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ESTIMATED SAILFISH CATCH-PER-UNIT-EFFORT FOR THE U.S. RECREATIONAL BILLFISH TOURNAMENTS AND U.S. RECREATIONAL FISHERY (1972-2014)

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SUMMARY

An index of abundance for sailfish from the United States recreational billfish tournament fishery is presented for the period 1972-2014 and for non-tournament recreational fisheries for the period 1981-2014. Tournament catch-per-unit-effort (number of fish caught per 100 hours fishing) was estimated from catch and effort data submitted by recreational tournament coordinators and U.S. National Marine Fisheries observers under the Recreational Billfish Survey program. A selection process was applied to restrict the data to tournaments that primarily target sailfish, using live bait only, along the Florida East coast. Non-tournament recreational data was compiled from the Marine Recreational Fisheries Statistical Survey (MRFSS). The catch per unit effort standardization procedure included the variables year, area, and season. Standardized indices were estimated using Generalized Linear Mixed Models under a Delta lognormal model approach.

RÉSUMÉ

Le présent document fournit un indice d'abondance pour les voiliers provenant de la pêcherie de tournois récréatifs d'istiophoridés aux États-Unis au titre de la période 1972-2014 et pour les pêcheries récréatives sans tournois au titre de la période 1981-2014. La capture par unité d'effort des tournois (nombre de poissons capturés en 100 heures de pêche) a été estimée à partir des données de prise et d'effort soumises par les coordinateurs des tournois récréatifs et les observateurs du Service National des Pêches Maritimes des États-Unis dans le cadre du Programme de prospection de la pêcherie récréative ciblant les istiophoridés. Un processus de sélection a été appliqué en vue de restreindre les données aux tournois qui ciblent principalement les voiliers, en utilisant uniquement l'appât vivant, menés le long de la côte orientale de la Floride. Les données de la pêcherie récréative hors tournoi ont été compilées au moyen de l'enquête statistique des pêcheries récréatives marines (MFRSS). La procédure de standardisation de la capture par unité d'effort incluait les variables année, zone et saison. Les indices standardisés ont été estimés à l'aide de modèles mixtes linéaires généralisés selon une approche du modèle delta-lognormale.

RESUMEN

Se presenta un índice de abundancia para el pez vela de la pesquería de torneos de recreo de istiofóridos de Estados Unidos para el periodo 1972-2014, y para las pesquerías de recreo sin torneos para el periodo 1981-2014. Se estimó la captura por unidad de esfuerzo de los torneos (número de ejemplares capturados por 100 horas de pesca) a partir de los datos de captura y esfuerzo presentados por los coordinadores de los torneos de recreo y por los observadores del Servicio nacional de pesquerías marinas de Estados Unidos, en el marco del Programa de prospección de pesquerías de recreo de istiofóridos. Se aplicó un proceso de selección para restringir los datos a los torneos dirigidos sobre todo al pez vela, que utilizan solo cebo vivo, a lo largo de la costa este de Florida. Los datos de pesquerías de recreo no procedentes de torneos fueron compilados por la Prospección estadística de pesquerías marinas de recreo (MRFSS). En el procedimiento de estandarización de la captura por unidad de esfuerzo se incluyeron las variables año, área y temporada. Los índices estandarizados se estimaron utilizando modelos lineales mixtos generalizados con un enfoque de modelo delta lognormal.

KEYWORDS

Catch/effort, abundance, sport fishing, pelagic fisheries, multivariate analysis

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1. Introduction

In general, information on relative abundance is necessary to tune stock assessment models. Two sources of this information for sailfish (*Istiophorus platypterus*) were used in this document: 1) the Recreational Billfish Tournament Survey (RBS), and 2) the non-tournament Marine Recreational Fishery Statistics Survey (MRFSS).

Tournament catch and effort data from U.S. recreational tournaments along the Atlantic East coast (including the Bahamas), Gulf of Mexico, and Caribbean (U.S. Virgin Islands and Puerto Rico) have been collected by the RBS program since 1972. Beardsley and Conser (1981), and Prince et al. (1990) have described the survey. From this data, indices of abundance for sailfish have been previously estimated (Farber 1994, Ortiz and Brown 2002, Hoolihan et al. 2009). 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) from 1972-1990 and became mandatory in 1991. In addition, scientific observers that monitored selected billfish tournaments in the Gulf of Mexico are also part of the RBS data base. This report documents the analytical methods applied to the available RBS data for the period 1972-2014 and presents correspondent standardized CPUE indices for sailfish.

Recreational catch and effort data are collected during the intercept survey component of the MRFSS, in which anglers are intercepted, screened, and interviewed at assigned access sites upon completion of their fishing trips (U.S. Department of Commerce 1990). Total recreational effort to estimate total catch is obtained via a telephone survey of coastal households. Intercepts are not conducted at tournament sites. Data from oceanic trips off the U.S. East Coast, south of North Carolina, from 1981-2014 were used to develop standardized CPUE indices.

2. Materials and Methods

2.1 RBS

Browder and Prince (1990) described the main features of the recreational tournaments that take place in the West Atlantic and Caribbean, and review the available catch and effort data from RBS data. Standardized catch rate indices of sailfish were previously estimated for the 2009 stock assessment using Generalized Linear Models (GLM) (Farber 1994) and, more recently, in 2001 using GLM with a Delta lognormal approach (Ortiz and Brown 2002). The present report updates the catch and effort information through 2014; and following the advice of the billfish working group of the ICCAT Standing Committee on Research and Statistics (SCRS), it includes analyses of variability associated with random factor interactions, particularly for the *Year* effect. Logbook records from the recreational tournaments have been collected since 1972 either by NMFS personnel or through voluntary submission by tournament organizers. Changes in U.S. regulations during the mid-1990's required mandatory recreational billfish tournaments to register and submit catch and effort data to the NMFS (Anonymous 1999).

To reduce the confounding effects of multiple gears and bait configurations on catch rates, we limited our analyses to tournaments using live-baiting techniques only. This reduced the geographical range of the tournaments analyzed to an area along the FEC (Figure 1), roughly extending from the city of Stuart (North), to Key West (South) Florida. This RBS data sub-sample comprised a total of 830 tournament records dating from 1972 through 2014. Each record represents information on hooked and caught fish by tournament. Fishing effort was estimated from the number of boats participating in the tournament multiplied by the average-fishing hours per boat-day. Records also include total number of fish hooked, their fate (i.e. lost, release, tagged and released, or boated) by species, and morphometric information (size and weight) for boated fish.

A general increase of recreational sailfish tournament fishing effort has been observed throughout the time series (Prince et al. 2007). To account for potential seasonal effects, tournament month and seasons were tested as fixed effects; the seasons were defined as: (1) January through April, (2) May through August, and (3) September through December.

Tournament logbooks primarily record numbers of fish caught and, sometimes, size and weight. The analysis of catch rates included the total number of caught sailfish (caught and released fish, tagged fish, and boated fish). This was because of the implementation of minimum size regulations (first implemented in 1988); and the prevalence of catch and releasing sailfish in U.S. tournaments throughout the time series (Prince *et al.* 2007).

For the RBS tournament data, a relative index of abundance for sailfish was estimated using a GLM approach. Because of the restriction of data to live bait fishing tournament effort, targeting primarily sailfish, the proportion of sailfish catch was over 95% in each year. Therefore, it was decided to restrict the analysis to positive sailfish catch observations. The mean catch rate of trip/day assumed a lognormal error distribution. The log-transformed frequency distributions of catch rates in numbers for sailfish are shown in **Figure 2**. Catch rates were modeled as a linear function of fixed factors and random effect interactions, particularly when the *Year* effect was within the interaction. Year and month were the factors included in the analysis.

A step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability. 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% were selected, , and b) Akaike Information Criterion for most parsimonious model.

Once a set of fixed factors was identified, statistically significant interactions were evaluated as random factors of the model, 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 of a successive nested model formulations (Littell *et al*. 1996). Analyses were done using the MIXED procedures from the SAS® statistical computer software (SAS Institute Inc. 1997).

2.2 MRFSS

The survey methodology of the MRFSS is described by the U.S. Department of Commerce (1990). The catch-effort data used in this study was restricted to the region off the eastern coast of Florida, North Carolina, the Caribbean (Puerto Rico and U.S. Virgin Islands), and the U.S. Gulf of Mexico. Only oceanic fishing in the charter or private/rental modes was included. Since the MRFSS is a generalized survey of all saltwater recreational fishing and sailfish targeted effort represents only a small component of oceanic fishing, the data was further restricted to fishing trips that target highly migratory species such as tunas, king mackerel, dolphin fish, sailfish and marlins. Thus, the MFRSS survey did not distinguish between live bait effort and other fishing methods. Catch rate was estimated as the number of sailfish caught (both kept and released alive fish) by angler hours. The log-transformed frequency distribution of catch rates in numbers for sailfish is shown in **Figure 3**. The available variables included year, month, season, region, state, and mode (charter or private/rental trip). Parameterization of the model used a Generalized Linear Model (GLM) with the delta lognormal model approach. The proportion of successful (i.e. positive observations) trips per strata was assumed to follow a binomial distribution where the estimated probability was a linearized function of fixed factors and interactions. The logit function linked the linear component and the assumed binomial distribution. Similarly, the estimated catch per angler hour on positive trips was modeled as function of similar fixed factors with the log function as a link.

A stepwise approach was used to quantify the relative importance of the main factors explaining the variance in catch rates. Factors and interactions which resulted in the greatest significant reduction in deviance per degree of freedom were incorporated into the model.

The product of the standardized proportion positives and the standardized positive catch rates was used to calculate overall standardized catch rates. For comparative purposes, each relative index of abundance was scaled by dividing the standardized catch rates by the mean value of each series during the overlapped period.

3. Results and Discussion

3.1 RBS

Table 1 shows the deviance analysis for sailfish from the U.S. RBS tournament data. For sailfish, the factors *Year* and *Month* were the main explanatory variables for the proportion of positive trip-days; and, all factors were significant for sailfish mean catch rate. Once a set of fixed factors was selected, we evaluated first level random interaction between the *Year* and other effects. The diagnostic plots of the fit to the proportion of positive model component (**Figure 4**), and fit of the positive observations model (**Figure 5**) corroborate the final model selection.

Standardized CPUE series for the U.S. RBS sailfish tournament data (1972-2014) are shown in **Table 2** and **Figure 6**. Catch rates of sailfish decreased to their lowest value in 1983, followed by a gradual increase. Coefficient of variation ranged from 30.3% to 55.2%.

3.2 MRFSS

The deviance analysis for sailfish from the U.S. MRFSS recreational survey data is shown in **Table 3**. The diagnostic plots of the fit to the proportion of positive model component (**Figure 7**), and fit of the positive observations model (**Figure 8**) corroborate the final model selection.

Standardized CPUE series for the U.S. MRFSS recreational survey sailfish data (1981-2014) are shown in **Table 4** and **Figure 9**. Catch rates of sailfish decreased to their lowest value in 1983, followed by a gradual increase. Coefficient of variation ranged from 20% to 53%. For comparative purposes, the standardized CPUE indices for the U.S. RBS tournament and MRFSS data are plotted together in **Figure 10**.

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Table 1. Deviance analysis table for the U.S. Recreational Billfish Survey (RBS) sailfish data (1972-2014). The dependent variable is the number of fish per 100 hours. The selected standardization model is shown in bold.

Model	Model df	Residual_Deviance	%Reduction	AIC	dAIC
Intercept only	1	1439		2802	632
Year	43	1219	15	2751	581
Month	11	718	50	2251	81
Season	3	990	37	2500	330
Year + Month	**54**	**586**	**18**	**2170**	**0**
Year + Month + Year*Month	262	400	32	2272	102

Table 2. Sailfish nominal and standardized CPUE (fish/100 hours), coefficient of variation, and 95% confidence intervals from the U.S. Recreational Billfish Survey (RBS) data (1972-2014).

Year	n	Prop_Pos	Nominal_CPUE	Standardized_Index	CV	LCI	UCI
1972	4	1.00	4.4	0.49	0.42	0.22	1.11
1973	5	1.00	15.3	0.97	0.38	0.46	2.03
1974	7	1.00	10.9	0.55	0.33	0.29	1.05
1975	9	1.00	26.9	1.40	0.29	0.79	2.46
1976	7	1.00	20.4	1.02	0.32	0.54	1.92
1977	8	1.00	23.6	1.39	0.31	0.76	2.54
1978	8	1.00	24.5	1.40	0.31	0.77	2.55
1979	8	1.00	23.0	1.29	0.31	0.71	2.36
1980	7	1.00	33.4	1.41	0.32	0.75	2.65
1981	3	1.00	25.6	1.13	0.47	0.46	2.78
1982	2	1.00	6.9	0.35	0.57	0.12	1.00
1983	5	1.00	4.0	0.36	0.38	0.17	0.75
1984	14	1.00	10.6	0.54	0.24	0.34	0.86
1985	15	1.00	8.7	0.40	0.23	0.25	0.63
1986	20	1.00	15.5	0.77	0.20	0.52	1.15
1987	25	1.00	11.0	0.62	0.18	0.43	0.88
1988	25	1.00	10.6	0.61	0.18	0.43	0.87
1989	25	1.00	8.1	0.50	0.18	0.35	0.71
1990	24	1.00	11.6	0.67	0.18	0.47	0.96
1991	30	1.00	8.6	0.62	0.16	0.45	0.87
1992	25	1.00	9.6	0.60	0.18	0.42	0.86
1993	12	1.00	13.2	0.73	0.25	0.44	1.19
1994	12	1.00	15.0	1.12	0.25	0.68	1.85
1995	19	1.00	15.4	0.94	0.20	0.63	1.40
1996	16	1.00	19.6	1.09	0.22	0.71	1.69
1997	17	1.00	20.5	1.06	0.21	0.70	1.62
1998	6	1.00	25.5	1.11	0.35	0.56	2.18
1999	17	1.00	14.8	0.66	0.21	0.44	1.01
2000	21	1.00	11.6	0.61	0.19	0.41	0.89
2001	27	0.96	13.6	0.74	0.18	0.52	1.05
2002	31	1.00	13.0	0.83	0.16	0.60	1.15
2003	33	0.97	13.0	0.94	0.16	0.68	1.29
2004	37	0.97	18.4	0.99	0.15	0.73	1.33
2005	39	1.00	17.5	0.97	0.15	0.72	1.29
2006	42	1.00	30.6	1.14	0.14	0.86	1.52
2007	44	0.98	18.3	0.97	0.14	0.74	1.29
2008	39	1.00	29.1	1.57	0.15	1.18	2.10
2009	33	0.97	36.4	1.74	0.16	1.27	2.39
2010	29	0.97	38.1	1.79	0.17	1.28	2.51
2011	23	1.00	37.7	2.03	0.19	1.40	2.93
2012	20	1.00	34.8	2.08	0.20	1.41	3.09
2013	17	1.00	26.6	1.45	0.21	0.95	2.21
2014	14	1.00	25.7	1.33	0.23	0.84	2.11

Table 3. Deviance analysis table of explanatory variables in the delta lognormal model for sailfish catch rates from the U.S. recreational survey (MRFSS) data (1981-2014).

Model factors proportion positive	Model df	Resid. Dev	% Dev Red	delta_AIC
Intercept only	1	60354		4994
Year	34	59599	1.3	4305
Month	12	57826	4.2	2488
Season	4	58240	3.5	2887
State	5	58886	2.4	3534
Region	3	59019	2.2	3663
Mode	2	55358	8.3	0
Mode	2	55358		2759
Mode + Year	35	54834	0.9	2301
Mode + Month	13	53217	3.9	641
Mode + Season	5	53546	3.3	953
Mode + State	6	52591	5.0	0
Mode + Region	4	52746	4.7	151
Mode + State	6	52591		1611
Mode + State + Year	39	52087	1.0	1174
Mode + State + Month	17	50957	3.1	0
Mode + State + Season	9	51213	2.6	240
Mode + State + Month	17	50957		356
Mode + State + Month + Year	**50**	**50536**	**0.8**	**0**
Mode + State + Month + Year				
Mode + State + Month + Year + Year*Month	Non-convergent			
Mode + State + Month + Year + Year*State	Non-convergent			
Mode + State + Month + Year + Year*Mode	Non-convergent			
Model factors positive CPUE	Model df	Resid. Dev	% Dev Red	delta_AIC
Intercept only	2	3508		1267
Year	35	3429	2.3	1202
Month	13	3277	6.6	898
Season	5	3301	5.9	922
Region	4	2813	19.8	1
State	6	2810	19.9	0
Mode	3	3392	3.3	1075
State	6	2810		57.1
State+Year	39	2764	1.6	27.8
State+Month	17	2775	1.2	7.5
State+Season	9	2779	1.1	0
State+Mode	7	2801	0.3	41.2
State+Year	39	2764		85.1
State+Year+State*Year	**119**	**2648.1**	**4.2**	**0**

Table 4. Sailfish nominal and standardized CPUE (fish/hour), coefficient of variation, and 95% confidence intervals from the U.S. recreational survey (MRFSS) data (1981-2014).

Year	n	Prop_Pos	Nominal_CPUE	Index	cv_i	LCI	UCI
1981	1515	0.007	0.0010	0.75	0.53	0.28	2.04
1982	2671	0.006	0.0007	0.58	0.45	0.25	1.36
1983	1883	0.012	0.0023	0.75	0.41	0.34	1.65
1984	2098	0.008	0.0018	0.48	0.46	0.20	1.15
1985	2486	0.006	0.0010	0.44	0.46	0.18	1.05
1986	6869	0.007	0.0019	0.54	0.29	0.30	0.96
1987	9709	0.005	0.0010	0.60	0.29	0.34	1.05
1988	9714	0.006	0.0013	0.68	0.27	0.40	1.15
1989	8151	0.007	0.0015	0.55	0.28	0.32	0.96
1990	7054	0.006	0.0014	0.55	0.31	0.30	1.00
1991	7685	0.012	0.0024	0.84	0.25	0.52	1.37
1992	12178	0.012	0.0027	1.05	0.23	0.66	1.64
1993	10473	0.009	0.0016	0.87	0.24	0.54	1.40
1994	12492	0.008	0.0016	0.70	0.24	0.43	1.12
1995	11805	0.011	0.0017	0.85	0.23	0.54	1.34
1996	14690	0.009	0.0016	0.75	0.23	0.47	1.18
1997	15458	0.009	0.0021	0.55	0.23	0.35	0.86
1998	16162	0.015	0.0029	1.01	0.21	0.67	1.52
1999	19120	0.021	0.0050	1.66	0.20	1.12	2.46
2000	18054	0.018	0.0035	1.33	0.20	0.89	1.99
2001	18852	0.015	0.0027	0.83	0.21	0.54	1.26
2002	20156	0.023	0.0047	1.37	0.20	0.92	2.03
2003	18938	0.020	0.0040	1.44	0.21	0.95	2.17
2004	17857	0.018	0.0035	1.47	0.21	0.97	2.23
2005	15859	0.020	0.0040	1.57	0.21	1.04	2.38
2006	17192	0.015	0.0033	1.30	0.22	0.84	2.01
2007	16350	0.016	0.0033	1.35	0.22	0.88	2.07
2008	15271	0.019	0.0039	1.68	0.21	1.11	2.54
2009	13055	0.018	0.0035	1.89	0.21	1.24	2.88
2010	14715	0.015	0.0029	1.36	0.21	0.89	2.07
2011	13797	0.014	0.0030	1.31	0.22	0.84	2.02
2012	13719	0.014	0.0025	1.24	0.22	0.80	1.92
2013	8368	0.011	0.0023	1.02	0.26	0.62	1.68
2014	13233	0.008	0.0014	0.66	0.25	0.40	1.07

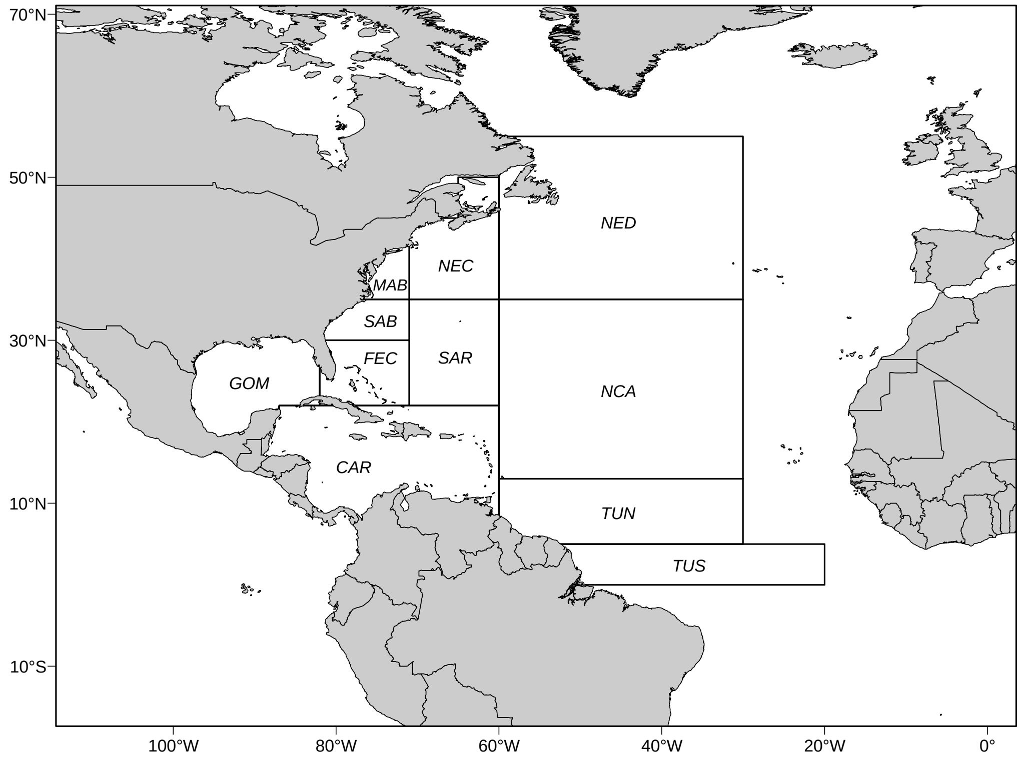

Figure 1. Geographical classifications of management areas used for the U.S. Recreational Billfish Survey (RBS), and recreational survey (MRFSS) sailfish catch data collection.

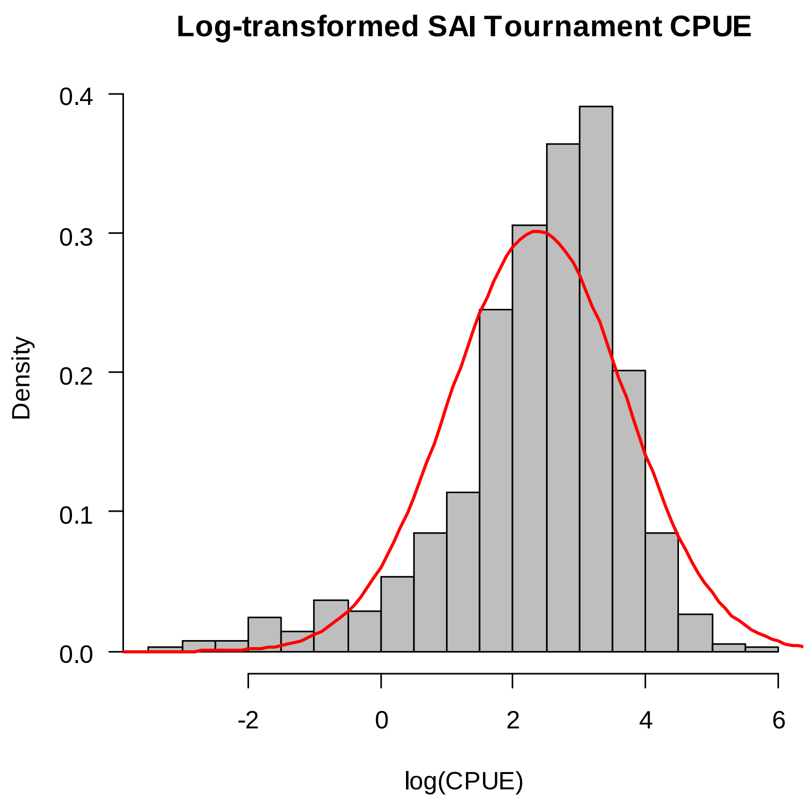

Figure 2. Frequency distribution for log transformed sailfish CPUE (fish/100 hours) of positive tournaments from the U.S. RBS tournament data (1972-2014).

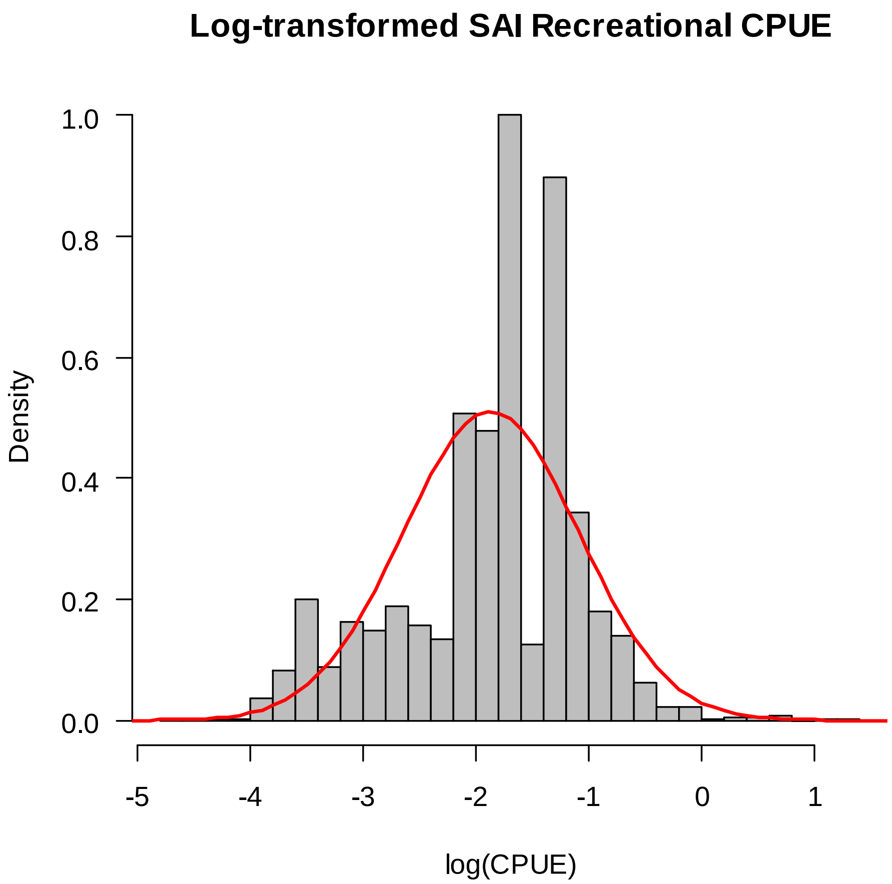

Figure 3. Frequency distribution for log transformed CPUE positive catches (number of sailfish) from the U.S. MRFSS recreational sailfish data (1981-2014).

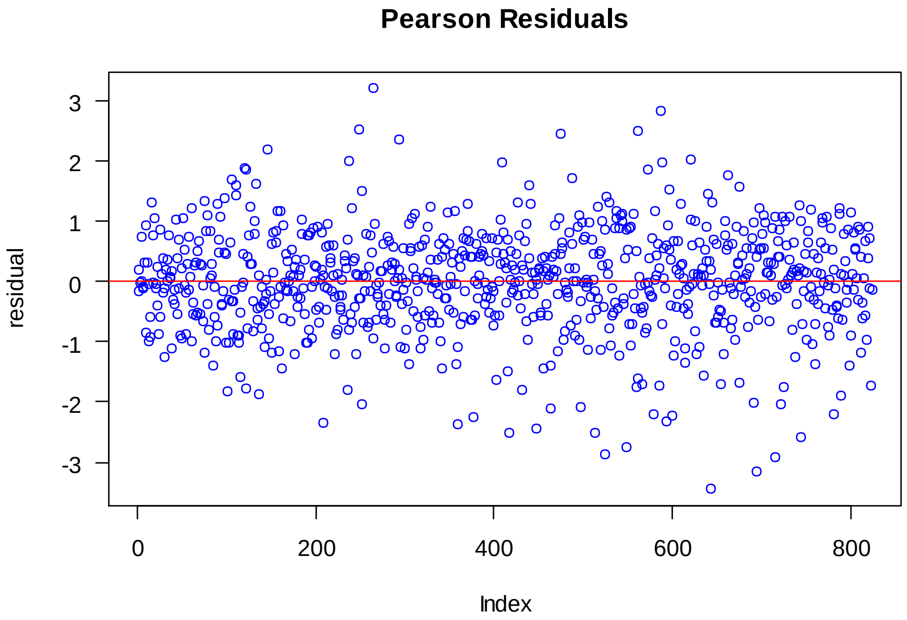

Figure 4. Lognormal standardization model Pearson residuals for the U.S. RBS sailfish tournament data (1972-2014).

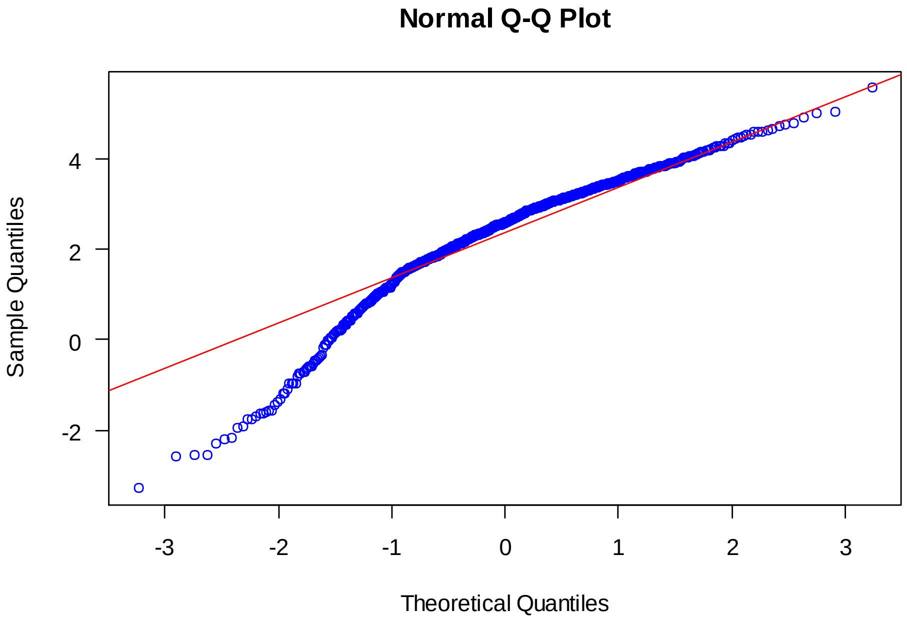

Figure 5. Normalized predicted plot (qq-plot) of residual fit of the positive observations (number of sailfish) GLM model fit for the U.S. RBS sailfish tournament data (1972-2014).

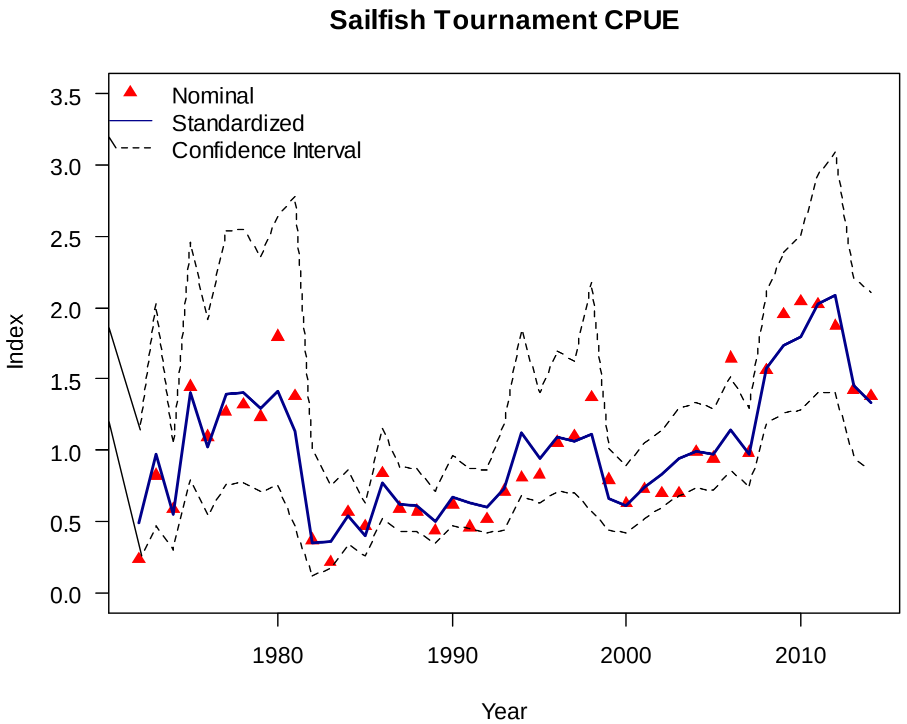

Figure 6. Estimated nominal (red diamonds) and standardized (blue line) CPUE for sailfish (fish /100 hours) from the U.S. Recreational Billfish Survey (RBS) tournament data (1972-2014). Dotted lines correspond to the 95% confidence interval for the standardized CPUE.

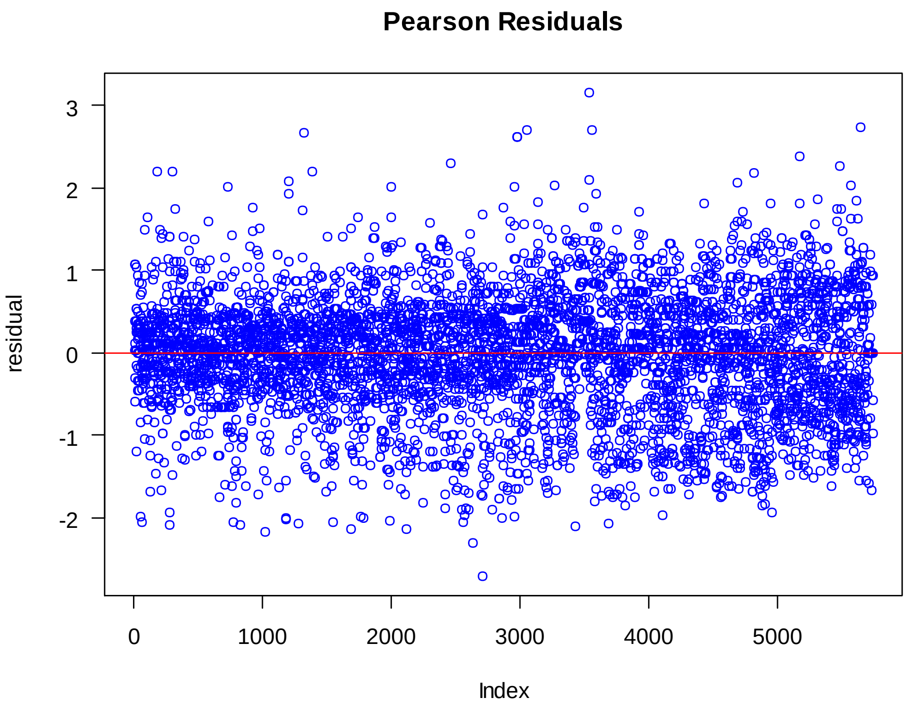

Figure 7. Lognormal standardization model Pearson residuals for the U.S. recreational data (1981-2014).

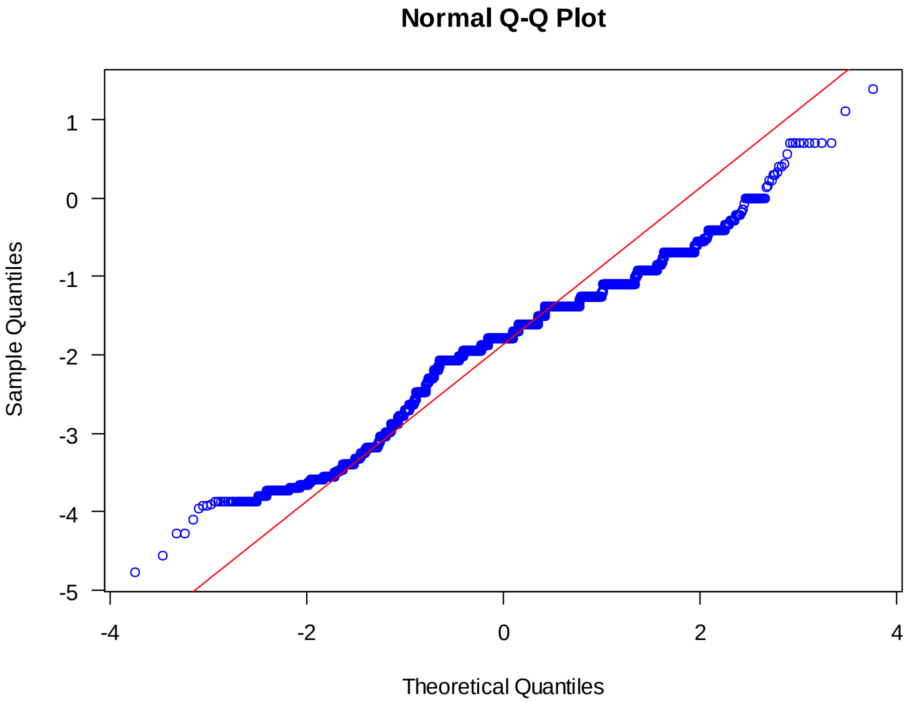

Figure 8. Normalized predicted plot (qq-plot) of residual fit of the positive observations (number of sailfish) GLM model fit for the U.S. recreational data (1981-2014).

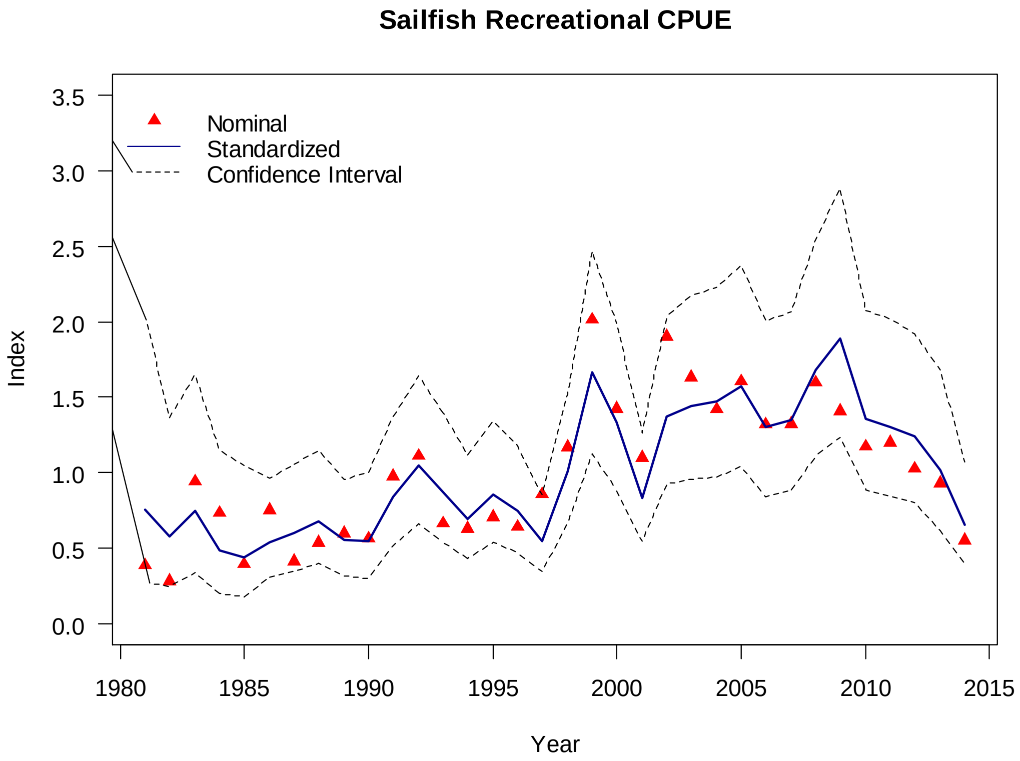

Figure 9. Estimated nominal (red diamonds) and standardized (blue line) CPUE for sailfish (fish /100 hours) from the U.S. Recreational data (1981-2014). Dotted lines correspond to the 95% confidence interval for the standardized CPUE.

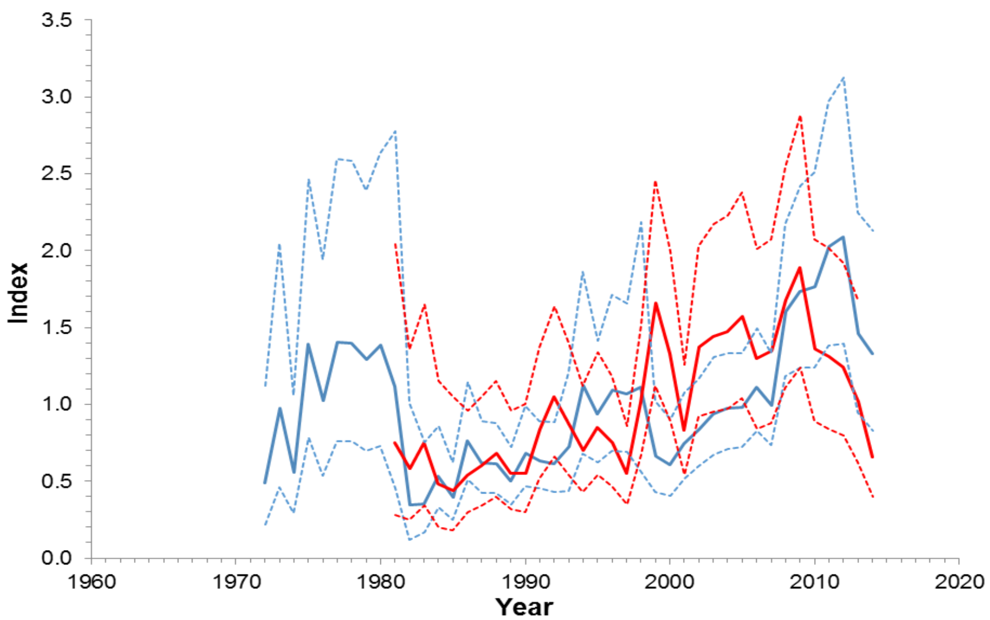

Figure 10. Estimated standardized CPUE for sailfish (fish/100 hours) from the U.S. RBS sailfish tournament data (1972-2014, blue line), and for sailfish (fish/hour) for the U.S. recreational survey (MRFSS) data (1981-2014, red line). Dotted lines correspond to the 95% confidence intervals.