Col. Vol. Sci. Pap. ICCAT, 53: 216-230. (2001)

STANDARDIZED CATCH RATES FOR BLUE MARLIN (*Makaira nigricans*) AND WHITE MARLIN (*Tetrapturus albidus*) FROM THE US RECREATIONAL TOURNAMENTS FISHERY IN THE NORTHWEST ATLANTIC AND THE GULF OF MEXICO

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SUMMARY

Indices of abundance of blue marlin (Makaira nigricans) and white marlin (Tetrapturus albidus) from the United States recreational billfish tournament fishery are presented for the period 1973-1999. The index of weight (kg) per 100 hours-fished was estimated from numbers of billfish caught and reported in the logbooks submitted by recreational tournament coordinators and NMFS observers under the Recreational Billfish Survey Program. The standardization analysis procedure included the following variables: Year, Area, and Season. The standardized index was estimated using Generalized Linear Mixed Models under a delta-lognormal model approach.

RÉSUMÉ

Le présent document présente les indices d'abondance du makaire bleu (Makaira nigricans) *et du makaire blanc* (Tetrapturus albidus) *capturés par la pêche sportive américaine pendant la période 1973-1999. L'indice en poids (kg) par 100 heures de pêche a été estimé d'après le nombre d'istiophoridés capturés et déclarés dans les livres de bord remis par les organisateurs des championnats sportifs et les observateurs du NMFS dans le cadre du Recreational Billfish Survey Program. Le processus de standardisation analytique comprenait les variables suivantes: année, zone et saison. L'indice standardisé a été estimé au moyen de modèles linéaires généralisés mixtes selon une approche modélique delta-lognormal.*

RESUMEN

*Se presentan, para el periodo 1973-1999, índices de abundancia de aguja azul (*Makaira nigricans*) y aguja blanca* (Tetrapturus albidus*) de la pesquería deportiva de torneos de marlines de Estados Unidos. El índice de peso (kg) por 100 horas de pesca fue estimado a partir de los números de marlines capturados y comunicados en los cuadernos de pesca enviados por los coordinadores de torneos deportivos y observadores del NMFS en el marco del Programa de Encuesta Deportiva de Marlines. El procedimiento de estandarización de análisis incluía las siguientes variables: año, área y temporada. El índice estandarizado fue estimado utilizando Modelos Lineales Mixtos Generalizados bajo un enfoque de modelo delta-lognormal.*

KEYWORDS

Catch/effort, Abundance, Sport Fishing, Pelagic fisheries, Logbooks, Multivariate analysis

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INTRODUCTION

Information on the relative abundance of blue marlin (*Makaira nigricans*) and white marlin (*Tetrapturus albidus*) are necessary to tune stock assessment models. Data were collected by the U.S. Recreational Billfish Survey (RBS) from U.S. recreational tournaments in the Atlantic East coast (including the Bahamas), the Gulf of Mexico, and Caribbean (U.S. Virgin Islands and Puerto Rico). Beardsley and Conser (1981) described the survey and discussed the potential for obtaining indices of abundance from survey data; and a comprehensive review of this survey was presented by Prince *et al.* (1990). Catch in numbers and effort data were obtained from tournament data documented by the RBS, which were voluntarily submitted to the National Marine Fisheries Service (NMFS) and from scientific observers that monitored selected billfish tournaments. These data have been used to develop standardized catch per unit of effort (CPUE) indices of abundance for Billfish (Browder and Prince 1988, Farber *et al.* 1994, Jones *et al.* 1998). This report documents the analytical methods applied to the available Recreational Billfish Survey data through 1999 and presents the resulting standardized CPUE indices for blue and white marlin.

MATERIALS AND METHODS

Browder and Prince (1990) describe the main features of the Recreational Tournaments that take place in the West Atlantic and Caribbean, and Farber *et al.* (1994) review the available catch and effort data from the RBS. Standardized catch rate indices were previously estimated for the 1996 ICCAT stock assessment using Generalized Linear Models (GLM) (Jones *et al.* 1998). The present report updates the catch and effort information through 1999 and includes analyses of variability associated with random factor interactions, particularly for the *Year* effect, following the suggestion of the billfish working group of the ICCAT Standing Committee on Research and Statistics (SCRS). Radio logbook records from the recreational tournaments have been collected since 1972 either by NMFS personnel or through voluntary submission by tournament organizers. Recent changes in U.S. regulations require all recreational tournaments to record catch and effort data and to provide it to the NMFS (Anonymous 1999).

The RBS data comprise a total of 11,066 records dating from 1973 through 1999. Each record represents information on hooked and caught fish by tournament-day. Fishing effort is estimated from the number of boats registered in the tournament times the fishing hours per day. Records also include total number of fish hooked, their fate (i.e. lost, release, tagged and released, or boated) species, and morphometric information (size and weight) for boated fish. There are a total of 459 registered tournaments in the RBS database. From those, the following selection criteria were applied: a) Only U.S and Bahamian recreational tournaments that target blue or white marlin were included (i.e. sailfish tournaments, particularly in the South Florida region, are excluded); b) data from tournament events only, excluding biological sampling programs and or dock sampling not associated with tournaments; and c) tournaments that have recorded at least one blue or white marlin as being caught in their records. The final working data set included a total of 5,098 records representing 297 recreational marlin tournaments from the North Atlantic, Gulf of Mexico, and the Caribbean.

Figure 1 shows the geographical distribution of the tournaments included in the analyses(points represent the main city/port from where the tournament operated).Each tournament was classified into one of six geographical regions for this analysis: (1) New England (Massachusetts and Rhode Island), (2) Mid Atlantic (New York, New Jersey, Delaware, Maryland, and Virginia), (3) South Atlantic (North Carolina, South Carolina, Georgia, and the East coast of Florida), (4) The Bahamas, (5) US Gulf of Mexico (Texas, Louisiana, Mississippi, Alabama and Florida West coast, and (6) the Caribbean (Puerto Rico and US Virgin Islands). Figure 2 shows the total number of registered tournaments and the number of boast per year within the registered tournaments. In general, an increase in recreational tournament fishing effort has been observed over the time series. To account for seasonal characteristics, 3 seasons were defined: (1) January through April, (2) May through August, and (3) September through December. In previous analyses, a categorical factor that reflected tournament and non-tournament data was included (Jones *et al.* 1998, Farber *et al.* 1994). A review of the RBS database indicated that biological and dock-sampling data are very restricted in both numbers of years and geographical areas sampled. In addition, there is uncertainty in the estimates of effort from those records, both in the total number of boats from which the sample were collected and in the total number of fishing hours per day. Thus, for the present analysis, only recreational tournaments that have registered and submitted catch and effort information were used.

Tournament logbooks record mainly numbers of fish and size (or weight) of boated fish. As per suggestion of the Billfish SCRS working group, indices of abundance should be reported in weight rather than numbers of fish. In order to convert numbers of fish to weight, size information on blue and white marlin boated by recreational tournaments was retrieved from the RBS database. There are 7,004 recorded sizes for blue marlin, and 6,413 for white marlin. Figure 3 shows the size-frequency distributions by year for blue and white marlin caught and measured in recreational tournament events. Mean size by each year/area/season stratum was estimated if there were 20 or more records per cell. For a cell with less than 20 fish, the annual mean size of the area was used; if, for a given area-year, the number of records by stratum was less than 20, then the mean size by year across all areas was applied. Figure 4 shows the mean size by strata used for the conversion of numbers of fish to weight of hooked fish. Mean size was converted to weight (kg) using the current size-weight relationships for combined sex (Prager *et al.* 1995). Analyses of catch rates were done on the total number of hooked fish (including hooked-and-lost fish, caught-and-released fish, and boated fish) rather than the number of fish caught, because of the implementation of minimum size regulations.

For the RBS tournament data, relative indices of abundance for blue and white marlin were estimated by a Generalized Linear Modeling approach assuming a delta-lognormal model distribution. The delta model estimates separately the proportion of trips/day having non-zero catch ("positive or successful trips") assuming a binomial error distribution, and the mean catch rate of trip/day where at least one marlin was caught assuming a lognormal error distribution. The log-transformed frequency distributions of catch rates in weight and numbers for blue and white marlins are shown in Figure 5. The estimated proportion of successful trip/sets per stratum is assumed to be the result of *r* positive trip/days of a total *n* number of trip/days, and each one is an independent Bernoulli-type realization. The estimated proportion is a linear function of fixed effects and interactions. The logit function was used as link between the linear factor component and the binomial error. For trip-days that caught at least one marlin, estimated catch rates were assumed to follow a lognormal error distribution. The factors included in the analyses were *Year*, *Area* and *Season*, and 1st level interactions. .

A step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability. Because the difference of deviance between two consecutive models follows a ?^{2} (Chi-square) distribution, this statistic was used to test for the significance of an additional factor in the model. The number of additional parameters associated with the added factor minus one corresponds to the number of degrees of freedom in the ?^{2} test (McCullagh and Nelder, 1989 pp 393). Deviance analysis tables for catch rates in weight are presented for both species, each table includes the deviance for the proportion of positive observations (i.e. positive trips/total trips), and the deviance for the positive catch rates. Final selection of explanatory factors was conditional on: a) the relative percent of deviance explained by adding the factor in evaluation (normally, factors that explained more than 5 or 10% were selected), b) the ?^{2} test of significance, and c) the type-III test significance within the final specified model.

Once a set of fixed factors was specified, possible interactions were evaluated, and in particular interactions between the *Year* effect and other factors. Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), the Schwarz's Bayesian Criterion (SBC), and a chi-square test of the difference between the [–2 loglikelihood] statistic between successive nested model formulations (Littell *et al.* 1996). Relative indices for the delta model formulation were calculated as the product of the year effect least square means (LSMeans) from the binomial and the lognormal model components.

The LSMeans estimates use a weighted factor of the proportional observed margins in the input data to account for the unbalanced nature of the data. LSMeans of lognormal positive trips were bias-corrected using Lo *et al.*, (1992) algorithms. Analyses were done using the GLIMMIX and MIXED procedures from the SASâ statistical computer software (SAS Institute Inc. 1997).

RESULTS AND DISCUSSION

Table 1 shows the deviance analysis for blue and white marlin from the recreational tournament data analyses. In the case of blue marlin, *Area*, *Year***Area* and *Year***Season* interactions were the major factors that explained tournament catch of at least one marlin. For the mean catch rate given that it is a positive observation, the factors *Area*, *Year***Area*, *Year***Season* were more significant. For white marlin, the factors *Area*, *Season*, *Year***Area*, and *Year***Season* were the main explanatory variables for the proportion of positive trip-days. And, for white marlin mean catch rate, *Area*, *Season*, *Year***Area*, and *Year***Season* were significant factors. Once a set of fixed factors was selected, we evaluated first levels random interaction between the year and other effects.

Table 2 shows the results from the random test analyses, for both marlin species, and the three statistical criteria used for final model selection. In the case of the binomial model component, the proportion of positive/total observations estimation for white marlin did not improve by including random interaction(s) between the year, area and season factors; for blue marlin, the mixed model did not converge to a solution. In contrast, for the mean catch rate of positive observations, all interactions were significant. In general, *Area* and the *Year***Area* interaction are the main factors that correlate with catch rates for blue and white marlin.

Standardized CPUE series for blue and white marlin are show in Tables 3 and 4 and in Figures 6 and 7. The figures show, in the top panel, the results of the standardization analysis using the weight CPUE (kg/100 hours) as the dependent variable, and, in the bottom panel, the results using the numbers of fish CPUE (fish/100 hours) as the dependent variable (both models are otherwise the same). Catch rates of blue marlin increased from 1973 to 1977, with a large drop in 1978, followed by a slow recovery to the overall average values in 1980/81 (1973-1999 mean catch rate = 307.5 kg/100 hours; horizontal reference line on the plot). During the 1980's, it appears that catch rates were just below the average with a drop again in 1993, then an increase trend is observed in 1994/96. However, the trends of the standardized CPUE series vary significantly from 1993 to 1999, depending upon which dependent variable is used. For CPUE observations based in weight, the values appear to increase above average values (Fig 6 and 8), while, for CPUE in numbers, the trend still remains below the overall average. Using normalized values (values minus the mean, divided by the standard deviation, Fig 8) is it clear that the two time series diverge since 1993. This also corresponds with the increasing trend in the mean size of blue marlin reported by recreational tournaments (Figure 5). Most likely, this is the result of the implementation of minimum size restrictions during those years.

In contrast, standardized CPUE series for white marlin show the same pattern, irrespective of whether weight or numbers of fish are used as the CPUE metric (Figs. 7 and 9). For white marlin, there is an overall declining trend after the 1979/80 peak in catch rate. Since 1985, catch rates have been below the overall mean, with no indication of recovery.

The analysis indicates that, at least for blue marlin, the conversion from numbers of fish to weight units needs to be carefully reviewed, as trends in mean size (or weight) associated with management regulations could bias the results of standardization procedures. An alternative data source for size/weight information for blue and white marlin comes from measurements taken by scientific observers aboard pelagic longline US vessels (Ortiz and Scott 2000). Table 5 and Figure 10 compare the mean size by year for blue and white marlin measured in the Pelagic Observer Program and in the Recreational Billfish Survey data. For both species, the observer data reported smaller mean size fish each year. Figure 11 shows the frequency distribution for the overlapping years between the data series. It is clear that the recreational tournament data recorded preferentially larger-size fish, and, at least for blue marlin, the overall mean size has increased since early 1990's.

REFERENCES

ANONYMOUS. 1999. Amendment 1 to the Atlantic Billfish Fishery Management Plan. U.S. Dept. of Comm., NOAA-NMFS. April 1999.

BEARDSLEY, G.L. and R.J. Conser. 1981. An analysis of catch and effort data from the U.S. recreational fishery for billfishes (Istiophoridae) in the western North Atlantic Ocean and Gulf of Mexico, 1971-78. Fish. Bull. 79:49-68.

BROWDER, J. A. and E. D. Prince. 1988. Explorations of use of tournament and dock catch and effort data to obtain indices of annual relative abundance for blue and white marlin, 1972 through 1986. Col. Vol. Sci. Pap. ICCAT, 28:287-299.

BROWDER, J.A. and E.D. Prince. 1990. Standardized estimates of recreational fishing success for blue marlin and white marlin in the western North Atlantic Ocean, 1972-1986. Pages 215-229 *in*: R.H. Stroud (ed.), Planning the Future of Billfishes, Research and Management in the 90's and Beyond. Proc. of the Second International Billfish Symposium, Kailua-Kona, HI, USA, August 1-5, 1988. National Coalition for Marine Conservation, Inc. Savannah, GA, USA.

FARBER, M. I., J. A. Browder and J. P. Contillo. 1994. Standardization of recreational fishing success for marlin in the western North Atlantic Ocean. Col. Vol. Sci. Pap. ICCAT, 41:363-392.

JONES, C. D., M. T. Judge and M. Ortiz. 1998. Standardization of recreational CPUE for blue and white marlin in the Western North Atlantic Ocean 1973-1995. Col. Vol. Sci. Pap. ICCAT, 47:279-287.

LITTELL, R.C., G.A. Milliken, W.W. Stroup, and R.D Wolfinger. 1996. SAS® System for Mixed Models, Cary NC, USA: SAS Institute Inc., 1996. 663 pp.

LO, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-2526.

MCCULLAGH, P. and J.A. Nelder. 1989. Generalized Linear Models 2nd edition. Chapman & Hall.

PRAGER, M.H., E. D. Prince and D. W. Lee. 1995. Empirical length and weight conversion equation: for blue marlin, white marlin, and sailfish from the North Atlantic Ocean. Bull of Mar. Sci. 56(1):201-210.

PRINCE, E. D., A.R. Bertolino and A. M. López. 1990. A comparison of fishing success and average weights of blue marlin and white marlin landed by the recreational fishery in the western Atlantic Ocean, Gulf of Mexico, and Caribbean Sea, 1972-1986. Pages 159-178 *in* R.H. Stroud (ed.), Planning the Future of Billfishes, Research and Management in the 90's and Beyond. Proc. of the Second International Billfish Symposium, Kailua-Kona, HI, USA, August 1-5, 1988. National Coalition for Marine Conservation, Inc. Savannah, GA, USA.

SAS Institute Inc. 1997, SAS/STAT® Software: Changes and Enhancements through Release 6.12. Cary, NC, USA:SAS Institute Inc., 1997. 1167 pp.

Table 1. Deviance analysis tables for blue and white marlin using the delta lognormal model. Proportion positive/ total observations assumed a binomial error distribution, positive catches assumed a lognormal error distribution. The dependent variable is the total hooked fish per hour (HPUE) in weight units. *p* refers to the Chi-square test probability (alpha=5%) test between two consecutive model specifications.

Recreational Billfish Survey data for Blue marlin

Model factors positive catch rates values	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	3796.53			
YEAR	26	3651.39	145.1	9.4%	< 0.001
YEAR SEASON	2	3623.44	28.0	1.8%	< 0.001
YEAR SEASON AREA	5	2690.05	933.4	60.6%	< 0.001
YEAR SEASON AREA YEAR:SEASON	52	2608.64	81.4	5.3%	0.006
YEAR SEASON AREA YEAR:SEASON YEAR:AREA	100	2290.27	318.4	20.7%	< 0.001
YEAR SEASON AREA YEAR:SEASON YEAR:AREA AREA:SEASON	6	2257.17	33.1	2.2%	< 0.001

Model factors proportion positive/total observations	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	4191.26			
YEAR	26	4110.95	80.3	7.1%	< 0.001
YEAR SEASON	2	4087.60	23.4	2.1%	< 0.001
YEAR SEASON AREA	5	3375.68	711.9	63.2%	< 0.001
YEAR SEASON AREA YEAR:SEASON	52	3274.28	101.4	9.0%	< 0.001
YEAR SEASON AREA YEAR:SEASON YEAR:AREA	107	3086.75	187.5	16.6%	< 0.001
YEAR SEASON AREA YEAR:SEASON YEAR:AREA AREA:SEASON	6	3064.70	22.0	2.0%	0.001

Recreational Billfish Survey data for White marlin

Model factors positive catch rates values	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	4334.78			
YEAR	26	3886.15	448.6	23.9%	< 0.001
YEAR SEASON	2	3725.17	161.0	8.6%	< 0.001
YEAR SEASON AREA	5	2862.61	862.6	45.9%	< 0.001
YEAR SEASON AREA YEAR:SEASON	51	2724.51	138.1	7.3%	< 0.001
YEAR SEASON AREA YEAR:SEASON YEAR:AREA	103	2469.10	255.4	13.6%	< 0.001
YEAR SEASON AREA YEAR:SEASON YEAR:AREA AREA:SEASON	5	2454.51	14.6	0.8%	0.012

Model factors proportion positive/total observations	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	6559.18			
YEAR	26	6401.02	158.2	9.9%	< 0.001
YEAR SEASON	2	6312.40	88.6	5.6%	< 0.001
YEAR SEASON AREA	5	5302.29	1010.1	63.3%	< 0.001
YEAR SEASON AREA YEAR:SEASON	52	5170.09	132.2	8.3%	< 0.001
YEAR SEASON AREA YEAR:SEASON YEAR:AREA	107	4973.68	196.4	12.3%	< 0.001
YEAR SEASON AREA YEAR:SEASON YEAR:AREA AREA:SEASON	6	4963.33	10.3	0.6%	0.111

Table 2. Random effects evaluation for blue and white marlin delta lognormal mixed model specifications. Highlighted rows refer to the final model.

Blue Marlin	Numb obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives						
Year Area Season	259	979.6352	-490.818	-492.526		
Year Area Season *Year*Area*	259	979.6352	-490.818	-492.526	Model did not converge	
Year Area Season *Year*Area Year*Season*	259	979.6352	-490.818	-492.526	Model did not converge	
Year Area Season *Year*Area Year*Season Area*Season*	259	979.6352	-490.818	-492.526	Model did not converge	
Positive Catch						
Year Area Season	4367	10404.62	-5203.31	-5206.5		
Year Area Season *Year*Area*	4367	10102.52	-5053.26	-5059.63	302.1	0.0000
Year Area Season *Year*Area Year*Season*	4367	10090.85	-5048.42	-5057.98	11.67	0.0006
Year Area Season *Year*Area Year*Season Area*Season*	4367	10041.78	-5024.89	-5037.64	49.07	0.0000

White Marlin	Numb obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives						
Year Area Season	259	783.6814	-392.841	-394.549		
Year Area Season *Year*Area*	259	783.6814	-393.841	-397.257	0	1.0000
Year Area Season *Year*Area Year*Season*	259	781.0416	-393.507	-398.631	2.6398	0.1042
Year Area Season *Year*Area Year*Season Area*Season*	259	773.547	390.774	397.606	10.1344	0.0015
Positive Catch						
Year Area Season	3347	9082.126	-4542.06	-4545.12		
Year Area Season*Year*Area*	3347	9003.624	-4503.81	-4509.92	78.502	0.0000
Year Area Seaon *Year*Area Year*Season*	3347	8995.426	-4480.71	-4489.89	8.198	0.0042
Year Area Season *Year*Area Year*Season Area*Season*	3347	8940.315	-4474.16	-4486.37	55.111	0.0000

Table 3. Nominal and standardized CPUE for blue marlin from the Recreational Billfish Survey data.

	Weight (kg) / 100 hours fishing				Number of fish/ 100 hours fishing			
Year	Nominal CPUE	Standard CPUE	*SE*	CV	Nominal CPUE	Standard CPUE	SE	CV
1973	469.39	259.87	78.87	30.4%	5.567	2.886	0.851	29%
1974	386.11	315.77	87.24	27.6%	4.099	3.166	0.846	27%
1975	345.47	320.86	80.66	25.1%	4.077	3.518	0.840	24%
1976	523.11	390.36	98.48	25.2%	4.337	3.415	0.818	24%
1977	443.12	371.71	100.01	26.9%	4.167	3.310	0.854	26%
1978	362.34	211.26	68.11	32.2%	3.967	2.162	0.687	32%
1979	298.35	248.33	81.18	32.7%	2.981	2.323	0.749	32%
1980	318.61	346.71	78.20	22.6%	3.071	3.539	0.746	21%
1981	337.70	331.86	73.72	22.2%	3.279	3.306	0.687	21%
1982	311.51	268.53	63.62	23.7%	3.045	2.617	0.584	22%
1983	281.61	266.43	56.56	21.2%	2.947	2.848	0.563	20%
1984	267.69	303.67	65.44	21.6%	2.797	3.082	0.619	20%
1985	321.08	274.44	63.13	23.0%	3.481	2.967	0.637	21%
1986	262.57	199.73	46.44	23.3%	2.813	2.157	0.472	22%
1987	364.88	316.32	68.14	21.5%	3.126	2.707	0.544	20%
1988	327.02	249.78	53.35	21.4%	3.516	2.498	0.499	20%
1989	353.85	274.70	59.90	21.8%	2.717	2.092	0.431	21%
1990	333.44	261.14	54.42	20.8%	2.638	2.051	0.400	20%
1991	310.81	308.99	65.61	21.2%	2.378	2.275	0.454	20%
1992	355.78	340.84	71.11	20.9%	2.477	2.308	0.451	20%
1993	295.71	222.70	47.94	21.5%	2.328	1.914	0.390	20%
1994	449.69	364.10	79.01	21.7%	3.040	2.374	0.483	20%
1995	456.46	410.18	86.30	21.0%	2.868	2.543	0.497	20%
1996	554.07	362.75	77.31	21.3%	3.674	2.408	0.479	20%
1997	438.19	361.80	75.90	21.0%	3.048	2.487	0.484	19%
1998	365.43	294.18	64.67	22.0%	2.267	1.822	0.379	21%
1999	527.93	424.63	90.25	21.3%	2.857	2.368	0.469	20%

Table 4. Nominal and standardized CPUE for White marlin from the Recreational Billfish Survey data.

	Weight (kg) / 100 hours fishing				Number of fish/ 100 hours fishing			
Year	Nominal CPUE	Standard CPUE	*SE*	CV	Nominal CPUE	Standard CPUE	SE	CV
1973	40.99	67.22	26.53	39.5%	1.533	2.562	1.005	39%
1974	67.84	80.84	29.55	36.6%	2.820	3.336	1.218	37%
1975	129.22	75.14	26.83	35.7%	5.415	3.204	1.141	36%
1976	60.28	67.40	23.83	35.4%	2.496	2.765	0.976	35%
1977	61.33	67.49	23.86	35.4%	2.446	2.707	0.956	35%
1978	117.17	72.41	25.44	35.1%	4.814	3.009	1.054	35%
1979	151.66	128.26	44.03	34.3%	7.429	6.088	2.074	34%
1980	157.70	115.04	35.07	30.5%	6.505	4.810	1.456	30%
1981	135.23	87.61	26.09	29.8%	5.510	3.606	1.067	30%
1982	79.33	51.68	15.72	30.4%	3.351	2.190	0.662	30%
1983	85.86	63.30	18.11	28.6%	3.725	2.779	0.790	28%
1984	96.83	55.13	16.13	29.3%	4.037	2.339	0.681	29%
1985	57.65	52.70	16.35	31.0%	2.314	2.111	0.652	31%
1986	36.28	29.96	9.42	31.4%	1.507	1.250	0.392	31%
1987	45.13	29.96	8.91	29.7%	1.910	1.287	0.384	30%
1988	42.13	31.63	9.47	29.9%	1.727	1.294	0.389	30%
1989	35.47	21.41	6.67	31.2%	1.482	0.900	0.284	32%
1990	39.83	23.23	6.95	29.9%	1.560	0.911	0.275	30%
1991	30.46	25.74	7.93	30.8%	1.226	1.033	0.321	31%
1992	33.33	20.90	6.46	30.9%	1.362	0.857	0.267	31%
1993	33.05	20.61	6.39	31.0%	1.276	0.798	0.251	31%
1994	44.66	31.63	9.76	30.9%	1.803	1.271	0.394	31%
1995	39.72	28.37	8.57	30.2%	1.507	1.091	0.331	30%
1996	36.97	28.04	8.43	30.1%	1.386	1.051	0.317	30%
1997	31.31	29.06	8.86	30.5%	1.264	1.172	0.358	31%
1998	59.53	33.28	10.35	31.1%	1.986	1.110	0.347	31%
1999	29.52	21.20	6.67	31.4%	1.067	0.769	0.244	32%

Table 5. Mean size of blue marlin a white marlin measured from the Recreational Billfish Tournaments (1973-1999) and the Pelagic Observer Program (1992-1999).

	Blue Marlin						White Marlin					
	Recreational Tournament			*Pelagic Observer Prg*			*Recreational Tournament*			*Pelagic Observer Prg*		
Year	N obs	Mean size (cm)	Std. dev.	N obs	Mean size (cm)	Std dev	N obs	Mean size (cm)	Std. dev.	N obs	Mean size (cm)	Std. dev.
1972	106	210.8	28.8				67	164.2	12.7			
1973	166	221.1	32.7				61	167.8	12.9			
1974	221	222.4	31.0				196	162.5	10.4			
1975	174	218.5	31.4				154	162.6	9.2			
1976	144	233.5	32.6				103	164.3	11.8			
1977	155	230.2	35.1				59	165.8	13.2			
1978	136	222.4	32.3				171	162.7	11.1			
1979	106	228.6	39.3				71	157.6	20.8			
1980	353	228.8	34.2				1346	163.0	13.0			
1981	569	227.3	34.5				837	163.2	12.5			
1982	384	227.6	33.3				473	162.3	11.0			
1983	807	220.4	34.6				880	160.8	11.2			
1984	623	222.8	36.3				642	163.1	10.2			
1985	568	220.4	34.5				327	163.0	12.6			
1986	389	221.4	34.0				210	163.2	9.2			
1987	277	237.3	33.1				201	162.0	10.1			
1988	400	221.3	36.7				140	164.4	9.8			
1989	118	241.4	30.8				88	162.9	8.4			
1990	140	244.2	26.5				52	167.1	8.5			
1991	121	246.8	29.5				99	165.1	9.4			
1992	128	250.4	28.6	52	175.3	53.0	61	163.9	9.9	99	146.2	24.1
1993	299	232.2	33.3	172	187.9	54.8	50	167.0	7.2	371	142.3	27.1
1994	132	252.8	27.0	124	190.5	56.5	47	164.8	10.6	172	156.8	30.0
1995	125	258.3	26.4	181	201.3	52.6	37	167.2	10.0	359	150.6	23.7
1996	109	253.4	24.6	138	207.4	48.2	37	169.6	7.4	124	151.5	18.5
1997	143	251.3	28.5	174	201.7	40.8	31	165.1	14.0	268	152.0	18.9
1998	93	261.0	23.7	65	194.0	46.3	18	175.6	6.1	108	156.5	20.6
1999	124	266.5	20.2	136	194.7	45.2	22	171.0	6.1	255	154.9	20.4
Totals	**7110**			**1042**			**6480**			**1756**		

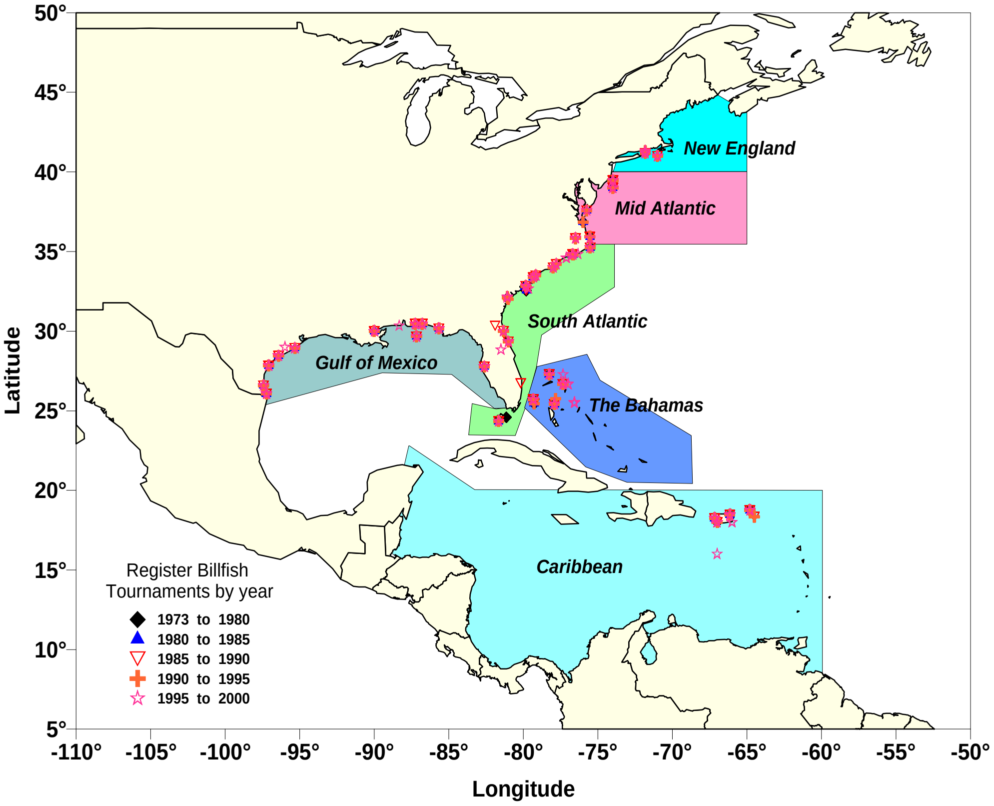


Figure 1. Geographical distribution of recreational tournaments that target marlins. The markers represent the main city/port from where the tournament operated.

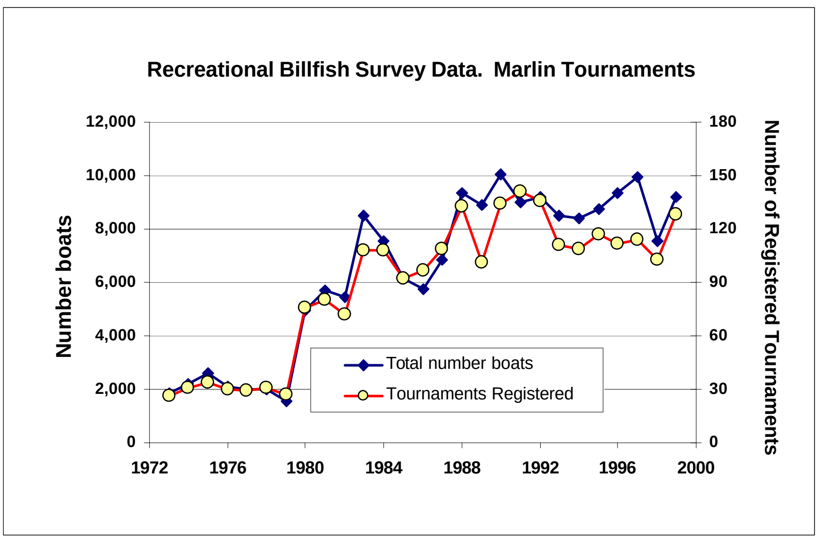


Figure 2. Total number of recreational marlin tournaments and numbers of boats associated by year. Data summary from the Recreational Billfish Survey (RBS).

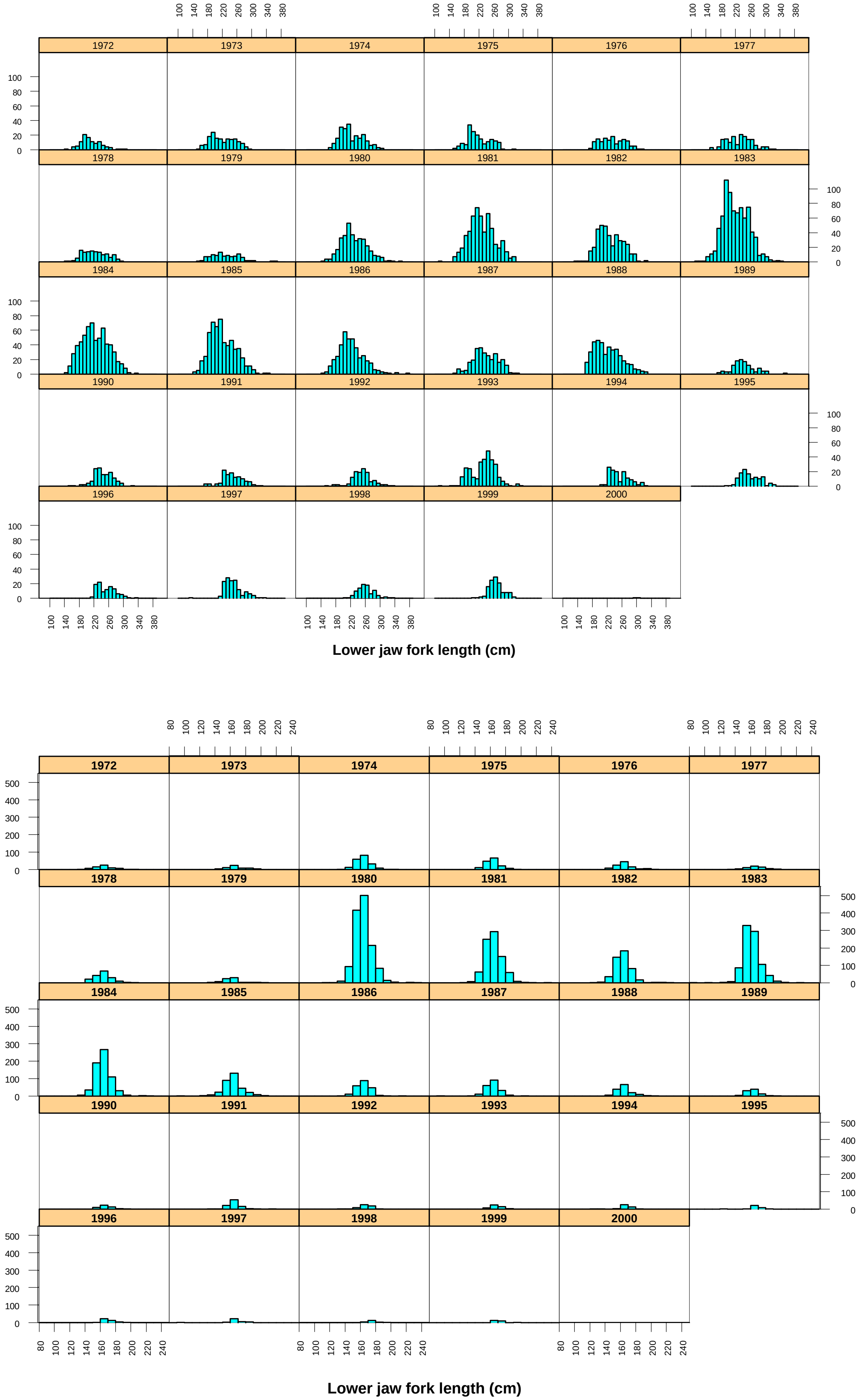
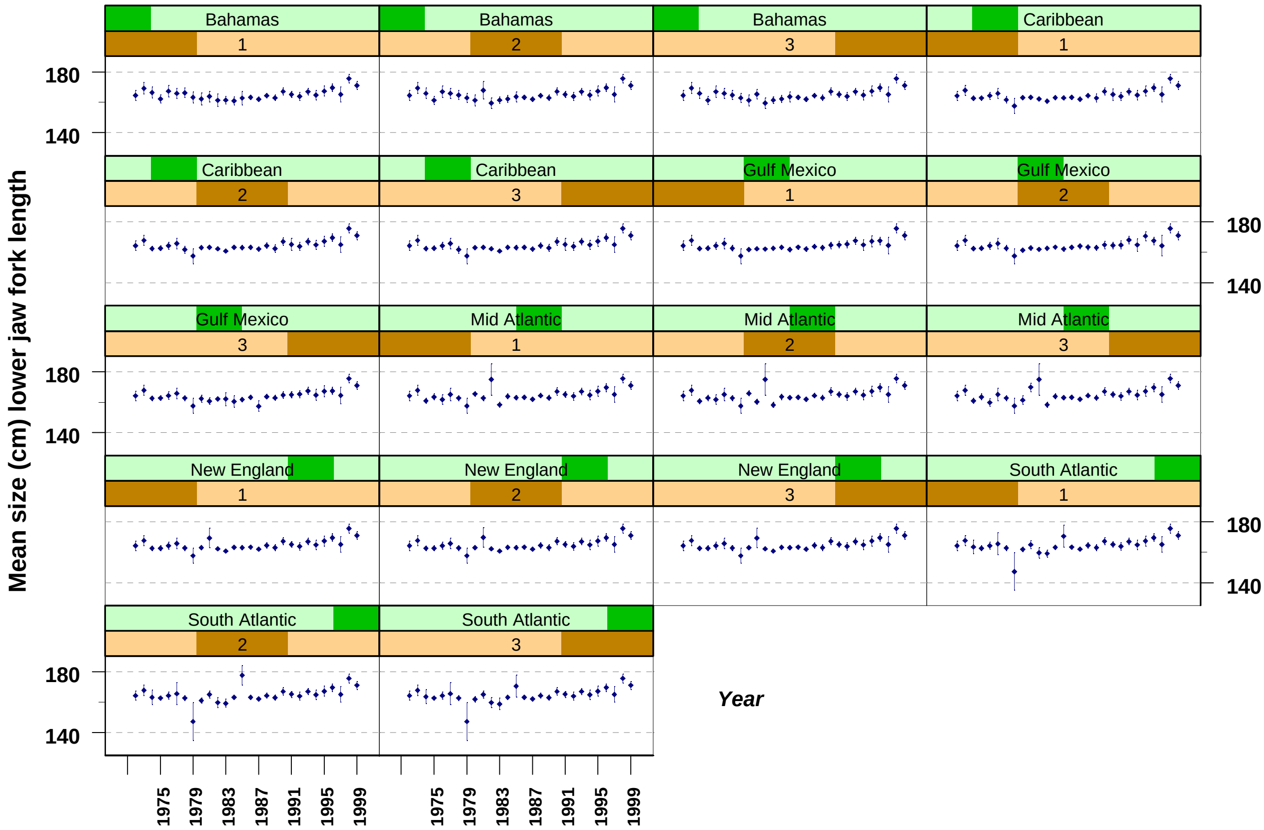


Figure 3. Size frequency distributions by year for blue (top) and white (bottom) marlin collected from landed fish on recreational tournaments.

White Marlin mean size by area and season from Recreational Tournament Sampling



White Marlin mean size by area and season from Recreational Tournament Sampling

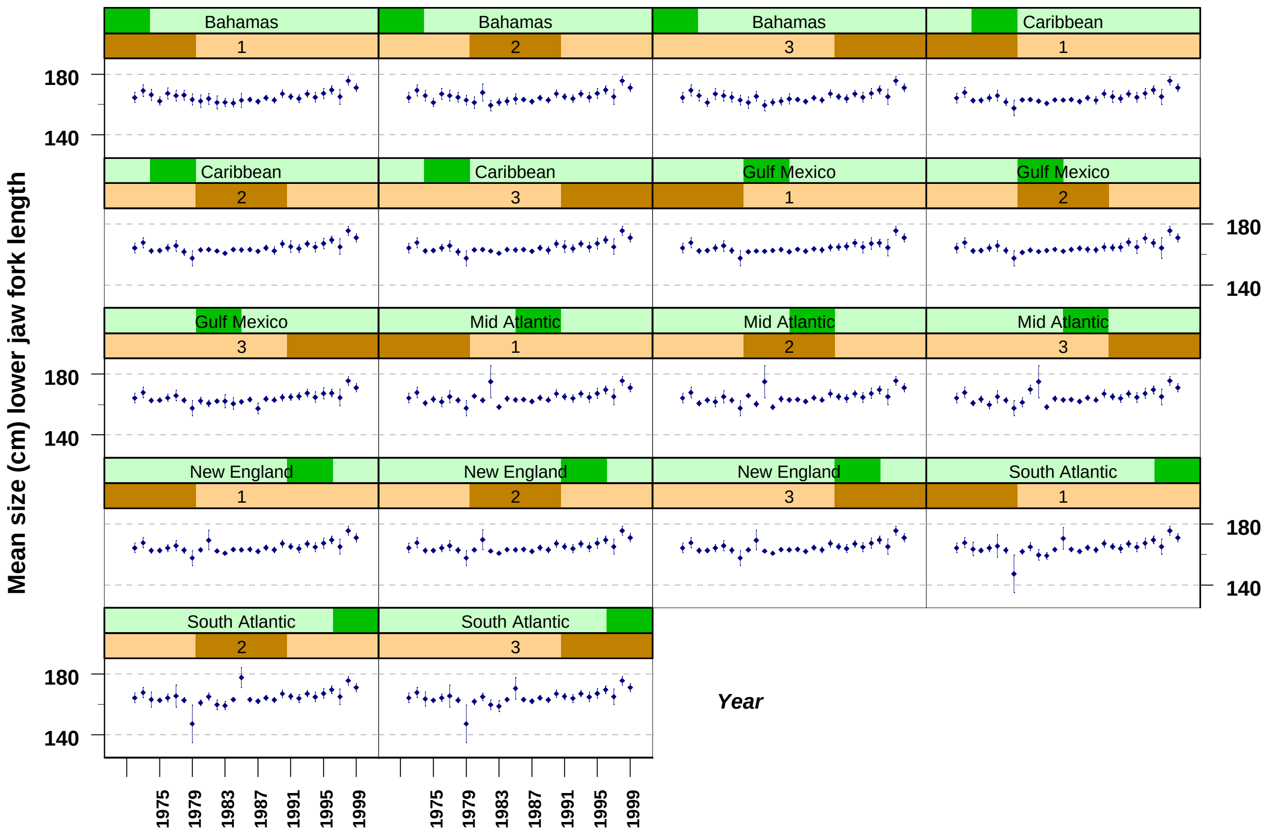


Figure 4. Mean size LJFL (cm) of marlins used for conversion of numbers of fish to weight in the CPUE standardization analyses. Data summary from the RBS including tournament and non-tournament sampling (+ 2 std error). Season 1 Jan-Apr, season 2 May-Aug, and season 3 Sep-Dec.

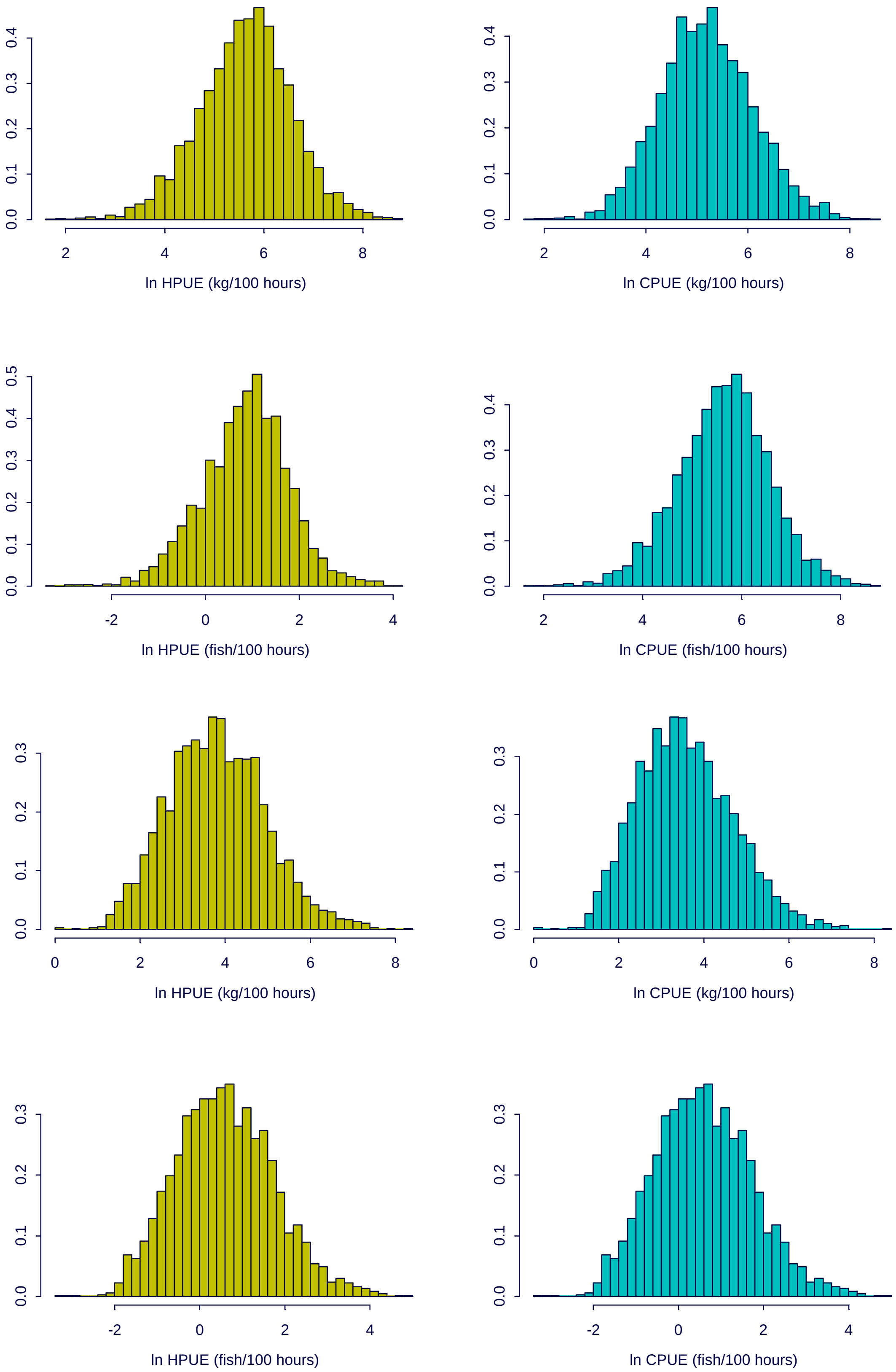


Figure 5. Frequency distribution for ln transformed catch rates of blue marlin (top) and white marlin (bottom). The HPUE refers to total number of fish hooked per 100 hours of fishing effort; The CPUE refers to catch fish per 100 hours. Catch rates are given in weight (kg/100 hours) and numbers of fish (fish/100 hours).

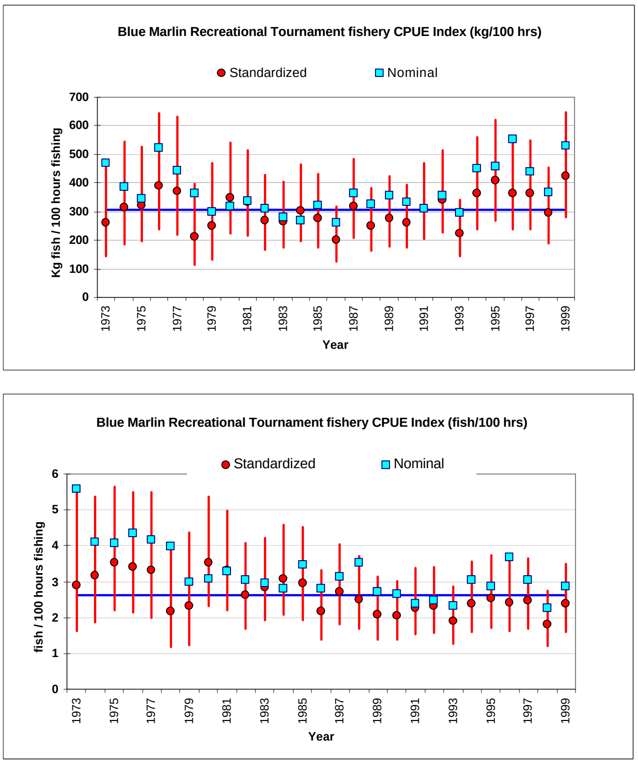


Figure 6. Nominal and standardized catch rates (HPUE) of blue marlin (1973-1999) from recreational tournaments. Standardized series are for the weight (top) and numbers of fish catch rates (+95% CI). Solid line represents the overall average for the standardized catch rates.

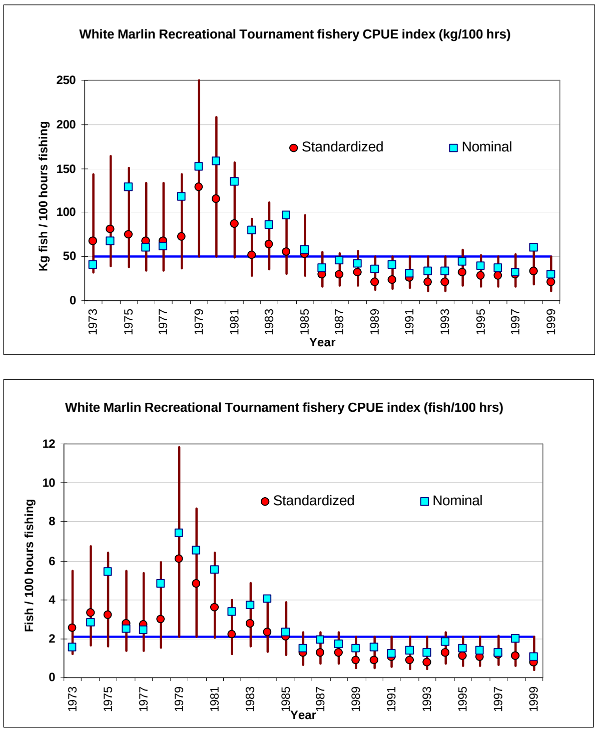


Figure 7. Nominal and standardized catch rates (HPUE) of white marlin (1973-1999) from recreational tournaments. Standardized series are for the weight (top) and numbers of fish catch rates (+ 95% CI). Solid line represents the overall average for the standardized catch rates.

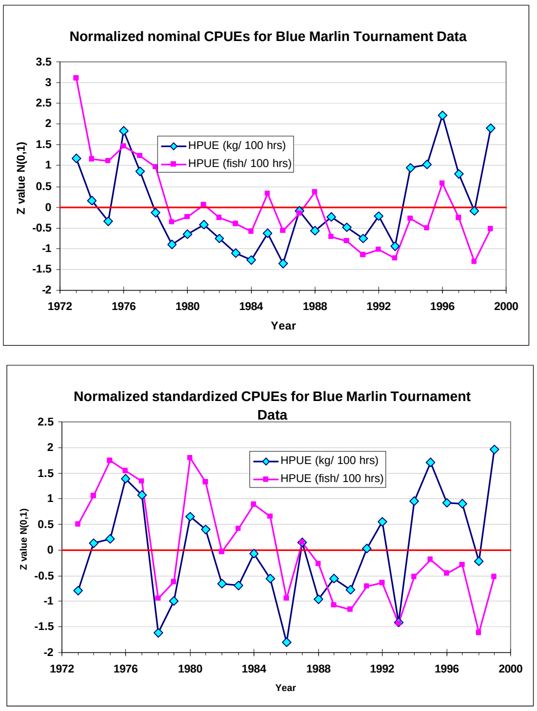


Figure 8. Normalized (value-mean/std deviation) values for the nominal (top) and standardized CPUE series of blue marlin. Diamond series is the total weight (kg) per 100 hours fishing, square series is the total number of fish per 100 hours fishing.

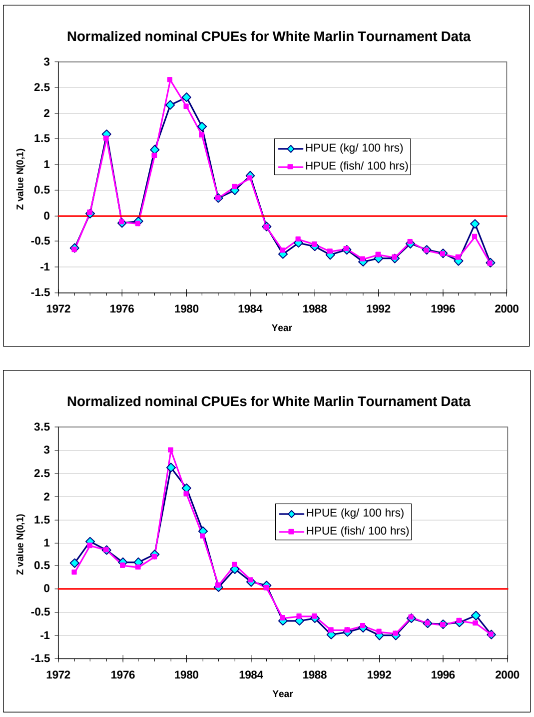


Figure 9. Normalized (value-mean/std deviation) values for the nominal (top) and standardized CPUE series of white marlin. Diamond series is the total weight (kg) per 100 hours fishing, square series is the total number of fish per 100 hours fishing.

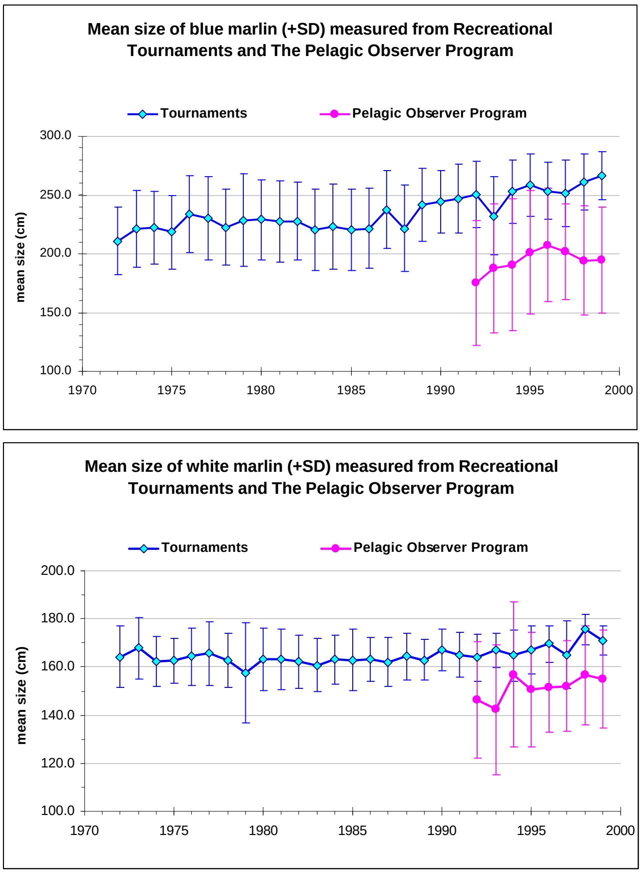


Figure 10. Mean size of blue and white marlins measured from recreational Billfish tournaments (RBS data) and from the Pelagic Observer Program.

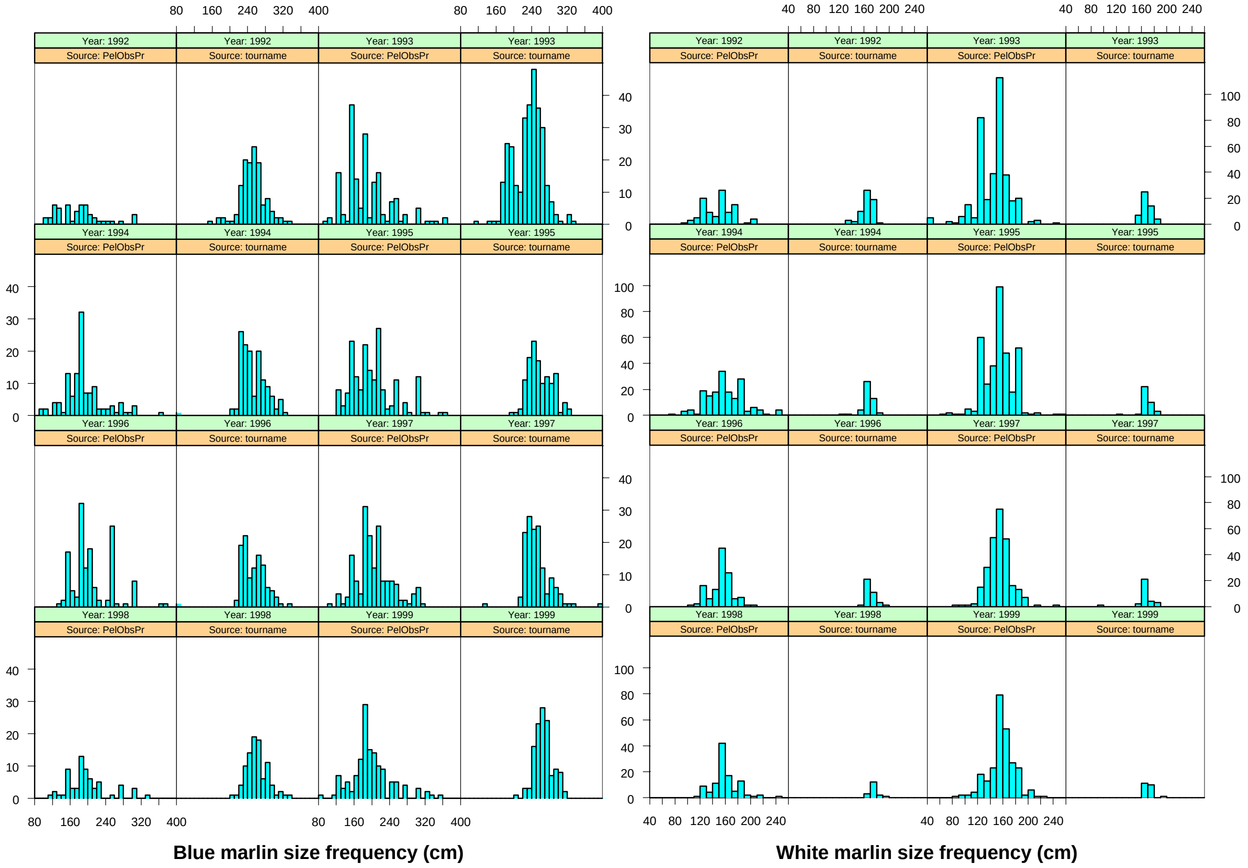


Figure 11. Size frequency distribution of blue (left) and white (right) marlin from fish measured on recreational tournaments (tournament) and from the Pelagic Observer Program, 1992-1999.