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REVISED ESTIMATES OF BLUEFIN TUNA DEAD DISCARDS BY THE U.S. ATLANTIC PELAGIC LONGLINE FLEET, 1992-1999

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SUMMARY

*Estimates of the dead discards of bluefin tuna (*Thunnus thynnus*) by the US Atlantic pelagic longline fleet permitted to land and sell Atlantic swordfish (*Xiphias gladius*) are based on logbook reported fishing effort levels and scientific observer records of catch rates from a representative sample of the fleet. Estimates are constructed using the Delta-lognormal method as described by Pennington (1983), taking into account possible geographical and time of year effects, and coefficients of variation are calculated. The estimates ignore information that may be available in self-reported data on catch rates of bluefin tuna. Catch rate samples are pooled as necessary across strata to achieve a minimum sample size of 30 observations. The estimates of bluefin tuna dead discards are compared to previous estimates and are converted to weight.*

RÉSUMÉ

Les estimations des thons rouges (Thunnus thynnus) *rejetés morts par la flottille palangrière pélagique des Etats-Unis qui est autorisée à capturer et à vendre de l'espadon de l'Atlantique* (Xiphias gladius) *se fondent sur le niveau d'effort de pêche enregistré dans les livres de bord et sur les enregistrements des observateurs concernant le taux de capture d'un segment représentatif de la flottille. Les estimations sont élaborées au moyen de la méthode delta-lognormal décrite par Pennington (1983) en tenant compte des effets éventuels dûs à la géographie ou à l'époque de l'année, et des coefficients de variation sont calculés. Les estimations négligent les informations qui pourraient être disponibles dans les données auto-déclarées sur le taux de capture de thon rouge. Les échantillons du taux de capture sont regroupés selon les besoins à travers les strates pour obtenir des échantillons d'un volume minimum de 30 observations. Les estimations des rejets de thons rouges morts sont comparés aux estimations antérieures et converties en poids.*

RESUMEN

Las estimaciones de los descartes muertos de atún rojo (Thunnus thynnus) *de la flota estadounidense de palangre pelágico del Atlántico autorizada a desembarcar y vender pez espada (*Xiphias gladius) *del Atlántico, se basan en los niveles de esfuerzo pesquero comunicados por los cuadernos de pesca y en los registros de los observadores científicos de tasas de capturas procedentes de una muestra representativa de la flota. Las estimaciones se han realizado utilizando el método delta- lognormal tal y como los describe Pennington (1983), teniendo en cuenta los posibles efectos geográficos y época del año, y calculando los coeficientes de variación. Las estimaciones ignoran la información que pueda estar disponible en datos auto-comunicados sobre tasas de captura del atún rojo. Las muestras de tasas de captura se agrupan, según sea necesario, a lo largo de estratos para lograr un tamaño mínimo de 30 observaciones. Las estimaciones de los descartes muertos de atún rojo se comparan con estimaciones previas y se convierten en peso.*

INTRODUCTION

Longline is the principal gear used by U.S. fleets to fish for tuna (*Thunnus spp.*) and swordfish (*Xiphias gladius*) in the North Atlantic (including the Gulf of Mexico) (Berkeley *et al.*, 1981; Hoey and Bertolino, 1988). Non-targeted bycatch of this fishery includes an array of marine species which are hooked or entangled in the longline. The catch of targeted species is also discarded at times due to market or regulatory considerations. Dead discards constitute fishing mortality and must be included in estimates of total catch. However, since dead discards are not landed and do not pass through the reporting system used to monitor U.S. landings, these bycatch estimates rely on the use of self-reported and/or at-sea observations of the fishery.

Most effort to develop approaches to estimate discards in the U.S. Atlantic longline fleet has focused upon marine mammal and marine turtle bycatch, which have been estimated using several methods. Witzell and Cramer (1995) applied a generalized linear model (GLM), based on a Poisson error distribution assumption, to model marine turtle catch per set by U.S. Atlantic longline vessels during 1992-1993. The observer data used in that analysis were obtained from the Pelagic Observer Programs managed by NOAA Southeast Fisheries Science Center (SEFSC, Lee et al. 1994; 1995) and Northeast Fisheries Science Center (NEFSC). Turtle catch and effort were obtained from the Atlantic Large Pelagic Logbook managed by the SEFSC (Farber 1990; Farber and Cramer 1992; Cramer 1993a; 1994a; 1995a; 1996a). The GLM was also applied to estimate marine mammal bycatch in U.S. Atlantic and Gulf of Mexico marine mammal stock assessment documents (Blaylock et al. 1995). This method allowed the estimation of uncertainty about the bycatch and provided a basis for modeling spatio-temporal and gear effects (*e.g.* fishing depth or the effect of light sticks) by taking advantage of the larger sample sizes from the self-reported data, relative to the sample sizes from observed catch rates only.

An alternative method, a simple proportional extrapolation of the observed catch rates to the logbook-reported total effort ($catch_{total} = catch_{observed} \div effort_{observed} \times effort_{logbook}$), was summarized in Cramer (1995a) for calendar year 1993. This method was used to provide a national report to the International Commission for the Conservation of Atlantic Tunas (ICCAT) on estimated total catch composition and disposition of the U.S. Atlantic longline fleet. The method ignored self-reported information on catch rates available from the Atlantic Large Pelagic Logbook data sets and did not provide a measure of uncertainty in the catch estimates.

Scott and Brown (1997) estimated marine mammal and marine turtle bycatch for the U.S. Atlantic pelagic longline fleet for 1994-1995 using a modification of the simple extrapolation method which provided measures of uncertainty in bycatch estimates. This method was considered to be less complicated than the GLM approach, although it ignored axillary information (e.g. light sticks, depth, details regarding gear configurations and methods) in the self-reported data that might provide a basis for further refining the estimates through a structured hypothesis testing procedure. The extrapolation method was utilized, with refinements, to estimate bycatch of marine mammals and turtles in subsequent years (Johnson *et al*., 1999; Yeung, 1999*a*, 1999*b*). In the previous reports, the robustness of the bycatch estimates from several different pooling schemes for bycatch rates were examined, from no pooling (stratified estimates by year-quarter-grouped fishing area (NAREA)) to the highest level of pooling (within year-large fishing region (MAREA)). No bycatch estimates were made for strata without observer effort in these reports; if no longline sets were observed by the Pelagic Observer Program, the reported bycatch was effectively zero.

Another pooling scheme is proposed by Yeung *et al.* (2000) in which a specified criterion of a minimum number of observed sets determines the level of pooling. The levels of quarter, year and NAREA are successively pooled in that order until the criterion is met. In many cases, this scheme leads to a redistribution of estimated bycatch across strata, so that there are fewer empty cells with no bycatch estimates than in previous reports, but the summed total of the bycatch estimates across strata are generally not greatly different.

This current report presents estimates of bluefin tuna discarded dead by the U.S. Pelagic longline fleet during 1992-1999 using the methodology described by Yeung *et al.* (2000), with the exception that the pooling order is year, quarter and NAREA. This pooling order is determined to be more appropriate for application with bluefin tuna. Previously, the levels of longline dead discards reported to ICCAT have been tallies of the self-reported numbers in the Atlantic Large Pelagic Logbook data. Since the logbook data do not represent a census and the self-reported numbers could be incomplete or mis-reported, it is proposed that the historical bycatch series be updated using the new estimation methodology.

METHODS

Data

Effort reported by the fishery was obtained from the Atlantic Large Pelagic Logbook database maintained by the SEFSC (Southeast Fisheries Science Center), which contains daily fishing effort reported by all permitted U.S. Atlantic longline vessels landing swordfish and tuna (Cramer and Adams, 2000). Observed catch and effort were obtained from the SEFSC Observer Program database (Lee and Brown, 1998), which now includes data collected by through the NEFSC Observer Program.

Large Pelagic Logbook Data

Daily logbook reports of catch and effort from permitted U.S. vessels targeting large pelagic fishes have been required under the Atlantic Swordfish Fishery Management Plan since 1986. This information is collected in the Large Pelagic Logbook database. Not withstanding errors due to mis-reporting, fishery-reported effort from the logbook (reported effort) is taken as representative of the actual permitted effort expended by the U.S. pelagic longline fleet in the Atlantic. Observed bycatch rates are raised to the amount of reported effort in the logbook for estimating total bycatch. Reported effort units are individual set (gear deployment) records reporting at least 100 hooks fished or otherwise indicated as being a pelagic longline set, and which were not reported to be bottom longline sets. Reported effort (hooks and sets fished) are classified by fishing area (Figure 1) and calendar quarters. Effort missing location data are proportionally distributed among fishing areas based on the distribution of known set locations for the pertinent year and calendar quarter. Effort missing calendar quarter data within a fishing area are proportionally distributed among quarters based on the distribution of effort across quarters within the area.

Observer Data

Systematic sampling by scientific observers on board U.S. pelagic longline vessels in the Atlantic permitted to land and sell swordfish was implemented in 1992, under the mandate of the 1991 amendments to the U.S. Fishery Management Plan (FMP) for Swordfish. The estimated bycatch rates in the pelagic longline fishery are based on the data collected by the observer sampling program. The fishing area is defined by the location where the haul-back of the longline began after fishing.

Geographical stratification

The span of ocean fished by the U.S. Atlantic pelagic longline fleet is divided into eleven areas, which are further classified into six NAREAs (grouped fishing areas) (Figure 1). The NAREAs are the 1) Caribbean (CAR), 2) Gulf of Mexico (GOM), and 3) Northeast Distant (NED) AREAs, along with the combined 4) Southeast Coastal (SEC) [Florida East Coast (FEC) + South Atlantic Bight (SAB)], 5) Northeast Coastal (NEC) [Northeast Coastal (NEC) + Mid-Atlantic Bight (MAB)], and 6) Offshore South

(OFS) [Sargasso (SAR) + North Central Atlantic (NCA) + Tuna South (TUS) + Tuna North (TUN)] AREAs.

In general, fishing effort is classified based on reported or observed latitude and longitudes. When in some cases location information was not available, fishing areas (for catch and effort) were assigned based on examination of neighboring sets (neighboring days of fishing on the same trip) or observer logs. Where specific locations could not be determined or extrapolated from neighboring days, the reported sets were proportionally assigned to fishing areas based on the overall distribution of the reported effort with known locations.

Dead Discard Estimation for 1992-1999

Estimates of bluefin tuna discarded dead are based solely on observer reports of release condition. Estimates were constructed using the delta-lognormal method (Pennington, 1983). The method assumes a lognormal distribution of the positive bycatch rate observations. Effectively, the estimates are constructed as a product of the proportion of successful occurrences of an event and the average rate at which the event occurs for those successful events. The variance is a function of the variability of the positive bycatch rates as well the number of successful and unsuccessful sets. Total bycatch for an analytical stratum (taxon-fishing area-quarter), C, is estimated as:

$$C = H\frac{m_c}{N} e^{L} G_{mc}\left(\frac{s_L^{\ 2}}{2}\right), \tag{1}$$

H = reported number of hooks that were set, divided by 1000,
m_c= number of sets in which a non-zero bycatch of the species group was observed (positive sets),
N = total number of sets observed,

$$L = \sum L_i / m_c, \quad s_L^{\ 2} = \frac{\sum (L_i - L)^2}{m_c - 1}$$

, where

$\mathrm{L_i} = \log_e(\mathrm{catch_i}/\mathrm{hooks_i} \times 1000)$, $\log_e$-transformed bycatch rate for the i^{th} positive set, i=1,...,m_c,
L = mean of L_i,
s_L^2 = sample variance of L_i;

and the function

$G_{m_c}\left(\frac{s_L^{\ 2}}{2}\right)$ is:
$$G_{m_c}\left(\frac{s_L^{\ 2}}{2}\right) = 1 + \frac{m_c - 1}{m_c}\left(\frac{s_L^{\ 2}}{2}\right) + \sum_{j=2}^{\infty} \frac{(m_c - 1)^{2j-1}}{m_c^{\ j}(m_c + 1)(m_c + 3)\ldots(m_c + 2j - 3)} \times \frac{\left(\frac{s_L^{\ 2}}{2}\right)^j}{j!}. \tag{2}$$

Numerically, the series was computed over j terms, until a convergence criterion of <0.001 change in the function was achieved (usually less than 10 terms were required). The estimate of variance of the bycatch takes the form:

$$V(C) = \frac{m_c}{N}(He^L)^2\left[\frac{m_c}{N}G_{m_c}{}^2\left(\frac{s_L{}^2}{2}\right) - \left(\frac{m_c-1}{N-1}\right)G_{m_c}\left(\frac{m_c-2}{m_c-1}s_L{}^2\right)\right]. \tag{3}$$

Bycatch estimates by stratum are assumed independent and as such estimated bycatch and the associated variances are summed across strata to produce region-wide annual estimates. The coefficient of variation for the stratum-wise estimate of bycatch is taken as:

$$CV = \frac{\sqrt{V(C)}}{C}. \tag{4}$$

Cells for which CV could not be calculated were assigned a CV of 1. Approximate (1-α) X 100% confidence intervals (α=0.05) are constructed assuming a lognormal distribution as: $(U_{1-\alpha/2}, L_{1-\alpha/2})=(Ck, C/k)$, where $U_{1-\alpha/2}$ and $L_{1-\alpha/2}$ represent the upper and lower confidence bounds, k= $\exp[z_\alpha(\log(1+CV2))^{1/2}]$, and z_α the associated (1-*a*) X 100th percentile *z*-score (Burnham *et al.*, 1987, see p. 212). The lack of incorporation of (a) covariance terms and (b) variance of proportion of positive sets (m_c/N) in $V(C)$, along with an assumption of effort (H) being a known constant, may cause the actual variance of bycatch estimate to be underestimated. This in turn will produce the narrower confidence interval which will have a lower than the desired confidence level.

Treatment of strata with few bycatch rate observations

In some previous reports (Johnson *et al.*, 1999; Yeung, 1999*a*, 1999*b*), when there was no observer effort for a particular analytical stratum, *i.e.*, N=0, the mean bycatch rate L and the proportion of positive sets, m_c/N were not estimated. No estimate of bycatch was made for the stratum even though logbooks show that there was fishing effort (H>0). When no pooling of observed effort was employed in estimating bycatch in the previous reports, *i.e.*, estimates stratified by NAREA, year and quarter (Johnson *et al.* 1999, Yeung, 1999*a*, Yeung 1999*b*), there were many cells with no observed effort. These empty cells occurred mainly in the NAREAs of CAR, NED, and OFS.

Furthermore, for many cells where there were bycatch rate observations, the number of sets observed was low. These low sample sizes could lead to bycatch rate estimates for each stratum which are either too high or too low. This potential problem is exacerbated when the bycatch event, such as dead discarded bluefin tuna, occurs relatively infrequently.

To reduce the potential problems associated with low numbers of bycatch rate observations within strata, a new approach to the pooling of bycatch rate observations was proposed by Yeung *et al.* (2000) and is used for this report. The methods used herein (and by Yeung *et al.* 2000) primarily differ from those used in the past in that the degree of pooling of observed effort was assessed stepwise using a criterion of minimum number of observed sets (N_{min}), which was set at 30.

First, the effect of year, quarter, and NAREA on the bluefin tuna discarded catch rate was evaluated using a GLM. The results indicated that NAREA was responsible for the greatest model effect, followed by quarter. Therefore, the standard pooling priority order of year, quarter, and NAREA was established according to the increasing order of variance explained by each effect. Thus, if the observer data contained less than 30 observed sets for a stratum, data were first pooled across years to obtain a minimum sample size of N_{min} (30) observed sets. If the pooling across years was insufficient to achieve the minimum sample size, data were then pooled across quarters, and (if necessary) across NAREAs to obtain an estimate of L and m_c/N, for the stratum. The variance for the bycatch $V(C)$ was then estimated over the pooled stratum.

Generation of dead discard estimates for 1987-1991

The observer data are only available beginning in 1992, although Large Pelagic Logbook data are available beginning in 1987. In order to generate estimates of dead discards for the period 1987-1991, it was assumed that the ratio of actual dead discards to the total number of discards reported in the logbook data was similar for 1987-1991 to the ratio of dead discard estimates to the total number of discards reported in the logbook data for 1992-1999. The ratio was calculated relative to the total number of discards (live+dead) reported in the logbook data, rather than to the number of dead discards, because there are significant differences in the live/dead ratio of discarded catch between the observer data and the logbooks (Brown *et al*. 2000). The total discards reported in the logbooks was therefore considered more reliable than was the reported dead discards (although still subject to under reporting).

The expansion ratio:

$$Ratio = \frac{\sum_{year=1992}^{year=1999} C_{\text{estimated}}}{\sum_{year=1992}^{year=1999} C_{\text{logbooks}}} , \tag{5}$$

where C is the number of bluefin tuna discarded dead, was then multiplied by the reported bluefin tuna total discards reported in the logbooks by year quarter and ICCAT area to obtain new estimates for the period 1987-1991.

Calculating the weight of dead discards

Bluefin tuna dead discard size distributions for each month and ICCAT area were obtained from the observer data. Both measured and estimated lengths were used, as there was information that there might be a selection bias between fish measured and estimated. Due to the overall paucity of observed lengths for dead discarded bluefin, observations were pooled across years.

The catch-at-length for bluefin dead discards was calculated by applying the area/month size distributions to the area/month estimates for each year. Length-weight conversion then provided estimates of dead discards in weight.

RESULTS AND DISCUSSION

Observed effort (in sets) for each year-quarter-NAREA stratum for 1992-1999 are summarized in Table 1. The extent of pooling can be determined by examination of Table 1; any cell with a number of observations less than 30 would have utilized a pooled sample. Most cells have fewer than 30 observations and therefore required the use of the bycatch rate sample pooled across years for the specific NAREA and quarter. However, in only five instances were there less than 30 observations in a sample pooled across years; in quarters 2 and 3 for CAR, in quarter 1 for NED, and in quarters 3 and 4 for OFS. For these cases, it was necessary to pool across both years and quarters to generate a sample of sufficient size.

The estimates of dead discarded bluefin tuna by year, quarter (presented as month, defined from the month in the middle of each quarter) and ICCAT reporting area are given in Table 2. For comparison, the number of dead discarded bluefin tuna reported in the Large Pelagic Logbook data (restricted as previously described to pelagic longline sets) are also shown. The calculation of the expansion ratio, which was used to generate estimates for 1987-1991, is also shown in Table 2. The resulting dead discard estimates, as well as the total reported discards from the logbooks, are shown in Table 3.

The yearly dead discard estimates for each ICCAT area are presented in Table 4. The calculated CV is also shown in Table 4, but these values do not incorporate the uncertainty in the sizing of the catch. Therefore, these CV values may apply to estimates if presented in numbers of fish, but are likely to underestimate the true CVs for the estimates of tonnage. The overall yearly estimates are compared to previous estimates which have been reported to ICCAT (or, in the case of 1999, would have been reported to ICCAT had the previous year's methodology been followed) in Table 5. A variety of methods have been used to calculate previous dead discard estimates, including relating the rate of dead discards to tuna and swordfish landings as reported in the logbooks, then expanding based upon total tuna and swordfish landings. The method used in recent years was to tabulate bluefin tuna dead discards reported through the logbooks, and then to add individual dead discards which were recorded in the observer program but which were not reported in the logbooks.

The pooling method presented in this paper does provide estimates of retained catch of commercial species from the U.S. Atlantic pelagic longline fishery that are similar to values reported in the commercial landings reporting system (Brown *et al.* 2000);this includes the estimates and reported landings for bluefin tuna. It should be noted, however, that the bluefin tuna estimates for both kept and discarded fish have large variances. Where there is a dearth of actual observations, this method may be an acceptable alternative when applied with a consideration of its limitations. A number of concerns remain regarding this methodology. The sensitivity of the pooling method to the N_{min} criterion is unclear. Also, pooling may obscure significant differences and trends within and across factors. The lack of independence of longline sets, which is used as the primary sampling unit, needs to be evaluated as well. The methodology and estimates presented in this report, however, are regarded as an improvement over previously available methodologies and bluefin tuna dead discard estimates.

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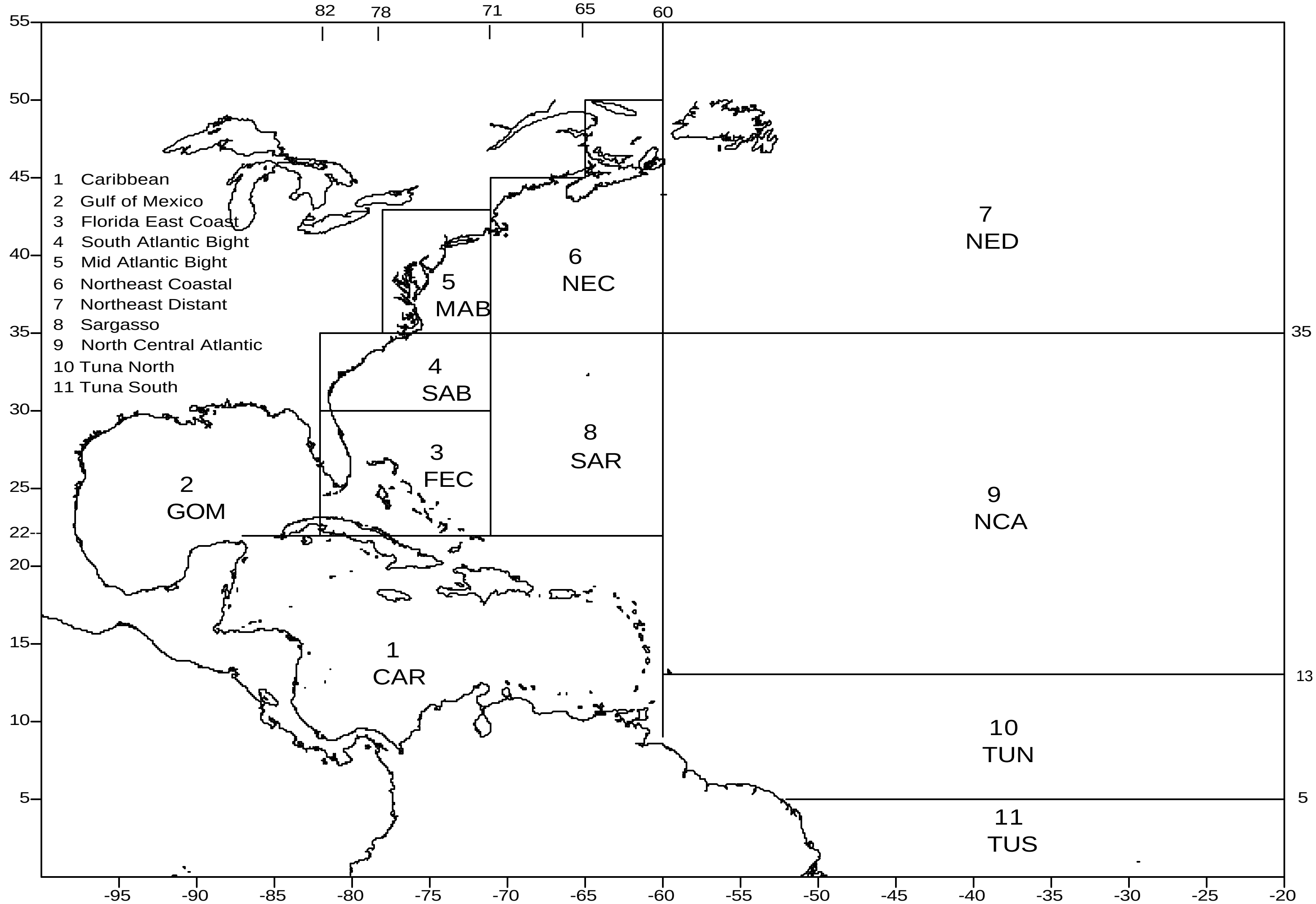

Figure 1. The geographical zones used to classify observed and reported U.S. Atlantic pelagic longline fishing effort. For the purpose of estimation, several strata were combined. The Southeast Coastal (SEC) stratum was defined as areas 3 and 4; the Northeast Coastal (NEC) stratum was defined as areas 5 and 6; and the Offshore South (OFS) was defined as areas 8, 9, 10, and 11.

Table 1: Available bycatch rate observations (longline sets observed)

NAREA	QUARTER	1st level of pooling, applied when observed sets < 30 (shaded cells) — YEARS: 1992	1993	1994	1995	1996	1997	1998	1999	pooled across years	2nd level of pooling, applied when 1st level pooled observations < 30 (shaded, bold cells)
CAR	1	0	21	35	23	3	9	0	17	108	
	2	0	9	0	12	0	0	0	0	**21**	
	3	0	0	0	12	0	0	0	0	**12**	
	4	11	10	0	1	3	0	10	0	35	
										176	pooled across years and quarters
GOM	1	0	43	25	43	30	44	25	47	257	
	2	16	79	33	58	19	42	14	42	303	
	3	8	49	49	47	43	39	21	35	291	
	4	37	64	47	49	32	32	12	53	326	
										1177	pooled across years and quarters
NEC	1	0	45	24	39	0	0	20	6	134	
	2	18	38	47	18	0	9	8	4	142	
	3	26	114	89	93	21	66	30	25	464	
	4	61	65	78	50	1	25	18	27	325	
										1065	pooled across years and quarters

Table 1 (continued): Available bycatch rate observations (longline sets observed)

NAREA	QUARTER	1st level of pooling, applied when observed sets < 30 (shaded cells) YEARS 1992	1993	1994	1995	1996	1997	1998	1999	pooled across years	2nd level of pooling, applied when 1st level pooled observations < 30 (shaded, bold cells)
NED	1	0	0	0	0	0	0	0	0	**0**	
	2	9	6	0	0	0	2	0	23	40	
	3	26	42	37	53	0	40	0	17	215	
	4	46	27	24	12	0	0	0	0	109	
										364	pooled across years and quarters
OFS	1	0	52	19	61	60	33	8	17	250	
	2	0	0	0	21	0	12	4	0	37	
	3	0	0	0	0	17	0	0	0	**17**	
	4	0	0	0	0	0	0	0	0	**0**	
										304	pooled across years and quarters
SEC	1	0	37	33	21	18	28	25	13	175	
	2	28	55	49	48	56	18	53	60	367	
	3	28	35	36	12	16	34	4	17	182	
	4	15	26	20	12	37	15	34	17	176	
										900	pooled across years and quarters

Table 2: 1992-1999 estimates of bluefin tuna dead discards for longline (in numbers of fish)

year	month	ICCAT area	logbook live+dead discards	logbook dead discards	estimated dead discards	cv	expansion ratio
1992	2	91		39	16	0.28	
1992	5	91		41	100	0.21	
1992	8	91		1	0		
1992	2	92		7	61	0.30	
1992	5	92		183	1562	0.14	
1992	8	92		86	62	0.29	
1992	11	92		45	709	0.32	
1992	11	93		3	0		
1992	2	94		2	15	0.21	
1992	5	94		4	144	1.00	
1992	8	94		20	28	0.29	
1992	11	94		11	48	0.17	
Total			987	442	2745	0.22	2.78
1993	2	91		2	0		
1993	5	91		21	85	0.22	
1993	11	91		1	0		
1993	2	92		8	138	0.28	
1993	5	92		258	490	0.14	
1993	8	92		191	16	0.37	
1993	11	92		20	57	0.22	
1993	5	94		78	89	1.00	
1993	8	94		11	92	0.33	
1993	11	94		26	29	0.17	
Total			1342	616	996	0.21	0.74
1994	2	91		0	10	0.28	
1994	5	91		7	45	0.28	
1994	2	92		31	19	0.31	
1994	5	92		438	823	0.15	
1994	8	92		35	48	0.28	
1994	11	92		11	3	0.37	
1994	11	93		2	0		
1994	2	94		8	16	0.21	
1994	5	94		18	77	1.00	
1994	8	94		6	0		
1994	11	94		2	40	0.18	
Total			1284	558	1081	0.18	0.84
1995	2	91		1	0		
1995	5	91		6	94	0.17	
1995	11	91		1	0		
1995	2	92		54	70	0.30	
1995	5	92		1090	1858	0.15	
1995	8	92		111	63	0.24	
1995	11	92		10	2	0.37	
1996	2	91		1	0		
1996	5	91		10	123	0.21	
1996	2	92		16	87	0.29	
1996	5	92		438	1735	0.14	
1996	8	92		81	70	0.29	
1996	11	92		16	48	0.27	
1996	2	94		9	102	0.21	
1996	8	94		0	28	0.28	
1996	11	94		0	29	0.18	
Total			1708	571	2222	0.17	1.30
1997	5	91		24	101	0.20	
1997	2	92		3	94	0.29	
1997	5	92		180	1191	0.15	
1997	8	92		36	202	0.18	
1997	11	92		43	116	0.27	
1997	5	94		18	128	1.00	
1997	8	94		0	2	0.21	
1997	11	94		0	9	0.21	
Total			690	304	1843	0.18	2.67
1998	2	91		8	14	0.28	
1998	5	91		28	87	0.21	
1998	2	92		31	73	0.29	
1998	5	92		342	817	0.15	
1998	8	92		50	36	0.37	
1998	11	92		38	125	0.28	
1998	2	94		0	19	0.21	
1998	5	94		0	41	1.00	
1998	8	94		2	20	0.29	
1998	11	94		3	14	0.18	
Total			1320	502	1246	0.20	0.94
1999	2	91		21	53	0.28	
1999	5	91		67	242	0.18	
1999	8	91		3	0		
1999	2	92		2	79	0.29	
1999	5	92		87	1003	0.18	
1999	8	92		5	50	0.29	
1999	11	92		8	94	0.27	
1999	2	94		0	9	0.21	
1999	5	94		27	47	1.00	
1999	8	94		0	12	0.28	
1999	11	94		0	13	0.18	
Total			601	220	1602	0.20	2.67
Overall Total			10822	4491	13920	0.19	1.29

1995	2	94		0	0		
1995	5	94		0	26	1.00	
1995	8	94		4	52	0.24	
1995	11	94		1	20	0.17	
Total			2890	1278	2185	0.16	0.76

Note: month defined from middle of each quarter
expansion ratio = estimated dead discards/total discards reported in logbooks

Table 3: 1987-1991 estimates of bluefin tuna dead discards for longline (in numbers of fish)

year	month	ICCAT area	logbook live+dead discards	estimated dead discards	year	month	ICCAT area	logbook live+dead discards	estimated dead discards
1987	1	91	6	8	1988	7	92	206	266
1987	2	91	22	28	1988	8	92	2	3
1987	3	91	35	45	1988	10	92	2	3
1987	4	91	123	159	1988	11	92	10	13
1987	5	91	172	222	1988	12	92	97	125
1987	6	91	26	34	1988	4	93	1	1
1987	7	91	2	3	1988	11	93	2	3
1987	9	91	1	1	1988	5	94	1	1
1987	12	91	4	5	1988	6	94	19	25
1987	1	92	2	3	1988	7	94	43	55
1987	2	92	1	1	1988	8	94	6	8
1987	3	92	16	21	1988	9	94	8	10
1987	4	92	56	72	1988	10	94	34	44
1987	5	92	139	179	1988	11	94	7	9
1987	6	92	87	112	**Total**			1066	1379
1987	7	92	38	49	1989	1	91	11	14
1987	8	92	1	1	1989	2	91	43	55
1987	9	92	2	3	1989	3	91	107	138
1987	10	92	16	21	1989	4	91	127	164
1987	11	92	2	3	1989	5	91	22	28
1987	12	92	5	6	1989	6	91	7	9
1987	3	93	2	3	1989	10	91	4	5
1987	4	93	1	1	1989	1	92	26	34
1987	6	93	5	6	1989	2	92	18	23
1987	7	93	1	1	1989	3	92	17	22
1987	5	94	7	9	1989	4	92	32	41
1987	6	94	19	25	1989	5	92	95	123
1987	7	94	35	45	1989	6	92	112	144
1987	8	94	10	13	1989	7	92	24	31
1987	9	94	2	3	1989	8	92	51	66
1987	10	94	6	8	1989	9	92	13	17
1987	11	94	1	1	1989	10	92	6	8
Total			845	1090	1989	11	92	15	19
1988	1	91	7	9	1989	12	92	193	249
1988	2	91	11	14	1989	3	93	2	3
1988	3	91	19	25	1989	4	93	1	1
1988	4	91	52	67	1989	12	93	1	1
1988	5	91	18	23	1989	1	94	1	1
1988	6	91	3	4	1989	2	94	1	1
1988	7	91	1	1	1989	3	94	1	1
1988	12	91	1	1	1989	4	94	6	8

1988	1	92	1	1	1989	6	94	8	10
1988	2	92	12	15	1989	7	94	9	12
1988	3	92	34	44	1989	8	94	6	8
1988	4	92	3	4	1989	9	94	12	15
1988	5	92	111	143	1989	10	94	14	18
1988	6	92	355	462	1989	11	94	46	59

Table 3 (cont.): 1987-1991 estimates of bluefin tuna dead discards for longline (in numbers of fish)

year	**month**	**ICCAT area**	**logbook live+dead discards**	**estimated dead discards**	**year**	**month**	**ICCAT area**	**logbook live+dead discards**	**estimated dead discards**
1989	12	94	1	1	1991	1	91	4	5
Total			1032	1331	1991	2	91	7	9
1990	1	91	6	8	1991	3	91	49	63
1990	2	91	25	32	1991	4	91	34	44
1990	3	91	9	12	1991	5	91	37	48
1990	4	91	17	22	1991	1	92	1	1
1990	5	91	43	55	1991	2	92	15	19
1990	6	91	3	4	1991	3	92	2	3
1990	8	91	1	1	1991	4	92	12	15
1990	1	92	15	19	1991	5	92	49	63
1990	2	92	51	66	1991	6	92	464	599
1990	3	92	47	61	1991	7	92	256	330
1990	4	92	9	12	1991	8	92	59	76
1990	5	92	60	77	1991	9	92	52	67
1990	6	92	594	766	1991	10	92	8	10
1990	7	92	189	244	1991	11	92	266	343
1990	8	92	5	6	1991	12	92	23	30
1990	9	92	7	9	1991	5	94	6	8
1990	10	92	40	52	1991	6	94	181	233
1990	11	92	56	72	1991	7	94	57	74
1990	12	92	61	79	1991	8	94	3	4
1990	1	93	2	3	1991	9	94	7	9
1990	2	94	1	1	1991	10	94	3	4
1990	6	94	39	50	1991	11	94	7	9
1990	7	94	20	26	1991	12	94	2	3
1990	9	94	4	5	**Total**			1604	2069
1990	10	94	19	25					
1990	11	94	15	19					
Total			1338	1726					

Note: estimated dead discards are calculated by multiplying the logbook reported total discards (live+dead) by the expansion ratio (1.29, from Table 2) obtained by comparing dead discard estimates to reported dead discards for the period 1992-1999

Table 4: Bluefin tuna yearly longline dead discard estimates

year	ICCAT area	metric tonnes	cv *	year	ICCAT area	metric tonnes	cv*
1987	91	107.55	na	1993	91	17.69	0.22
1987	92	39.24		1993	92	56.45	0.19
1987	93	1.51		1993	94	25.47	0.28
1987	94	12.14		1994	91	11.63	0.28

1988	91	31.37	na
1988	92	67.17	
1988	93	0.39	
1988	94	18.05	
1989	91	93.46	na
1989	92	63.08	
1989	93	0.84	
1989	94	17.55	
1990	91	29.82	na
1990	92	96.49	
1990	93	0.48	
1990	94	14.02	
1991	91	37.58	na
1991	92	110.49	
1991	94	39.75	
1992	91	24.36	0.22
1992	92	162.24	0.22
1992	94	29.40	0.24
1994	92	56.14	0.16
1994	94	17.22	0.22
1995	91	19.58	0.17
1995	92	122.79	0.16
1995	94	11.84	0.23
1996	91	25.76	0.21
1996	92	121.35	0.16
1996	94	20.46	0.22
1997	91	21.26	0.20
1997	92	110.19	0.17
1997	94	16.43	0.24
1998	91	21.31	0.22
1998	92	68.35	0.19
1998	94	11.91	0.24
1999	91	62.53	0.20
1999	92	78.86	0.20
1999	94	9.98	0.24

*ignores uncertainty due to sizing of catches

Table 5: Comparison of current and previous methodology
Estimates of bluefin tuna dead discards

year	numbers of fish			metric tonnes	
	previous	current	cv	previous	current
1987	833	1091	na	192	160
1988	1403	1379	na	215	117
1989	1190	1329	na	248	175
1990	929	1726	na	133	141
1991	1047	2069	na	199	188
1992	435	2745	0.22	44	216
1993	617	996	0.21	31	100
1994	554	1081	0.18	76	85
1995	1350	2185	0.16	141	154
1996	572	2222	0.17	73	168
1997	312	1843	0.18	37	148
1998	516	1246	0.20	64	102
1999	225	1602	0.20	30	151