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ANALYSES OF THE POSSIBLE MAGNITUDE OF THE U.S. RECREATIONAL BLUE MARLIN AND WHITE MARLIN HARVEST[1]

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SUMMARY

*Some components of the U.S. recreational marlin landings are not precisely measured and have not been routinely included in the landings reported to ICCAT. This problem is reflected by the caveat in the annual reports that these landings are "minimum estimates." This paper explores the possible integration of the U.S. Marine Recreational Fishery Statistics Survey (MRFSS) and the U.S. Atlantic Recreational Billfish Survey (RBS) catch estimates for blue and white marlin (*Makaira nigricans *and* Tetrapturus albidus*, respectively). The resulting models attempt to estimate total U.S. recreational marlin landings by adjusting for the bias in the relatively precise annual RBS estimates using the statistical relationships between the relatively unbiased, but highly imprecise, MRFSS estimates and the RBS estimates. The resulting relationships are used to predict the U.S. recreational landings of Atlantic blue marlin and white marlin for 1972-1997. The merits and liabilities of the predicted values are discussed.*

RÉSUMÉ

Certaines composantes des débarquements de la pêche sportive américaine ne sont pas mesurées avec précision, et n'ont pas été incluses de façon régulière dans les débarquements signalés à l'ICCAT. Ce problème est reflété par la réserve des rapports annuels à l'effet qu'il s'agit d'"estimations minimales". Le présent document recherche l'éventuelle intégration des estimations des prises de makaire bleu (Makaira nigricans) *et de makaire blanc* (Tetrapturus albidus) *de la U.S. Marine Recreational Fishery Statistics Survey (MRFSS) et de la U.S. Atlantic Recreational Billfish Survey (RBS). Les modèles qui en découlent tentent d'estimer les débarquements totaux de la pêche sportive américaine en ajustant les biais des estimations annuelles relativement précises de la RBS au moyen du rapport statistique entre les estimations relativement libres de biais, mais très imprécises, de la MRFSS et celles de la RBS. Les rapports qui en découlent sont utilisés pour prédire les débarquements de makaire bleu et de makaire blanc par la pêche sportive américaine en 1972-1997. Les avantages et inconvénients des valeurs prédites font l'objet d'une discussion.*

RESUMEN

*Algunos componentes de los desembarques deportivos de marlines en Estados Unidos no están medidos de forma precisa y no han sido incluidos de forma rutinaria en los desembarques comunicados a ICCAT. Este problema se refleja en la advertencia de los informes anuales de que estos desembarques son "estimaciones mínimas". Este documento explora la posible integración de las estadísticas de captura de la U.S. Marine Recreational Fishery Statistics Survey (MRFSS) y la U.S. Atlantic Recreational Billfish Survey (RBS) para la aguja azul y aguja blanca (*Makaira nigricans *y* Tetrapturus albidus *respectivamente). Los modelos resultantes pretenden estimar los desembarques deportivos totales de marlines de Estados Unidos ajustando el sesgo en las estimaciones anuales RBS, relativamente precisas, utilizando las relaciones estadísticas entre las estimaciones MRFSS, relativamente poco sesgadas pero muy imprecisas, y las estimaciones RBS. Las relaciones resultantes se utilizan para pronosticar los desembarques deportivos de Estados Unidos de aguja azul y aguja blanca del Atlántico para 1972-1997. Se discuten los méritos y responsabilidades de los valores pronosticados.*

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KEYWORDS

Sport fishing, Fish catch statistics, Statistical sampling, Prediction

INTRODUCTION

U.S. Atlantic recreational marlin catches and landings (i.e. Task I data) have been estimated using the National Marine Fisheries Service's (NMFS) Recreational Billfish Survey (RBS) since 1972. This survey includes mostly billfish tournaments, although some sampling of non-tournament billfishing activity has been conducted (Prince *et al*. 1990). Because the RBS did not routinely measure non-tournament billfishing activity in a comprehensive way, Task I data resulting from this survey are reported to ICCAT as "minimum estimates." A description of the RBS and associated problems of conducting this survey, over such a large geographical area, are discussed by Prince *et al*. (1990) and Beardsley and Conser (1981).

The RBS was initiated in the Gulf of Mexico in 1971 and then expanded in 1972 to include the U.S. East Coast (from Massachusetts through the Florida East Coast and Keys), and the U.S. Caribbean (i.e., Puerto Rico and the U.S. Virgin Islands, Figure 1). Data from Bahamian billfish tournaments have historically been included in the RBS and reported to ICCAT as part of the U.S. Task I data because most of the participants are U.S. citizens fishing from U.S. flagged vessels. In addition, billfishing at Bahamian tournaments often takes place closer to the U.S. mainland than most of the U.S. billfisheries in the Gulf of Mexico and off the northeast U.S. coast. In an effort to resolve the major limitation of the RBS, which primarily covers only the tournament portion of the recreational fishery, we explore the feasibility of estimating the total U.S. recreational marlin landings through a statistical integration of the RBS and the U.S. NMFS Marine Recreational Fishery Statistics Survey (MRFSS).

METHODS

Data to characterize the U.S. recreational landings of marlin are available from several sources. These include the RBS, NMFS Large Pelagics Survey (LPS), and the MRFSS. The RBS is designed to census a subset of billfish tournaments patronized by U.S. recreational fishermen. The areal extent of the RBS is shown in Figure 1 and includes tournaments in both the continental U.S. and in the Bahamas and Caribbean. The MRFSS and LPS estimate catches from a combination of telephone interviews to obtain estimates of total effort, and dockside sampling to obtain estimates of the species composition, size composition and catch per unit effort for anglers participating in the fishery. Neither MRFSS nor LPS is designed specifically to estimate the catch of marlin, but rather both were designed to estimate the total catch of a large number of species by the recreational fishery. The LPS focuses on obtaining estimates of large pelagic species from the northeast coast of the U.S., from Virginia through Maine in most years since the early to mid-1980s. The MRFSS, on the other hand, estimates all finfish species caught in the recreational fisheries from the Texas-Louisiana border through Maine since 1981. Consequently, the catch estimated by LPS is a subset of a catch estimated by MRFSS. The MRFSS data set was selected for inclusion in this study because it is more geographically extensive.

Because the RBS data are a census of the sampled tournaments, they are characterized by high precision, but underestimate the total recreational catch of marlin because few observations are taken outside of tournaments. The MRFSS, on the other hand, covers the entire fishery from the Texas-Louisiana border through Maine and is designed to provide unbiased estimates of the catch. However, because marlin encounters are rare events in the dockside sampling, the MRFSS estimates of marlin catch suffer from low precision and the estimates tend to vary widely from year to year. This study evaluates the potential for adjusting the RBS upward to account for the entire catch by evaluating the relationship between the "unbiased" MRFSS estimates and the RBS.

MRFSS estimates are the product of effort estimated by telephone surveys and catch per unit effort (CPUE) from dockside samples of trips (fishermen intercepts) aggregated over bimonthly state-area-mode strata. Although this process does not by itself introduce bias in the resulting estimates for rarely encountered species such as marlin (Appendix 1), it decreases the precision in the estimates. Also, marlin are sometimes observed but not weighed or measured during fishermen interviews. When marlin are observed in a stratum but not measured, MRFSS only estimates the numbers harvested for that stratum. We expanded these estimates to biomass using time-averaged mean weights derived from MRFSS data. Where lengths but no weights were recorded, we estimated weight from length using relationships derived from MRFSS observations where both length and weight were recorded.

We regressed the MRFSS estimates of numbers and biomass harvested on the corresponding values estimated by RBS in the area from Louisiana-Maine (RBS_1) to determine if statistically significant relationships exist among the data. We also regressed the annual (log transformed) MRFSS/ RBS_1 ratios of harvested biomass estimates on year to evaluate whether or not there were temporal trends in the relationships of the estimates from the two programs. The absence of temporal trends would support the notion of simply adjusting the RBS_1 marlin catch estimates upward by the average MRFSS/ RBS_1 marlin catch-estimate ratio. We also explore the possibility of accommodating temporal trends by applying the associated regression models to predict the annual MRFSS/ RBS_1 ratio, and compare results to the proportions of tags retuned from marlin caught during tournaments.

Analyses were performed for blue marlin and white marlin separately to estimate the number of individuals harvested and the total biomass of the harvest. The estimates of the totals were the sums of the catches observed by the RBS in Texas, the Bahamas, and the Caribbean (RBS_2) plus the Louisiana-Maine total predicted from the relation between the MRFSS and the RBS_1. In addition to the point estimates, the statistics associated with the regressions and means allow construction of confidence intervals about those portions of the catch estimates that involve expansions based upon the MRFSS/ RBS_1 ratios for the Louisiana-Maine fit segments of the fishery. These are presented where appropriate, but do not reflect any source of variation that may be related to the RBS estimates.

RESULTS

The Louisiana-Maine blue and white marlin data available from MRFSS and RBS_1, and various ratios, are presented in Tables 1 and 2, respectively. The mean weight of blue marlin increased significantly with time (Table 3). However, inspection of the data indicated the increase was the result of a shift in the size distribution of marlin landed that occurred between 1986 and 1987 (Figure2). Blue marlin mean weights within the pre-1987 and post-1986 periods showed no temporal patterns. As a consequence, the MRFSS harvest biomass estimates in Table 1 were derived as the product of the MRFSS estimates of numbers of annual blue marlin harvested and the 1980-1986, or 1987-1999 mean weight (73 and 166 kg, repectively) as appropriate. The mean weights of white marlin showed no statistically significant trend with time (Table 3) so the harvest biomass estimates in Table 2 were derived as the product of the 1980-1992 mean weight (21.7 kg) of all measured white marlin (there were no white marlin measured after 1992, in part because most marlin have been released in recent years).

The regressions of MRFSS estimates of both blue and white marlin on the corresponding RBS_1 estimates were significant, but the precision of each relationship was low (Table 3). The low precision of the relation is an expected result given the low precision in the MRFSS estimates themselves (Tables 1 and 2). The 1981-1999 blue marlin MRFSS/ RBS_1 ratios of harvested biomass showed a significant ($p=0.001$) negative trend with time (Table 3). Inspection of the scattergram indicated that the overall pattern included an early period from about 1981-1989 when the harvest ratios were increasing, followed by a later period from 1990-1999 when the harvest ratios were decreasing (Figure 3). Separate regressions for these periods indicated significant trends with opposite sign (Table 3).

Two alternative estimates of the U.S. recreational biomass harvest of blue marlin were constructed from these results (Tables 4 and 5, Figures 4 and 5). The first (scalar expansion) ignored the temporal trends and multiplied RBS_1 by the geometric mean of the annual $MRFSS/RBS_1$ ratios (6.72) and added the RBS sums for the remaining areas (Tables 4 and 5, Figure 4). The second alternative assumed an increasing trend from 1981-1987 and a decreasing trend thereafter (Blue Marlin - dual regression, Table 4, Figure 5) with the values estimated from the regression equations. The regression equations predicted total catches less than RBS_1 for the earliest and most recent years included in the analysis. Since the total biomass harvest in the RBS_1 area cannot be less than the observed harvest the regression estimates were truncated to the RBS_1 observations whenever the regression prediction of the $MRFSS/RBS_1$ ratio fell below 1.0.

In contrast to blue marlin, the regressions of the white marlin $MRFSS/RBS_1$ ratios on year showed no significant trend ($p=0.56$) (Table 3). Consequently, the annual white marlin biomass harvest was estimated by multiplying RBS_1 by the geometric mean of the annual $MRFSS/RBS_1$ ratios (5.75) and added the RBS sums for the remaining areas (White Marlin - scalar expansion, Table 4, Figure 6).

A limited number of observations of blue and white marlin tag recaptures by recreational fishermen are available where we know whether or not the fish were caught during tournaments (Jodi Rice, The Billfish Foundation, personal communication). The ratios of the totals of these returns to those recaptured during tournaments give independent estimates of the proportions of the two marlin species that are caught by tournament fishermen. In the period 1993-1998, 3 blue marlin recaptured by recreational fishermen were known to have been caught during tournaments and 7 were known not to have been caught during tournaments. This would suggest the total catch of blue marlin is about 3.3 times larger than the tournament catch (10/3). Similarly, the 17 categorized recaptures for white marlin suggest the total recreational catch is about 8.5 times larger than the tournament catch (17/2). Given the low numbers of observations involved, these estimates compare favorably with the 1993-1998 mean $MRFSS/RBS_1$ biomass harvest ratios of 2.0 and 8.5 for blue marlin and white marlin, respectively. However, this comparison is not strictly valid since some or all of the recaptured marlin may have been released rather than harvested.

DISCUSSION

The MRFSS program began in 1979 and extends to the present. However, the very early years are thought to be less reliable than subsequent years and catch estimates are currently available for only 1981-1999. This corresponds to about the last two decades of the RBS, which began in the Gulf of Mexico in 1971 and was then expanded to include the U.S. East Coast and U.S. Caribbean in 1972. Data from the RBS represent minimum estimates of the total U.S. catch with little information from non-tournament sources. The MRFSS represents a survey of all species of finfish caught in the recreational fisheries and is not limited to tournament sampling. Therefore, we explored the potential to use the relationship between the MRFSS and RBS to expand the annual RBS point estimates in order to obtain estimates of total recreational marlin landings for the period covered by RBS. This process necessarily extrapolates estimates to the 1972-1980 period, before MRFSS estimates are available, so these early estimates should be viewed with additional caution.

The projected average total landings were larger than the RBS estimates for both species. For the scalar expansion, this trend was true for each year from 1972-1999 (Tables 5 and 6). This result is expected since the procedures applied account for effort not sampled using the RBS alone. The results for white marlin seem reasonable, given that there was no significant temporal trend in the $MRFSS/RBS_1$ ratio, and the size distributions of white marlin were similar for the two research programs.

The existence of temporal trends in the $MRFSS/RBS_1$ ratios for blue marlin (Table3, Figure 3) raises concern that different trends in fishermen behavior, gear employed, access to the fish, or some unknown aspect of the MRFSS or RBS_1 sampling of the blue marlin fishery may have contaminated the results.

This would not necessarily negate the results of our analyses since we attempted to accommodate the trends through the regression procedures. However, we have no a priori knowledge about conditions that may have led to the temporal disparity in the trends of the results of the two research programs. Because RBS_1 is a near census of the sampled fishery, MRFSS is the most likely source of any potential problem, and the abrupt change in the size distribution of MRFSS samples between 1986 and 1987 (Figure 2) is cause for concern in this respect. Half of the biomass harvest estimates from RBS_1 for the 1981-1986 period are from fish 137 kg or greater, but only one of the marlin intercepted by MRFSS during this period was in this size interval. While this fact does not necessarily condemn the current results for blue marlin, we are suspicious that some statistical or other anomaly has had an important unknown effect on our results for this species.

We also note that recent research related to the estimation of the MRFSS charter-boat catches (which contribute heavily to billfish landing estimates) will result in the application of a revised algorithm to re-estimate historical charter-boat catches. It is likely that the resulting MRFSS charter boat estimates will be revised downward, but several more years of data will be needed before any adjustment to the historical data will be attempted (Van Voorhees, personal communication[4]). Because of these concerns, we feel that additional research is required to characterize the historical total U.S. recreational harvest, particularly for blue marlin. It seems likely that changes in MRFSS charter boat estimates will cause our current estimates for both blue marlin and white marlin to be revised downward in the future. These concerns suggest that stock assessments for the two species should include some sensitivity analyses that address the possible magnitudes of the US recreational harvests of blue and white marlin estimated herein, but that they should not yet be adopted as best estimates for the historical record.

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APPENDIX 1

Simulation Study Results Of The Robustness Of Catch Estimates Of Rare Event Species In MRFSS

The following table provides the results of simulations of the estimation of CPUE (catch per unit effort) for a rare event species. It is assumed the underlying true distribution of catch and angler trips consisted of 10,000 angler trips that caught 20 of the rare-event species (thus the average CPUE expressed in terms of catch per trip (cpt) is 0.002). The simulation randomly selected the 20 angler trips out of the 10,000 that caught the rare-event species. Duplication was allowed so that individual angler trips could have caught more than one of the rare-events species.

The estimation process randomly selected 100 of the 10,000 trips for inclusion as interviews, and catch per trip was estimated as the average catch of the rare-event species for the 100 trips sampled. This process was repeated for 1,000 iterations to mimic the state-area-mode-wave stratification in MRFSS, and mean statistics were derived from the resulting data considering only those cells where the catch per trip estimates were positive, and also all sampled cells. The experiment was replicated ten times.

When only the positive cells were considered the estimates of mean catch per trip where about 0.01, or somewhat greater than five times the true value 0.002. These estimates are clearly biased upwards. However, because positive simulated observations are rare, only about 16 to 19% of the "cells" had positive estimates of catch per trip. When all the trips (which includes those with no observed catch) were included in the estimates of average catch per trip, the estimated average catch per trip was very close to the true value of 0.002 (see table below), and the ratio of the estimated catch per trip (Ecpt) to the true value was about 1.0.

These results demonstrate that the catch per trip estimated for those cells with positive intercepts for rare-event species will on average be biased high, and the extent of the bias can be substantial. However, when all cells are included (which includes cells with positive catches which were missed in the intercepts because of their rare occurrence), there is no bias in the overall average CPUE. As a consequence, it can be concluded that the fact that a particular species is a rare-event species in the intercepts does not confer in and of itself any expectation that the overall estimate for a particular year will be biased. However, depending on the size of the sample universe, annual estimates may vary widely from the true value.

	Considering only Cells With positive CPT estimates			Considering All Cells	
Replicate	% of Total Cells	Est. Catch/ Trip	Ratio Ecpt/ True	Est. Catch/ Trip	Ratio Ecpt/ True
1	19.0	0.0114	5.684	0.0022	1.080
2	17.2	0.0108	5.378	0.0018	0.925
3	17.4	0.0112	5.603	0.0019	0.975
4	17.2	0.0111	5.552	0.0019	0.955
5	16.6	0.0107	5.361	0.0018	0.890
6	17.8	0.0109	5.449	0.0019	0.970
7	19.1	0.0109	5.445	0.0021	1.040
8	17.5	0.0106	5.286	0.0018	0.925
9	19.1	0.0108	5.393	0.0021	1.030
10	18.0	0.0109	5.444	0.0020	0.980

Table 1. U.S. recreational catch statistics for blue marlin from the U.S. Marine Recreational Fishery Statistics Survey (MRFSS) and the NMFS Recreational Billfish Survey (RBS) from Louisiana through Maine (excludes Texas). MRFSS columns containing the notation SD refer to standard deviations of the associated item. The MRFSS/ RBS columns give ratios of estimates from the two research programs.

Blue Marlin

	US Marine Recreational Statistics Fishing Survey								Recreational Billfish Survey					MRFSS/RBS		
YR	Catch	SD Catch	Kept	SD Kept	Kg	SD KG	Rel	% Rel	Catch	Kept	Kg	Rel	% Rel	Catch	Kill	Kg
81	16784	8714	3871	3871	282899	282899	12913	76.9	543	425	50148	118	21.7	30.9	9.1	5.6
82	7568	3691	5317	2924	388511	213674	2252	29.8	300	233	28181	67	22.3	25.2	22.8	13.8
83	18955	14677	4472	2371	326754	173255	14484	76.4	550	380	44747	170	30.9	34.5	11.8	7.3
84	6043	2823	6043	2823	441609	206261	0	0.0	373	284	35285	89	23.9	16.2	21.3	12.5
85	11768	6443	11400	6432	833065	470047	368	3.1	345	263	29646	82	23.8	34.1	43.3	28.1
86	14096	4690	12623	4453	922453	325418	1473	10.4	331	222	24509	109	32.9	42.6	56.9	37.6
87	8273	3319	5850	2856	975145	476179	2423	29.3	379	207	26927	172	45.4	21.8	28.3	36.2
88	6270	2693	6129	2691	1021688	448551	141	2.2	486	237	31300	249	51.2	12.9	25.9	32.6
89	5137	2171	3284	1871	547490	311865	1853	36.1	256	92	12158	164	64.1	20.1	35.7	45.0
90	2302	1938	1932	1932	322071	322071	370	16.1	394	137	19459	257	65.2	5.8	14.1	16.6
91	7211	2904	187	133	31168	22137	7024	97.4	446	111	17195	335	75.1	16.2	1.7	1.8
92	1878	903	720	670	120032	111709	1158	61.7	449	118	17222	331	73.7	4.2	6.1	7.0
93	7004	2521	413	226	68780	37620	6591	94.1	337	88	12220	249	73.9	20.8	4.7	5.6
94	4661	2069	214	84	35645	13986	4447	95.4	302	90	12718	212	70.2	15.4	2.4	2.8
95	4584	1740	55	55	9096	9106	4530	98.8	392	90	13485	302	77.0	11.7	0.6	0.7
96	2932	942	0	0	0	0	2932	100.0	439	93	12069	346	78.8	6.7	0.0	0.0
97	2048	841	226	115	37736	19178	1822	89.0	429	120	19194	309	72.0	4.8	1.9	2.0
98	6094	1887	60	60	10037	10034	6034	99.0	349	57	9485	292	83.7	17.5	1.1	1.1
99	3265	760	0	0	0	0	3265	100.0	731	72	13998	659	90.2	4.5	0.0	0.0

Table 2. U.S. recreational catch statistics for white marlin from the U.S. Marine Recreational Fishery Statistics Survey (MRFSS) and the NMFS Recreational Billfish Survey (RBS) from Louisiana through Maine (excludes Texas). MRFSS columns containing the notation SD refer to standard deviations of the associated item. The MRFSS/ RBS columns give ratios of estimates from the two research programs.

White Marlin

	US Marine Recreational Statistics Fishing Survey								Recreational Billfish Survey					MRFSS/RBS		
YR	Catch	SD Catch	Kept	SD Kept	Kg	SD KG	Rel	% Rel	Catch	Kept	Kg	Rel	% Rel	Catch	Kill	Kg
81	39163	16052	19628	10395	426415	225829	19535	49.9	2185	915	21706	1270	58.1	17.9	21.5	19.6
82	6128	3482	2487	1587	54035	34474	3641	59.4	735	379	9165	356	48.4	8.3	6.6	5.9
83	12671	5272	8048	4862	174848	105634	4623	36.5	2407	903	20708	1504	62.5	5.3	8.9	8.4
84	21034	12322	15570	11045	338269	239948	5464	26.0	1593	687	15935	906	56.9	13.2	22.7	21.2
85	249	189	249	189	5403	4111	0	0.0	553	280	6784	273	49.4	0.5	0.9	0.8
86	9635	4440	1572	895	34161	19440	8062	83.7	388	216	5216	172	44.3	24.8	7.3	6.5
87	11438	3269	4982	2162	108242	46966	6456	56.4	749	231	5761	518	69.2	15.3	21.6	18.8
88	15497	9031	2596	2130	56392	46275	12901	83.2	835	193	4722	642	76.9	18.6	13.5	11.9
89	10350	2705	6590	2278	143175	49498	3759	36.3	815	70	1723	745	91.4	12.7	94.1	83.1
90	5780	1935	1483	758	32222	16464	4297	74.3	978	101	2688	877	89.7	5.9	14.7	12.0
91	7227	2535	151	83	3283	1805	7076	97.9	664	87	2216	577	86.9	10.9	1.7	1.5
92	5772	1486	657	357	14276	7756	5115	88.6	829	77	2038	752	90.7	7.0	8.5	7.0
93	7794	2089	0	0	0	0	7794	100.0	647	120	3119	527	81.5	12.0	0.0	0.0
94	6974	2485	42	21	903	465	6933	99.4	691	71	1812	620	89.7	10.1	0.6	0.5
95	22047	8554	1390	875	30191	19006	20658	93.7	694	45	1156	649	93.5	31.8	30.9	26.1
96	9524	2394	0	0	0	0	9524	100.0	853	60	1585	793	93.0	11.2	0.0	0.0
97	3832	1475	1398	1398	30375	30375	2434	63.5	718	44	1256	674	93.9	5.3	31.8	24.2
98	15969	2436	0	0	0	0	15969	100.0	1713	29	879	1684	98.3	9.3	0.0	0.0
99	3649	799	58	58	1261	1261	3591	98.4	1401	32	871	1369	97.7	2.6	1.8	1.4

Table 3. Regression models for blue marlin (BUM) and white marlin (WHM) fitted to MRFSS and RBS estimates of total catch, numbers harvested and biomass harvested.

Model	Fitted equation	N	Adj R^2	p
BUM harvest numbers	MRFSS = -549.24 + 22.06 * RBS	19	0.338	0.005**
BUM harvest kilograms	MRFSS = -14199 + 14.20 * RBS	19	0.16	0.050*
MRFSS BUM mean weights	Kg = -602.02 + 8.31* Year	56	0.13	0.004**
81-99 BUM ln(1+Kg ratio)	KgR =16.26 - 0.16* Year	19	0.469	0.001**
81-90 BUM ln(1+Kg ratio)	KgR = -17.17 + 0.24 * Year	9	0.791	0.001**
87-99 BUM ln(1+Kg ratio)	KgR = 30.86 – 0.31* Year	13	0.79	<0.001**
WHM harvest numbers	MRFSS = -347.28 + 16.30 * RBS	19	0.69	<0.001**
WHM harvest kilograms	MRFSS = -14300 + 15.54 * RBS	19	0.694	<0.001**
MRFSS WHM mean weights	Kg = -10.06 + 0.36 * RBS	68	0.002	0.287
81-99 WHM ln(1+Kg ratio)	KgR = 56.31 - 0.47 * Year	19	-0.038	0. 564

Table 4. Equations used to predict US recreational harvest biomass totals (kg) for blue marlin and white marlin. RBS1 is the RBS estimate for the U.S. mainland, exclusive of Texas. RBS_2 is the RBS estimate for the Bahamas and the Caribbean. Texas is the RBS estimate from Texas, and MRFSS is the U.S. National Marine Fisheries Service (NMFS) Marine Recreational Fishery Statistics Survey (MRFSS) estimate for the area from Louisiana through Maine. See text for explanation of "dual regression" and "scalar expansion."

Blue Marlin – scalar expansion

$KG = 6.72 * RBS_1 + Texas + RBS_2$

Blue Marlin - dual regression

81-87: $KG = (\exp(-17.17 + 0.24 * year) - 1) * RBS_1 + Texas + RBS_2$

88-99: $KG = (\exp(30.86 - 0.31 * year) - 1) * RBS_1 + Texas + RBS_2$

White Marlin - scalar expansion

$KG = 5.75 * RBS_1 + Texas + RBS_2$

Table 5. Estimates of blue marlin harvested (kg) by US recreational anglers from scalar (Expanded) and regression (Dual regression) expansions of the RBS estimates of blue marlin harvest. Mid refers the point estimate. LB and UB are the approximate lower and upper 95% confidence bounds, respectively.

	MODEL					
	BUM Expanded			BUM Dual Regression		
Yr	LB	Mid	UB	LB	Mid	UB
72	15517	24235	40226	10037	10037	57899
73	29765	47961	81339	18326	18326	119067
74	44160	76693	136370	23708	23708	205503
75	34517	59462	105219	18836	18836	159698
76	24824	35928	56295	17845	19249	81305
77	32000	52233	89347	19281	25619	136567
78	30555	54491	98399	15508	28680	156654
79	29257	51612	92619	15204	34224	149852
80	137293	272677	521020	52187	218985	890347
81	194673	374458	704250	113426	390075	1236866
82	120523	220706	404477	115015	290836	736481
83	196763	355880	647761	277600	591026	1266213
84	156078	281668	512048	311067	591142	1127968
85	134837	242984	441366	353872	644783	1178421
86	106534	195341	358247	347612	666192	1276820
87	111041	209829	391042	428876	932388	2017060
88	134107	247289	454908	229405	823947	2949003
89	75539	124603	214606	102276	280371	829244
90	80028	155471	293862	99457	288238	801439
91	67464	131253	248267	66125	177034	451697
92	77184	142016	260942	58629	138760	327445
93	71276	120931	212016	45135	90347	196807
94	60312	113163	210111	27088	58589	149573
95	69554	124864	226322	34785	50770	132411
96	66357	117510	211345	34200	37416	104808
97	89241	161409	293793	43874	43874	122992
98	53934	91876	161478	30081	30081	63327
99	64011	113825	205201	32697	32697	67520

Table 6.Estimates of white marlin harvested (kg) by US recreational anglers from scalar expansions of the RBS estimates of blue marlin harvest. Mid refers the point estimate. LB and UB are the approximate lower and upper 95% confidence bounds, respectively.

	WHM Expanded		
Yr	LB	Mean	UB
72	2303	2939	4147
73	2168	2982	4526
74	10840	22533	44735
75	9951	20570	40732
76	6790	13896	27389
77	4097	8777	17664
78	4279	8036	15169
79	12043	25274	50393
80	92788	204579	416827
81	59018	128320	259898
82	31308	60570	116127
83	58507	124622	250151
84	45192	96069	192664
85	20139	41799	82922
86	14980	31633	63252
87	17239	35631	70551
88	13140	28217	56842
89	4549	10051	20499
90	7388	15971	32267
91	5949	13025	26459
92	5731	12237	24589
93	8370	18329	37236
94	4938	10724	21710
95	3315	7006	14013
96	4461	9523	19133
97	3773	7783	15396
98	2299	5105	10432
99	2305	5086	10366

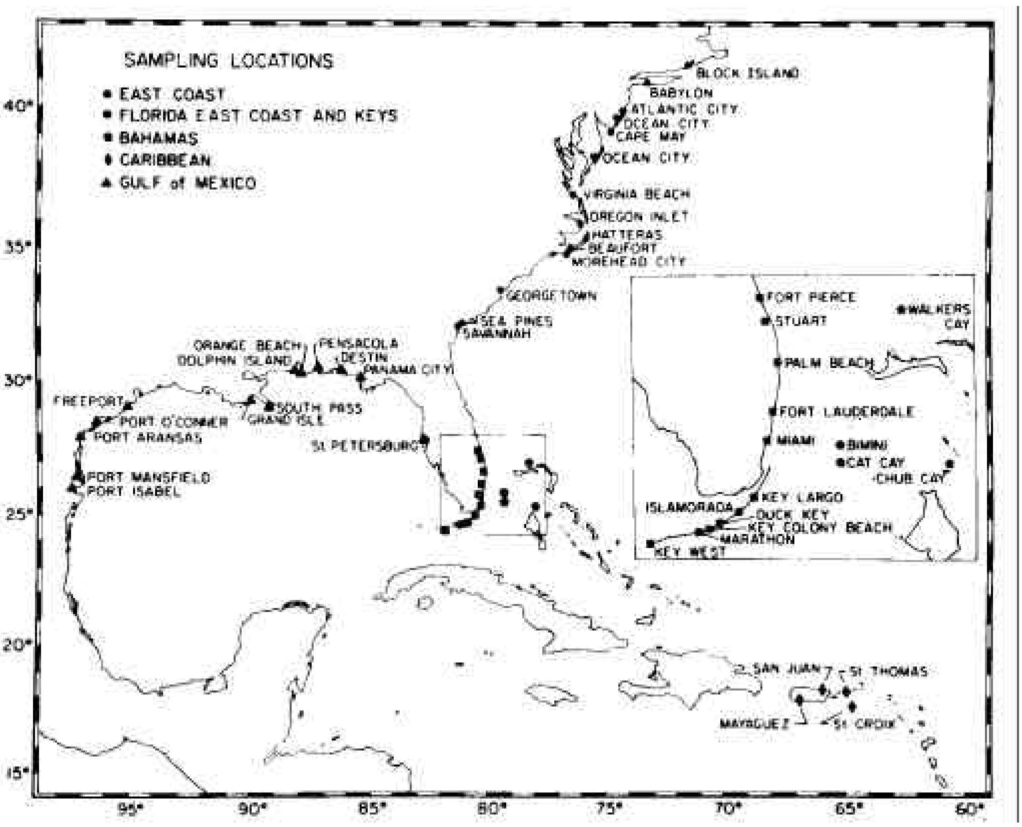

Figure 1. Sampling locations for the Recreational Billfish Surveys (RBS) of the National Marine Fishery Service, Southeast Fisheries Science Center, Miami, Florida. Not all locations are sampled every year.

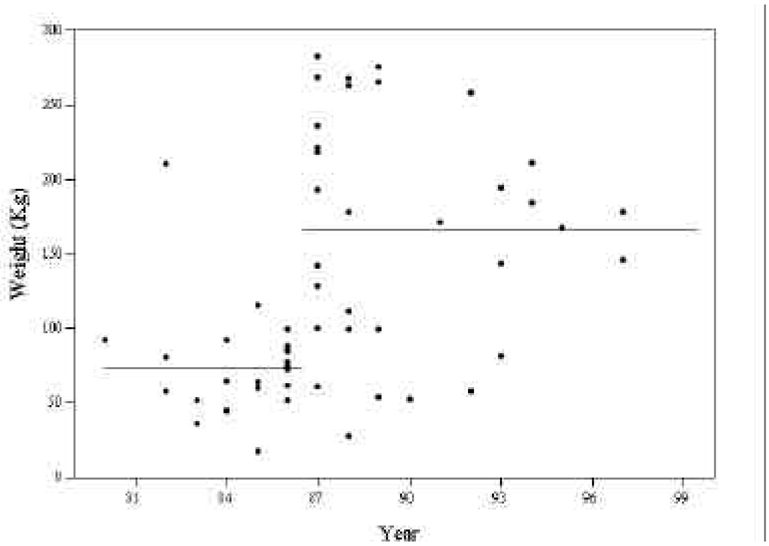

Figure 2. Scattergram of weights of blue marlin encountered during the intercept portion of MRFSS and the 1980-1986 and 1987-1999 period mean weights (indicated by the horizontal lines).

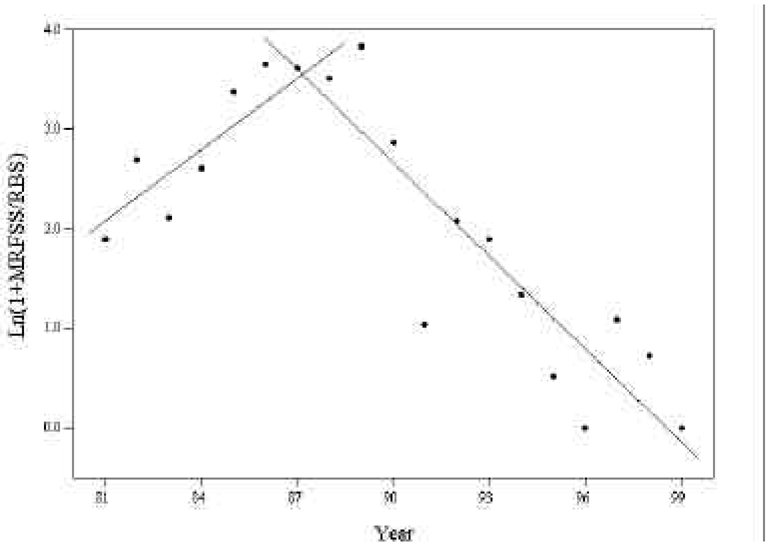

Figure 3. Scattergram of natural log of 1+ the ratios of blue marlin Kg harvest estimates by MRFSS and RBS for the same geographic area by year and the fitted equations employed in the dual regression model. Regression statistics for the two fitted equations are given in Table 3.

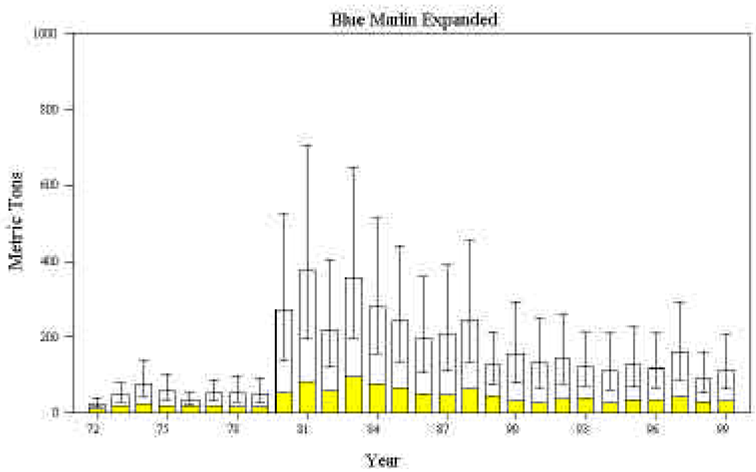

Figure 4. Total US recreational catch of blue marlin estimated from the scalar expansion of the RBS estimates of blue marlin harvested during tournaments (shaded region) and approximate 95% confidence intervals.

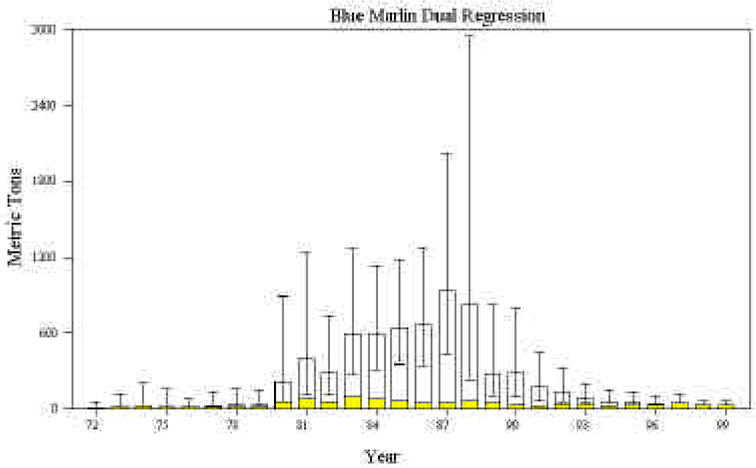

Figure 5. Total US recreational catch of blue marlin estimated from the "dual regression" expansion of the RBS estimates of blue marlin harvested during tournaments (shaded region) and approximate 95% confidence intervals.

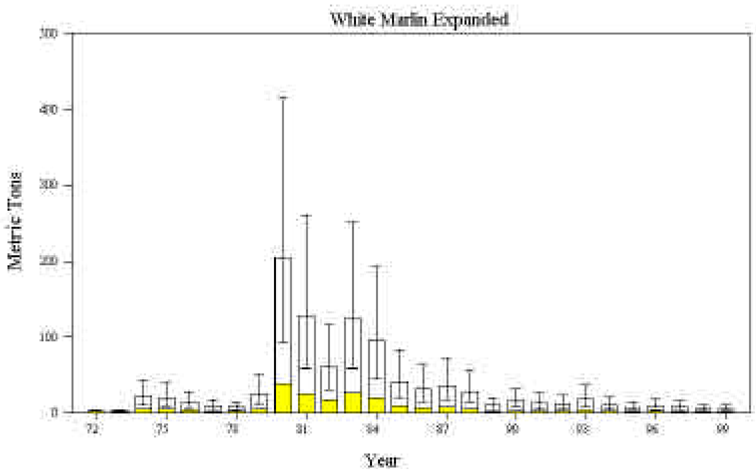

Figure 6. Total US recreational catch of white marlin estimated from the scalar expansion of the RBS estimates of blue marlin harvested during tournaments (shaded region) and approximate 95% confidence intervals.