SC/37/SM12

Incidental Mortality of Dolphins in the Eastern Tropical Pacific Tuna Fishery: Description of a New Method and Estimation of 1984 Mortality

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ABSTRACT

Estimates of dolphin mortality incidental to the tuna purse-seine fishery in the eastern tropical Pacific (ETP) have been made for 1984. Information on mortality per-set and per-ton of tuna caught on dolphins, as well as additional data has been collected by scientific technicians sampling vessels of the international fleet. Sampling coverage in 1984 was 13.0% of all trips that made dolphin sets, accounting for 18.6% of the catch of tuna on dolphins. A new method is briefly described which incorporates a stratification scheme based on the spatio-temporal distribution of the effort and on stock boundaries. The 'bootstrap' statistical technique was used to reduce bias of ratio estimates and to provide non-parametric variance estimates. Observed trips, or fractions of trips, falling within a stratum were used as the resampling units. A combined total mortality was estimated for the international fleet, after verifying that performances of vessels from the United States fleet were not significantly different from those of other sampled fleets in most strata considered. The total estimated mortality was 39,400 (SE = 7,399) using the kill-per-set estimate, and 31,991 (SE = 6,233) using the kill-per-ton estimate. A statistically valid comparison of these figures with those from previous years must be put off until revised estimates with the same methodology are provided. In 1984, there were large increases in fishing effort on dolphins, and on the catch of tuna per set on dolphins. These factors, together with an almost doubling of school sizes of dolphins captured and perhaps a partial loss of a behavioral 'conditioning' of dolphins and/or fishermen after a period of time with reduced fishing effort, are likely to result in higher mortalities. The revision of previous years is under way, as well as an analysis of the effect of fishing effort (historic and current) on dolphin school size and on behavior when captured.

INTRODUCTION

Several species of dolphins are incidentally killed in the tuna fishery of the eastern tropical Pacific (including spotted dolphins, *Stenella attenuata*, eastern and whitebelly stocks of spinner dolphins, *S. longirostris*, common dolphins, *Delphinus delphis*, striped dolphins, *S. coeruleoalba*, and others). Because of the association existing between them and some species of tuna, dolphins are used to detect tuna, and dolphins and tuna are captured together in the purse seines used by the international fleet that operates in these waters (Perrin, 1969).

Mortality has been estimated to be high in the past (e.g. over 500,000 in 1961, Smith, 1983) but in recent years regulations concerning the gear used and the way it is operated (Bratten, 1983; Coe *et al.*, 1984) have significantly reduced mortalities to about 28,000–32,000 in 1982 (Hammond, 1984). However, there remains a concern about the status of the dolphin populations involved. To monitor the impact of the fishery on these populations, research programs were created by the National Marine Fisheries Service (NMFS) of the US government, the Inter-American Tropical Tuna Commission (IATTC) and the US Porpoise Rescue Foundation.

In the case of the NMFS and IATTC research programs, scientific technicians are placed on the fishing vessels, where they record information on catches, kills, etc. The NMFS program samples US flag vessels, while the IATTC program samples the international fleet. This information is processed to provide estimates of mortality and confidence intervals for the different species/stocks involved. Prior to 1979, the NMFS was responsible for estimating dolphin kill (Lo *et al.*, 1982; Smith and Lo, 1983; Smith, 1983). Currently NMFS produces real-time estimates for the US fleet based on radio reports. The IATTC program, which started in 1979, has been producing annual mortality estimates for the international fleet since then (Allen and Goldsmith, 1981, 1982; Hammond and Tsai, 1983; Hammond, 1984; Hammond and Hall, 1985). After the first five years the IATTC program was examined to look for ways to improve these estimates using the information accumulated over those years.

In 1984, the NMFS and IATTC programs combined covered 13% of all trips by the international fleet that made dolphin sets, accounting for 18.6% of the total catch of tuna (yellowfin, *Thunnus albacares* and skipjack, *Katsuwonus pelamis*). Mexican-flag vessels, the largest component of the non-US fleet (approximately 50% of the effort in number of sets, or of the catch in tons) were not sampled in 1984. As a result of this, some extrapolation procedure is required to provide an estimate of the total mortality. Regardless of which approach is used, the lack of data on an important fraction of the fleet is almost certain to cause bias. The magnitude of this bias depends on several factors, perhaps the most important being the degree of difference of the technology and procedures used, and the spatial and temporal distribution of the effort. The Mexican government and the IATTC are, and have been for some time, trying to reach an agreement to start a cooperative program.

MATERIAL AND METHODS

The data used for most analyses are from the NMFS and IATTC observer programs in 1984. The NMFS kindly provided us with an extraction from their data base. The data include, among other things, information on the type of set made (i.e. on dolphins or on a floating object, or on a school of tuna detected by signs on the water surface, etc.), its position, the catch of tuna, and dolphin kill by species. Also the tuna logbook data base of the IATTC was used to estimate total number of sets, totals by type, tons of tuna caught, etc. by area. The data base covered over 94% of the trips made by the international fleet in 1984. For some comparisons, observer data for the period 1979–1984 were used.

Previous method of estimation of total mortality

In previous years, total mortality was estimated using the ratio of the number of dolphins killed per set (or per ton of tuna caught) obtained from observer data and extrapolating to the total number of sets made (or tons caught) by the fleet. These totals were estimated using an algorithm developed by Punsly (1983) that allowed proration of those sets whose type was not known. Another correction was required to account for those logbooks not available in the data base, and this was done by a simple expansion factor: the estimated total of logged sets (or tons) is multiplied by (100/C) where C is the percent coverage. The data were stratified by flag (US and non-US.).

The variance of the estimate was calculated using the formula for the variance of a ratio, and assuming that the estimate for total number of dolphin sets was obtained without error (Hammond and Tsai, 1983). The formula used is adequate if (a) the ratio is nearly normally distributed and (b) the large-sample formula for its variance is valid. As a working rule, the large-sample results may be used if the sample size exceeds 30 and is large enough so that the coefficients of variation of numerator and denominator are both less than 10%. As Cochran (1977) points out 'When these conditions do not apply, the formula for the variance of the ratio tends to give values that are too low and the positive skewness in the distribution of the ratio becomes noticeable'.

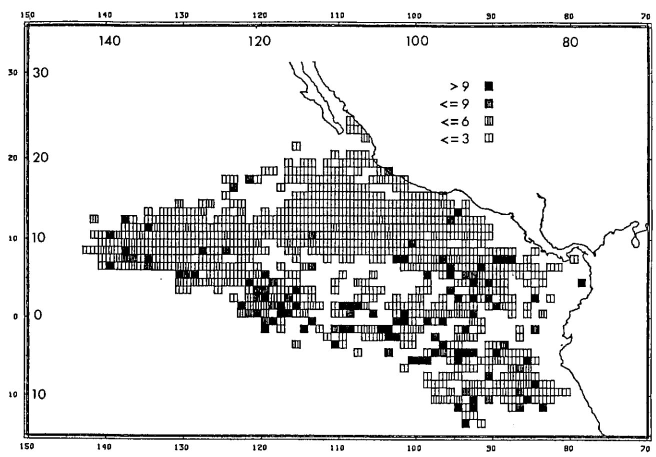

Fig. 1a. Average mortality rate of offshore spotted dolphins per set, in the period 1979–1983, by 1° squares (IATTC and NMFS data).

New method proposed

The method used in the past has some problems:

(a) *Spatial heterogeneity of mortality and mortality rates.* Some species are only vulnerable within limited areas, while others, although vulnerable in the entire region, show differences in mortality rates among areas (Figs 1 and 2). This can be a result of differences in school size among regions, in some environmental factors, or of differences in behavior of dolphins caught in the net. It appears that one of the causes of the latter is the previous history of the area.

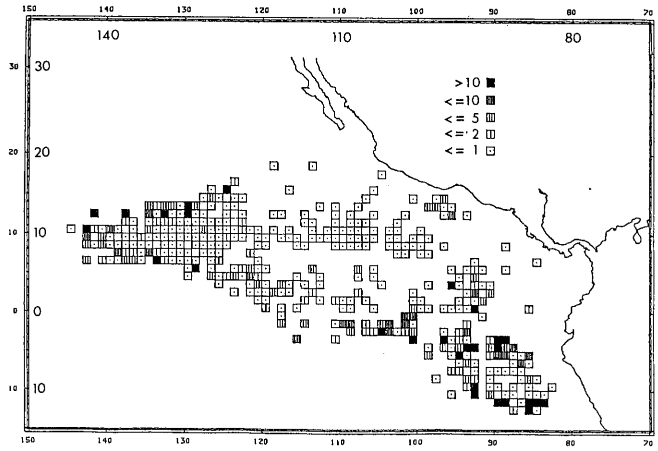

Fig. 1b. Average mortality rate of whitebelly spinner dolphins per set, in the period 1979–1983, by 1° squares (IATTC and NMFS data).

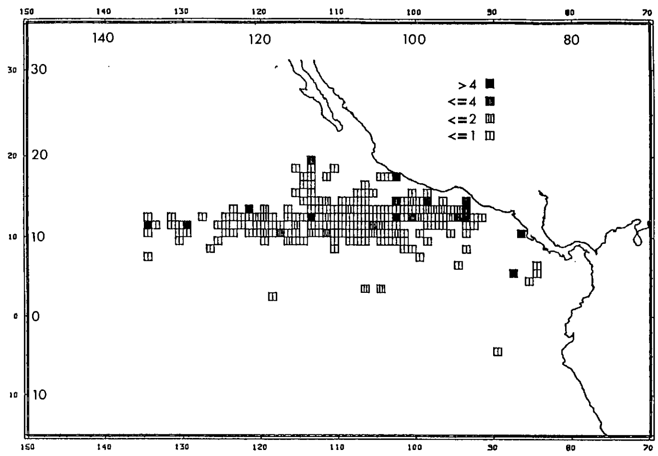

Fig. 2a. Average mortality rate of eastern spinner dolphins per set, in the period 1979–1983, by 1° squares (IATTC and NMFS data).

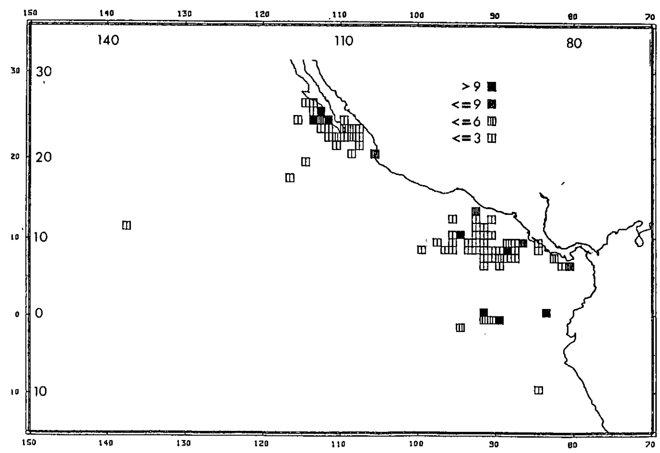

Fig. 2b. Average mortality rate of common dolphins per set, in the period 1979–1983, by 1° squares (IATTC and NMFS data).

In areas with intense fishing effort, dolphins learn to react to capture in a way that reduces their mortality. These sources of heterogeneity are presently being investigated.

(b) *Temporal heterogeneity.* Different areas of the fishery are fished in different periods of the year. For instance, the offshore dolphin area (area 4: Fig. 3a) is heavily fished from June to August; the southern areas

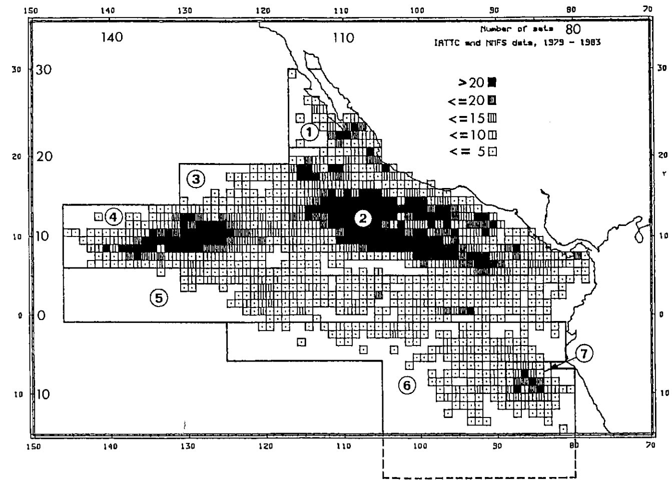

Fig. 3a. Distribution of dolphin sets by 1° square (IATTC and NMFS data, 1979–1983) and original strata for offshore spotted and whitebelly spinner dolphins.

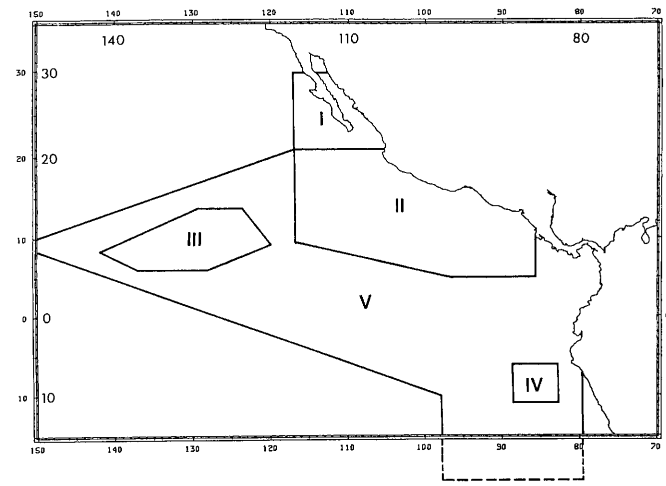

Fig. 3b. Revised stratification used to produce mortality estimates for offshore spotted and whitebelly spinner dolphins.

from November to February; etc. Only the inshore dolphin area (area 2, Fig. 3a) receives some effort during most of the year. Because of this, spatial and temporal effects cannot be separated, and any stratification will reflect that.

(c) *The validity of the variance formula used is questionable.* Some of the assumptions on which it is based are very clearly violated, resulting in an underestimate of the true variance.

(d) *The same procedure was used for all species or stocks involved.* Given the differences observed in Figs 1 and 2, it seems desirable to design methods which take into account the peculiarities of each species or stock.

As a result of the experience and data accumulated over the past five years, some improvements can be made to the estimation methods.

Area of vulnerability

The spatial distribution of dolphin mortality was studied by grouping the results for quadrats of 1° × 1°. The average kill per set over the period 1979–1983 obtained from the observer program was used to indicate the relative mortality rate of each quadrat. Figs 1 and 2 show the results for some of the species or stocks involved. It is clear that for some species there exists one or a few well-defined areas in which most of the mortality takes place. This area is in some cases much smaller than their geographical range and the analysis could be limited to where mortality actually occurs. As the estimation of variance depends in part on the total number of sets or tons involved, a reduction of variance could be achieved in this way.

It is necessary to define objectively the 'area of vulnerability'. Basically the idea was to enclose an area containing a significant portion of the total mortality of a species and to obtain for it the best possible estimates of ratios and variances. This significant proportion was arbitrarily selected to be 90%, trying to reduce the possible error outside, while providing a reasonably large sample size inside. The figures obtained for this area can then be extrapolated to the remainder by means of a correction factor. This correction factor was computed simply by calculating the proportion of the observed kill that occurred outside with respect to inside. Its variance can be estimated using a parametric formula for a proportion or, as was done in this case, it can be included in the bootstrap technique described later.

Where such an area of vulnerability exists, the procedure was the following:

(1) core areas, defined as blocks of contiguous quadrats containing a large majority of the mortality, were identified visually in Figs 1 and 2.

(2) While all contiguous quadrats were included as a part of the core area, the number of empty quadrats enclosed was minimized.

(3) Other quadrats with high values, or groups of two or more adjacent quadrats with any value different from zero and separated from the core by only one or two blank spaces, were also joined.

(4)The program used was EVOLVE (Wahlen and Boyer, 1981). This program allocates individual records with a geographical position to strata which have previously been defined by the vertices of polygons enclosing them. It identifies the records with a stratum number and can provide different statistics for each of them. In this case, it summarizes information by cruise and produces totals of sets and tons for each stratum.

If it were not possible to define an area including such a large proportion of the total mortality, it would still be profitable to attempt to stratify spatially, separating the zones of different mortality rates. In this case, the estimation should be based on a simple stratified sampling design. Fig. 3a shows the seven-strata scheme used for the offshore spotted and whitebelly spinner dolphins to compare fleet performances, changes in school size, etc. For the purposes of mortality estimation several spatial stratification schemes were tested. The five-strata scheme shown in Fig. 3b proved to be the best, and was used to produce the mortality estimates in Table 2. The main differences with 3a are the elimination of strata with small samples at the expense of discrimination between northern and southern stocks. Overall, the statistical gains in simplification and precision seem to justify its use for mortality estimation. Arabic numerals are used to refer to strata in 3a; roman numerals for those in 3b. Fig. 4 a–b shows the strata used for eastern spinner and common dolphins.

The eastern spinner stock shows a single area of vulnerability, while common dolphins have three areas of mortality which correspond to the geographical distribution of the stocks (Perrin *et al.*, 1985). If enough data were available, separate estimates could be made, but for 1984 the only area with mortality was the central one, so the estimate refers to it.

The stratification for offshore spotted and whitebelly spinner dolphins is based on the distribution of cumulative fishing effort in the last five years. Strata 2, 4, and 7 correspond to areas with high historical effort; strata 5 and 6 are southern areas with low effort, the separation between them roughly coinciding with stock boundaries for both species. Stratum 1 is the Baja California area, with very little observer effort and a high concentration of Mexican fishing effort. Stratum 3 has had very little historical effort.

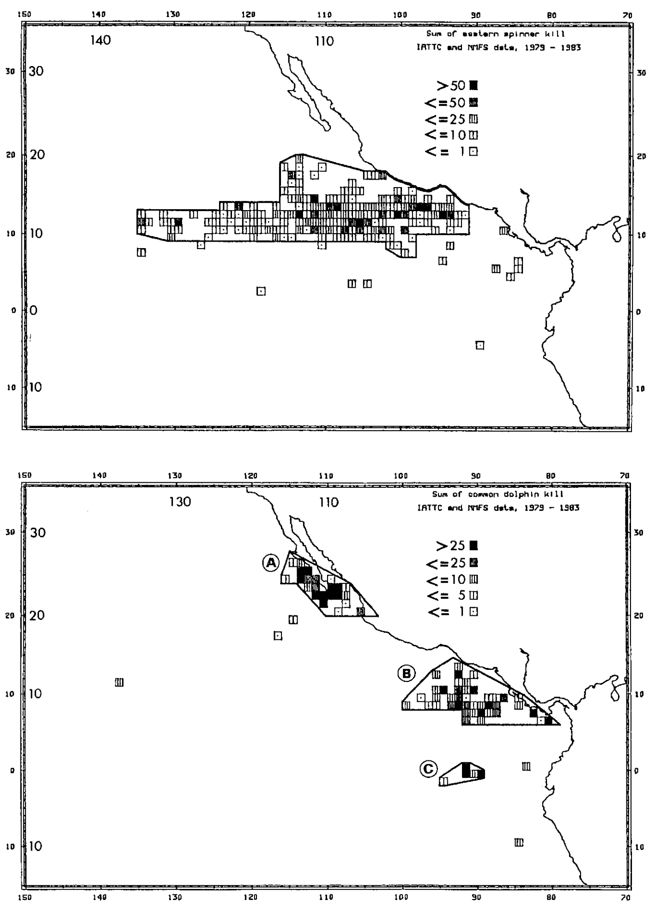

Fig. 4. Areas of vulnerability of eastern spinner (a) and common dolphins (b).

The entire stratification scheme is preliminary in nature, and different alternatives will be considered prior to the revision of past years' data. At the same time, the scheme must retain some flexibility to compensate if dolphin ranges contract or expand, or if the fishery does so. Besides the known statistical advantages of stratification, this method would provide a better basis to compare performances among years or fleets.

Estimation of number of sets (or tons) for extrapolation
In the past, an algorithm by Punsly (1983) has been used to estimate the total number of dolphin sets. The approach is based on the utilization of information from nearest sets in time and in space to determine in a probabilistic way the type of set for those sets which are not specified as a dolphin or non-dolphin set in the logbooks. With the definition of different areas of vulnerability for the different species or stocks involved, it becomes difficult to continue using the same approach. From a logistic point of view, this requires the estimation of the number of dolphin sets in too many areas, some of which are small (e.g. common dolphin in Fig. 2). At the same time, the proportion of unidentified sets in the logbooks has been declining steadily and currently amounts to less than 2% of the total number of sets. For these reasons, an alternative method is used to estimate the number of sets on the species or stock involved in each stratum. We have four categories of sets that may have been made on dolphins:

(i) sets identified as sets on species *i* in the logbooks (specific dolphin sets);
(ii) sets only identified as dolphin sets without reference to any species (generic dolphin sets);
(iii) sets with type not identified (unidentified sets)—it is unknown whether the set was made on dolphins or not;
(iv) unlogged sets not recorded in our database (unlogged sets).

To handle these sources the following methods have been used:

Source (i) Unlike the observer data, the identification of the species or stock in the logbook is made by an individual who has not been trained by the NMFS or IATTC observer programs and is not supported by sketches, descriptions, or specimens. In these cases it was decided to preserve the standardization and use a more generic identification to set type. An additional problem would have been created by the fact that most logbooks only specify a few species or stocks, and combine others (e.g. 'spinners') so it was not possible to match the identifications when they were present. All dolphin sets were combined in a single class, disregarding the specific identification, and included in the next group (ii).
Source (ii) those sets identified as dolphin sets in the logbooks (S_D).
Source (iii) The unidentified sets in the logbooks (S_U) are prorated using the proportion of sets on dolphins (S_D) over all sets of all types (S_A) in the data base for the same area:

$$S_X = S_U \frac{S_D}{S_A}$$

where

S_X = number of unidentified sets prorated as dolphin sets.
Source (iv) To estimate the number of unlogged dolphin sets, we use the number of logged sets and the percentage of trips covered in our logbook data base (C). We expand the number of logged sets multiplying by a factor (100/C).

$$S_T = S_D \left(1 + \frac{S_U}{S_A}\right) \frac{100}{C}$$

where S_T = estimated total number of dolphin sets for the stratum.

Estimation of the ratios kill-per-set and kill-per-ton
Ratio estimates are known to be biased when sample sizes are low (Cochran, 1977). Several solutions have been proposed to try to compensate for this problem. One possibility is to use a formula with a built-in adjustment. Another is to use some resampling technique to reduce the bias. A simulation method was used to compare the biases of these alternatives. Besides the traditional formula, those proposed by Tin, Beale, Mickey, Hartley-Ross and Pascual were considered, as well as a 'jackknife' and a

'bootstrap' approach using the traditional formula. Rao (1969) compares the properties of these formulas in a more general context. The bootstrap and the jackknife are two methods to reduce bias that at the same time provide a non-parametric estimate of variance. In both cases the samples are used repeatedly. Details of the techniques can be found in Efron (1981).

Three years of the data base were used separately to give an idea of inter-annual variability in the observed distributions. Random samples were taken from the data base generating 1,000 replicates at each of 14 preselected sampling levels. Four main ratios (spotted and eastern spinner dolphins using both kill-per-set and kill-per-ton methods) were computed with the eight different formulas mentioned above. The detailed results are beyond the scope of this paper, but in a first round of comparisons three were selected because of their clearly superior performance (Pascual, Hartley-Ross and bootstrap). In a second round, the bootstrap method was also applied to the other two formulas. The results in this round were not so clear as before. They were not consistent for different years or ratios, but it was clear that (a) bootstrap estimators are better than the others, (b) the differences between the three cases in the second round are quite small, and disappear at fairly low sample sizes and (c) the biases of all of them are quite acceptable (only a few cases over 10% at the lowest sample size tested, n = 5; most cases being less than 5%). The variances were also compared, the results between the three cases being quite similar. The same simulations were performed on the spatially stratified data. The Pascual estimator (Rao, 1969) gave the best results in this case.

Based on these results, the bootstrap version of the Pascual estimator was used. Observer trips (or fractions of them) that fell inside a stratum were considered the resampling units. They were sampled with replacement to obtain 1,000 replicates, from which the ratio, and also the variance were estimated. The advantages of the method are quite clear with respect to bias reduction, and it appears that the non-parametric variance estimate is more realistic than the traditional one. It also allows the simultaneous handling of several terms in a formula (i.e. the kill ratio and the correction factor). The possibility of using Monte Carlo confidence intervals (Buckland, 1984) should also be listed as a significant advantage, and it is being considered in this case. The main disadvantage is the amount of computer time it requires. From a non-statistical point of view, the stochastic element present in the calculation results in different figures in repeated runs of the same process, which may cause problems in the application of the results, but with a high number of replicates (i.e. 1,000) that variability was reduced to less than 3%.

The kill-per-set and kill-per-ton estimates were obtained for each stratum using observer data for all trips making at least one set inside it. Several cases had to be considered.

(a) If a species is vulnerable throughout the whole area of study, but there were spatial differences in mortality rates, then mortalities were estimated for all strata separately. The corresponding mortality rate and number of sets were used to obtain bootstrap estimates of the total and its variance.

(b) If a species was vulnerable throughout the whole area of study, but no clear pattern appeared, or the number of cases was not enough for more detailed consideration, then we considered the whole area as a stratum, as in the traditional method. We still used bootstrap methods for the estimates.

(c) If a species was vulnerable only in a restricted area (or areas) then we obtained an estimate for that area as described before, and extended the process to the outside stratum using a correction factor (second term in equation below. The total mortality was estimated as:

$$\hat{K} = ((\frac{k_i}{s_{d_i}}) S_{T_i}) (1 + \frac{k_o}{k_i})$$

where
the sub-index *i* means inside the area of vulnerability while *o* means outside.

k = observed kill of the species in question.
s_d = observed dolphin sets.
S_T = total number of dolphin sets for logbook data.
$\hat{K}$ = estimated total kill.

In this case the bootstrap process included all terms except S_{T_i}.

The estimate of the kill per set, the variance and the correction factor were all calculated by bootstrapping observer trips. Arbitrarily, we have set a limit for the application of this method: if the mortality outside the area of vulnerability exceeded 10%, then the correction factor was not used, and one more additional strata was generated.

(d) Unidentified spinner dolphins. In this case, the area of vulnerability of the eastern spinner dolphins was used, and the kill of unidentified spinner dolphins inside and outside was prorated according to the proportions of eastern and whitebelly spinners in the observed kill.

The first step was to estimate the mortality of unidentified spinners inside and outside, in the same way it was done for the eastern spinner dolphins. K_i and K_o were obtained, and then prorated such that

$$K_{ea.i} = K_i (\frac{k_{ea.i}}{k_{ea.i} + k_{wb.i}})$$

$$K_{wb.i} = K_i (\frac{k_{wb.i}}{k_{ea.i} + k_{wb.i}})$$

$$K_{ea.o} = K_o (\frac{k_{ea.o}}{k_{ea.o} + k_{wb.o}})$$

$$K_{wb.o} = K_o (\frac{k_{wb.o}}{k_{ea.o} + k_{wb.o}})$$

where ea = eastern spinner dolphin
wb = whitebelly spinner dolphin
i = inside eastern spinner area of vulnerability
o = outside
K = estimated kill
k = observed kill

In this case, the terms used in the proration, were also included in the bootstrap.

Pooling over the international fleet

In previous years, IATTC estimates of mortality for the international fleet have been stratified by flag in US and non-US fleets because of differences in sampling intensity and regulations (Allen and Goldsmith, 1982). In recent years, an increase in the number of vessels operating from southern ports (Manta, Ecuador; Cumana, Venezuela; and Panama, Panama) has made evident the need for some kind of spatial stratification as has been mentioned before. Conditions in the southern section of the ETP (i.e. school sizes, catch per set, dolphin behavior, mortality rates, stocks, environmental factors, etc.) are quite different from those prevailing in the north. In addition the western areas, at the fringes of the fishery, are different from the more inshore core areas.

The number of samples available in area-time-flag strata was not enough to retain the flag stratification at the same time that the other was developed, and a choice had to be made. This problem is compounded by the lack of Mexican samples mentioned earlier. There were two alternatives: (1) extrapolate the values of the sampled non-US fleet (about 90% of its total effort south of the Equator, in areas 5, 6 and 7, Fig. 3a) to Mexican vessels that fish in the northern section (about 90% of their total effort in areas 1 and 2, same figure), or (2) extrapolate to the Mexican fleet values from other vessels fishing in the same area, regardless of flag.

To choose between the two approaches, the performances of vessels from different flags (US and non-US) were compared for the period 1979–1984, pooling over years, but using the spatial strata suggested in Fig. 3a. Six of the seven strata had matched data that could be used. A group of US-flag vessels operating under a bare-boat charter to non-US companies from South American ports was not included because of their somewhat ambiguous character. Three variables were used for the comparison: kill-per-set, kill-per-ton and the proportion of those dolphins captured that are killed. Of these, the second adjusted for catch size, whereas the third corrected for school size. As sample sizes were slightly different, mainly because of missing values in the capture data, two data sets were used. Data set A contained all sets with complete records of kill and tons (the vast majority); data set B contained only those records with complete capture data (between 90–95% of the total). The variable kill-per-set was used in both cases to provide a common ground for the comparison. The results show (Table 1) that there is a highly significant difference in Area 2 that is consistent for all variables and tests (better performance of the US fleet). In Area 5 the Mann-Whitney test shows a significant difference at the 5% level for kill-per-set in data set A. (In this case the performance of the non-US fleet is better). All other comparisons, including those coming for the adjusted variables show no significant differences, and most p-values are quite far from the limits. The observer data from non-US vessels show that the gear and the procedures used are quite similar to those employed by the US fleet. Sample sizes are not as high as desirable in some areas but, up to this point, pooling over flags seems more reasonable than pooling over geographical areas and ignoring the differences mentioned earlier. At the same time, a spatial stratification provides a better frame for handling changes in the distribution of fishing effort, avoiding the confusion of changes in area of operations with real changes in performance, in school sizes encountered, etc. The problem of uncertainty concerning Mexican vessels' performance is limited to areas 1 and 2; in these areas, however, the problem is serious.

Table 1

Comparison of performance of US versus non-US fleets, 1979–83 combined. Charters were excluded. Kill-per-set and kill-per-ton were calculated on an individual set basis. Proportion killed is the percent of those animals captured that are subsequently killed. All tests were performed on two data sets: one that includes all sets (Data set A) and another that excludes the cases where the number captured was unknown or the kill was zero (Data set B) to avoid division by zero in proportion killed. Median and Mann-Whitney tests were used. The area numbers correspond to those of Fig. 3. Area was excluded because of lack of non-US sets

	Data set A		Data set B	
Area	Kill/set	Kill/ton	Proportion killed	Kill/set
Median test				
1	p = 0.280	p = 0.602	p = 0.168	p = 0.534
2	p < 0.001	p < 0.001	p < 0.001	p < 0.001
4	p = 0.701	p = 0.821	p = 0.677	p = 0.753
5	p = 0.271	p = 0.262	p = 0.835	p = 0.692
6	p = 0.982	p = 0.812	p = 0.133	p = 0.923
7	p = 0.973	p = 0.976	p = 0.637	p = 0.949
Mann-Whitney test (2-tailed p)				
1	p = 0.100	p = 0.725	p = 0.070	p = 0.337
2	p < 0.001	p < 0.001	p < 0.001	p < 0.001
4	p = 0.689	p = 0.624	p = 0.284	p = 0.742
5	p < 0.05	p = 0.566	p = 0.166	p = 0.963
6	p = 0.856	p = 0.457	p = 0.144	p = 0.775
7	p = 0.661	p = 0.785	p = 0.154	p = 0.682
	US	Non-US	US	Non-US
Sample sizes				
1	307	15	232	14
2	6,574	121	6,164	105
4	2,450	31	2,413	31
5	868	139	802	105
6	499	152	493	149
7	251	82	250	82
Totals	10,949	540	10,354	486
	11,489		10,840	

RESULTS AND CONCLUSIONS

The estimates for 1984 are shown in Table 2. While comparisons between methods cannot be safely made, and the revised figures for previous years are needed for that purpose, there are some features of the data and the fishery in 1984 that deserve mention.

Table 2

Mortality estimates for 1984

Species or stock	Mortality estimate (based on kill/set)	SE	Mortality estimate (based on kill/ton)	SE
Offshore spotted dolphins	16,352	2,887	12,869	2,242
Eastern spinner dolphins	5,263	2,330	4,848	2,268
Whitebelly spinner dolphins	10,094	4,739	7,279	3,266
Common dolphins	6,441	4,197	5,849	4,147
Unidentified spinners				
Prorated as eastern spinners	957	938	908	130
Prorated as whitebelly spinners	137	153	889	146
Other dolphins	157	72	108	49
All species	39,400	7,399	32,750	6,171

Two trips with novice skippers had very high kills that accounted for 42% of the observed mortality. These trips include one set on common dolphins which caused 98% of the observed mortality of the species.

The economic conditions prevailing caused a major shift in the effort to fishing on dolphins, which resulted in catches of the best priced fish. Using only observer data, the overall averages were 19.0 tons per set in 1984 versus

11.1 in 1983. Areas 2 and 6 practically doubled the 1983 figures, while Areas 4 and 5 experienced increases of close to 50%. Large tuna catches are directly or indirectly (i.e. because of longer sets) associated with higher dolphin mortality.

It is also possible that with the return to the eastern Pacific of part of the fleet that previously operated in the western Pacific, both fishermen and dolphins may have needed to re-learn the behavioral pattern developed in the fishery after a lower effort in previous years. There is some evidence to suggest that mortality rates are lower in the area of the fishery where effort is more intense (see Figs 1 and 3) and this may be a result of a mutual adaptation between dolphins and fishermen. Another possible explanation with some support is the fact that school sizes are lower in the area with more fishing effort, perhaps as a consequence of it.

The number of sets on dolphins and the amount of tuna caught on dolphins increased significantly, and their impact on the estimates is direct. Another variable of interest, size of dolphin school captured, also increased; the overall mean went from 470 in 1983 to 599 in 1984. Area 2 went from 262 to 394; Area 4 had the largest change, from 533 to 940, and Area 6 showed the only decrease (771 to 603). This encouraging increase in school size may have been brought about by the reduced effort in previous years. Information on other variables is required to interpret this correctly.

These hypotheses are being considered at the present time, and a more formal treatment is forthcoming.

ACKNOWLEDGEMENTS

We thank N. Lo, T. Smith and I. Barrett, (NMFS, Southwest Fisheries Center) and Frank Alverson, (U.S. Porpoise Rescue Foundation) for critical review of the manuscript. The above mentioned, plus B. Wahlen and G. Sakagawa (NMFS) and D. G. Chapman (Marine Mammal Commission) are also thanked for valuable suggestions that led to improvements in the manuscript and further testing of the method.

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