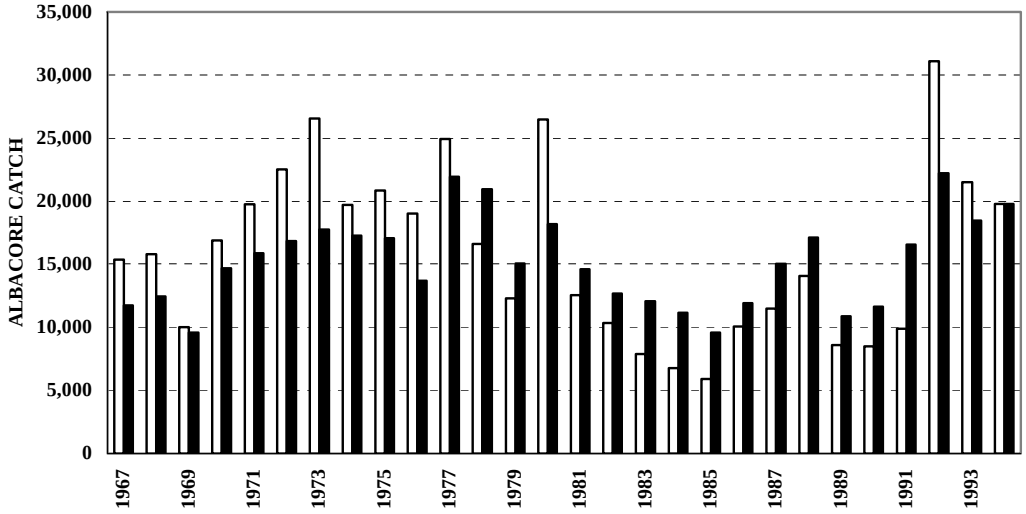

Figure 3. Comparison of estimates of the albacore catch (metric tonnes) in the whole Pacific Ocean determined from 5° by 5° data based on effort (white bars) to estimates determined from 5° by 5° data based on landings (black bars)

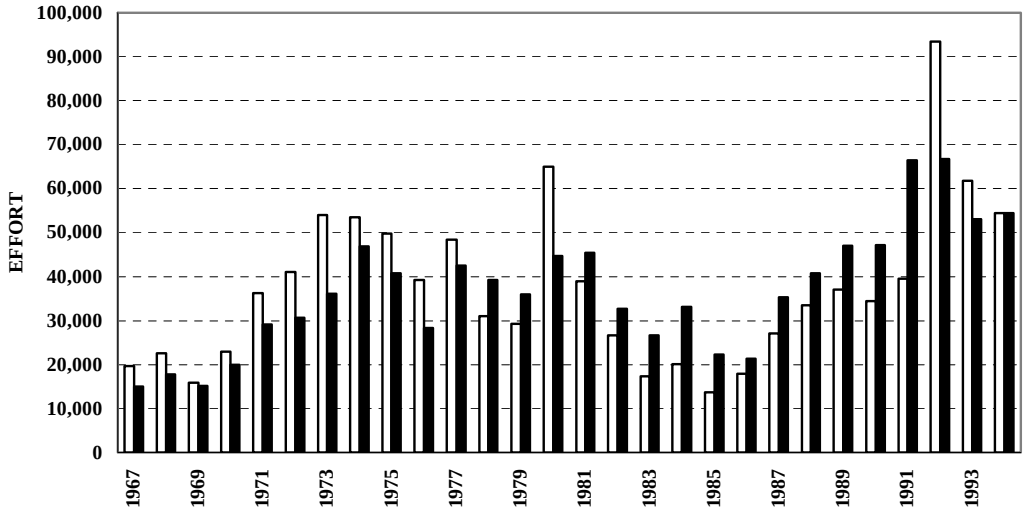

Figure 4. Comparison of estimates of effort (thousands of hooks) in the whole Pacific Ocean determined from 5° by 5° data based on effort (white bars) to estimates determined from 5° by 5° data based on landings (black bars)

Table 1. A comparison of albacore catch estimates (mt) for Taiwanese distant-water longliners in the south Pacific Ocean, based on landings, presented to the Sixth Meeting of the South Pacific Albacore Research Group by National Taiwan University (SPAR), and raised annual catch estimates determined from data aggregated by 5° latitude by 5° longitude (5x5). The difference (DIFF) between the two estimates, and the ratio (%) of the estimate based on 5x5 data to the estimate based on landings, expressed as a percentage of the latter, are also shown. Sources: SPAR6 = South Pacific Commission (1996); 5x5 = catch data aggregated by 5° by 5° provided to the South Pacific Commission by National Taiwan University. Catch data aggregated by 5° by 5° for 1994–1995 were not available at the time of writing.

YEAR	SPAR6	5x5	DIFF	%
1967	11,723	15,036	3,313	128
1968	12,375	15,570	3,195	126
1969	9,557	9,948	391	104
1970	14,682	16,651	1,969	113
1971	15,880	19,714	3,834	124
1972	16,780	22,322	5,542	133
1973	17,742	26,563	8,821	150
1974	17,246	19,219	1,973	111
1975	16,939	19,611	2,672	116
1976	13,653	18,363	4,710	134
1977	21,452	24,356	2,904	114
1978	20,935	16,403	-4,532	78
1979	14,952	12,214	-2,738	82
1980	25,579	26,177	598	102
1981	14,367	12,379	-1,988	86
1982	12,644	10,324	-2,320	82
1983	12,106	7,873	-4,233	65
1984	11,155	6,785	-4,370	61
1985	9,601	5,934	-3,667	62
1986	11,913	10,053	-1,860	84
1987	15,009	11,508	-3,501	77
1988	17,120	14,056	-3,064	82
1989	10,867	8,563	-2,304	79
1990	9,689	8,486	-1,203	88
1991	11,235	9,840	-1,395	88
1992	18,989	29,325	10,336	154
1993	12,986	20,628	7,642	159
1994	17,034			
1995	15,201			

Table 2. Coverage (percent) of total effort (thousand hooks) by logbook data for Taiwanese distant-water longliners in the Pacific Ocean. Source: TRC bulletins

	LOGBOOKS		TOTAL		COVERAGE	
YEAR	SETS	HOOKS	SETS	HOOKS	SETS	HOOKS
1967		2,191		19,739		11.10
1968		6,469		22,540		28.70
1969		2,551		15,836		16.11
1970		6,538		23,688		27.60
1971		11,860		36,191		32.77
1972		10,171		41,113		24.74
1973		9,188		54,692		16.80
1974		5,850		53,573		10.92
1975		6,209		38,163		16.27
1976	2,834	4,091	26,008	39,284	10.90	10.41
1977	8,828	12,599	34,211	48,374	25.80	26.04
1978	11,468	16,335	24,032	34,361	47.72	47.54
1979	13,663	20,347	20,289	29,611	67.34	68.71
1980	23,019	37,101	25,643	69,566	89.77	53.33
1981	19,655	31,613	22,875	38,080	85.92	83.02
1982	12,245	20,468	15,533	26,184	78.83	78.17
1983	7,828	14,052	8,655	17,235	90.44	81.53
1984	7,441	13,763	10,723	19,781	69.39	69.58
1985	4,895	9,653	7,383	14,210	66.30	67.93
1986	3,327	6,644	6,381	11,696	52.14	56.81
1987	5,135	12,526	7,354	17,506	69.83	71.55
1988	3,878	10,246	13,252	33,517	29.26	30.57
1989	2,189	5,926	14,399	37,033	15.20	16.00
1990	1,723	4,336	13,742	34,433	12.54	12.59
1991	2,036	5,703	16,238	39,595	12.54	14.40
1992	2,442	7,525	30,312	93,406	8.06	8.06
1993	6,098	17,493	19,457	61,852	31.34	28.28

1. Coverage for 1967–1969 is based on the number of cruises, determined from radio reports.

2. Coverage for 1970–1971 is based on the number of sets, determined from radio reports.

3. Coverage for 1972–1987 is based on the number of hooks, determined from radio reports.

4. The total number of hooks for 1988–1993 is determined by multiplying the average number of hooks per vessel per month, determined from logbook data, by the monthly number of vessels registered to fish in the Pacific Ocean.

Table 3. Raised catch estimates (mt) determined from 5° by 5° data, landings (mt), and the ratio (percent) of raised catch estimates to landings, for Taiwanese distant-water longliners in the Pacific Ocean. Source: Tuna Research Center (1987–1993, 1995).

	RAISED CATCH ESTIMATES				LANDINGS				RATIO			
YEAR	ALB	BET	YFT	TOTAL	ALB	BET	YFT	TOTAL	ALB	BET	YFT	TOTAL
1980	27,287	3,211	6,024	39,099	18,180	2,539	5,603	28,091	150	126	108	139
1981	12,232	1,239	1,642	16,290	14,595	1,478	2,031	19,448	84	84	81	84
1982	10,193	488	767	12,308	12,680	987	1,015	15,827	80	49	76	78
1983	7,830	265	541	9,065	12,083	768	862	14,556	65	35	63	62
1984	6,771	334	592	8,117	11,155	919	1,430	14,770	61	36	41	55
1985	6,095	234	613	7,179	9,601	672	1,210	12,357	63	35	51	58
1986	6,530	155	339	7,180	11,913	648	1,213	14,583	55	24	28	49
1987	7,428	365	450	8,525	15,009	766	1,017	17,734	49	48	44	48
1988	14,056	588	1,291	16,407	17,120	793	3,054	22,030	82	74	42	74
1989	8,563	777	867	10,748	10,867	433	1,207	13,416	79	180	72	80
1990	8,490	925	1,391	11,301	9,689	788	1,421	12,987	88	118	98	87
1991	9,852	726	991	12,186	14,030	592	1,152	16,662	70	123	86	73
1992	31,106	3,062	2,000	38,494	21,395	2,131	1,325	25,852	145	144	151	149
1993	21,529	681	835	24,843	21,529	682	1,637	25,646	100	100	51	97

Table 4. Derivation of estimates of albacore catches by the Taiwanese distant-water longline fleet presented to meetings of the South Pacific Albacore Research group by National Taiwan University. Columns B–G were determined from catch and effort data published by NTU, aggregated by 5° by 5° and month. Source: Wang (personal communication, April 1993).

YEAR	PACIFIC OCEAN LANDINGS	PACIFIC OCEAN			NORTH PACIFIC OCEAN		
		HOOKS	NUMBER OF FISH	METRIC TONNES	HOOKS	NUMBER OF FISH	METRIC TONNES
	A	B	C	D	E	F	G
1967	11,751	19,739	863,351	15,461	181	2,348	37
1968	12,424	22,540	896,889	15,787	163	3,365	62
1969	9,565	15,836	582,862	10,013	43	457	9
1970	14,689	23,688	967,438	16,664	19	471	8
1971	15,887	36,191	1,233,756	19,703	150	519	8
1972	16,814	41,113	1,366,196	22,147	242	2,323	45
1973	17,742	54,692	1,628,583	26,796	81	11	0
1974	17,283	53,573	1,335,934	19,391	340	1,559	42
1975	17,071	38,163	913,221	14,010	441	4,537	109
1976	13,700	39,284	1,152,538	18,742	245	3,148	64
1977	21,932	48,374	1,720,919	25,171	2,160	27,049	551
1978	20,942	34,361	1,348,992	18,738	943	336	6
1979	15,086	29,611	834,390	12,487	666	5,487	111
1980	25,844	69,566	1,900,714	27,287	2,938	11,786	280
1981	14,595	38,080	861,142	12,232	1,584	8,175	191
1982	12,689	26,184	693,155	10,193	173	1,353	36
1983	12,119	17,235	551,791	7,830	60	457	8
1984	11,155	19,781	463,664	6,771	0	0	0
1985	9,601	14,210	418,864	6,095	0	0	0
1986	11,913	11,696	465,767	6,530	0	0	0
1987	15,009	17,139	506,088	7,428	980	0	0
1988	17,120	33,517	953,520	14,056	80	0	0
1989	10,867	37,033	602,165	8,563	2,653	2	0
1990	9,689	34,433	511,066	8,490	2,236	224	4

Table 4 continued

YEAR	SOUTH PACIFIC OCEAN						SOUTH PACIFIC, CORRECTED		
	HOOKS	NUMBER OF FISH	METRIC TONNES	RATIO	CPUE	AVG WT	HOOKS	NUMBER OF FISH	METRIC TONNES
	H = B - E	I = C - F	J = D - G	K = J / D	L = I / H / 10	M = J / I * 1000	N = O / L	O = P / M	P = A * K
1967	19,558	861,003	15,424	0.998	4.40	17.9	148,649	654,398	11,723
1968	22,377	893,524	15,725	0.996	3.99	17.6	176,102	703,183	12,375
1969	15,793	582,405	10,004	0.999	3.69	17.2	150,864	556,347	9,556
1970	23,669	966,967	16,656	1.000	4.09	17.2	208,638	852,363	14,682
1971	36,041	1,233,237	19,695	1.000	3.42	16.0	290,607	994,388	15,881
1972	40,871	1,363,873	22,102	0.998	3.34	16.2	310,293	1,035,452	16,780
1973	54,611	1,628,572	26,796	1.000	2.98	16.5	361,587	1,078,300	17,742
1974	53,233	1,334,375	19,349	0.998	2.51	14.5	474,460	1,189,315	17,246
1975	37,722	908,684	13,901	0.992	2.41	15.3	459,638	1,107,219	16,938
1976	39,039	1,149,390	18,678	0.997	2.94	16.3	285,367	840,179	13,653
1977	46,214	1,693,870	24,620	0.978	3.67	14.5	402,672	1,475,903	21,452
1978	33,418	1,348,656	18,732	1.000	4.04	13.9	373,487	1,507,288	20,935
1979	28,945	828,903	12,376	0.991	2.86	14.9	349,695	1,001,428	14,952
1980	66,628	1,888,928	27,007	0.990	2.84	14.3	631,046	1,789,037	25,579
1981	36,496	852,967	12,041	0.984	2.34	14.1	435,464	1,017,745	14,367
1982	26,011	691,802	10,157	0.996	2.66	14.7	323,804	861,206	12,644
1983	17,175	551,334	7,822	0.999	3.21	14.2	265,829	853,335	12,107
1984	19,781	463,664	6,771	1.000	2.34	14.6	325,885	763,871	11,155
1985	14,210	418,864	6,095	1.000	2.95	14.6	223,840	659,805	9,601
1986	11,696	465,767	6,530	1.000	3.98	14.0	213,376	849,722	11,913
1987	16,159	506,088	7,428	1.000	3.13	14.7	326,508	1,022,600	15,009
1988	33,437	953,520	14,056	1.000	2.85	14.7	407,258	1,161,373	17,120
1989	34,380	602,163	8,563	1.000	1.75	14.2	436,304	764,184	10,867
1990	32,197	510,842	8,486	1.000	1.59	16.6	367,440	582,986	9,684

Table 5. Estimates of albacore landings for Taiwanese distant-water longliners in the Pacific Ocean. Albacore landings (mt) reported by the Taiwan Fisheries Bureau (TFB), by the Tuna Research Center (TRC), the Taiwan Deep Sea Tuna Boatowners and Exporters Association (TA) and by Dr Chien-Hsiung Wang of National Taiwan University are compared. Landings have been published by the Tuna Research Center only for 1980–1993. Sources: TFB 1971–1988 = Wang (1993); TFB 1989–1994 = Taiwan Fisheries Bureau (1990–1995); TFB 1995 = Lu (Overseas Fisheries Development Council, personal communication, September 1996); TRC = Tuna Research Center (1987–1993, 1995); TA = Lu (Overseas Fisheries Development Council, personal communication, September 1996); Wang 1967–1990 = Wang (personal communication, April 1993); Wang 1994 = Wang (personal communication, March 1996); Wang 1995 = Wang (1996).

YEAR	TFB	TRC	TA	Wang
1967				11,751
1968				12,424
1969				9,565
1970				14,689
1971	13,928			15,887
1972	13,666			16,814
1973	28,974			17,742
1974	19,638			17,283
1975	14,580			17,071
1976	18,642			13,700
1977	27,211			21,932
1978	18,617			20,942
1979	16,178			15,086
1980	18,190	18,180		25,844
1981	14,595	14,595		14,595
1982	12,680	12,680		12,689
1983	12,082	12,083		12,119
1984	11,155	11,155		11,155
1985	9,601	9,601		9,601
1986	11,913	11,913		11,913
1987	15,009	15,009		15,009
1988	17,120	17,120		17,120
1989	10,867	10,867		10,867
1990	9,689	9,689	10,837	9,689
1991	15,205	14,030	15,785	
1992	30,404	21,395	21,270	
1993	20,974	21,529	16,260	
1994	22,100		17,034	17,034
1995	19,596		15,201	15,201

Table 6. Comparison of estimates of the albacore catch, for the whole Pacific Ocean, in metric tonnes (TONNES), the albacore catch in thousands of fish (NUMBER) and effort in thousands of hooks (HOOKS) determined from 5° by 5° data based on effort to estimates determined from 5° by 5° data based on landings. The annual conversion factor (RATIO) is also shown.

	EFFORT-BASED 5X5 DATA			LANDINGS-BASED 5X5 DATA			
YEAR	TONNES	NUMBER	HOOKS	TONNES	NUMBER	HOOKS	RATIO
1967	15,368	863	19,725	11,751	660	15,082	0.765
1968	15,786	896	22,539	12,423	705	17,738	0.787
1969	10,013	582	15,835	9,564	556	15,124	0.955
1970	16,886	987	23,009	14,689	859	20,015	0.870
1971	19,734	1,233	36,186	15,886	993	29,132	0.805
1972	22,507	1,366	41,107	16,814	1020	30,708	0.747
1973	26,564	1,628	54,010	17,742	1,087	36,072	0.668
1974	19,705	1,335	53,552	17,283	1,171	46,969	0.877
1975	20,850	1,382	49,858	17,071	1131	40,820	0.819
1976	19,049	1,152	39,284	13,700	828	28,252	0.719
1977	24,927	1,720	48,377	21,932	1,514	42,563	0.880
1978	16,592	1,173	31,073	20,942	1,480	39,218	1.262
1979	12,294	822	29,311	15,086	1,009	35,966	1.227
1980	26,455	1,841	65,033	18,190	1,266	44,716	0.688
1981	12,554	881	39,031	14,595	1,025	45,372	1.162
1982	10,361	702	26,704	12,680	860	32,679	1.224
1983	7,880	556	17,435	12,082	853	26,731	1.533
1984	6,784	465	20,129	11,155	765	33,096	1.644
1985	5,934	411	13,745	9,600	665	22,238	1.618
1986	10,052	728	17,980	11,913	863	21,307	1.185
1987	11,508	773	27,036	15,009	1,008	35,261	1.304
1988	14,055	953	33,517	17,120	1,161	40,824	1.218
1989	8,563	602	37,032	10,867	764	46,995	1.269
1990	8,490	511	34,432	11,625	699	47,146	1.369
1991	9,852	712	39,595	16,529	1,196	66,427	1.678
1992	31,105	2,432	93,406	22,229	1,738	66,750	0.715
1993	21,528	1,673	61,852	18,474	1,436	53,075	0.858
1994	19,796	1,486	54,433	19,809	1,487	54,465	1.001