STANDARDIZATION OF RECREATIONAL CPUE FOR BLUE AND WHITE MARLIN IN THE WESTERN NORTH ATLANTIC OCEAN 1973-1995

Christopher D. Jones[1], Michael T. Judge[1] and Mauricio Ortiz[2]

SUMMARY

*Recreational tournament and non-tournament catch and effort statistics for blue marlin (*Makaira nigricans*) and white marlin (*Tetrapturus albidus*) are updated from an earlier National Marine Fisheries Service Recreational Billfish Survey (RBS) database for the years 1973-1991. An additional 4 years of nominal data are added, and the entire time series restandardized using a general linear model (GLM) analysis. Updated data preparation methods are presented. The model analyzes the fishing success and effort of each day-location, weighted by the number of boat trips. Factors in the analysis include years, region, period, and two-way interactions. Historical standardized CPUE by year for each species is presented. The CPUE trends for the most recent years appear to be increasing for blue marlin and have stabilized at low levels for white marlin.*

RÉSUMÉ

Les statistiques de prise et d'effort de makaire bleu (Makaira nigricans) *et de makaire blanc* (Tetrapturus albidus) *de la pêche sportive (en championnat et hors championnat) ont été actualisées avec la base de données du* National Marine Fisheries Service Recreational Billfish Survey *pour les années 1973 à 1991. Quatre années de données nominales ont été ajoutées et la série temporelle a été entièrement restandardisée à partir d'une analyse du modèle linéaire généralisé. Des méthodes actualisées de préparation des données sont également présentées. Le modèle analyse la prise et l'effort quotidien, pondéré par le nombre de sorties en mer. L'analyse tient compte des facteurs suivants : année, zone, saison et doubles interactions. La CPUE historique standardisée par an pour chaque espèce est également présentée. La CPUE des années les plus récentes semble avoir tendance à augmenter dans le cas du makaire bleu et à se stabiliser à des niveaux peu élevés dans le cas du makaire blanc.*

RESUMEN

Se actualizan las estadísticas de captura y esfuerzo para la aguja azul (Makaira nigricans) *y aguja blanca* (Tetrapturus albidus) *de la pesquería de recreo, procedentes de torneos y otros, partiendo de una base de datos de los años 1973-1991 de la "National Marine Fisheries Service Recreational Billfish Survey (RBS)". Se añaden datos nominales de 4 años y se estandariza de nuevo toda la serie temporal por medio de un análisis del modelo lineal generalizado (GLM). Se presentan métodos de preparación de datos actualizados. El modelo analiza el éxito de la pesca y el esfuerzo diario, ponderado por el número de salidas de los barcos. El análisis incluye factores tales como año, región, periodo e interacciones en dos sentidos. Se presenta la CPUE histórica estandarizada para cada especie. Las tendencias de la CPUE de los últimos años parecen ir en aumento en el caso de la aguja azul y se han estabilizado a niveles bajos en el caso de la aguja blanca.*

1. INTRODUCTION

Catch per unit effort (CPUE) estimates are widely used in virtual population analysis (VPA) and surplus production modeling to index changes in relative abundance. Prior to any analysis which uses CPUE estimates, effort in nominal units must first be standardized to generate consistent indices across spatial and temporal boundaries. The North Atlantic recreational U.S. CPUE estimates were first established for blue marlin (*Makaira nigricans*) and white marlin

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(*Tetrapturus albidus*) from recreational fishing data for the western North Atlantic by Browder and Prince (1988). Historical CPUE data for these species has since been standardized by Browder and Prince (1990) and Farber *et al.* (1992). Similar to Farber *et al.* (1992), we used a general linear model to standardize the nominal recreational catch and effort data for blue and white marlin based on three main factors: region, time-period, and type of fishing (tournament or non-tournament).

The standardized estimates of U.S. recreational CPUE for 1973-1990 were used along with other CPUE series to examine blue marlin (Cramer and Prager, 1994) and white marlin (Farber and Jones 1994) production models in previous assessments of these species. In this study, we update the nominal U.S. recreational database through 1995 and restandardize the entire time series. The analysis examines individual regions and years, and uses the same analytical techniques as Farber *et al.* (1994).

2. DATA AND METHODS

2.1 Raw Data

Data used for this analysis came exclusively from the National Marine Fisheries Service Recreational Billfish Survey (RBS) at the Southeast Fisheries Science Center (SEFSC). Data collected for the RBS database prior to 1992 has been described by Farber at el. (1994), Browder and Prince (1990), Browder and Prince (1988), and Prince *et al.* (1990). In recent years the RBS database has had to depend less on data collected by NMFS personnel and rely more on voluntarily submitted data from tournament organizers. Tournaments, identified through advertisement, word of mouth, or historical knowledge are requested by NMFS to voluntarily submit copies of their radio logs to the SEFSC. Radio logs are forms that tournament organizers use to keep track of fishing success of boats fishing in their event. Data recorded on radio logs includes tournament name, location, date, boat name, number of boats fishing, fishing times, hook-up time, end of fight time, species, and results (i.e. lost, released, tagged, or boated). Data from radio logs are then quality controlled and entered into the RBS database by SEFSC personal.

2.2 Working Data

The database used in this analysis for the period 1973-1991 is the same as that analyzed in Farber at el. (1994) and consists of one record per day and geographic area which contains data on the number of boats fishing, the combined fishing effort (in boat hours), and the number of each species caught. An equivalent database which contained RBS data from 1992 - 1995 was then appended to the original database for our updated analysis.

To produce the first working dataset, records from the RBS database which contained the target years of 1992-1995 were selected. We then deleted records from all known tournaments which use live bait, tournaments with sailfish in the title, known sailfish tournaments which took place during November through February, and records from dock samples to produce our second working dataset. Records left in our second dataset were then grouped together by tournament and date. Fishing effort and catches of blue marlin and white marlin (i.e. released, tagged, or boated) were summed for a given day and tournament and placed into new fields to produce our third working dataset. The third working dataset was then combined with the original data series used by Farber *et al.* (1994) to form the database used for this analysis.

The geographic regions for each tournament or non-tournament sampling were broken down into seven areas for this analysis: (1) New England (Massachusetts and Rhode Island), (2) Mid-Atlantic Bight (South Carolina to Daytona Beach, FL), (4) South Florida (Cape Canaveral to Key West), (5) the Bahamas, (6) the Caribbean (Puerto Rico, U.S. Virgin Islands, Dominican Republic, Cayman Islands, and Cozumel), and (7) the Gulf of Mexico. Data for some regions were excluded from the analysis, given a very low probability of capturing blue or white marlin. For blue marlin, regions 2, 5, 6 and 7 were used. For white marlin, regions 1, 2, 5, 6, and 7 were used.

To reduce the problem of small sample sizes within a time-area-type strata, we defined two month periods (referred in previous work as "waves") to take into account the seasonal variation in the data. Periods 1 through 4 begin in March-April and end in September-October.

2.3 Data Analysis

The GLM analysis examined the total accumulated fishing hours and total numbers of blue and white marlin for each region and period. The computed standardized estimates were bias-corrected and 1973 was used as a standard year.

Methods used to generate standardized CPUE estimates from this dataset are identical to those presented in Farber *et al.* (1994), and further details of analytical procedures and model specifics can be obtained from that source.

3. RESULTS AND DISCUSSION

Total number of records by period (wave) and area and total records by year and area for blue marlin are presented in Appendix 1. Appendix 2 includes the model results from the GLM fit for blue marlin. Summary statistics from the model fits for blue marlin are presented in Appendix 3, and Appendix 4 is a frequency histogram of model residuals for all years combined. The output of the standardized CPUE estimates for blue marlin, along with upper and lower 95% confidence intervals and standard errors are presented in Table 1. Table 2 is the standardized CPUE estimates for blue marlin rescaled to 1973. Figure 1 is a plot of the rescaled standardized CPUE estimates for blue marlin. From this, it appears that there has been a general increase in the CPUE for the years 1990 to 1995. The most recent years represents the highest historical CPUE since the recreational catch efforts statistics have been collected. The overall CPUE trend appears to be increasing with variation across the entire time series. The last two years (1994-1995) are substantially higher than historical CPUEs, with rescaled point estimates over 2 (relative to 1.0 in 1973).

The total number of records by period (wave) and area and total records by year and area for white marlin are listed in Appendix 5. Appendix 6 includes the model results from the GLM fit for white marlin. Summary statistics from the model fits for white marlin are presented in Appendix 7, and Appendix 8 is a frequency histogram of model residuals for all years combined. The model output of the standardized CPUE estimates for white marlin, along with upper and lower 95% confidence intervals and standard errors are presented in Table 3. Table 4 is the standardized CPUE estimates for white marlin rescaled to 1973. Figure 2 is a plot of the rescaled standardized CPUE estimates for white marlin. From this, it appears that the recreational CPUE estimates have stabilized in the most recent 8 years, but at a low level compared to historical highs in the late 1970s and early 1980s.

4. LITERATURE CITED

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Table 1. Standardized annual CPUE (per 100 hours) for blue marlin. Upper confidence limits (Upper CL) and lower confidence limits (Lower CL), and standard error (S.E.) are included.

YEAR	Upper CL	CPUE	Lower CL	S.E.
1973	0.72187	0.60986	0.50974	0.057254
1974	0.98780	0.85625	0.73779	0.053518
1975	0.71597	0.62245	0.53728	0.047624
1976	0.65379	0.56656	0.48703	0.047207
1977	0.73075	0.64019	0.55733	0.045382
1978	0.66446	0.58672	0.51504	0.041385
1979	0.85610	0.75483	0.66218	0.045402
1980	0.98562	0.88571	0.79337	0.040190
1981	1.09407	0.99218	0.89757	0.037782
1982	0.91840	0.82357	0.73594	0.040191
1983	1.01953	0.93197	0.85007	0.034141
1984	1.02861	0.93649	0.85060	0.035732
1985	1.12975	1.02181	0.92182	0.039104
1986	0.95931	0.85521	0.75950	0.042836
1987	1.24198	1.12152	1.01027	0.040587
1988	1.24997	1.13987	1.03743	0.036771
1989	1.11544	1.01551	0.92247	0.036466
1990	0.98979	0.89840	0.81331	0.036519
1991	1.09944	0.99748	0.90278	0.037664
1992	1.21060	1.09949	0.99637	0.038107
1993	1.19836	1.08630	0.98244	0.038763
1994	1.48902	1.35390	1.22880	0.039305
1995	1.52612	1.39855	1.27972	0.036263

Table 2. Adjusted standardized annual CPUE (per 100 hours) for blue marlin rescaled to 1973. Upper confidence limits (Upper CL) and lower confidence limits (Lower CL) are included.

YEAR	Upper CL	STD CPUE	Lower CL
1973	1.18367	1.00000	0.83583
1974	1.61972	1.40400	1.20976
1975	1.17398	1.02065	0.88098
1976	1.07204	0.92899	0.79859
1977	1.19822	1.04973	0.91387
1978	1.08953	0.96206	0.84452
1979	1.40377	1.23771	1.08578
1980	1.61614	1.45231	1.30090
1981	1.79396	1.62690	1.47177
1982	1.50591	1.35043	1.20673
1983	1.67175	1.52816	1.39387
1984	1.68664	1.53558	1.39475
1985	1.85248	1.67547	1.51153
1986	1.57300	1.40231	1.24536
1987	2.03650	1.83897	1.65655
1988	2.04959	1.86907	1.70110
1989	1.82901	1.66515	1.51259
1990	1.62298	1.47312	1.33361
1991	1.80277	1.63559	1.48030
1992	1.98505	1.80285	1.63377
1993	1.96498	1.78123	1.61093
1994	2.44157	2.22001	2.01488
1995	2.50241	2.29322	2.09839

Table 3. Standardized annual CPUE (per 100 hours) for white marlin. Upper confidence limits (Upper CL) and lower confidence limits (Lower CL), and standard error (S.E.) are included.

YEAR	Upper CL	CPUE	Lower CL	S.E.
1973	0.79394	0.65471	0.53267	0.067263
1974	0.92911	0.7837	0.65504	0.062434
1975	0.83808	0.71641	0.60738	0.055951
1976	0.71475	0.60679	0.50995	0.055462
1977	0.58313	0.49219	0.41027	0.053319
1978	0.54125	0.46175	0.38948	0.048622
1979	0.81455	0.70059	0.59795	0.053343
1980	1.33667	1.18945	1.05521	0.047085
1981	0.86381	0.76426	0.67298	0.044297
1982	0.84646	0.74219	0.64713	0.047211
1983	0.76873	0.68543	0.60842	0.0401
1984	0.66728	0.5883	0.51554	0.041954
1985	0.44086	0.37419	0.31326	0.045943
1986	0.51897	0.43891	0.36637	0.050329
1987	0.59221	0.51164	0.43809	0.046466
1988	0.38626	0.32867	0.2757	0.042555
1989	0.33319	0.28012	0.23126	0.042338
1990	0.3264	0.2736	0.22503	0.042556
1991	0.29251	0.24101	0.19375	0.043809
1992	0.4054	0.34391	0.28754	0.044341
1993	0.33749	0.2806	0.22854	0.045213
1994	0.35204	0.29315	0.23933	0.045833
1995	0.35821	0.30306	0.25231	0.042402

Table 4. Adjusted standardized annual CPUE (per 100 hours) for white marlin rescaled to 1973. Upper confidence limits (Upper CL) and lower confidence limits (Lower CL) are included.

YEAR	Upper CL	STD CPUE	Lower CL
1973	1.21267	1	0.8136
1974	1.41912	1.19703	1.00051
1975	1.28007	1.09424	0.92771
1976	1.0917	0.9268	0.7789
1977	0.89068	0.75177	0.62665
1978	0.8267	0.70527	0.59489
1979	1.24414	1.07009	0.91331
1980	2.04163	1.81676	1.61172
1981	1.31939	1.16733	1.02791
1982	1.29287	1.13361	0.98842
1983	1.17415	1.04692	0.92931
1984	1.01921	0.89856	0.78744
1985	0.67336	0.57154	0.47848
1986	0.79268	0.67039	0.55959
1987	0.90454	0.78148	0.66913
1988	0.58997	0.50201	0.4211
1989	0.50892	0.42785	0.35323
1990	0.49854	0.4179	0.34372
1991	0.44677	0.36812	0.29594
1992	0.61921	0.52529	0.43918
1993	0.51548	0.42859	0.34907
1994	0.5377	0.44776	0.36555
1995	0.54713	0.46289	0.38537

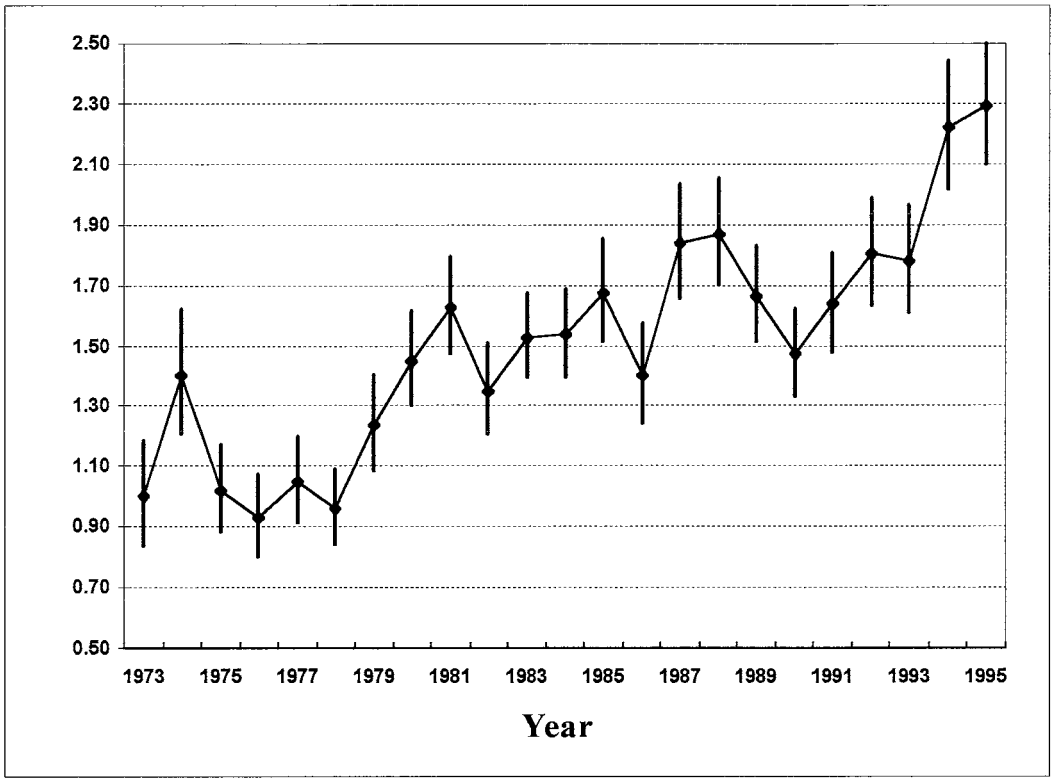


Figure 1. Blue marlin standardized CPUE estimates (per 100 hr) 1973 to 1995.

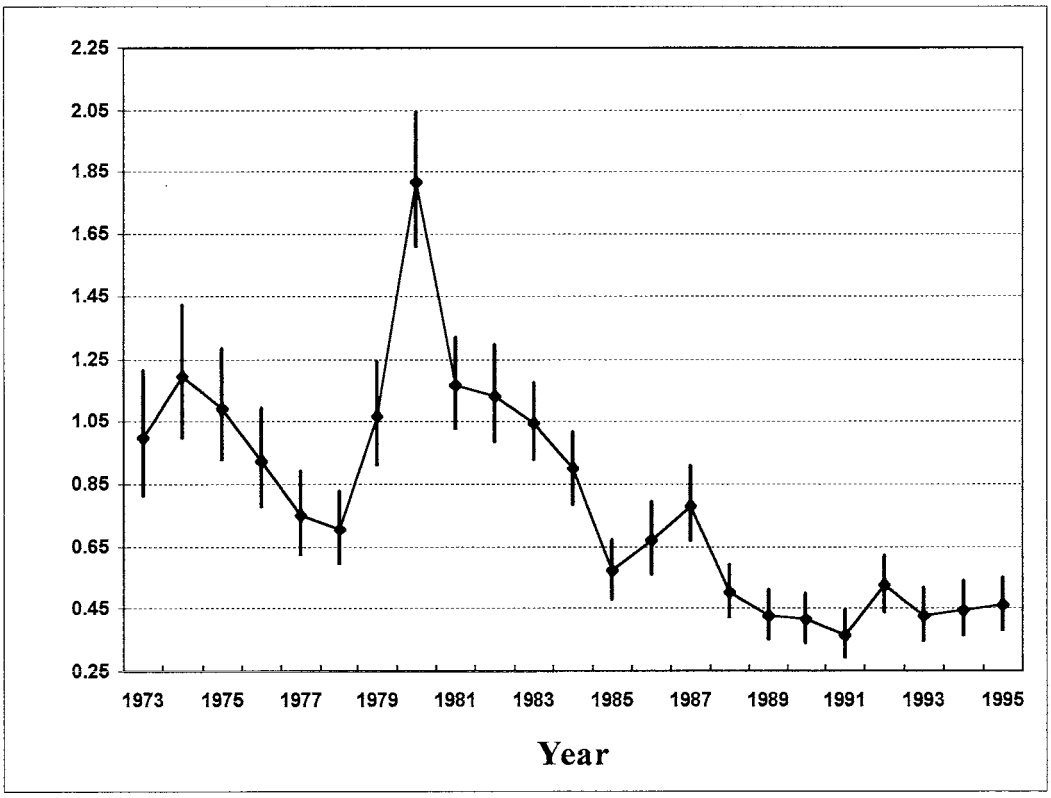


Figure 2. White marlin standardized CPUE estimates (per 100 hr) 1973 to 1995.

Apendix 1. Matrix of total number of records by period (wave) and area and total records by year and area for blue marlin from U.S. recreational surveys, NMFS, SEFSC, 1973-1995.

WAVE	AREA				
Frequency					
Percent	2	5	6	7	Total
1	0	560	35	201	796
	0	4.49	0.28	1.61	6.38
2	382	471	154	2685	3692
	3.06	3.78	1.24	21.54	29.61
3	1086	176	311	4000	5573
	8.71	1.41	2.49	32.08	44.7
4	267	0	237	1903	2407
	2.14	0	1.9	15.26	19.31
Total	1735	1207	737	8789	12468
	13.92	9.68	5.91	70.49	100

YR	AREA				
Frequency					
Percent	2	5	6	7	Total
73	4	43	19	290	356
	0.03	0.34	0.15	2.33	2.86
74	32	34	18	345	429
	0.26	0.27	0.14	2.77	3.44
75	22	35	19	353	429
	0.18	0.28	0.15	2.83	3.44
76	18	42	15	493	568
	0.14	0.34	0.12	3.95	4.56
77	13	36	7	490	546
	0.1	0.29	0.06	3.93	4.38
78	18	47	11	593	669
	0.14	0.38	0.09	4.76	5.37
79	18	43	8	490	559
	0.14	0.34	0.06	3.93	4.48
80	191	47	4	472	714
	1.53	0.38	0.03	3.79	5.73
81	162	52	44	676	934
	1.3	0.42	0.35	5.42	7.49
82	107	50	51	510	718
	0.86	0.4	0.41	4.09	5.76
83	359	50	198	525	1132
	2.88	0.4	1.59	4.21	9.08
84	266	61	38	448	813
	2.13	0.49	0.3	3.59	6.52
85	14	44	43	451	552
	0.11	0.35	0.34	3.62	4.43
86	8	59	10	363	440
	0.06	0.47	0.08	2.91	3.53
87	27	61	15	344	447
	0.22	0.49	0.12	2.76	3.59
88	53	72	32	425	582
	0.43	0.58	0.26	3.41	4.67
89	68	78	34	358	538
	0.55	0.63	0.27	2.87	4.32
90	72	71	18	445	606
	0.58	0.57	0.14	3.57	4.86
91	74	58	27	387	546
	0.59	0.47	0.22	3.1	4.38
92	75	51	30	88	244
	0.6	0.41	0.24	0.71	1.96
93	51	50	38	77	216
	0.41	0.4	0.3	0.62	1.73
94	35	43	39	86	203
	0.28	0.34	0.31	0.69	1.63
95	48	80	19	80	227
	0.38	0.64	0.15	0.64	1.82
Total	1735	1207	737	8789	12468
	13.92	9.68	5.91	70.49	100

Appendix 2. General Linear Model (GLM) output for blue marlin for U.S. recreational survey data, NMFS, SEFSC, 1973-1995.

GLM RESULTS, BY YEAR, WAVE, AND AREA

Dependent Variable: LNBUCT
Weight: BOATNO

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	36	43188.07791371	1199.66883094	150.80	0.0
Error	12431	98890.69968565	7.95516850		
Corrected Total	12467	142078.77759937			

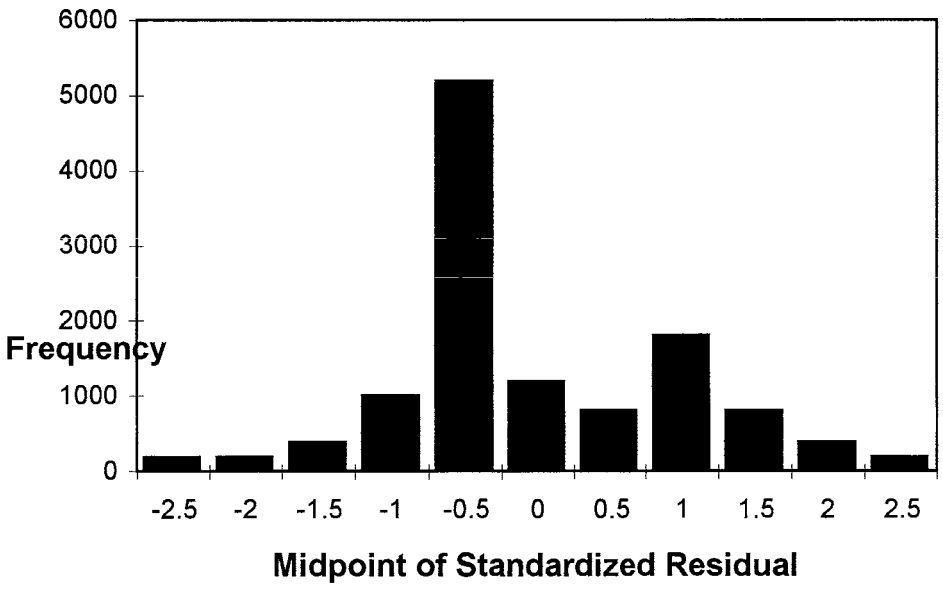
R-Square	C.V.	Root MSE	LNBUCT Mean
0.303973	218.7916	2.82049083	1.28912198

Appendix 3. Output statistics from General Linear Model (GLM) results for blue marlin analysis from U.S. recreational survey data, NMFS, SEFSC, 1973-1995.

STANDARDIZED RESIDUALS FOR ALL YEARS COMBINED

Moments				Quantiles(Def=5)		Extremes			
N	12468	Sum Wgts	12468	100% Max	5.69265	99%	2.49341	Lowest Obs	Highest Obs
Mean	-0.06244	Sum	-778.454	75% Q3	0.738334	95%	1.666143	-5.42796(11880)	4.46593(10825)
Std Dev	0.999422	Vari	0.9988	50% Med	-0.33735	90%	1.289927	-4.69904(6697)	4.470024(11640)
Skewness	0.296213	Kurt	1.077048	25% Q1	-0.5669	0%	-1.042	-4.65285(12321)	4.757912(576)
USS	12501.2	CSS	12452.59	0% Min	-5.42796	5%	-1.56036	-4.27779(10050)	4.877257(6383)
CV	-1600.71	Std Mean	0.008951			1%	-2.53031	-4.2441(11089)	5.692653(11883)
T:Mean=0	-6.97567	Prob>|T|	0.0001	Range	11.12061				
Sgn Rank	-4072087	Prob>|S|	0.0001	Q3-Q1	1.305235				
Num ^= 0	12468			Mode	-0.36335				
D:Normal	0.184747	Prob>D	<.01						

Appendix 4. Frequency of residuals from the General Linear Model (GLM) fit for blue marlin analysis from U.S. recreational survey data, NMFS, SEFSC, 1973-1995, all years combined.



Appendix 5. Matrix of total number of records by period (wave) and area and total records by year and area for white marlin from U.S. recreational surveys, NMFS, SEFSC, 1973-1995.

AVE	AREA					
Frequency						
Percent	1	2	5	6	7	Total
1	0	0	560	35	201	796
	0	0	4.42	0.28	1.59	6.28
2	2	382	471	154	2685	3694
	0.02	3.02	3.72	1.22	21.2	29.16
3	184	1086	176	311	4000	5757
	1.45	8.57	1.39	2.46	31.58	45.45
4	13	267	0	237	1903	2420
	0.1	2.11	0	1.87	15.02	19.1
Total	199	1735	1207	737	8789	12667
	1.57	13.7	9.53	5.82	69.39	100

WAVE	AREA					
Frequency						
Percent	1	2	5	6	7	Total
73	0	4	43	19	290	356
	0	0.03	0.34	0.15	2.29	2.81
74	3	32	34	18	345	432
	0.02	0.25	0.27	0.14	2.72	3.41
75	0	22	35	19	353	429
	0	0.17	0.28	0.15	2.79	3.39
76	0	18	42	15	493	568
	0	0.14	0.33	0.12	3.89	4.48
77	0	13	36	7	490	546
	0	0.1	0.28	0.06	3.87	4.31
78	0	18	47	11	593	669
	0	0.14	0.37	0.09	4.68	5.28
79	0	18	43	8	490	559
	0	0.14	0.34	0.06	3.87	4.41
80	36	191	47	4	472	750
	0.28	1.51	0.37	0.03	3.73	5.92
81	29	162	52	44	676	963
	0.23	1.28	0.41	0.35	5.34	7.6
82	3	107	50	51	510	721
	0.02	0.84	0.39	0.4	4.03	5.69
83	2	359	50	198	525	1134
	0.02	2.83	0.39	1.56	4.14	8.95
84	19	266	61	38	448	832
	0.15	2.1	0.48	0.3	3.54	6.57
85	0	14	44	43	451	552
	0	0.11	0.35	0.34	3.56	4.36
86	0	8	59	10	363	440
	0	0.06	0.47	0.08	2.87	3.47
87	12	27	61	15	344	459
	0.09	0.21	0.48	0.12	2.72	3.62
88	13	53	72	32	425	595
	0.1	0.42	0.57	0.25	3.36	4.7
89	10	68	78	34	358	548
	0.08	0.54	0.62	0.27	2.83	4.33
90	11	72	71	18	445	617
	0.09	0.57	0.56	0.14	3.51	4.87
91	16	74	58	27	387	562
	0.13	0.58	0.46	0.21	3.06	4.44
92	14	75	51	30	88	258
	0.11	0.59	0.4	0.24	0.69	2.04
93	14	51	50	38	77	230
	0.11	0.4	0.39	0.3	0.61	1.82
94	10	35	43	39	86	213
	0.08	0.28	0.34	0.31	0.68	1.68
95	7	48	80	19	80	234
	0.06	0.38	0.63	0.15	0.63	1.85
Total	199	1735	1207	737	8789	12667
	1.57	13.7	9.53	5.82	69.39	100

Appendix 6. General Linear Model (GLM) output for white marlin for U.S. recreational survey data, NMFS, SEFSC, 1973-1995.

GLM RESULTS, BY YEAR, WAVE, AND AREA

Dependent Variable: LNWHCT
Weight: BOATNO

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	39	90339.49245358	2316.39724240	210.91	0.0001
Error	12627	138682.74742101	10.98303219		
Corrected Total	12666	229022.23987459			

R-Square	C.V.	Root MSE	LNWHCT Mean
0.394457	274.2155	3.31406581	1.20856240

Appendix 7. Output statistics from General Linear Model (GLM) results for white marlin analysis from U.S. recreational survey data, NMFS, SEFSC, 1973-1995.

STANDARDIZED RESIDUALS FOR ALL YEARS COMBINED

Moments			Quantiles(Def=5)		Extremes				
N	12667	Sum Wgts	12667	100% Max	7.137973	99%	2.696707	Lowest Obs	Highest Obs
Mean	-0.06609	Sum	-837.153	75% Q3	0.586791	95%	1.637957	-6.56785(9616)	6.883171(10166)
Std Dev	0.999421	Variance	0.998841	50% Med	-0.25776	90%	1.192944	-6.15266(11915)	6.911093(10167)
Skewness	0.535273	Kurtosis	3.439332	25% Q1	-0.5836	10%	-1.0615	-5.39092(9617)	6.979667(11226)
USS	12706.65	CSS	12651.32	0% Min	-6.56785	5%	-1.47714	-5.13985(12564)	7.020325(11227)
CV	-1512.23	Std Mean	0.00888			1%	-2.56587	-5.13985(12563)	7.137973(11225)
T:Mean=0	-7.44251	Prob>|T|	0.0001	Range	13.70582				
Sgn Rank	-5537452	Prob>|S|	0.0001	Q3-Q1	1.170388				
Num ^= 0	12667			Mode	-0.4333				
D:Normal	0.140736	Prob>D	<.01						

Appendix 8. Frequency of residuals from the General Linear Model (GLM) fit for white marlin analysis from U.S. recreational survey data, NMFS, SEFSC, 1973-1995, all years combined.