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Dolphin Mortality Incidental to Purse-Seining for Tunas in the Eastern Tropical Pacific, 1982

P. S. Hammond

Inter-American Tropical Tuna Commission, La Jolla, California, USA

ABSTRACT

Estimates of dolpin mortality incidental to purse-seining for tunas in the eastern tropical Pacific have been made using data collected by scientific technicians aboard seiners of the international fleet during 1982. The data were analysed using a kill-per-set and a kill-per-ton estimator. Approximately 32% of all sets made on tuna associated with dolphins were sampled. The estimate of total mortality for the US registered fleet was 23,300 using kill-per-set and 23,900 using kill-per-ton. These estimates are higher, but not significantly, than estimates made for the previous three years. The estimate of non-US mortality was 5,500 using kill-per-set and 4,400 using kill-per-ton. These estimates are much lower than those for 1980 and 1981 but about the same as those for 1979. Overall mortality for 1982 was estimated to be 28,300–31,700 (range of point estimates) depending upon estimator and whether or not the data were stratified by US/non-US flag of registry.

INTRODUCTION

The objectives of the tuna-dolphin investigation of the Inter-American Tropical Tuna Commission (IATTC) are to maintain a high catch of tuna whilst reducing incidental dolphin mortality and ensuring the survival of all dolphin stocks involved in the purse-seine fishery for tunas, primarily yellowfin tuna (*Thunnus albacares*), in the eastern tropical Pacific. Each year since 1979 the staff of the IATTC have calculated estimates of dolphin mortality incidental to purse-seining operations for various species groupings of dolphins. This paper is the fourth in a series of publications (Allen and Goldsmith, 1981, 1982; Hammond and Tsai, 1983) in which such estimates have been presented.

DATA

The data analysed in this paper were collected aboard tuna purse-seiners by scientific technicians from the IATTC, which samples the international fleet, and the US National Marine Fisheries Service (NMFS), which samples the US registered fleet. The data include, for each net set on tuna associated with dolphins (dolphin set), the tonnage of tuna brought aboard and the observed number of dolphins known to have been killed, by species. Injured animals, which may have died later, were excluded, as were a small number of animals killed in sets made on tuna not associated with dolphins.

Table 1 shows those countries whose registered vessels made dolphin sets according to IATTC records and the number of trips which made dolphin sets sampled by the IATTC and the US NMFS in 1982. For IATTC data, the sets in trips which overlap years are assigned to the year in which they were made so that these trips are present in the samples for both years. For US NMFS data, all the sets in overlapping trips are assigned to a particular year so that some sets in a yearly sample were not made in that year. This should have a negligible effect on mortality estimates. Table 2 shows the sample and total number of dolphin sets, tons of tuna caught in dolphin sets and number of trips making dolphin sets for the US and non-US fleets. The totals were calculated from IATTC records, which cover a high (and known) proportion of the international fleet. Table 3 shows a summary of the observed dolphin mortality by species grouping for the US and non-US fleets.

Table 1

Countries whose registered vessels made dolphin sets during 1982 according to IATTC records and the number of sampled trips which made dolphin sets in 1982.

Country	Number of trips sampled
British Grand Cayman Islands	1
Ecuador	0
Mexico	0
Panama	5
Salvador	0
Spain	0
United States of America	43 (+29 US NMFS)
Venezuela	2
Total	51 (+ 29 US NMFS)

METHODS

All the dolphin sets in each trip were treated as a cluster sample (Cochran, 1977) under the assumption that the variation in kill rates within trips is less than the variation among trips. Total kill was estimated using a ratio

Table 2

Total and sampled numbers of trips which made dolphin sets, dolphin sets and tons of tuna caught in dolphin sets for the US and non-US fleets in 1982. Totals were calculated from IATTC records.

	US			Non-US		
	Sampled	Total	Coverage	Sampled	Total	Coverage
Trips which made dolphin sets	72	213	33.8%	8	105	7.6%
Dolphin sets	1,828	4,568	40.0%	163	1,881	8.7%
Tons of tuna caught in dolphin sets	19,828	50,891	39.0%	2,197	20,379	10.8%

Table 3

Observed dolphin mortality by species grouping for the sampled trips of the US and non-US fleets in 1982.

Fleet	Offshore spotted	Eastern spinner	Whitebelly spinner	Unident. spinner	Common	Striped	Other + Unident.	Total
US	6,294	770	1,602	39	167	190	249	9,311
non-US	362	42	38	0	10	11	15	478

estimator for the sample trips multiplied by independent data for the entire fleet. Figure 1 shows the relationship between total kill and sets and between total kill and tons for all sampled trips in 1982. Regressions constrained through the origin give r^2 values of 0.25 for kill on sets and 0.36 for kill on tons. Thus, a kill-per-ton ratio estimator should describe kill better than should a kill-per-set estimator. Values of r^2 are similar for the two regressions when the kill data are restricted to offshore spotted dolphins. Stratifying by fleet (US/non-US) gives similar r^2 values for regressions of the US data but r^2 values of 0.31 and 0.32 for the non-US data, indicating that the kill-per-set and the kill-per-ton estimators should describe the kill equally well for the non-US fleet.

The kill-per-ton estimator is given by

$$\hat{R}_j = \frac{\sum_{i=1}^{n} k_{ij}}{\sum_{i=1}^{n} t_i}$$

where k_{ij} is the number of dolphins of species j killed in trip i, t_i is the number of tons caught in dolphin sets in trip i and n is the number of sampled trips which made dolphin sets.

The total number of dolphins killed is then given by

$$\hat{K}_j = \hat{R}_j T$$

where T is the total tons of tuna caught in dolphin sets in all trips, with variance

$$\text{var}(\hat{K}_j) = \frac{N(N-n)}{n(n-1)} \left(\sum_{i=1}^{n} k_{ij}^2 + \hat{R}_j^2 \sum_{i=1}^{n} t_i^2 - 2\hat{R}_j \sum_{i=1}^{n} k_{ij} t_i \right)$$

where N is the total number of trips which made dolphin sets. The total tons of tuna, T, has been treated as a constant whereas, in fact, it has been calculated by multiplying mean tons caught per set, for sets identified as dolphin sets in IATTC records, by the total number of dolphin sets estimated from the same data. The calculated variances of total mortality are therefore underestimated, although the variance of T is probably small compared to the variance of the estimated R_j. The kill-per-set ratio estimator is calculated in the same way by substituting sets for tons in the above equations. The total number of dolphin sets was also treated as constant although it has been estimated from IATTC records.

In the following analyses, the mortality data were stratified into those collected aboard US registered vessels and those collected aboard non-US registered vessels. This was because of differences in sampling intensity (Table 2) and the possibility that rates of mortality may have differed. For comparison, estimates were also made using the unstratified data. The data were stratified by species of dolphin because of differences in the rates of mortality amongst those species involved in tuna purse-seining operations (Table 3).

The data were not stratified by the number of sets made per trip nor by the number of tons of tuna caught. Hammond and Tsai (1983) investigated the effects of this and found little justification for it. Neither were they stratified by area because of the problems of including trips in more than one stratum.

RESULTS AND DISCUSSION

Table 4 presents estimates of mortality for 1982 with standard errors in parenthesis for each species grouping for the kill-per-set and kill-per-ton estimators. Estimates are given for the US registered fleet, the non-US registered fleet, the US and non-US strata combined and the unstratified (by flag of registry) data.

The results for 1982 show that there are no significant differences in estimates of mortality between the kill-per-

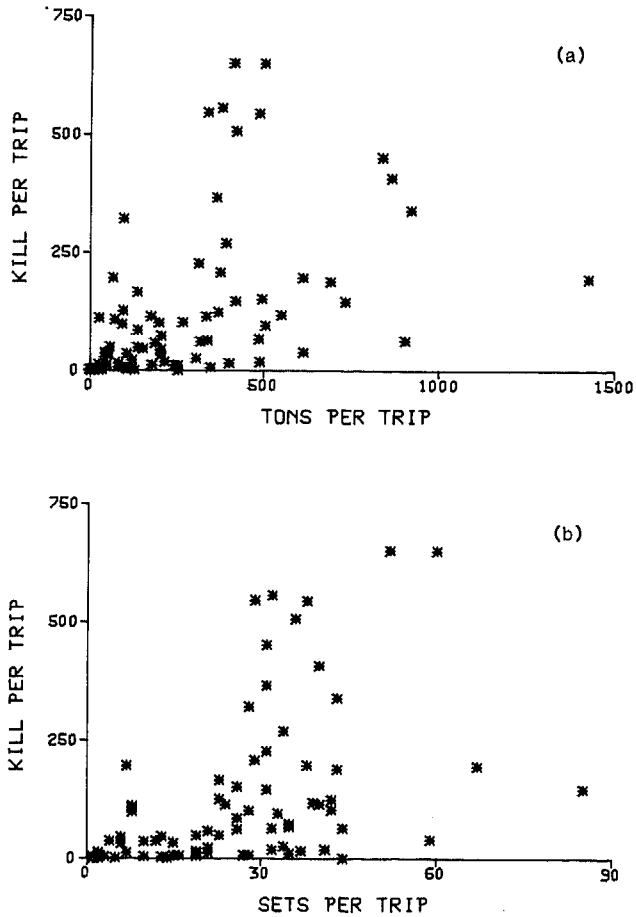

Fig. 1. The relationship between dolphin kill and (a) tons of tuna caught in dolphin sets and (b) dolphin sets. Each point represents one sampled trip.

Table 4

Estimates of mortality for 1982, with standard errors in parentheses, for (a) the kill-per-set estimator and (b) the kill-per-ton estimator

Species grouping	US fleet		Non-US fleets		US + Non-US fleets		All fleets unstratified	
(a) KILL-PER-SET ESTIMATOR								
Offshore spotted	15,728	(2,174)	4,177	(2,619)	19,905	(3,404)	21,559	(3,183)
Eastern spinner	1,924	(747)	485	(298)	2,409	(804)	2,630	(1,070)
Whitebelly spinner	4,003	(907)	439	(246)	4,442	(940)	5,312	(1,304)
Unidentified spinner	98	(60)	0	—	98	(60)	126	(86)
Common	417	(189)	115	(126)	532	(227)	573	(272)
Striped	475	(424)	127	(120)	602	(441)	651	(606)
Others + unidentified	622	(243)	173	(129)	795	(275)	855	(348)
All species	23,267	(2,527)	5,516	(2,656)	28,783	(3,666)	31,707	(3,681)
(b) KILL-PER-TON ESTIMATOR								
Offshore spotted	16,154	(2,077)	3,358	(2,962)	19,512	(3,618)	21,538	(3,111)
Eastern spinner	1,976	(769)	390	(298)	2,366	(825)	2,628	(1,101)
Whitebelly spinner	4,112	(923)	353	(296)	4,465	(969)	5,307	(1,334)
Unidentified spinner	100	(62)	0	—	100	(62)	126	(88)
Common	429	(198)	93	(132)	522	(238)	573	(285)
Striped	488	(429)	102	(97)	590	(440)	650	(613)
Others + unidentified	639	(244)	139	(145)	778	(284)	854	(352)
All species	23,898	(2,458)	4,434	(3,000)	28,332	(3,878)	31,676	(3,641)

set and the kill-per-ton estimators for any species grouping. The kill-per-ton estimator gives more precise estimates for the US fleet with coefficients of variation of 13% for offshore spotted dolphins, 39% for eastern spinner dolphins, 22% for whitebelly spinner dolphins, 46% for common dolphins and 10% for total mortality, and for the unstratified estimates with coefficients of variation of 14%, 39%, 22%, 46% and 10%, respectively. The kill-per-set estimator gives more precise estimates for the non-US fleets but only for total mortality is the coefficient of variation less than 50%.

As in previous years, if the data are stratified into US and non-US there are considerable differences in the precision of the estimates between the two strata. Precision is acceptable for the US estimates but not for the non-US estimates. If the data are not stratified, the precision of the overall estimates is acceptable. The combined stratified estimates are similar in magnitude and precision to the unstratified estimates.

The US estimates are higher for 1982 than for any of the three previous years. Estimates of total annual mortality varied only slightly from about 16,000–19,000, depending upon estimator and year, between 1979 and 1981 (Hammond and Tsai, 1983). In 1982, total mortality is estimated to be approximately 23,000 using kill-per-set and 24,000 using kill-per-ton. The kill-per-ton estimate is probably better than the kill-per-set estimate by virtue of the higher correlation between kill and tons and the lower coefficient of variation.

The non-US estimates are lower for 1982 than for 1980 and 1981 but about the same as for 1979. Estimates of total annual mortality varied between 4,000 (kill-per-ton) and 6,500 (kill-per-set) in 1979 and between 16,500 and 31,000 in 1980 and 1981 depending upon year and estimator (Hammond and Tsai, 1983) although coefficients of variation are high in all cases due to the small samples available for analysis. The fluctuation in estimates of non-US mortality is probably also largely a function of small sample size rather than a reflection of actual changes in annual mortality.

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