SCRS/2016/075 Collect. Vol. Sci. Pap. ICCAT, 73(5): 1697-1706 (2017)

STANDARDIZED CPUE FROM THE ROD AND REEL AND ARTISANAL DRIFT-GILLNET FISHERIES OFF LA GUAIRA, VENEZUELA, UPDATED THROUGH 2014

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SUMMARY

*Catches of sailfish (*Istiophorus albicans*), white marlin (*Tetrapturus albidus*) and blue marlin (*Makaira nigricans*) and effort data were available from the recreational rod and reel fishery based at the Playa Grande Yacht Club, Central Venezuela, from 1961 to 2001. Data were also available from an artisanal drift- gillnet fishery in the same area from 1991 to 2014. Each dataset was standardized independently using a generalized linear mixed model (GLMM). The two datasets were also combined in a GLMM analysis that included the year, season, fishery and some two-way interactions as potential explanatory variables. The combined analysis produced a CPUE index of abundance that runs from 1961 to 2014. The index shows a decline followed by a period of stability for both sailfish and white marlin. The blue marlin index is variable with no clear trend.*

RÉSUMÉ

*Il existe des données disponibles de prise et d'effort de voilier (*Istiophorus albicans*), de makaire blanc (*Tetrapturus albidus*) et de makaire bleu (*Makaira nigricans*) de la pêcherie récréative à la canne et moulinet basée à Playa Grande Yacht Club, centre du Venezuela pour la période 1961-2001. On disposait également de données provenant d'une pêcherie artisanale au filet maillant dérivant dans la même région couvrant la période 1991-2014. Chaque jeu de données a été standardisé de manière indépendante, au moyen d'un modèle linéaire généralisé mixte (GLMM). Les deux jeux de données ont également été combinés dans une analyse GLMM qui incluait l'année, la saison, la pêcherie et quelques interactions à double sens comme variables explicatives potentielles. L'analyse combinée produit un indice d'abondance de la CPUE qui s'étend de 1961 à 2014. L'indice affiche une baisse, suivie d'une période de stabilité tant pour le voilier que le makaire blanc. L'indice du makaire bleu est variable et ne présente pas de tendance claire.*

RESUMEN

Se dispuso de datos de captura y esfuerzo de pez vela (Istiophorus albicans), aguja blanca (Tetrapturus albidus) y aguja azul (Makaira nigricans) de la pesquería de recreo de caña y carrete con base en el Playa Grande Yacht Club, Venezuela central, desde 1961 hasta 2001. También hay datos disponibles de una pesquería artesanal de redes de enmalle en la misma zona para 1991-2014. Cada conjunto de datos se estandarizó de forma independiente utilizando un modelo lineal mixto generalizado (GLMM). Los dos conjuntos de datos se combinaron también en un análisis GLMM que incluía el año, la temporada, la pesquería y algunas interacciones de dos direcciones como posibles variables explicativas. El análisis combinado produjo un índice de abundancia de CPUE que va desde 1961 a 2014. El índice muestra un descenso, seguido de un periodo de estabilidad tanto para el pez vela como para la aguja blanca. El índice para la aguja azul es variable y no muestra ninguna tendencia clara.

KEYWORDS

Billfish, catch/effort, mathematical models, La Guaria hot-spot, Venezuela

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1. Introduction

The fishing site known as "Placer de la Guaira", off central Venezuela, has been a known hot-spot for billfishes since the 1960s. Data are available from 1961 to 2001 on the number of rod and reel fishing trips taken each month from the Playa Grande Yacht Club, and the number of sailfish, white marlin and blue marlin caught in each month. Gaertner and Alio (1997) evaluated trends in this dataset from 1961 to 1995 for all three billfish species and found apparent declines in all three species. Beginning in 1991, this fishery was required to release all billfish caught, so the records are less complete in the 1990s, and there are no records after 2001. A dataset is also available from the artisanal drift-gillnet fishery that operates in the same area, from 1991 to 2012. This dataset includes the number of sets and the monthly total catch in kg of all three billfish species. Arocha et al. (2008) standardized the drift-gillnet fishery data to calculate an index of abundance for sailfish, and found no trend over time. Babcock and Arocha (2015) used a generalized linear mixed model (GLMM) to produce a combined index that included the data from both fisheries with data through 2012. The objective of this paper is to update the gillnet index and the combined index with data through 2014. Because there is no new data from the rod and reel fishery, the analysis from Babcock and Arocha (2015) was not updated.

2. Methods

For both the rod and reel fishery and the artisanal drift-gillnet fishery, and for the two datasets combined, the data were standardized using a generalized linear mixed model (GLMM). The response variable was log(CPUE+0.01) for either sailfish, white marlin or blue marlin. For the rod and reel fishery, CPUE was in numbers caught per trip. For the drift-gillnet fishery, CPUE was in kilograms caught per set. For the combined analysis, both CPUE data sets were divided by their mean in 1991 to 2001 in order to make the units approximately comparable. The explanatory variables were year, season (Winter: December-February, Spring: March-May, Summer: June-August, Autumn: September-November), and the interaction between year and season. For the analysis that included both fisheries, fishery was an explanatory variable, along with a fishery × season interaction. It was not possible to include an interaction between fishery and year because most years only had data from one fishery. Season and any interactions were treated as random effects, while year and fishery were fixed effects. Explanatory variables were included in the model if they were supported by the Akaike information criterion (AIC) and the Bayesian information criterion (BIC), and if they explained more than 5% of the model deviance (Ortiz and Arocha 2004). All analyses were conducted in R version 3.2.4 (R Core Team 2016), using the MASS (Venables and Ripley 2002) and lme4 (Bates et al. 2016) libraries.

3. Results

For both the rod and reel and the drift-gillnet fishery, there were consistent seasonal trends in CPUE for all three species (**Figure 1**). In both fisheries, white marlin were more commonly caught in the second half of the year, and blue marlin in the first half of the year. The trend in sailfish catch rates was not as consistent between the two fisheries. The monthly catch rates appeared to be lognormally distributed in both fisheries for all three species, with the exception of blue marlin, which had a large number of zero observations in the rod and reel fishery (**Figure 2**).

For the drift-gillnet fishery, both AIC and BIC were consistent with each other, but the information criteria preferred different models for each species (**Table 1**). The preferred models included year only for sailfish, year and season for white marlin, and year, season and their interaction for blue marlin. Year explained more than 90% of the deviance for both sailfish and blue marlin, but only 45% of the deviance for white marlin. The diagnostics (**Figure 2**) show generally normal residuals, except for some outliers at low predicted values. The standardized CPUE index looked very similar to the raw arithmetic mean, or the raw lognormal mean, and was also very similar to the values calculated by Arocha et al. (2008) for sailfish (**Figure 3**).

When both datasets were combined, the AIC and BIC preferred the same model for sailfish, but preferred different models for the two marlins, with the BIC preferring the simpler model in both cases (**Table 2**). The AIC preferred the most complex model (year+fishery+season+fishery:season) for all three species. For all three species, much of the deviance was explained by year and the interaction between year and season, perhaps because of changes over time in the seasonal trend in abundance. The diagnostics of the AIC-preferred models looked fairly normal (**Figure 5**), except at low predicted values. The predicted values of the index look very low and flat over the recent time period for all three species (**Figure 6**). Combining the data from the two sources gives very similar trends to what would be obtained by fitting the two series separately and dividing them by their mean in the time period when they overlap (**Figure 7, Table 3**).

4. Discussion

Because "Placer de la Guaira" is a billfish hotspot, catch rates from the area may provide a useful index of abundance. Given that the rod and reel dataset has not been continued since 2001, it would be useful to be able to combine the two datasets to estimate a long term index of abundance. Combining the two indices requires several assumptions. First, the average weight must be assumed to be constant in each fishery over time, so that CPUE in numbers in the rod and reel fishery are directly proportional to CPUE in weight in the drift-gillnet fishery. This is a reasonable assumption because the rod and reel fishery did not select for a specific size of fish, and the average size of fish in the drift-gillnet fishery has not changed over time.

Second, although the two fisheries may have different catchabilities, both catchabilities must be constant over time. Because information is not available on vessel characteristics such boat size, gear used, time spent fishing, or targeting in either fishery, these variables could not be added to the standardization. Any change in fishing methods over time in either fishery would bias the index. It is known that fishing methodology in the drift-gillnet fishery has not changed over time (Arocha et al. 2008). Whether rod and reel fishermen have become more efficient over time is not known.

Third, the combined GLMM makes the assumption that the error structure in the two fisheries is comparable. This may not be a good assumption, because catch rates are more variable in the rod and reel fishery than the artisanal drift-gillnet fishery. For this reason, it may be preferable to model the fisheries separately if they are to be used in a stock assessment model that uses the variances of the indices as an input (**Table 3**).

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Table 1. Artisanal drift-gillnet GLMM results.

(a) DIC and AIC

Model	SAI		WHM		BUM	
	Δ-AIC	Δ-BIC	Δ-AIC	Δ-BIC	Δ-AIC	Δ-BIC
Year	0	0	179.7	176.1	68.7	61.4
year+season	112.0	115.6	0	0	3.9	0.2
year+season+year:season	104.9	112.2	2.0	5.6	0	0

(b) Analysis of deviance

Species	Factor	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)	% deviance
SAI	NULL			288	3139.52			
	Year	24	3134.14	264	5.38	7801.63	0.000	0.998
	Season	3	0.02	261	5.36	0.36	0.784	0.000
	year:season	69	2.15	192	3.21	1.86	0.001	0.001
WHM	NULL			283	3144.43			
	Year	24	2859.80	259	284.63	234.12	0.000	0.909
	Season	3	159.34	256	125.29	104.36	0.000	0.051
	year:season	69	30.12	187	95.18	0.86	0.767	0.010
BUM	NULL			286	668.41			
	Year	24	299.94	262	368.46	14.61	0.000	0.449
	Season	3	105.76	259	262.71	41.21	0.000	0.158
	year:season	69	100.16	190	162.55	1.70	0.003	0.150

Table 2. Both datasets combined.

(a) AIC and BIC

Model	SAI		WHM		BUM	
	Δ-AIC	Δ-BIC	Δ-AIC	Δ-BIC	Δ-AIC	Δ-BIC
Year	154.2	140.7	172.3	162.3	68	62.6
year+fishery	155.9	146.9	168.5	163.0	69.8	69.0
year+fishery+season	77	72.5	0.9	0	4.3	8.1
year+fishery+season+fishery:season	0	0	0	3.6	0	8.3
year+season+year:season	51.2	51.2	2.6	6.2	5.0	13.3
year+season	76.0	67.0	8.7	3.2	0.8	0
year+season+year:seaon	50.3	45.8	10.1	9.2	1.4	5.2

(b) Analysis of Deviance

Species	Model	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)	% deviance
SAI	NULL			672	1429.29			
	year	52	424.84	620	1004.46	7.62	0.000	0.297
	fishery	1	0.36	619	1004.10	0.34	0.563	0.000
	season	3	162.80	616	841.30	50.61	0.000	0.114
	year:season	156	338.23	460	503.07	2.02	0.000	0.237
	fishery:season	3	13.02	457	490.05	4.05	0.007	0.009
WHM	NULL			689	1497.89			
	year	52	353.55	637	1144.34	5.31	0.000	0.236
	fishery	1	9.68	636	1134.66	7.57	0.006	0.006
	season	3	301.05	633	833.61	78.39	0.000	0.201
	year:season	156	220.47	477	613.13	1.10	0.216	0.147
	fishery:season	3	6.33	474	606.80	1.65	0.177	0.004
BUM	NULL			714	1750.21			
	year	52	464.72	662	1285.49	5.52	0.000	0.266
	fishery	1	0.34	661	1285.15	0.21	0.648	0.000
	season	3	160.93	658	1124.22	33.16	0.000	0.092
	year:season	156	312.28	502	811.94	1.24	0.045	0.178
	fishery:season	3	4.69	499	807.25	0.97	0.408	0.003

Table 3. Means and standard errors of the indices.

(a) Artisanal drift-gillnet

Year	SAI	SE	WHM	SE	BUM	SE	Year	SAI	SE	WHM	SE	BUM	SE
1991	16.04	0.66	29.51	15.93	3.41	1.84	2003	19.74	0.81	28.45	14.34	3.17	1.64
1992	29.02	1.20	11.80	5.95	0.74	0.39	2004	21.12	0.87	41.22	20.77	4.49	2.33
1993	24.03	1.15	19.04	9.92	0.70	0.39	2005	25.17	1.04	35.09	17.69	4.04	2.10
1994	22.21	0.92	26.40	13.31	4.52	2.35	2006	28.43	1.17	28.22	14.22	3.58	1.86
1995	23.24	0.96	34.73	17.50	4.48	2.33	2007	31.02	1.28	38.08	19.19	5.32	2.76
1996	20.16	0.83	27.00	13.61	0.80	0.42	2008	31.75	1.31	22.78	11.48	3.83	1.99
1997	29.17	1.08	34.53	17.05	0.82	0.42	2009	32.35	1.33	19.85	10.01	2.93	1.52
1998	28.55	1.18	39.49	19.90	2.57	1.34	2010	31.56	1.30	22.06	11.12	2.01	1.05
1999	28.92	1.19	44.55	22.45	4.72	2.45	2011	37.75	1.56	18.35	9.25	1.42	0.74
2000	23.83	0.98	28.16	14.19	3.19	1.66	2012	36.13	1.49	32.80	16.53	3.70	1.92
2001	22.42	0.92	22.61	11.40	1.90	0.99	2013	37.80	1.56	22.02	11.10	3.07	1.59
2002	20.51	0.85	15.98	8.05	2.64	1.37	2014	40.24	1.66	21.77	10.97	3.18	1.65

(b) Combined

Year	SAI	SE	WHM	SE	BUM	SE	Year	SAI	SE	WHM	SE	BUM	SE
1961	8.17	4.65	3.35	1.95	0.73	0.40	1988	2.11	1.21	1.75	1.02	0.30	0.17
1962	6.69	3.81	5.41	3.14	1.30	0.70	1989	2.30	1.32	1.32	0.77	0.59	0.32
1963	3.00	1.71	2.98	1.73	0.73	0.39	1990	NA	NA	NA	NA	NA	NA
1964	3.21	1.83	3.59	2.08	0.65	0.35	1991	0.81	0.42	0.77	0.39	0.39	0.17
1965	3.56	2.03	1.76	1.03	0.46	0.25	1992	0.60	0.29	0.61	0.30	0.27	0.12
1966	7.45	4.25	2.77	1.61	1.61	0.87	1993	0.62	0.35	0.32	0.18	0.52	0.25
1967	4.24	2.42	2.61	1.52	0.72	0.39	1994	0.95	0.47	1.05	0.52	1.09	0.47
1968	7.41	4.22	2.30	1.34	1.18	0.63	1995	0.97	0.48	1.49	0.74	1.39	0.59
1969	5.79	3.30	2.06	1.20	1.35	0.73	1996	0.65	0.33	0.26	0.14	0.45	0.19
1970	6.12	3.49	0.96	0.56	1.20	0.65	1997	0.69	0.33	0.23	0.12	0.74	0.30
1971	9.29	5.29	12.38	7.18	0.21	0.12	1998	0.93	0.47	0.69	0.37	0.77	0.34
1972	7.59	4.33	6.13	3.56	0.21	0.12	1999	0.89	0.45	1.05	0.54	1.21	0.55
1973	6.59	3.76	10.68	6.20	0.11	0.07	2000	0.79	0.41	0.63	0.33	0.73	0.33
1974	6.00	3.42	2.37	1.38	0.20	0.11	2001	0.71	0.36	0.76	0.39	0.68	0.29
1975	3.02	1.72	3.81	2.21	0.04	0.03	2002	0.47	0.25	0.79	0.43	0.50	0.25
1976	3.86	2.20	6.35	3.68	0.05	0.03	2003	0.79	0.42	0.94	0.51	0.60	0.30
1977	1.80	1.03	3.56	2.07	0.06	0.04	2004	1.13	0.59	1.34	0.72	0.72	0.36
1978	1.24	0.71	1.91	1.11	0.09	0.05	2005	0.97	0.51	1.20	0.65	0.69	0.34
1979	1.01	0.58	3.14	1.82	0.17	0.10	2006	0.78	0.41	1.06	0.58	0.88	0.44
1980	1.66	0.95	6.11	3.54	0.18	0.10	2007	1.05	0.55	1.57	0.85	1.01	0.50
1981	1.81	1.03	7.48	4.34	0.74	0.40	2008	0.63	0.33	1.13	0.62	0.79	0.39
1982	0.50	0.29	8.02	4.65	0.12	0.07	2009	0.55	0.29	0.88	0.48	0.55	0.28
1983	2.99	1.70	3.94	2.29	0.82	0.44	2010	0.61	0.32	0.60	0.33	0.93	0.46
1984	5.16	2.94	3.39	1.97	1.30	0.70	2011	0.51	0.27	0.42	0.23	0.50	0.25
1985	4.19	2.39	3.28	1.91	0.63	0.34	2012	0.90	0.47	1.10	0.60	0.72	0.36
1986	2.54	1.45	1.56	0.91	0.36	0.20	2013	0.61	0.32	0.91	0.50	0.73	0.36
1987	4.17	2.38	1.64	0.96	0.68	0.37	2014	0.61	0.32	0.94	0.51	0.82	0.41

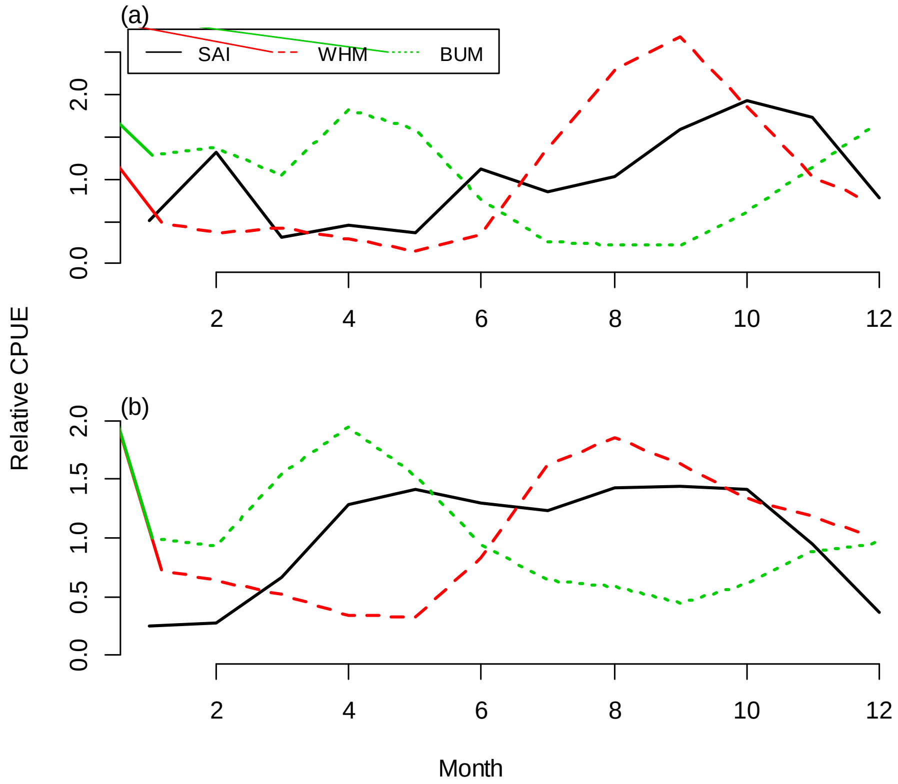

Figure 1. Average CPUE divided by its mean for each species, by month, in (a) the rod and reel fishery before 1990, and (b) the artisanal drift-gillnet fishery.

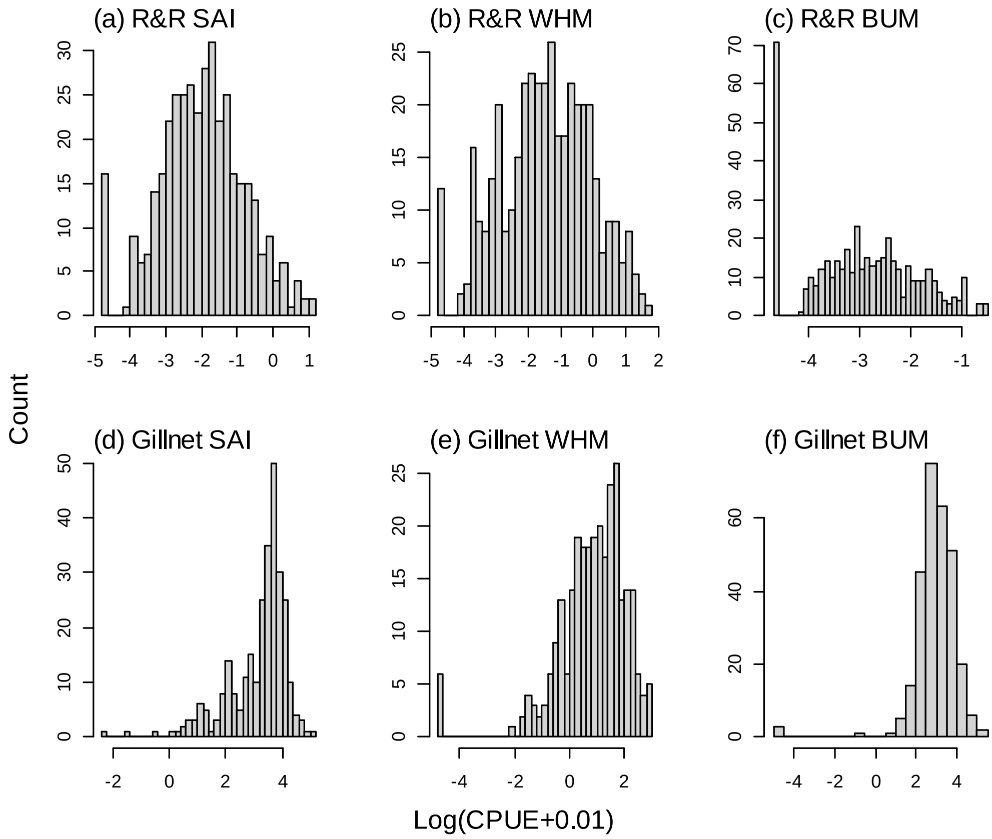

Figure 2. Histograms of log of CPUE for each species in each fishery.

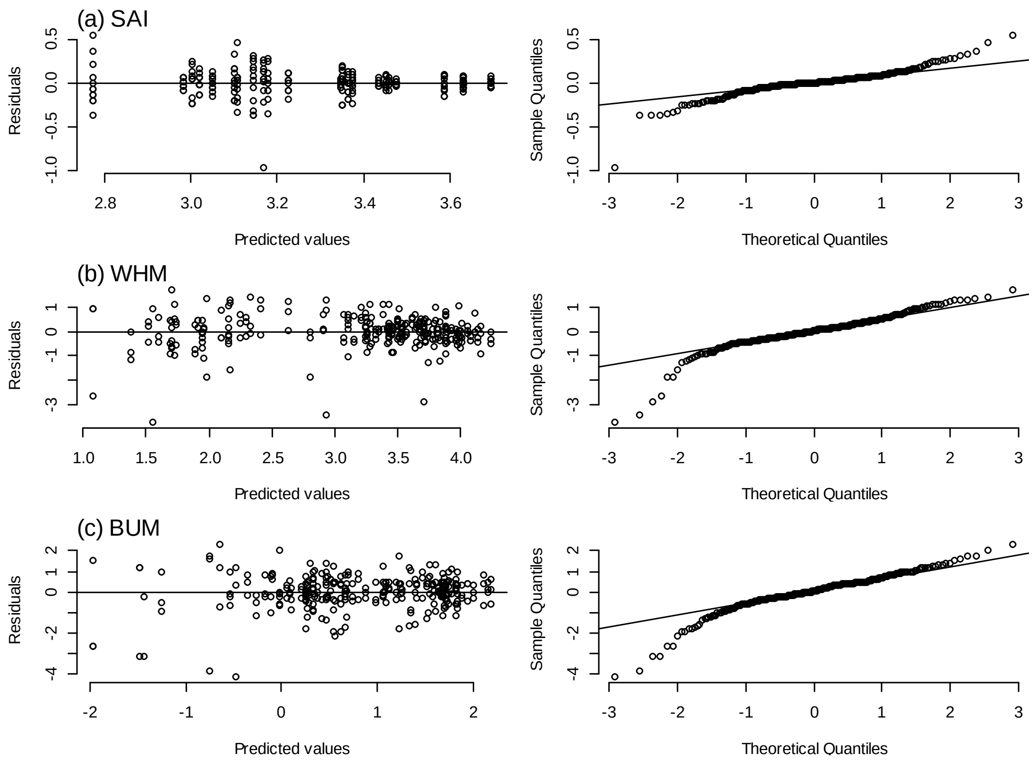

Figure 3. Artisanal drift-gillnet diagnostics.

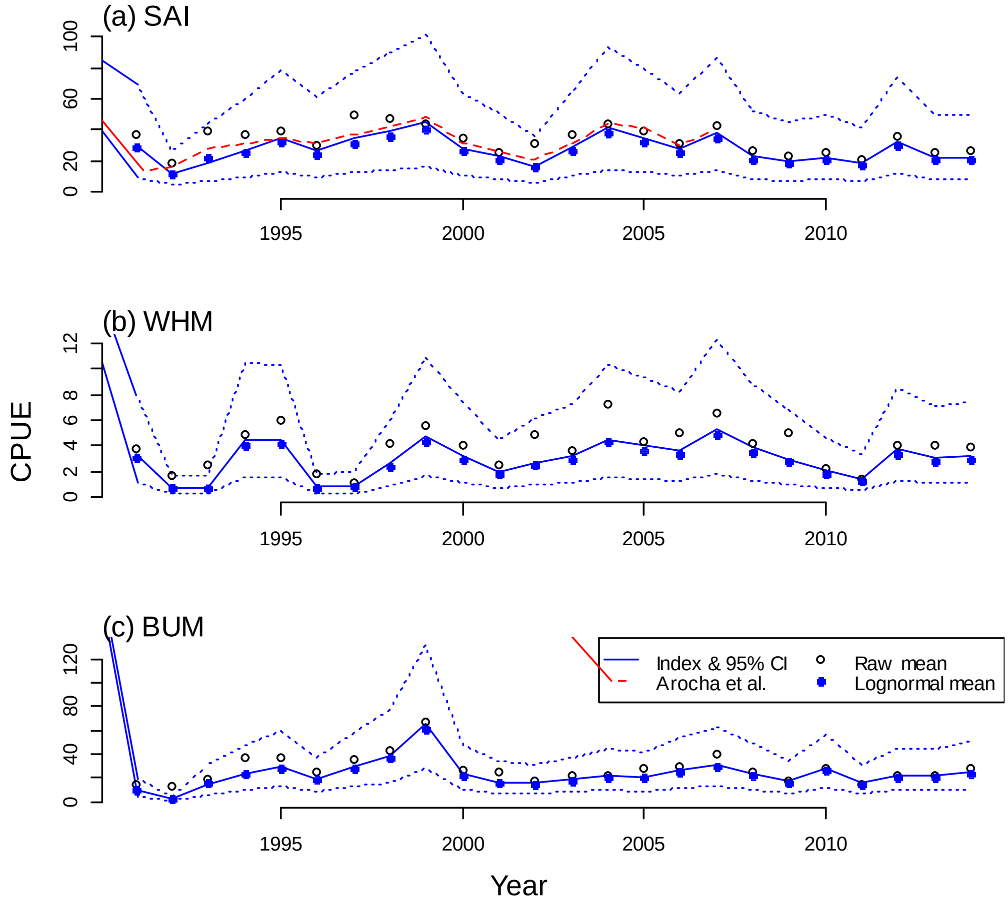

Figure 4. Artisanal drift-gillnet fitted values.

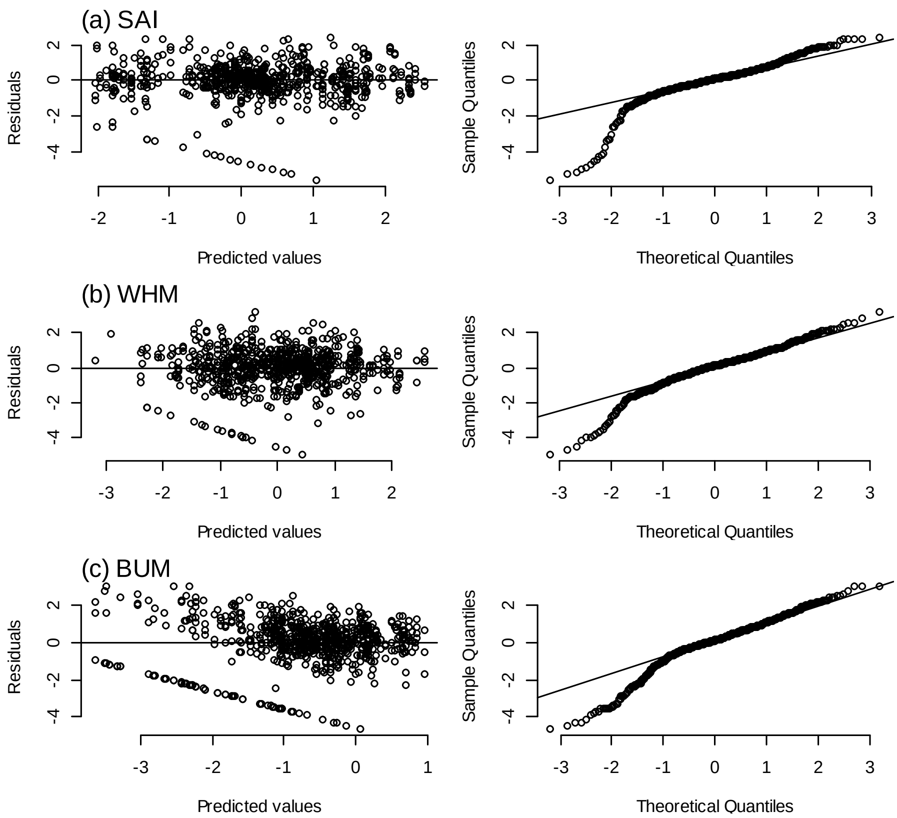

Figure 5. Diagnostics for the model with both datasets.

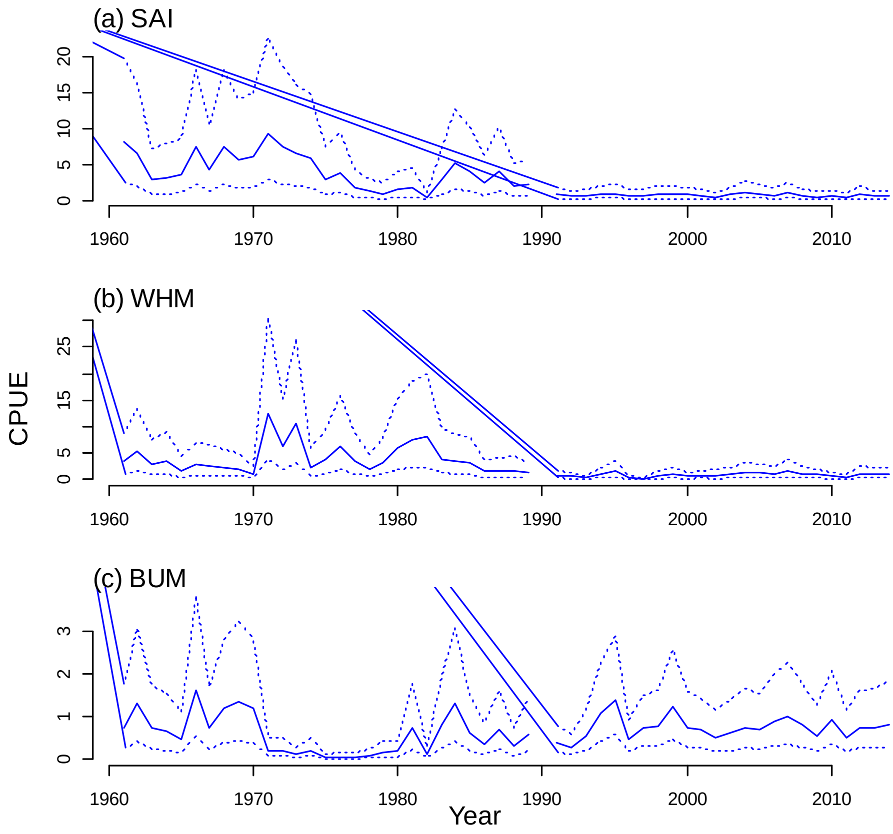

Figure 6. Fitted values for both datasets together.

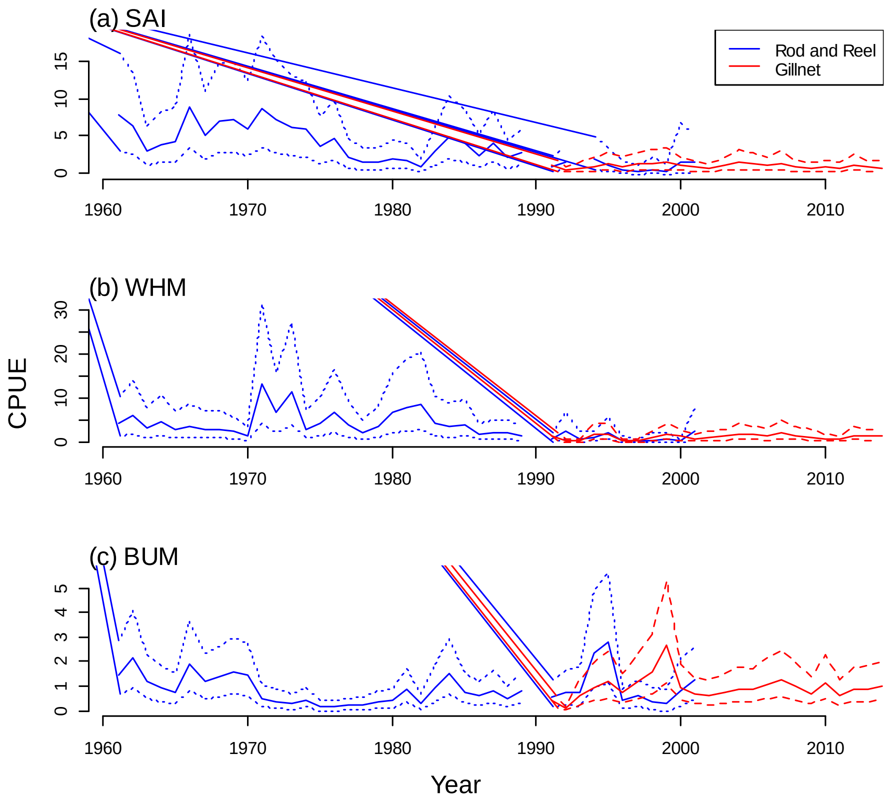

Figure 7. Fitted values for the two series separately.