

## A STATISTICAL PROCEDURE FOR ESTIMATING THE MORTALITY ON DISCARDED BILLFISH CAUGHT BY LONGLINE GEAR

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## SUMMARY

Procedures are presented for estimating the percent mortality of blue marlin, white marlin, and sailfish caught and discarded as a by-catch of the tuna and swordfish directed longline fisheries in the northwest Atlantic Ocean and adjacent seas. Data collected by at-sea observer agents on board Japanese longline vessels fishing in the U.S. Exclusive Economic Zone (1978-1988), U.S. longline vessels along U.S. coastal waters and the Caribbean Sea (1985-1990), and Venezuelan longline vessels fishing in the lower Caribbean Sea (1987-1990) were analyzed.

## RESUME

Des procédures ont été présentées pour estimer le pourcentage de la mortalité de makaira bleu, makaira blanc et voilier capturés et relâchés en tant que prises accessoires des pêcheries palangrières du nord-ouest de l'Atlantique et des mers adjacentes visant les thonidés et l'espardon. Les données rassemblées par les observateurs en mer, à bord de palangriers japonais, pêchant dans la Zone exclusive économique (1978-1988), des palangriers américains le long de la côte américaine et la mer des Caraïbes (1985-1990) ainsi que les palangriers vénézuéliens qui pêchent dans la partie inférieure de la mer des Caraïbes (1987-1990) ont été analysées.

## RESUMEN

Se presentan procedimientos para estimar el porcentaje de mortalidad de la aguja azul, aguja blanca y pez vela capturado y descartado como captura secundaria de la pesquería de palangre dirigida a los túnidos y pez espada en el Atlántico noroeste y mares adyacentes. Se analizaron los datos recogidos por observadores a bordo de palangreros japoneses que faenaban en la ZEE de Estados Unidos (1978-1988), los palangreros norteamericanos frente a las costas de su país y del Mar Caribe (1985-1990), y la pesquería de palangre de Venezuela que faena en la parte sur del Mar Caribe (1987-1990).

## INTRODUCTION

The three major Atlantic billfish species (white marlin, *Tetrapterus albidus*; blue marlin, *Makaira nigricans*; and sailfish, *Istiophorus platypterus*) are targets of the U.S. recreational (rod and reel) fishery and also represent a commercial by-catch of the U.S. and foreign longline fisheries. Several steps have been undertaken in an effort to manage the fisheries affecting these species within the U.S. Exclusive Economic Zone (EEZ). The Fisheries Conservation and Management Act of 1976 (FCMA) authorized the United States to manage all marine resources within its EEZ with the exception of the highly migratory species of tunas. More recently, in October 1988, the National Marine Fisheries Service (NMFS) implemented the U.S. Fishery Management Plan for Atlantic Billfishes (Federal Register 1988) which includes a requirement for all U.S. longline vessels to release all billfish species (marlins and sailfish) and prohibited the sale of billfish caught in the management area (Atlantic and adjacent seas) to U.S. markets. Data on longline catches of the U.S. fleet are obtained through mandatory logbook reports from vessels permitted to fish for swordfish (*Xiphias gladius*).

In order to assess the status of the billfish stocks, accurate information on fishery induced mortality of these species, including those fish that are released or discarded by the various fisheries in the U.S. coastal waters, is required. Currently, the NMFS Miami Laboratory receives mandatory swordfish daily logbook reports from U.S. longline captains/owners. These reports include the numbers of fish caught, by species, that were kept and/or discarded on a set-by-set basis. Some proportion of those fish discarded are dead or will die due to the stress of handling, and therefore, though not landed, need to be included in estimates of total catch. Therefore, a technique is needed to estimate the proportion of dead fish retrieved by longlines and subsequently discarded. The objective of this analysis was to provide a statistical procedure for estimating the proportion of dead blue marlin, white marlin, sailfish and swordfish retrieved on longlines within the U.S. EEZ by the observed commercial longline vessels.

## METHODS

Trained observers were placed on-board U.S. and foreign longline vessels fishing within the U.S. EEZ, as well as Venezuelan longline vessels fishing in the southeastern Caribbean Sea, to monitor fishing activities. They were responsible for collecting comprehensive data pertaining to gear specifications and deployment, location, environmental conditions, condition of species caught (alive, dead or unknown condition), and biological sampling of the catch. Three primary data sources were utilized in estimating the proportion of dead discards for blue marlin, white marlin, sailfish and swordfish during longline fishing activities. A brief description of these three data sources follows.

(1) Japanese longline

The data from the Japanese longline fishery used in our analysis contains 5,583 longline sets during the years 1978 - 1988. From 1978 to 1981 fishing occurred in the U.S. EEZ in both the Gulf of Mexico and the northwest Atlantic Ocean, while from 1982 to 1988 the Japanese ceased fishing in the Gulf of Mexico and moved their efforts to the coastal waters off the U.S. mid-Atlantic and New England states. There has been no Japanese longline effort in U.S. east coast EEZ waters since 1988. Fishing activities were recorded on a set-by-set basis. Because no target species information was recorded, we assumed that all effort was directed at tunas (yellowfin, *Thunnus albacares* and bluefin, *T. thynnus*). The observed Japanese vessels fished a traditional longline gear of tarred, hard laid nylon cord for the mainline and gangions, and typically set more hooks over a longer mainline than the U.S. fishery (Lopez et al. 1979).

(2) U. S. longline

Observers were placed on-board U.S. commercial longline vessels, on a voluntary basis, to monitor their fishing activities in the Gulf of Mexico, the northwest Atlantic Ocean, and the Caribbean Sea. The data used in the analysis recorded 292 sets during the years 1985 - 1990. The primary fishing area was in the Gulf of Mexico, with only three longline trips occurring in the Atlantic Ocean (Grand Banks and offshore of Florida east coast), and four Caribbean trips near Puerto Rico and the U.S. Virgin Islands. Fishing activities were recorded on a set-by-set basis as being directed either at yellowfin tuna or swordfish. The U.S. commercial fleet mainly uses monofilament mainline and gangions, and typically sets fewer hooks over a shorter mainline than foreign fisheries.

(3) Venezuelan longline

Observers sponsored by the International Commission for the Conservation of Atlantic Tunas (ICCAT) Enhanced Research Program for Billfish (ICCAT 1989) were placed on-board Venezuelan longline vessels to monitor fishing activities in the Caribbean Sea off the coast of Venezuela. The data used in this analysis recorded 131 sets during the years 1987 - 1990. A total of 13 trips was reported with fishing activities recorded on a set-by-set basis as being directed either at yellowfin tuna or swordfish. The Venezuelan fleet fishes longline gear that closely resembles the traditional Japanese gear. The length of the mainline is typically similar to that of the U.S. fleet but generally consists of a higher number of hooks.

For each of the three data sources the following information was examined with respect to individual sets: the number of billfish by species (including swordfish) recorded as alive, dead or unknown condition; the latitude and longitude of the set; and the primary target species (i.e., whether the longline set was directed at tuna or swordfish). There were three possible circumstances leading to the "unknown" condition of a billfish:

(i) the observer saw the fish but was not able to discern if it was alive or dead; (ii) the observer did not directly observe the fish; or (iii) the condition data were not recorded and therefore subsequently treated as unknown. Only fish of known condition were included in the analysis.

The proportion dead,  $P_i$ , was determined by the ratio of total dead divided by the sum of Alive plus Dead (i.e.,  $P_i = D_i / (A_i + D_i)$ ) for each of the  $i$  species (Tables 1-4). These proportions were initially computed for each of the species across all years by data sources (Japanese, U.S., and Venezuelan), areas (Gulf of Mexico, N.W. Atlantic, and Caribbean Sea), and target species (tuna or swordfish directed). Though not used in any calculations, the total number of sets associated with each category is included in the tables for completeness and reference.

An *a priori* decision was made that if the sample size,  $n$  ( $= A + D$ ), was not at least 30, then the data would be pooled. Pooling was initially between data sources within geographical strata and subsequently at higher levels of analytical stratification. For large samples, the binomial estimate  $P$  is approximately normally distributed about some unknown population proportion with standard deviation  $[(P_i)(1-P_i)/n]^{1/2}$ . With the inclusion of the binomial correction for continuity, the 95% confidence limits for  $P$  were calculated from

$$P_i \pm (1.96[(P_i)(1-P_i)/n]^{1/2} + 1/2n) \quad (1)$$

(Snedecor and Cochran 1973). The choice of 95% limits was arbitrary, and other confidence probabilities could be obtained by substituting the appropriate values of the normal deviate,  $z$ , for 1.96.

The null hypothesis tested is that there is no significant difference between proportions dead based on the analytical stratum being considered; i.e., between target species for a given data source within area, between data sources within area, or between areas. For the purpose of this analysis, the  $z$ -test, corrected for continuity, was used (Snedecor and Cochran 1973). To calculate this corrected  $z$ -value for the difference between two proportions ( $= D / (A + D)$ ), say  $P_1$  and  $P_2$ , where  $P_1 < P_2$

$$z = \frac{(P_1' - P_2')}{[(P_{\infty})(1-P_{\infty})((1/n_1) + (1/n_2))]^{1/2}} \quad (2)$$

$$\text{where } P_1' = (D_1 - 0.5) / n_1; \quad n_1 = A_1 + D_1$$

$$P_2' = (D_2 + 0.5) / n_2; \quad n_2 = A_2 + D_2$$

$$P_{\infty} = (D_1 + D_2) / (A_1 + D_1 + A_2 + D_2)$$

The z-values and associated probabilities,  $P(z)$ , are presented in Tables 1-4 along with the 95% confidence bounds. The null hypothesis is rejected if  $P(z) < 0.05$ .

## RESULTS and DISCUSSION

Data were initially analyzed for blue marlin, white marlin, sailfish and swordfish by a breakdown of each data source, by target species, for each geographic area, (not included in Tables 1-4). These data were available from the U.S. fishery in the Gulf of Mexico and from the Venezuelan fishery in the Caribbean. For blue marlin and sailfish, the sample size was considered insufficient ( $n < 30$ ) for both the Gulf of Mexico and Caribbean data. For white marlin, the sample size was considered sufficient for a statistical comparison for Caribbean data from the Venezuelan fishery. There was no significant statistical difference between the proportion dead when the target species was tuna ( $P=0.582$ ,  $n=244$ ) versus swordfish ( $P=0.700$ ,  $n=30$ ). The swordfish data were similarly analyzed from the U.S. fishery in the Gulf of Mexico and from the Venezuelan fishery in the Caribbean where sample sizes were considered sufficient for both comparisons. For the U.S. fishery in the Gulf of Mexico, there was no statistical difference between the proportion dead when the target species was tuna ( $P=0.725$ ,  $n=160$ ) versus swordfish ( $P=0.698$ ,  $n=43$ ). However, for the Venezuelan fishery there was a statistical difference between the proportion dead when the target species was tuna ( $P=0.489$ ,  $n=45$ ) versus swordfish ( $P=0.844$ ,  $n=224$ ).

Comparisons were then made by species by area for each data source available in that area, and then for all data sources pooled by area. For any case with  $n < 30$  the data were tabulated and plotted on the appropriate figures, but no test of hypothesis is proper and the data were combined across sources and used to estimate a proportion dead for that geographical stratum.

### Blue Marlin

The sample sizes were considered sufficient to compare the Japanese and U.S. observer data in the Gulf of Mexico and to compare the U.S. and Venezuelan observer data in the Caribbean (Table 1 and Figure 1a). In the former case the estimates of proportion dead ( $P=0.500$  Japanese;  $P=0.382$  U.S.) were not significantly different; in the latter case the estimated proportion dead from the Venezuelan data ( $P=0.686$ ) was significantly greater than that from the U.S. data ( $P=0.286$ ). The reason for this difference is unexplained at this time.

With observer data pooled from all three sources (Table 1 and Figure 2), there was no significant difference between estimated proportion dead for the Gulf of Mexico ( $P=0.472$ ), the N.W. Atlantic ( $P=0.501$ ) and the Caribbean ( $P=0.570$ ).

### White Marlin

The sample sizes were considered sufficient only to compare the Japanese and U.S. observer data in the Gulf of Mexico (Table 2 and Figure 1b). The estimates of proportion dead ( $P=0.564$  Japanese;  $P=0.364$  U.S.) were not significantly different.

With observer data pooled from all three sources (Table 2 and Figure 2), there was no significant difference between estimates of proportion dead for the Gulf of Mexico ( $P=0.543$ ) and the Caribbean ( $P=0.584$ ). However, both were significantly less than the estimated proportion dead from the N.W. Atlantic data ( $P=0.673$ ).

### Sailfish

Sample sizes were considered sufficient only to compare the Japanese and U.S. observer data in the Gulf of Mexico (Table 3 and Figure 1c). The estimated proportion dead from the Japanese data ( $P=0.511$ ) was not significantly different from that of the U.S. data ( $P=0.532$ ).

With observer data pooled from all three sources (Table 3 and Figure 2), there was no significant difference between estimated proportion dead for the Gulf of Mexico ( $P=0.519$ ), the N.W. Atlantic ( $P=0.642$ ) and the Caribbean ( $P=0.618$ ).

### Swordfish

Sample sizes in all three areas were considered sufficient for statistical comparison (Table 4 and Figure 1d). There was a significant difference between the estimated proportion dead for the Japanese ( $P=0.793$ ) and U.S. ( $P=0.719$ ) observer data in the Gulf of Mexico. Similarly, in the N.W. Atlantic, the estimated proportion dead for the Japanese data ( $P=0.611$ ) was significantly less than that of the U.S. data ( $P=0.717$ ). Also, there was a significant difference between the estimated proportion dead for the U.S. ( $P=0.862$ ) and Venezuelan ( $P=0.784$ ) observer data in the Caribbean.

Observer data have been combined from all three sources in order to make the similar comparisons as was done for the blue marlin, white marlin and sailfish data. It should be noted that presently there are no management restrictions on the swordfish fishery. In the U.S. fleet, swordfish are rarely discarded. Those that are discarded may either have severe damage or be extremely small in size. Comparison between areas (Table 4) shows that there was a significant difference between estimates of proportion dead between the N.W. Atlantic data ( $P=0.620$ ) and the Gulf of Mexico ( $P=0.785$ ); and between the Gulf of Mexico data and the Caribbean ( $P=0.827$ ).

## LITERATURE CITED

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Table 1: Estimates of proportion of dead fish retrieved from longline gear,  $P$ , derived for Atlantic blue marlin. Number of longline sets, data sources (JPN = Japanese longline observer data; USA = U.S. longline observer data; and VEN = Venezuelan longline observer data), geographical areas (GOM = Gulf of Mexico; NWA = northwest Atlantic Ocean; and CAR = Caribbean Sea), number of alive (A), dead (D), alive plus dead (A+D), proportion dead ( $P$ ), and 95% binomial confidence intervals (C.I.'s). No C.I.'s were calculated for sample sizes ( $=A+D$ ) less than 30.  $z$ -values with associated probabilities,  $P(z)$ , are presented along with the 95% confidence bounds calculated on the proportion dead.

Number of Sets	Data Source	Area	Number of			$P = D/(A+D)$	$z$	$P(z)$	95% C.I.	
			Alive	Dead	(A+D)				lower	upper
805	JPN	GOM	108	108	216	.500	1.56	0.12	.431	.569
212	USA	GOM	42	26	68	.382			.259	.505
4778	JPN	NWA	356	362	718	.504	NA	NA	.467	.541
37	USA	NWA	5	1	6	.167			-	-
43	USA	CAR	25	10	35	.286	-3.83	<0.01	.122	.450
131	VEN	CAR	27	59	86	.686			.582	.790
1017	JPN+USA	GOM	150	134	284	.472	-0.77	0.44	.412	.532
4815	JPN+USA	NWA	361	363	724	.501	-1.30	0.19	.464	.538
174	USA+VEN	CAR	52	69	121	.570			.478	.663

Table 2: Estimates of proportion of dead fish retrieved from longline gear, P, derived for Atlantic white marlin. Number of longline sets, data sources (JPN = Japanese longline observer data; USA = U.S. longline observer data; and VEN = Venezuelan longline observer data), geographical areas (GOM = Gulf of Mexico; NWA = northwest Atlantic Ocean; and CAR = Caribbean Sea), number of alive (A), dead (D), alive plus dead (A+D), proportion dead (P), and 95% binomial confidence intervals (C.I.'s). No C.I.'s were calculated for sample sizes (=A+D) less than 30. z-values with associated probabilities, P(z), are presented along with the 95% confidence bounds calculated on the proportion dead.

Number of Sets	Data Source	Area	Number of			P = D/(A+D)	z	P(z)	95% C.I.	
			Alive	Dead	(A+D)				lower	upper
805	JPN	GOM	461	596	1057	.564	4.09	<0.01	.533	.594
212	USA	GOM	77	44	121	.364			.274	.453
4778	JPN	NWA	1151	2370	3521	.673	NA	NA	.657	.689
37	USA	NWA	3	0	3	.000			-	-
43	USA	CAR	5	0	5	.000	NA	NA	-	-
131	VEN	CAR	111	163	274	.595			.535	.655
1017	JPN+USA	GOM	538	640	1178	.543	-1.17	0.24	.514	.572
174	USA+VEN	CAR	116	163	279	.584	-2.94	<0.01	.525	.644
4815	JPN+USA	NWA	1154	2370	3524	.673			.657	.688

Table 3: Estimates of proportion of dead fish retrieved from longline gear, P, derived for Atlantic sailfish. Number of longline sets, data sources (JPN = Japanese longline observer data; USA = U.S. longline observer data; and VEN = Venezuelan longline observer data), geographical areas (GOM = Gulf of Mexico; NWA = northwest Atlantic Ocean; and CAR = Caribbean Sea), number of alive (A), dead (D), alive plus dead (A+D), proportion dead (P), and 95% binomial confidence intervals (C.I.'s). No C.I.'s were calculated for sample sizes (=A+D) less than 30. z-values with associated probabilities, P(z), are presented along with the 95% confidence bounds calculated on the proportion dead.

Number of Sets	Data Source	Area	Number of			P = D/(A+D)	z	P(z)	95% C.I.	
			Alive	Dead	(A+D)				lower	upper
805	JPN	GOM	67	70	137	.511	0.16	0.87	.424	.598
212	USA	GOM	36	41	77	.532			.415	.650
4778	JPN	NWA	83	150	233	.644	NA	NA	.580	.707
37	USA	NWA	4	6	10	.600			.246	.954
43	USA	CAR	0	0	0	-	NA	NA	-	-
131	VEN	CAR	26	42	68	.618			.495	.741
1017	JPN+USA	GOM	103	111	214	.519	-1.29	0.20	.449	.588
174	USA+VEN	CAR	26	42	68	.618	0.23	0.82	.495	.741
4815	JPN+USA	NWA	87	156	243	.642			.580	.704

Figure 1: Estimates of proportion of longline catch retrieved dead are compared using 95% binomial confidence intervals (C.I.'s) for the data sources (JPN = Japanese longline observer data; USA = U.S. longline observer data; and VEN = Venezuelan longline observer data) available for each of the 3 geographical areas for (a) blue marlin, (b) white marlin, (c) sailfish, and (d) swordfish. Values in parentheses represent the sample size, calculated as the summation of alive plus dead. No confidence intervals were computed for sample sizes less than 30.

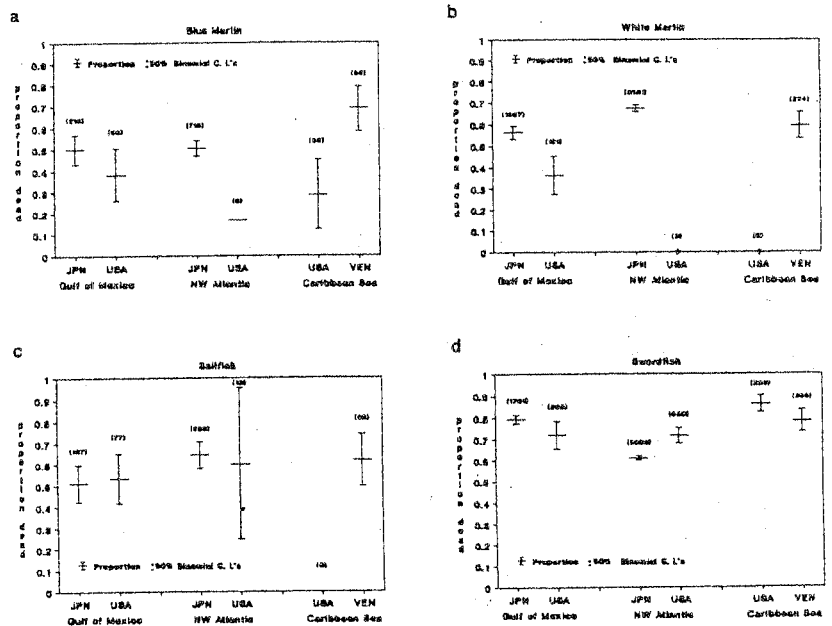


Table 4: Estimates of proportion of dead fish retrieved from longline gear, P, derived for Atlantic swordfish. Number of longline sets, data sources (JPN = Japanese longline observer data; USA = U.S. longline observer data; and VEN = Venezuelan longline observer data), geographical areas (GOM = Gulf of Mexico; NWA = northwest Atlantic Ocean; and CAR = Caribbean Sea), number of alive (A), dead (D), alive plus dead (A+D), proportion dead (P), and 95% binomial confidence intervals (C.I.'s). No C.I.'s were calculated for sample sizes (=A+D) less than 30. z-values with associated probabilities, P(z), are presented along with the 95% confidence bounds calculated on the proportion dead.

Number of Sets	Data Source	Area	Number of		P =	z	P(z)	95% C.I.	
			Alive	Dead (A+D)				Lower	Upper
805	JPN	GOM	352	1349	.793	2.33	0.02	.774	.813
212	USA	GOM	57	146	.719			.655	.783
4778	JPN	NWA	2718	4278	.611	-5.21	<0.01	.600	.623
37	USA	NWA	178	452	.717			.682	.753
43	USA	CAR	45	281	.862	2.38	0.02	.823	.901
131	VEN	CAR	58	211	.784			.733	.835
4815	JPN+USA	NWA	2896	4730	.620	-13.50	<0.01	.609	.631
1017	JPN+USA	GOM	409	1495	.785			.766	.804
174	USA+VEN	CAR	103	492	.827	-2.14	0.03	.796	.858

Figure 2: Estimates of proportion of longline catch retrieved dead and the 95% binomial confidence intervals (C.I.) are compared for the 3 geographical areas (JPN = Japanese longline observer data; USA = U.S. longline observer data; and VEN = Venezuelan longline observer data) between blue marlin, white marlin, and sailfish. Values in parentheses represent the sample size, calculated as the summation of alive plus dead. No confidence intervals were computed for sample sizes less than 30.

