OBSERVER EFFECT ON INCIDENTAL DOLPHIN MORTALITY IN THE EASTERN TROPICAL PACIFIC TUNA FISHERY

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ABSTRACT

Scientific observers placed aboard a sample of purse seine vessels collect data that are used to estimate the total number of dolphins killed incidentally in the eastern tropical Pacific tuna fishery. If the presence of these observers, who are not crew members, affects incidental kill levels, then the kill estimates will be biased. To test for the existence of such an observer effect, we compared dolphin kill data that had been recorded by observers who differed in levels of obtrusiveness according to their purposes for data collection. Some observers were placed on board primarily to collect data for estimating the total number of dolphins killed annually. Other observers collected data both for that purpose and for monitoring compliance with dolphin-release regulations. Our results confirm that the presence of an observer does affect dolphin kill. The primary effect is an increase in the proportion of sets with no dolphins killed, and a decrease in the proportion of sets with one to nine dolphins killed. While the magnitude of the effect of observers cannot be estimated from our data, estimates of total dolphin mortality based on data collected by the scientific observers are biased downward.

Schools of dolphins of several species, primarily *Stenella attenuata* and *S. longirostris*, have been used since the late 1950s by purse seine fishermen in the eastern tropical Pacific Ocean (ETP) to locate and catch yellowfin tuna, *Thunnus albacares*. Perrin (1969) described the process of deploying, or setting, the net around the tuna and dolphins, and then releasing the dolphins while retaining the tuna. Significant numbers of dolphins have been killed incidentally in this fishery by becoming entangled in the purse seines (Smith 1983).

The National Marine Fisheries Service (NMFS) and the Inter-American Tropical Tuna Commission (IATTC) place scientific observers who are not crew members aboard a sample of tuna purse seine vessels to collect data related to dolphin kill. Both the NMFS and IATTC have used the data collected by these scientific observers to estimate the total number of dolphins killed annually by the entire tuna purse seine fleet (Lo et al. 1982; Hammond and Tsai 1983).

Additionally, the NMFS uses these data to monitor dolphin kills relative to annual kill limits established for the U.S. registered fleet (Lo et al. 1982). Periodic estimates of the cumulative numbers of dolphins killed are compared with the annual limit. If the limit is exceeded, U.S. vessels must stop fishing on the affected populations for the remainder of the year.

Data collected by the NMFS observers have also been used to monitor compliance of vessel operators with dolphin-release regulations, including the release of all live dolphins from the net (Federal Register 1977, 1980). Until recently, data collected by an NMFS observer could be used as evidence to prosecute vessel operators for violations of these regulations.

Observer effects have been defined in a general context as measurement procedures which influence and thereby change the behavior of the subject (Johnson and Bolstad 1973, p. 38). Researchers have encountered such effects in a variety of empirical sciences, including psychology (Johnson and Bolstad 1973), social science (Webb et al. 1966, p. 18), and biology (Ricker 1975, p. 87).

We defined an observer effect on the number of dolphins killed as a differential in levels of dolphin kill between trips made with and without a scientific observer. The existence of such a differential would introduce a bias into estimates of the total number of dolphins killed (Smith 1983; Powers[3]). Large numbers of sets involving dolphins (dolphin sets) are made each year (Punsly 1983), so even a moderate observer effect could result in a substan-

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[3] Powers, J. E. 1979. A discussion of incidental mortality by unobserved United States purse seiners. Unpubl. manuscr., 7 p. Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038.

Manuscript accepted November 1984.
FISHERY BULLETIN: VOL. 83, NO. 4, 1985.

tial bias in the estimates of annual dolphin kill.

Directly testing for the existence of an observer effect on dolphin kills would require comparison of covert observations with observations by NMFS and IATTC observers. Based on the large difference between the kill rate observed covertly by one crew member and the kill rates recorded by NMFS observers during other fishing trips made by the same operator and vessel, Smith (1983) speculated that a large observer effect existed. We investigated the significance of the difference in kill rates reported by Smith (1983) by grouping NMFS-observed trips into sequences of trips with common operator and vessel. A few of these sequences of NMFS-observed trips revealed between-trip kill rate differences as large or larger than in the sequence that included the covert observations.

The existence of an observer effect can be indirectly tested without relying on data from covert observers. Johnson and Bolstad (1973) established the existence of an observer effect by comparing measurements made by observers with various levels of obtrusiveness to the human subjects whose responses were being measured. They concluded that the differences in the responses measured by observers with different levels of obtrusiveness implied that the observer's presence had affected the subjects' behavior. They noted, however, that the magnitude of an observer effect cannot be estimated using this approach.

Following this indirect approach, we tested for the existence of an observer effect on the numbers of dolphins killed by comparing dolphin kill data collected by scientific observers who differed in their purposes of data collection, and hence, in their levels of obtrusiveness.

DATA

The scientific observers were placed aboard a random sample of U.S. registered tuna purse seine vessels (Lo et al. 1982). Assignment of an NMFS or IATTC observer to vessels in the sample was also made randomly, subject to the constraint that any vessel sampled twice within a calendar year would be accompanied by an NMFS observer on at most one trip (Table 1).

Information collected for each NMFS- or IATTC-sampled fishing trip included departure date and data pertaining to each set (such as set type, date, and location), and for dolphin sets, the number of dolphins killed. Data available to the authors from NMFS-sampled trips included all of this information. However, data available from IATTC-sampled trips did not include departure date, and set dates were available only to the quarter of the year.

While the data items collected by both types of scientific observer have been similar over the years, for NMFS observers the purposes of the data collection changed after March 1981. The primary purposes of data collection, as explained to each vessel operator at a placement meeting held prior to departure, were as follows: 1) On NMFS-sampled trips begun from 1978 through March 1981, data were collected for estimating the annual kill of dolphins and for monitoring compliance with dolphin-release regulations; 2) on NMFS-sampled trips begun after March 1981 through the end of 1982, the data were still used for estimating dolphin kills but were no longer used to monitor compliance with dolphin-release regulations[4]; 3) on all IATTC-sampled trips, since the inception of that sampling program in 1979, data were collected for estimating total kill but were never collected for monitoring compliance with dolphin-release regulations.

As described above, the data collected by both NMFS and IATTC observers to estimate total dolphin kill can be used by the NMFS to halt fishing by U.S. vessels on specific dolphin populations for the remainder of the year. The data collected before March 1981 by the NMFS observers for monitoring compliance with dolphin-release regulations, however, can be used by the NMFS as evidence to prosecute operators who failed to comply. Thus, the operators are likely to be more conscious of the presence of an observer who is collecting data both for estimating dolphin kill and for monitoring com-

TABLE 1.—Number of observed fishing trips which made at least one dolphin set from 1978 through 1982, by observer type and year. NMFS totals are subdivided according to departure date of trips (previous year, Jan.-Mar., Apr.-Dec.) and exclude trips in which fishing gear research was conducted.

Observer type	1978	1979	1980	1981	1982
NMFS					
Previous year	5	4	3	3	7
Jan.-Mar.	44	33	15	7	13
Apr.-Dec.	56	32	28	28	18
Total	105	69	46	38	38
IATTC	0	31	57	58	44
Total	105	100	103	96	82

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[4] The change in data collection purposes of NMFS observers after March 1981 was prompted by a court order forbidding the NMFS from using data collected by observers for monitoring compliance with dolphin-release regulations. No NMFS observers were placed on fishing trips begun from 1983 through part of 1984 because of a subsequent court order forbidding placement of NMFS observers without a search warrant.

pliance with dolphin-release regulations than an observer who is collecting data only for estimating dolphin kill. That this is the case is implied by the constraint in the sampling procedure that any vessel sampled twice within a calendar year may be accompanied by an NMFS observer on at most one trip.

METHODS

We tested for the existence of an observer effect on dolphin kills by comparing the number of killed dolphins recorded by more obtrusive observers with the number recorded by less obtrusive observers. We considered observers who collected data both for estimating dolphin kill and for monitoring compliance with dolphin-release regulations to be more obtrusive to vessel operators than observers who collected data only for estimating dolphin kill. Thus, we compared kills recorded by (1a) NMFS observers before and after March 1981, and (1b) NMFS and IATTC observers before March 1981. As a control, we compared the number of killed dolphins recorded by observers of equal obtrusiveness. That is, we compared kills recorded by (2a) IATTC observers before and after March 1981, and (2b) NMFS and IATTC observers after March 1981.

The frequency distributions of numbers of dolphins killed were extremely skewed, with very long right tails (Fig . 1). Normality assumptions were violated so strongly by these skewed distributions that ANOVA tests for differences in means, particularly one-sided tests, would be difficult to interpret (Glass et al. 1972). Therefore, we tested for differences in the percent of dolphin sets in which no dolphins were killed (zero-kill sets). This percent relates directly to the regulation requiring release of all live dolphins, and is a dominant feature of the dolphin kill distributions.

When comparing frequency distributions, we entertained the null hypothesis of equality of percent zero-kill sets. When comparing observers of different obtrusiveness levels, we tested this hypothesis against a one-sided alternative that distributions from more obtrusive observers had a higher percent

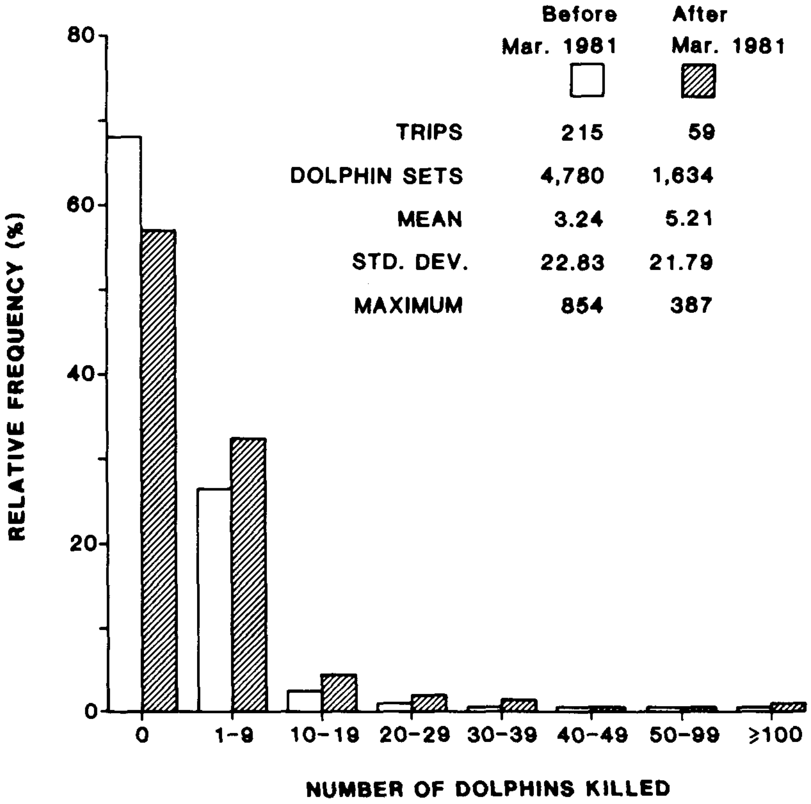

FIGURE 1.—Relative frequency distributions of number of dolphins killed incidentally during sets of NMFS-observed trips, 1978 through 1982, by trip departure date.

of zero-kill sets than distributions from less obtrusive observers. When comparing distributions from observers of equal obtrusiveness, we tested the null hypothesis against the two-sided alternate of inequality (Table 2). Results from all of our tests are reported at the 0.05 significance level.

TABLE 2.—Alternate hypotheses to the null hypothesis of equality of percent zero-kill sets for each of four comparisons, where Before and After refer to before or after March 1981. See text for details.

Comparison	Alternate hypothesis
1a. NMFS before vs NMFS after	Before > After
2a. IATTC before vs IATTC after	Before ≠ After
1b. NMFS before vs IATTC before	NMFS > IATTC
2b. NMFS after vs IATTC after	NMFS ≠ IATTC

For two-sided tests of differences in percents, we used the standard chi-square (χ^2) statistic with one degree of freedom (df). For one-sided tests, we used the square root of the chi-square statistic (Z), which is approximately normal (Snedecor and Cochran 1980, p. 126-127). In some instances, the expected cell frequencies were less than the traditionally accepted minimum of five. However, recent Monte Carlo results (Fienberg 1980, p. 172) suggest that the chi-squared distribution is an adequate approximation at the 0.05 significance level even when minimum expected values are as low as one.

While the sampling of vessels was nearly random, the actual sample obtained may not have been representative of factors affecting dolphin kills. It has been demonstrated that within the ETP, dolphin kills vary among three geographic areas[5] (Fig. 2) and by periods within the year (Lo et al. 1982). We divided the year into two periods: January-March and April-December. This division corresponds to the date of the change in data collection purposes of NMFS observers in 1981, and also tends to equalize sample size since vessels in this fishery are more active in the early part of the year.

We stratified the data by area and period of the year to account for biases due to possible nonrepresentativeness of the sample with respect to these two factors. When data on numbers of dolphins killed were available in all six area-period strata, we made overall two-sided tests for differences in per-

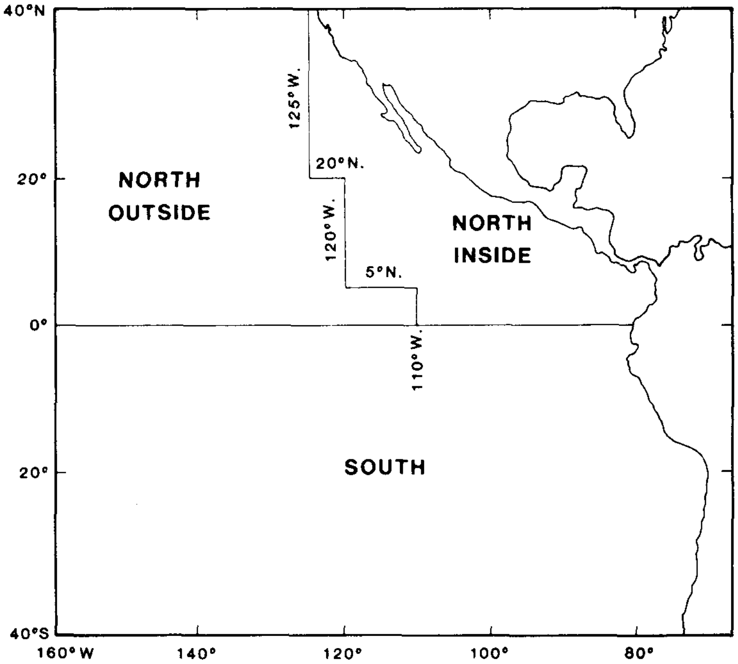

FIGURE 2.—The three areas of the eastern tropical Pacific used to stratify the data, bounded by lat. 40°N., long. 160°W., lat. 40°S., and the western coastline of the North and South American Continents.

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[5] K.-T. Tsai, Inter-American Tropical Tuna Commission, c/o Scripps Institute of Oceanography, La Jolla, CA 92093, pers. commun. December 1983.

cent zero-kill sets (conditional on period of the year and geographic area) by summing chi-square values and degrees of freedom from each stratum. When observations were not available in one of the strata, or when the alternative was one-sided, an overall test based on the chi-square statistic was not possible. In those cases, results of the tests within each stratum were considered separately.

RESULTS

The first two comparisons of frequency distributions test for differences in the percent of zero-kill sets in data collected by observers on trips begun before compared with trips begun after the change in NMFS observer data collection purposes in March 1981 (Comparisons 1a and 2a, Table 2). The last two comparisons test for differences in the percent of zero-kill sets in data collected by observers on trips begun during the same time period (Comparisons 1b and 2b, Table 2).

Before versus After

The percent of zero-kill sets for NMFS-observed trips was higher before March 1981 than after that date (Fig. 1), and within all area-period strata with complete data, the percent of zero-kill sets was larger before March 1981 (Table 3). The one-sided test of this difference (Comparison 1a, Table 2) was significant within four of the five area-period strata which had complete data, and was very nearly significant within the fifth (Table 3). Thus, the percent of zero-kill sets recorded by NMFS observers was significantly larger before March 1981.

The significant difference in percent of zero-kill sets for NMFS observers before compared with after March 1981 could be due to the change in data collection purposes of NMFS observers which occurred then. Alternatively, the difference could be due to a temporal decline begun before that date.

Allowing for period, the data prior to March 1981 do not show a pronounced trend for any of the three areas (Fig. 3). Although there appears to be a decline in the South for Period 2, this is unreliable as it depends entirely on the 1980 and 1981 data points representing a total of only 17 sets. Similarly, there seems to be a declining trend for the two northern areas. However, for the North Inside area the Period 1 points show no decline, and the possible decline of Period 2 points depends on the 1980 Period 2 point. A 95% confidence interval about this point (observed percent ±2 × standard error), however, is large relative to the difference between it and the Period 2 point of 1979. Further, any such declining trend in Period 2 points for the North Inside area is not reflected in the low 1978 point. A similar argument can be made for North Outside area data to reject the alternative explanation of the difference in percent zero-kill sets before and after March 1981 being the result of a temporal trend begun prior to March 1981.

That the differences in percent of zero-kill sets for NMFS-observed trips was not due to a temporal trend was also tested by comparing the percent of such sets for IATTC-observed trips before and after March 1981. The percent of zero-kill sets for IATTC-observed trips was higher before March 1981, but within the six area-period strata the differences were not consistent (Table 4). The two-sided test (Comparison 2a, Table 2) was significant within only one of the six area-period strata (Period 1, South), and the sample size within that stratum was very small (Table 4). The overall conditional test given area and period was not significant. Thus, IATTC-observed trips with dolphin sets from 1979 through 1982 did

TABLE 3.—Numbers of dolphin sets (n) made during NMFS-observed trips, 1978 through 1982. Sets are classified by trip departure date relative to March 1981 (before or after) and to period (1 = Jan.-Mar., 2 = Apr.-Dec.), by area of set (North Inside, North Outside, South), and by numbers of dolphins killed (0, >0). Percents of column totals (%), expected frequencies (e), and the statistic Z are also tabulated. Values of $Z > 1.64$ are significant, as indicated by an asterisk.

		Period 1						Period 2							
		North Inside		North Outside		South		North Inside		North Outside		South		Total	
Kill		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
0	n	1,498	226	0	21	107	0	972	421	591	229	86	33	3,254	930
	%	72.9	62.1	—	52.5	61.1	0.0	69.4	62.7	60.4	55.7	50.6	23.1	68.1	56.9
	e	1,464.7	259.3	0	21	104.0	3.0	941.9	451.1	577.4	242.6	64.6	54.4	—	—
>0	n	558	138	0	19	68	5	429	250	387	182	84	110	1,526	704
	%	27.1	37.9	—	47.5	38.9	100.0	30.6	37.3	39.6	44.3	49.4	76.9	31.9	43.1
	e	591.3	104.7	0	19	71.0	2.0	459.1	219.9	400.6	168.4	105.4	88.6	—	—
Total	n	2,056	364	0	40	175	5	1,401	671	978	411	170	143	4,780	1,634
	Z	4.18*		—		2.75*		3.01*		1.63		4.99*		—[1]	

[1] Computation of overall test statistic not possible because of one-sided alternative, and because of lack of data in one stratum (Period 1, North Outside).

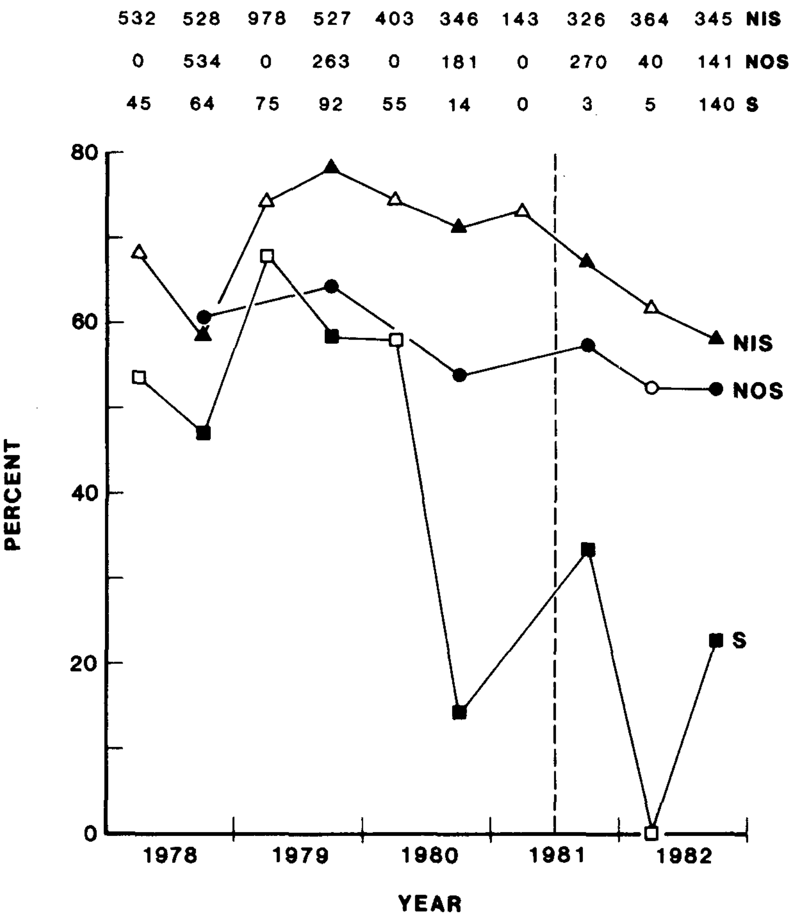

FIGURE 3.—Number of dolphin sets (upper portion) and percent of zero-kill dolphin sets (lower portion) for each of 3 areas (NIS = North Inside, NOS = North Outside, S = South) by period within year (open symbol = Jan.-Mar., closed symbol = Apr.-Dec.). Data are from NMFS-observed trips, 1978 through 1982. Vertical line separates data before and after March 1981.

TABLE 4.—Numbers of dolphin sets (*n*) made from 1979 through 1982, during IATTC-observed trips. Sets are classified by date of set relative to March 1981 (before or after) and to period (1 = Jan.-Mar., 2 = Apr.-Dec), by area of set (North Inside, North Outside, South), and by numbers of dolphins killed (0, >0). Percents of column totals (%), expected frequencies (*e*), and the statistic χ^2 with degrees of freedom (*df*) are also tabulated. *Values of* $\chi^2 > 3.84$ *(1 df) or 12.59 (6 df) are significant, as indicated by an asterisk.*

		Period 1						Period 2							
		North Inside		North Outside		South		North Inside		North Outside		South		Total	
Kill		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
0	*n*	537	188	9	3	13	3	709	721	291	328	5	35	1,564	1,278
	%	67.1	71.2	26.5	14.3	38.2	12.0	70.0	70.1	58.7	55.6	33.3	24.1	65.4	61.6
	e	545.1	179.9	7.4	4.6	9.2	6.8	709.8	720.2	282.7	336.3	3.8	36.2	—	—
>0	*n*	263	76	25	18	21	22	304	307	205	262	10	110	828	795
	%	32.9	28.8	73.5	85.7	61.8	88.0	30.0	29.9	41.3	44.4	66.7	75.9	34.6	38.4
	e	254.9	84.1	26.6	16.4	24.8	18.2	303.2	307.8	213.3	253.7	11.2	108.8	—	—
Total	*n*	800	264	34	21	34	25	1,013	1,028	496	590	15	145	2,392	2,073
	χ^2	1.53		1.13		5.02*		0.01		1.04		0.61		9.34	
	df	1		1		1		1		1		1		6	

not differ significantly in their percent of zero-kill sets before or after March 1981.

Same Time Period

Before March 1981 the percent of zero-kill sets was higher for NMFS-observed trips than for IATTC-observed trips (Fig. 4), and within all area-period strata with complete data, the percent of zero-kill sets was larger for the NMFS observers (Table 5). The one-sided test (Comparison 1b, Table 2) was significant within four of the five area-period strata which had complete data (Table 5). Thus, for trips making dolphin sets from 1979 through March 1981, NMFS observers recorded a significantly higher percent of zero-kill sets than did IATTC observers.

According to our hypothesis, the difference in percent of zero-kill sets between NMFS- and IATTC-observed trips before March 1981 should have disappeared after March 1981 when the purposes for data collection of NMFS observers became nearly the same as for IATTC observers. After March 1981 the percent of zero-kill sets was higher for IATTC-observed trips than for NMFS-observed trips (Fig. 5), but within the six area-period strata the differences were not consistent (Table 6). The two-sided test (Comparison 2b, Table 2) was significant within only one of the six area-period strata (Period 1, North Inside), yet this one chi-square statistic was so large that the overall conditional test for all six strata was also significant (Table 6). It is difficult to interpret the overall result in this situation because of the extraordinary influence of one stratum. However, after March 1981 the percent of zero-kill sets on NMFS-observed trips was clearly not higher than on IATTC-observed trips.

While one would expect the mean number of dolphins killed to decrease when the percent of zero-kill sets increases, this is not necessarily so because of the sensitivity of the mean of a sample to the maximum value in the sample. For instance, in Figure 4 the NMFS maximum is nearly twice that of the IATTC, resulting in a larger NMFS mean despite the higher percent of zero-kill sets in the NMFS sample.

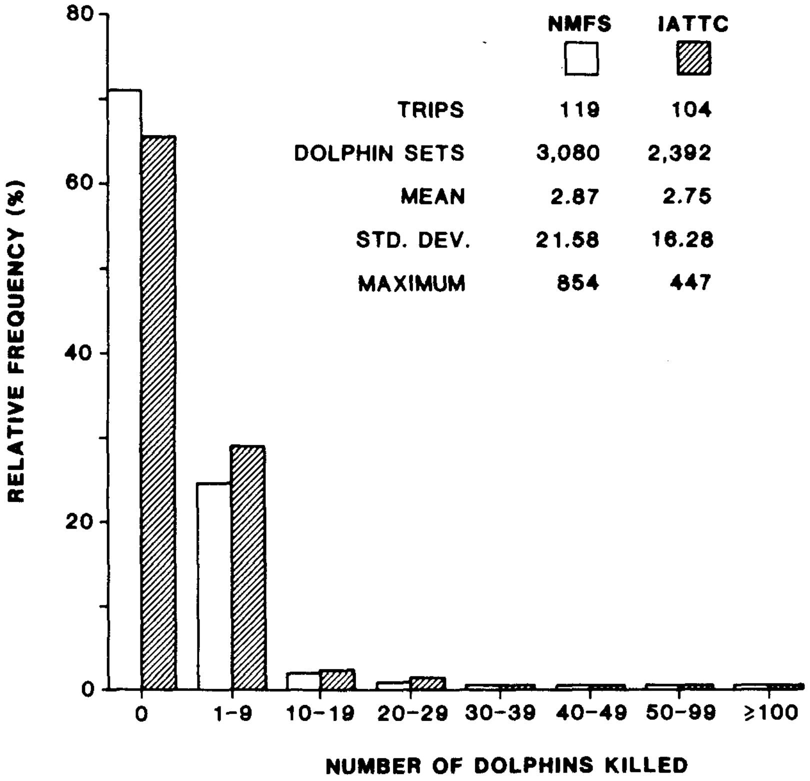

FIGURE 4.—Relative frequency distributions of number of dolphins killed incidentally during sets made from 1979 through March 1981, by observer type.

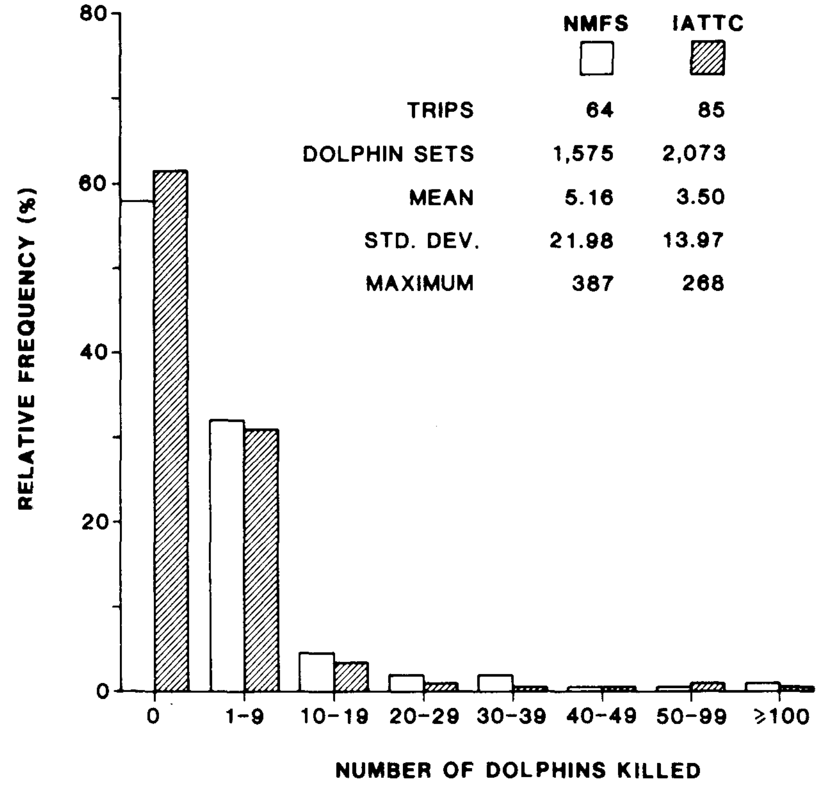

FIGURE 5.—Relative frequency distributions of number of dolphins killed incidentally during sets made after March 1981 through 1982, by observer type.

TABLE 5.—Numbers of dolphin sets (*n*) made from 1979 through March 1981. Sets are classified by observer type (NMFS, IATTC), by area of set (North Inside, North Outside, South), by date of set relative to period (1 = Jan.-Mar., 2 = Apr.-Dec.), and by numbers of dolphins killed (0, >0). Percents of column totals (%), expected frequencies (*e*), and the statistic *Z* are also tabulated. Values of *Z* > 1.64 are significant, as indicated by an asterisk.

		Period 1						Period 2							
		North Inside		North Outside		South		North Inside		North Outside		South		Total	
Kill		NMFS	IATTC	NMFS	IATTC	NMFS	IATTC	NMFS	IATTC	NMFS	IATTC	NMFS	IATTC	NMFS	IATTC
0	*n*	820	537	0	9	96	13	942	709	267	291	62	5	2,187	1,564
	%	72.7	67.1	—	26.5	53.9	38.2	76.8	70.0	60.1	58.7	59.6	33.3	71.0	65.4
	e	793.9	563.1	0	9	91.5	17.5	904.0	747.0	263.6	294.4	58.6	8.4	—	—
>0	*n*	308	263	0	25	82	21	284	304	177	205	42	10	893	828
	%	27.3	32.9	—	73.5	46.1	61.8	23.2	30.0	39.9	41.3	40.4	66.7	29.0	34.6
	e	334.1	236.9	0	25	86.5	16.5	322.0	266.0	180.4	201.6	45.4	6.6	—	—
Total	*n*	1,128	800	0	34	178	34	1,226	1,013	444	496	104	15	3,080	2,392
	Z	2.64*		—		1.68*		3.66*		0.46		1.92*		—[1]	

[1] Computation of overall test statistic not possible because of one-sided alternative, and because of lack of data in one stratum (Period 1, North Outside).

DISCUSSION AND CONCLUSIONS

We established the existence of an observer effect on the number of dolphins killed incidentally in the ETP yellowfin tuna fishery by following two lines of argument. First, we demonstrated a decrease in the percent of sets with no dolphins killed on NMFS-observed trips after March 1981, when monitoring compliance with dolphin-release regulations was removed as a data collection purpose (Table 3). We further showed that this difference was not due to a temporal trend in fishing conditions by examin-

TABLE 6.—Numbers of dolphin sets (*n*) made from April 1981 through 1982. Sets are classified by observer type (NMFS, IATTC), by area of set (North Inside, North Outside, South), by date of set relative to period (1 = Jan.-Mar., 2 = Apr.-Dec.), and by numbers of dolphins killed (0, >0). Percents of column totals (%), expected frequencies (*e*), and the statistic χ^2 with degrees of freedom (df) are also tabulated. Values of $\chi^2 > 3.84$ (1 df) or 12.59 (6 df) are significant, as indicated by an asterisk.

		Period 1						Period 2							
		North Inside		North Outside		South		North Inside		North Outside		South		Total	
Kill		NMFS	IATTC	NMFS	IATTC	NMFS	IATTC	NMFS	IATTC	NMFS	IATTC	NMFS	IATTC	NMFS	IATTC
0	*n*	193	188	1	3	1	3	455	721	249	328	13	35	912	1,278
	%	55.6	71.2	14.3	14.3	10.0	12.0	66.4	70.1	56.1	55.6	15.9	24.1	57.9	61.6
	e	216.4	164.6	1.0	3.0	1.1	2.9	470.3	705.7	247.8	329.2	17.3	30.7	—	—
>0	*n*	154	76	6	18	9	22	230	307	195	262	69	110	663	795
	%	44.4	28.8	85.7	85.7	90.0	88.0	33.6	29.9	43.9	44.4	84.1	75.9	42.1	38.4
	e	130.6	99.4	6.0	18.0	8.9	22.1	214.7	322.3	196.2	260.8	64.7	114.3	—	—
Total	*n*	347	264	7	21	10	25	685	1,028	444	590	82	145	1,575	2,073
	χ^2	15.53*		0.00		0.03		2.63		0.02		2.16		20.37*	
	df	1		1		1		1		1		1		6	

ing the data by period (Fig. 3) and by demonstrating the lack of a corresponding change in data collected by IATTC observers (Table 4).

Second, we demonstrated that before March 1981 the percent of sets with no dolphins killed was higher for NMFS observers collecting data both for estimating dolphin kill and for monitoring compliance with dolphin-release regulations than for IATTC observers collecting data only for estimating dolphin kill (Table 5). To validate this comparison we also demonstrated that the difference disappeared, or perhaps was reversed, following March 1981 when monitoring compliance with dolphin-release regulations was removed from the NMFS observers' responsibilities (Table 6). Following Johnson and Bolstad (1973), these differences in the data collected by observers differing in their purposes of data collection, and hence in their obtrusiveness, imply the existence of an observer effect.

In making these comparisons, we stratified the data to account for possible differences in fishing conditions in different geographic areas and throughout the year because both area and time of year are important determinants of dolphin mortality. Thus, the differences in the percent of zero-kill sets which we identified cannot be attributed to nonrepresentativeness of the data with respect to area and time of year.

We did not attempt to test for other differences in the frequency distributions of kills, such as changes in the percent of moderate or large kill sets. Sets with large numbers of dolphins killed are rare, and are generally associated with unusual circumstances, such as mechanical failures. The percent of sets with 1-9 dolphins killed appears to vary inversely with the percent of sets with zero dolphins killed (Figs. 1, 4, 5).

Powers et al.[6] showed that the use of some dolphin-release procedures significantly reduces dolphin mortality. Thus, more time and effort expended by the operator on release of dolphins could result in an increase in the frequency of sets with no dolphins killed, and a corresponding decrease in the frequency of sets with 1-9 dolphins killed. A greater tendency for vessel operators to take the additional time in the presence of an observer collecting data for monitoring compliance with dolphin-release regulations could account for the differences we have demonstrated.

The significantly different relative frequency of zero-kill sets recorded by NMFS observers after March 1981 (Table 6) was not expected under our hypothesis. As noted above, this difference was localized to one area-period stratum, and the other five strata were consistent with the null hypothesis of no difference. Either this difference is merely a sampling anomaly, or there are differences between observers in more recent years that we have not taken into account.

Gulland (1983, p. 111) described a method of testing for the existence of a tagging effect that is analogous to our indirect method of testing for an observer effect. He suggested comparing the proportions of tags returned from fish tagged under poor and good conditions. In both Gulland's and our methods, the absolute magnitude of the effects cannot be estimated. For instance, in Gulland's example improvement in the conditions under which tags are applied is unlikely to eliminate entirely the tagging effect. Similarly, the reduction in observer ob-

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[6] Powers, J. E., N. C. H. Lo, and B. E. Wahlen. 1979. A statistical analysis on effectiveness of porpoise rescue procedures in reducing incidental mortality. Southwest Fish. Cent. La Jolla Lab., Natl. Mar. Fish. Serv., NOAA, Admin. Rep. LJ-79-7, 29 p.

trusiveness after March 1981 is unlikely to have eliminated entirely the observer effect because the data collected by scientific observers after 1981 were still used to monitor dolphin kills relative to annual kill limits. Observers collecting data that could not be used for monitoring kill limits would be even less obtrusive than the scientific observers, and covert observers would be, of course, completely unobtrusive.

Based on our analysis, we would expect that the frequency of zero-kill sets would be lower on unobserved vessels than on vessels with a scientific observer. This lower frequency of zero-kill sets, coupled with an increased frequency of sets with 1-9 dolphins killed, suggests that the average kill rate on unobserved vessels would be higher. Estimates of total kill, based on the average kill rates from the scientific observers, would therefore be underestimated.

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance of M. M. Croom in providing data and in early discussions of the problem. We also acknowledge the assistance of K. E. Wallace and J. S. Cole in providing data. We are indebted to D. G. Chapman and W. F. Perrin for suggesting analytical methods. We also appreciate the helpful reviews by F. G. Alverson, I. Barrett, P. S. Hammond, R. S. Holt, N. C. H. Lo, N. A. Mendes, J. M. Michalski, G. T. Sakagawa, and K.-T. Tsai, as well as the reveiws by two anonymous individuals.

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