Standardization of commercial catch per unit effort of hogfish (*Lachnolaimus maximus*) from Florida Trip Ticket landings, 1994-2012.

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Introduction

Indices of relative abundance were developed from the Florida Trip Ticket database for the two primary hogfish stocks within Florida: West Florida (WFL) and Southeast Florida including the Florida Keys (FLK/SEFL). These stock delineations are based on genetic analyses conducted on sampling from the WFL through North Carolina, suggesting little if any contemporaneous exchange between three distinct geographic groupings (WFL, FLK/SEFL, and N. Carolina; Seyoum et al. 2014).

Methods

Spatial and Temporal Extent

Given the distribution and stock structure of hogfish, two separate indices were constructed: one for the WFL and one for the FLK/SEFL. For the two Florida-centered stocks, only those landings from fishing areas and/or counties in the core distribution area were used: Franklin to Collier for the WFL stock, and Monroe to Indian River for the FLK/SEFL stock (Figure 1). Analyses were done for only years 1994-2012 when the gear code became a requirement on the trip tickets. Prior to 1994, all gear information from the trip ticket data should be considered as an estimate.

Identification of Appropriate Surveys

To identify those commercial trips that were appropriate for catching hogfish, a cluster analysis was conducted to identify species often caught in association with hogfish. By identifying those trips that caught associated species but failed to catch hogfish, one can infer zero-catch trips that were appropriate to include in the analysis. While catching hogfish on hook and line is often considered rare, the total landings of hogfish using hook and line versus spear is of a comparable magnitude over the time frame when recording of gear used was required on the Florida Trip Tickets (1994-present; Tables 1 and 2). As such, both gear types were analyzed and indices of abundance were computed separately for the two for comparison. The SEDAR 6 review found that the use of hook and line data for hogfish was contentious due to lack of evidence for either recreational or commercial fisheries targeting hogfish with hook and line gear (Kingsley 2004). For this analysis, we use only those species objectively determined to be caught in association with hogfish for a given gear type in order to identify appropriate valid trips.

The data was filtered to remove all uncommon species that occurred on only a small proportion of the total trips and in particular those species that were rarely caught with hogfish. For both gear types, species caught on less than 1% of the total trips that caught hogfish were removed. Affinity propagation clustering (APC) was chosen to determine associated species, because it has been shown to perform well relative to other cluster techniques and does not require that the number of cluster be pre-specified (Frey and Dueck 2007). APC automatically chooses an optimal number of clusters in the dataset, thereby providing an objective criterion for which to group associated species. For the APC procedure, the Bray measure of similarity was used where data were converted to presence/absence of landings for each species and fishing trip. Once the associated species within the hogfish cluster were identified for each of the stocks and gear types, all trips on which these species were caught for a specific gear type were used as suitable valid trips in the subsequent analyses. The APC technique was done in R 3.0.1 (R Core Team 2013) using the apcluster package (Bodenhofer et al. 2011).

Standardization Model

Standardized indices of abundance were calculated using a generalized linear modeling procedure that combined the analysis of the binomial information on presence/absence with the lognormal-distributed positive catch data (also known as two-part, hurdle, or zero-adjusted models, Zuur et al. 2009) as:

$$I_y = c_y p_y \quad [1]$$

where c_y are estimated annual mean CPUEs of non-zero catches modeled as lognormal distributions and p_y are estimated annual mean probabilities of capture modeled as binomial distributions. The lognormal submodel considers only trips in which a hogfish was caught (*i.e.*, non-zero catches). The binomial model considers all trips in which hogfish or associated species were caught. While other approaches exist to model zero-inflated data (i.e., Poisson and negative binomial distributions; zero-inflated models; Zuur et al. 2009), the two-part model used here is advantageous in that it provides inferences on both the presence-absence and abundance processes occurring within a population, and can easily accommodate different predictor variables for each sub-model in the statistical analysis.

To determine the most appropriate models, predictor variables were selected using a forward step-wise approach where each predictor was added to each submodel individually and the resulting reduction in deviance per degree of freedom (Dev/DF) analyzed. The factor causing the greatest reduction in Dev/DF was then added to the base model. Year was retained in all models to obtain an index of abundance over time. Other potential predictors included month, depth fished, days fished, and region fished. The region fished variable applied only to the FLK/SEFL stock, where the Keys (Monroe county) and SEFL (Miami-Dade to Indian River counties) were keyed as separate regions to accommodate differences in reef habitat structure. We assume that there are no significant interaction terms with year in this model and consider only the main effects. Criteria for model inclusion also include a reduction in Dev/DF≥0.5%. This process was then repeated until no factor met criteria for model inclusion. Final year-specific marginal means estimates and standard errors of the two sub-models were used to generate distributions of estimates for each sub-model from a Monte Carlo simulation (5000 Student's t distributed realizations). The product of these distributions (eq. 1) provided an estimate of the median catch rate with year-specific variability. All analyses were done using R 3.0.1 (R Core Team 2013).

Results and Discussion

Species Prevalence on Commercial Fishing Trips

In order to ascertain valid trips, species often caught in association with hogfish were selected through multiple procedures. The first filtering step was to determine only those species caught on greater than 1% of the trips that caught a hogfish. This was done to eliminate any species that were rarely caught with hogfish in order to simplify the cluster analysis (see section below). For the WFL spear fishery, hogfish was recorded on 1,688 trip tickets from 1994-2012. In the filtered data, flounders were the most often caught species, with nearly three times more records than hogfish for the WFL spear fishery. Hogfish were recorded a similar number of times on trip tickets where hook and line was the primary gear type (1,507), but this was a small fraction of the total hook and line trips conducted relative to the total number of spear fishing trips. A similar pattern was evident in the FLK/SEFL, where 6,068 trip tickets recorded hogfish when the primary gear was spear, and a similar magnitude of hook and line trips additionally recorded hogfish (4,479). However, hogfish were the most often caught species on spear fishing trips, but were caught on only a small fraction of the total hook and line trips in the FLK/SEFL region (Table 3).

Identification of Valid Commercial Trips

The APC technique was performed separately for the WFL gears and two stocks (hook-and-line versus spear; WFL versus FLK/SEFL stocks). For the WFS spear, the APC procedure selected 3 clusters from a total of 20 species. The species group in which hogfish clustered comprised the largest cluster with a total of twelve other species (Table 4), including the major groupers, snappers and grunts. For the WFL hook and line, the APC procedure selected 6 total clusters from a total of 35 species. The species group in which hogfish clustered was the 2nd largest cluster with eight other species, and similarly included the groupers, grunts, and snappers as in the spear fishing trips (Table 4). For the FLK/SEFL spear, the APC procedure selected 5 clusters from a total of 22 species. The species group in which hogfish clustered was the 2nd largest cluster with four other species of groupers and snappers (Table 4). And lastly, for the FLK/SEFL hook and line, the APC procedure selected 6 clusters from a total of 26 species. The species group in which hogfish clustered included four other species (Table 4). Figure 2 presents the frequencies of pounds of hogfish caught per trip for the two stocks and gear types after filtering for only those trips expected to encounter a hogfish (i.e., those trips either catching a hogfish or the associated species).

Standardization Model

The results from the forward-stepwise model selection procedure are presented in Tables 5-12. The final predictor variables for each model component (binomial and positives model components, two stocks, and two gear types: eight total models) were those that explained greater than 0.5 % of the residual deviance/DF in the deviance tables (percent.reduction column). Figures 3-10 present the diagnostics plots for each of the eight component models. In general, the models had relatively good fits to the positives data using a lognormal distribution (QQ plots are approximately normal).

The indices of abundance are presented in Tables 13-16 and Figures 11-14. Overall the indices were moderately variable with average coefficients of variation (CVs) of 18, 23, 5, and 12 % for the WFL spear, WFL hook-and-line, FLK/SEFL spear, and FLK/SEFL hook-and-line, respectively. The WFL spear CPUE increased from 1994 to 2012 in a stepwise fashion, with a first increase from 1999-2002, and a second increase from 2008-2012. The WFL hook-and-line CPUE did not demonstrate a similar pattern to the WFL spear CPUE, but instead was relatively stable across the entire time frame, marked with a temporary increase from 2000-2003, and a large temporarily increase in 2010 and 2011, both of which were followed by declines in abundance. The FLK/SEFL CPUE indices for both spear and hook and line were relatively stable across the time frame (1994-2012), marked with year to year fluctuations that generally did not correspond between the spear and hook and line CPUE trends. Given that hogfish are one of the primary species targeted on spear and rarely targeted on hook and line for commercial fisheries in the Florida stocks, the CPUE trends from the spear landings should be considered as a more accurate representation of the abundance than the hook and line landings data.

References

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Tables

Table 1. Commercial landings (pounds) by year and gear type for the West Florida (WFL) stock.

Year	Diving	Hook and Line	Long Line	Other	Traps	Unknown
1978	--	--	--	--	--	3092
1979	--	--	--	--	--	11202
1980	--	--	--	--	--	16503
1981	--	--	--	--	--	5084
1982	--	--	--	--	--	3837
1983	--	--	--	--	--	7506
1984	--	--	--	--	--	3167
1985	--	--	--	--	--	2294.37
1986	65.49	3544.23	246.42	1071.15	1165.5	541.68
1987	2.22	4000.44	384.06	2646.24	853.59	1583.97
1988	140.97	5228.1	97.68	3439.89	642.69	1939.17
1989	1026.75	8785.65	13294.47	2094.57	893.55	4353.42
1990	1141.08	8994.33	412.92	1380.84	2128.98	24949.47
1991	1728.27	29042.04	137.64	3054.72	3542.01	56.61
1992	6114.99	15904.08	194.25	1357.53	3384.39	--
1993	8451.54	22645.11	132.09	990.12	9911.19	--
1994	10382.94	15302.46	271.95	167.61	4763.01	--
1995	6398.04	8618.04	288.6	31.08	1703.85	--
1996	8369.4	5714.28	347.43	172.05	2380.95	--
1997	8613.6	5698.74	365.19	467.31	3825.06	--
1998	6948.6	2729.49	216.45	--	3152.4	--
1999	4900.65	4541.01	147.63	--	3444.33	55.5
2000	7525.345	8368.024	190.698	--	1792.65	586.635
2001	12345.97	6691.191	39.96	5.55	2767.23	230.88
2002	17615.99	4984.122	19.98	--	3594.18	--
2003	16205.6	5646.36	80.475	--	1330.89	--
2004	17820.3	2051.824	52.17	--	781.44	--
2005	13207.3	2553.666	148.74	--	24.42	--
2006	11865.62	1183.815	--	--	1.11	--
2007	13695.31	1608.679	34.41	--	1.11	--
2008	20328.26	1991.063	107.67	--	--	--
2009	27416.05	2829.057	--	--	--	--
2010	27997.83	5356.527	--	--	144.3	--
2011	38326.74	5441.331	87.69	--	19.98	--
2012	37177.74	3877.43	--	--	--	--

Table 2. Commercial landings by year and gear type for the Florida Keys and Southeast Florida (FLK/SEFL) stock.

Year	Diving	Hook and Line	Long Line	Other	Traps	Unknown
1978	--	--	--	--	--	36640
1979	--	--	--	--	--	38916
1980	--	--	--	--	--	49805
1981	--	--	--	--	--	57425
1982	--	--	--	--	--	28351
1983	--	--	--	--	--	29521
1984	--	--	--	--	--	35993
1985	--	--	--	--	--	42042.36
1986	1778.22	14209.11	6623.37	2417.58	4256.85	18642.45
1987	2717.28	25829.7	10231.98	3488.73	9220.77	12722.82
1988	2534.13	35930.7	3619.71	2314.35	10516.14	9665.88
1989	5857.47	45134.82	7050.72	3313.35	9810.18	8507.04
1990	4608.72	48376.02	7404.81	2074.59	8104.11	6817.62
1991	9825.72	39446.07	4826.28	816.96	13850.58	1485.18
1992	20274.15	51678.27	2267.73	270.84	16290.36	1776
1993	22317.66	52330.95	1712.73	39.96	18280.59	85.47
1994	21769.32	33816.15	942.39	97.68	6248.19	--
1995	17856.57	22630.68	1254.3	287.49	6026.19	--
1996	16157.16	21555.09	136.53	219.78	5443.44	--
1997	14588.73	24474.39	27.75	6.66	8015.31	--
1998	14739.69	12311.01	19.98	32.19	7059.6	--
1999	9252.627	8719.938	2.22	5.55	15366.84	881.34
2000	10802.75	7724.115	13.32	--	10691.95	1441.835
2001	11651.3	9246.985	155.4	1.11	2258.632	155.622
2002	12596.79	9190	--	17.649	1907.092	--
2003	7857.3	14560.86	218.67	--	2683.925	--
2004	11824.43	13522.15	88.8	--	2404.374	--
2005	8488.885	6718.018	17.76	--	1336.82	--
2006	7902.12	4113.95	--	13.709	1891.551	--
2007	10044.6	5414.64	314.13	--	1314.962	--
2008	13817.93	4368.683	14.43	--	1395.215	--
2009	7108.854	5308.821	--	1.998	1653.46	--
2010	5652.165	5337.179	--	--	994.838	--
2011	6262.791	4915.748	--	57.72	1273.392	--
2012	8446.721	3844.419	--	7.77	2136.084	--

Table 3. Number of Florida trip tickets from 1994-2012 with recorded landings of each species for the two stocks (West Florida, WFL; Florida Keys and Southeast Florida, FLK/SEFL) and gear types (spearfishing, Spear; and hook-and-line, HL). Note: only those species that were caught on greater than 1% of the total trips catching hogfish are presented and subsequently used in the cluster analysis.

WFL Spear		WFL HL		FLK/SEFL Spear		FLK/SEFL HL	
Species	**# Trips**	**Species**	**# Trips**	**Species**	**# Trips**	**Species**	**# Trips**
FLOUNDERS	4624	GROUPER, RED	38978	HOGFISH	6068	MACKEREL, KING	112127
GROUPER, GAG	1921	GROUPER, GAG	32891	SNAPPER, GREY	5083	SNAPPER, YELLOWTAIL	79263
SNAPPER, GREY	1825	SNAPPER, GREY	22057	GROUPER, BLACK	4493	DOLPHIN	50967
HOGFISH	1688	GRUNTS	18541	GROUPER, RED	4434	SNAPPER, GREY	36839
GROUPER, RED	1670	TRIGGERFISH	9561	SNAPPER, MUTTON	2750	BLUE RUNNER	35317
FLOUNDERS	1660	GROUPER, SCAMP	9472	GROUPER, GAG	1938	TUNNY, LITTLE (BONITO)	32735
SHEEPSHEAD	1093	SEATROUT, SPOTTED	8587	SHEEPSHEAD	1375	SNAPPER, MUTTON	27094
TRIGGERFISH	612	PORGIES	7504	SNAPPER, YELLOWTAIL	748	GRUNTS	19296
GROUPER, SCAMP	582	SNAPPER, VERMILION	7380	FLOUNDERS	709	GROUPER, BLACK	17419
AMBERJACKS	531	SNAPPER, LANE	6699	COBIA	611	JACK, CREVALLE	15546
MULLET, BLACK	400	SNAPPER, RED	5861	FLOUNDERS	558	AMBERJACKS	14269
GRUNTS	399	PINFISH	4917	AMBERJACKS	527	GROUPER, RED	11388
GROUPER, BLACK	259	AMBERJACKS	4413	GRUNTS	492	SEATROUT, SPOTTED	8921
PORGIES	253	JACK, CREVALLE	4181	TRIGGERFISH	486	MACKEREL, SPANISH	8914
SNAPPER, RED	239	GROUPER, BLACK	4091	GRUNTS	344	COBIA	7084
COBIA	173	MACKEREL, SPANISH	3577	JACK, CREVALLE	304	GROUPER, SNOWY	6329
SNAPPER, VERMILION	143	SHEEPSHEAD	3089	DOLPHIN	288	POMPANO	6043
GRUNTS	120	PORGIES	3023	MOJARRA	283	WAHOO	5230
PORGIES	100	MULLET, BLACK	2889	MULLET, BLACK	255	HOGFISH	4479
SNAPPER, MUTTON	94	MACKEREL, KING	2831	BLUE RUNNER	236	BLUEFISH	4242
		POMPANO	2758	MACKEREL, KING	223	MOJARRA	4135
		COBIA	2731	PORGIES	182	SNAPPER, LANE	4052
		LADYFISH	2125			TRIGGERFISH	3807
		MOJARRA	2024			TILEFISH, BLUELINE	3664
		DOLPHIN	1985			GROUPER, GAG	3194
		GRUNTS	1620			PORGIES	3095
		BLUEFISH	1573				
		HOGFISH	1507				
		PORGIES	1393				
		FLOUNDERS	1350				
		SNAPPER, MUTTON	1319				
		FLOUNDERS	1194				
		SNAPPER, YELLOWTAIL	1122				
		KINGFISH (WHITING)	1019				
		AMBERJACKS	862				

Table 4. Species clusters for the two stocks (West Florida, WFL; Florida Keys and Southeast Florida, FLK/SEFL) and gear types (spearfishing, hook-and-line) used to select those trips where a hogfish was likely to occur.

WFL Spear	WFL HL	FLK/SEFL Spear	FLK/SEFL HL
AMBERJACKS	COBIA	GROUPER, BLACK	AMBERJACKS
COBIA	GROUPER, BLACK	GROUPER, RED	GROUPER, BLACK
GROUPER, BLACK	GROUPER, GAG	SNAPPER, GREY	GROUPER, RED
GROUPER, GAG	GROUPER, RED	SNAPPER, MUTTON	SNAPPER, MUTTON
GROUPER, RED	GRUNTS		
GROUPER, SCAMP	SNAPPER, GREY		
GRUNTS	SNAPPER, LANE		
SNAPPER, GREY			
SNAPPER, MUTTON			
SNAPPER, RED			
TRIGGERFISH			

Table 5. Deviance table for the binomial component of the WFL spear model. The null model with year as a predictor is listed as step 0, and subsequent steps list the most predictive factors.

Step	Variable	Deviance	Resid. Df	Resid. Dev	AIC	percent.reduction
0	year	NA	2399	3053.141	3091.141	0
1	dep	75.14035	2394	2978.001	3026.001	2.257368
2	days_fish	59.63743	2391	2918.363	2972.363	1.837211
3	month	15.5944	2386	2902.769	2966.769	0.312573

Table 6. Deviance table for the positives component of the WFL spear model. The null model with year as a predictor is listed as step 0, and subsequent steps list the most predictive factors.

Step	Variable	Deviance	Resid. Df	Resid. Dev	AIC	percent.reduction
0	year	NA	1580	2434.649	5250.023	0
1	days_fish	418.2462	1577	2016.402	4954.632	17.02136
2	dep	58.9649	1572	1957.438	4917.176	2.170304
3	month	24.97277	1567	1932.465	4906.645	0.776389

Table 7. Deviance table for the binomial component of the WFL hook-and-line model. The null model with year as a predictor is listed as step 0, and subsequent steps list the most predictive factors.

Step	Variable	Deviance	Resid. Df	Resid. Dev	AIC	percent.reduction
0	year	NA	53177	12408.67	12446.67	0
1	dep	603.9875	53172	11804.69	11852.69	4.858516
2	days_fish	16.74285	53170	11787.94	11839.94	0.131368
3	month	14.24564	53165	11773.7	11835.7	0.105894

Table 8. Deviance table for the positives component of the WFL hook-and-line model. The null model with year as a predictor is listed as step 0, and subsequent steps list the most predictive factors.

Step	Variable	Deviance	Resid. Df	Resid. Dev	AIC	percent.reduction
0	year	NA	1344	2153.797	4531.659	0
1	days_fish	63.94796	1342	2089.849	4494.578	2.824474
2	month	28.73183	1337	2061.117	4485.709	0.977584
3	dep	24.27294	1332	2036.844	4479.562	0.776033

Table 9. Deviance table for the binomial component of the FLK/SEFL spear model. The null model with year as a predictor is listed as step 0, and subsequent steps list the most predictive factors.

Step	Variable	Deviance	Resid. Df	Resid. Dev	AIC	percent.reduction
0	year	NA	10086	13666.27	13704.27	0
1	dep	663.2373	10081	13003.03	13051.03	4.805905
2	month	26.76368	10076	12976.27	13034.27	0.148794
3	days_fish	6.166926	10074	12970.1	13032.1	0.026309
4	region	2.641209	10073	12967.46	13031.46	0.009918

Table 10. Deviance table for the positives component of the FLK/SEFL spear model. The null model with year as a predictor is listed as step 0, and subsequent steps list the most predictive factors.

Step	Variable	Deviance	Resid. Df	Resid. Dev	AIC	percent.reduction
0	year	NA	5674	6654.467	17084.43	0
1	days_fish	288.7315	5672	6365.735	16835.9	4.305182
2	month	150.6689	5667	6215.066	16709.53	2.182542
3	dep	25.00458	5662	6190.062	16696.58	0.293974
4	region	15.12473	5661	6174.937	16684.65	0.211342

Table 11. Deviance table for the binomial component of the FLK/SEFL hook-and-line model. The null model with year as a predictor is listed as step 0, and subsequent steps list the most predictive factors.

Step	Variable	Deviance	Resid. Df	Resid. Dev	AIC	percent.reduction
0	year	NA	49528	27161.82	27199.82	0
1	dep	1593.844	49524	25567.98	25613.98	5.860354
2	region	790.5567	49523	24777.42	24825.42	2.908936
3	month	408.526	49518	24368.9	24426.9	1.495137
4	days_fish	17.17966	49516	24351.72	24413.72	0.05964

Table 12. Deviance table for the positives component of the FLK/SEFL hook-and-line model. The null model with year as a predictor is listed as step 0, and subsequent steps list the most predictive factors.

Step	Variable	Deviance	Resid. Df	Resid. Dev	AIC	percent.reduction
0	year	NA	3896	5906.238	12760.11	0
1	days_fish	331.9104	3894	5574.328	12537.68	5.571184
2	dep	48.39531	3890	5525.932	12511.54	0.723558
3	region	17.55149	3889	5508.381	12501.09	0.273609
4	month	20.83023	3884	5487.551	12496.25	0.233494

Table 13. Standardized index of abundance from the WFL spear model.

year	Total.num.trips	Num.pos	Mean	std.dev	CV
1994	50	28	24.83549	7.144333	0.287666
1995	85	58	28.51978	5.799997	0.203367
1996	158	101	25.12175	3.890817	0.154878
1997	130	91	24.75848	4.044583	0.163362
1998	111	71	23.85446	4.432902	0.185831
1999	117	62	19.58608	4.105368	0.209606
2000	145	95	24.03803	3.833815	0.15949
2001	137	87	53.12662	8.79615	0.16557
2002	152	106	45.99106	6.993925	0.152071
2003	153	97	41.2072	6.548965	0.158928
2004	111	77	38.03491	6.571957	0.172788
2005	103	59	41.2495	8.404146	0.203739
2006	92	56	33.58897	7.045026	0.209742
2007	92	49	38.45632	8.918896	0.231923
2008	151	114	56.48918	8.077882	0.142999
2009	178	123	67.77923	9.611339	0.141804
2010	178	125	73.95688	10.18725	0.137746
2011	149	102	80.56392	12.44911	0.154525
2012	126	98	84.02584	12.52194	0.149025

Table 14. Standardized ndex of abundance for the WFL hook-and-line model.

year	Total.num.trips	Num.pos	Mean	std.dev	CV
1994	2639	149	0.777395	0.106599	0.137124
1995	2795	86	0.735322	0.131493	0.178824
1996	3025	111	0.65381	0.104474	0.159792
1997	3115	92	0.530552	0.091877	0.173173
1998	3620	70	0.297956	0.059951	0.201209
1999	3628	78	0.366005	0.068313	0.186646
2000	4228	136	0.702338	0.102033	0.145277
2001	3773	141	0.680889	0.099156	0.145628
2002	3408	118	0.862523	0.135837	0.157488
2003	3271	64	0.515478	0.106161	0.205947
2004	3227	53	0.243458	0.055887	0.229554
2005	2658	47	0.424661	0.101453	0.238904
2006	2154	28	0.411451	0.129055	0.313659
2007	2083	21	0.273016	0.099745	0.365345
2008	2137	24	0.465299	0.153976	0.330919
2009	2737	36	0.517842	0.142109	0.274426
2010	1605	30	1.033917	0.305846	0.295813
2011	1525	58	1.629565	0.350885	0.215324
2012	1568	21	0.634684	0.230154	0.362627

Table 15. Standardized index of abundance for the FLK/SEFL spear model.

year	Total.num.trips	Num.pos	Mean	std.dev	CV
1994	474	241	12.37902	0.6157	0.049737
1995	517	264	11.37773	0.547645	0.048133
1996	669	403	11.2784	0.467984	0.041494
1997	855	487	8.482529	0.3399	0.040071
1998	834	487	9.593651	0.387129	0.040353
1999	498	274	8.141443	0.406499	0.04993
2000	570	346	9.375735	0.415985	0.044368
2001	677	401	9.775725	0.428915	0.043875
2002	748	444	8.417263	0.351025	0.041703
2003	552	292	8.885067	0.433152	0.048751
2004	538	342	10.69344	0.495633	0.046349
2005	479	317	10.45703	0.492758	0.047122
2006	428	265	8.781702	0.444302	0.050594
2007	428	259	8.429941	0.431315	0.051165
2008	336	214	10.83168	0.602682	0.055641
2009	412	197	8.991021	0.495166	0.055073
2010	308	141	9.595727	0.621361	0.064754
2011	369	156	9.98716	0.626561	0.062737
2012	413	163	9.724014	0.590992	0.060777

Table 16. Standardized index of abundance for the FLK/SEFL hook-and-line model.

year	Total.num.trips	Num.pos	Mean	std.dev	CV
1994	2399	231	1.133401	0.121854	0.107512
1995	3428	364	1.105646	0.097814	0.088468
1996	3799	326	1.011449	0.093184	0.092129
1997	3817	239	0.778278	0.082037	0.105408
1998	3605	241	0.689917	0.073333	0.106292
1999	2395	117	0.631448	0.092312	0.146192
2000	2398	218	1.096454	0.120615	0.110005
2001	3014	280	1.118615	0.112262	0.100358
2002	2754	286	1.287162	0.12568	0.097641
2003	2928	317	1.607304	0.152012	0.094576
2004	2968	253	1.232936	0.129378	0.104935
2005	2504	150	0.860383	0.113504	0.131922
2006	1883	133	1.086084	0.149848	0.137971
2007	1790	122	0.887981	0.127245	0.143297
2008	1795	129	1.173346	0.164415	0.140125
2009	2192	152	1.397413	0.180595	0.129235
2010	2099	119	1.577364	0.229983	0.145802
2011	2057	114	1.162097	0.172045	0.148047
2012	1722	124	1.285118	0.183549	0.142827

Figures

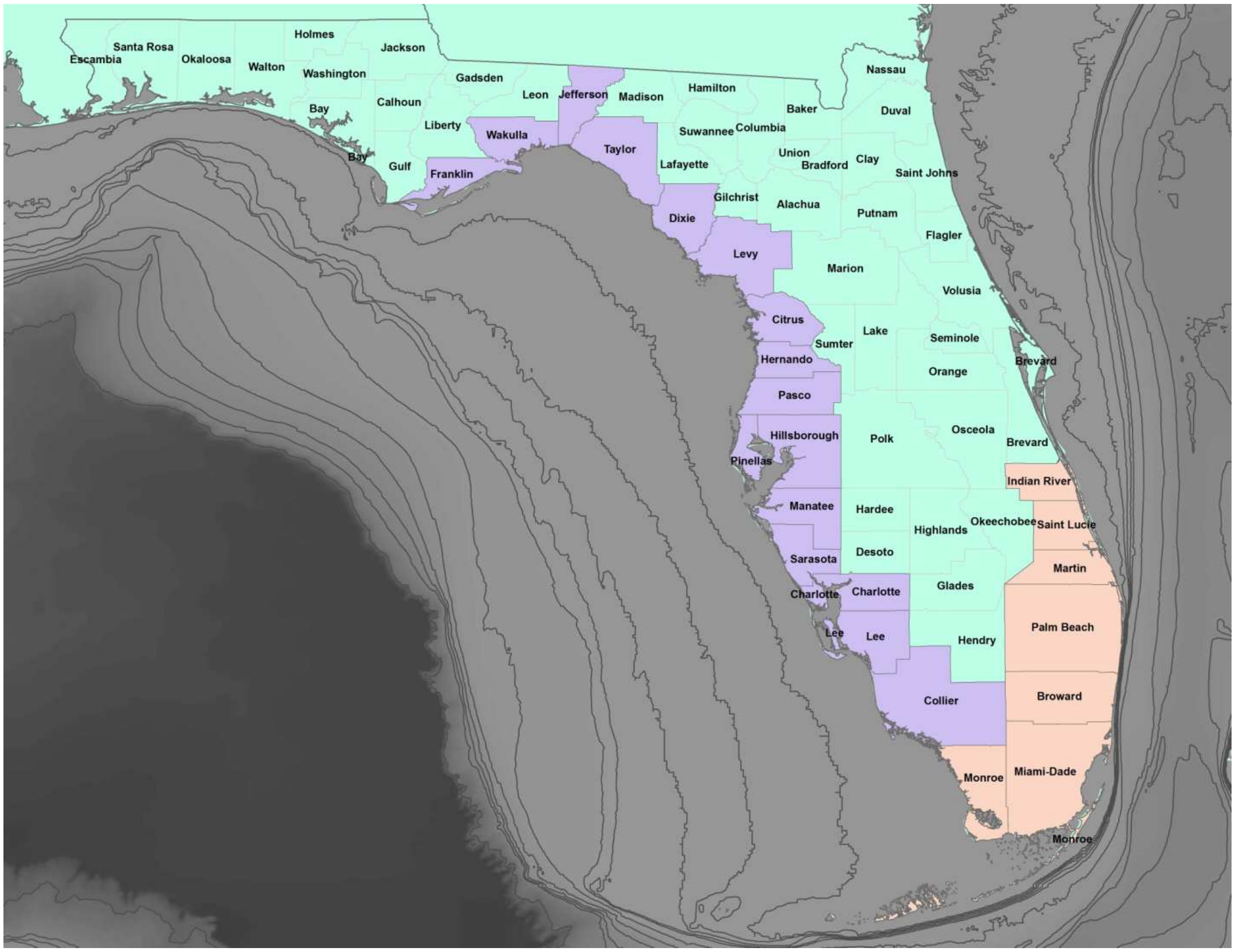

Figure 1. Florida county delineations used to represent the core distributions of the two hogfish stocks: West Florida (WFL; purple) and Southeast Florida including the Keys (FLK/SEFL; peach).

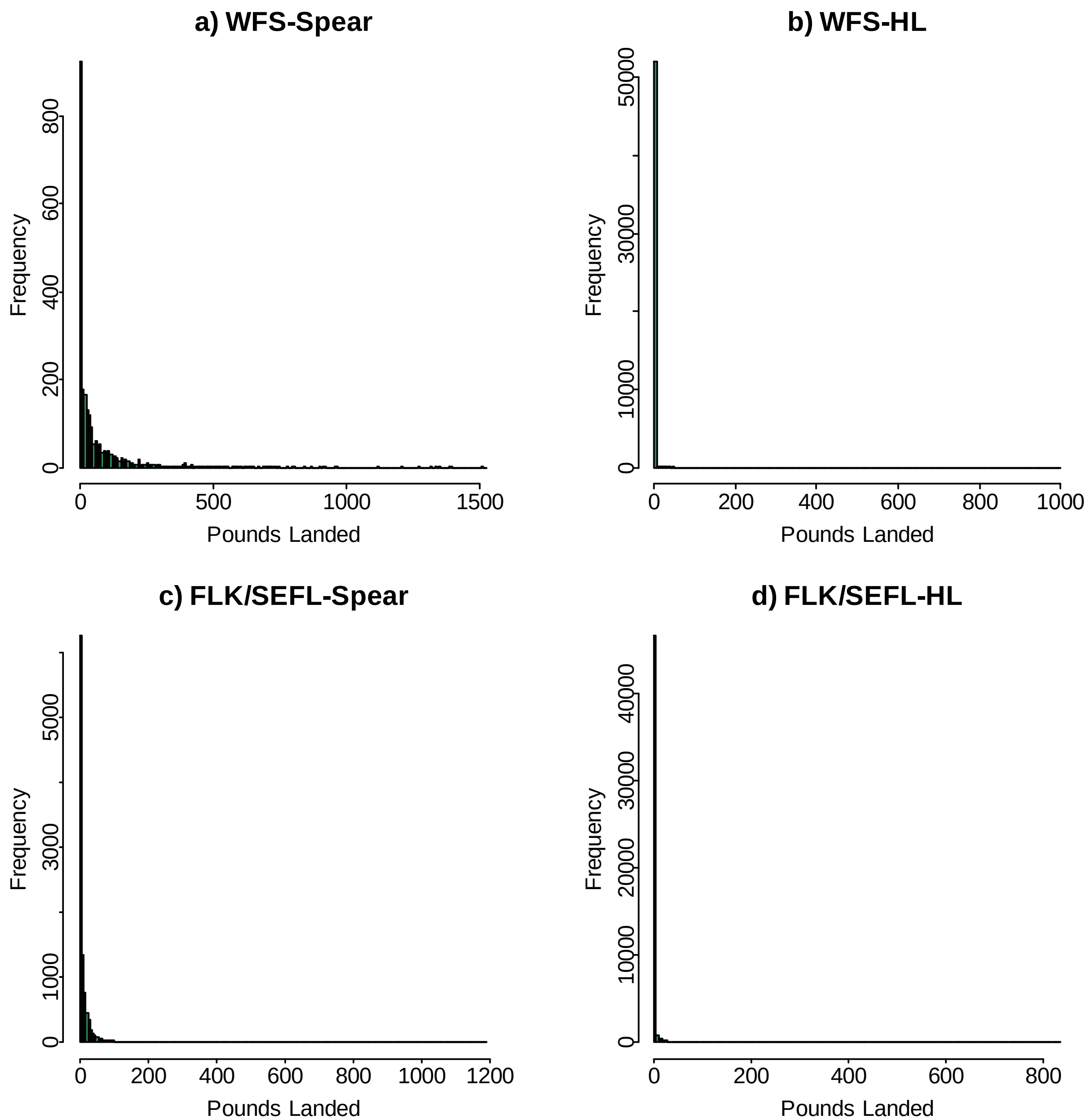

Figure 2. Frequencies for the pounds of hogfish landed per trip using spear fishing (a, c) and hook and line (b, d) for the WFL stock (a, b) and the FLK/SEFL stock (c, d).

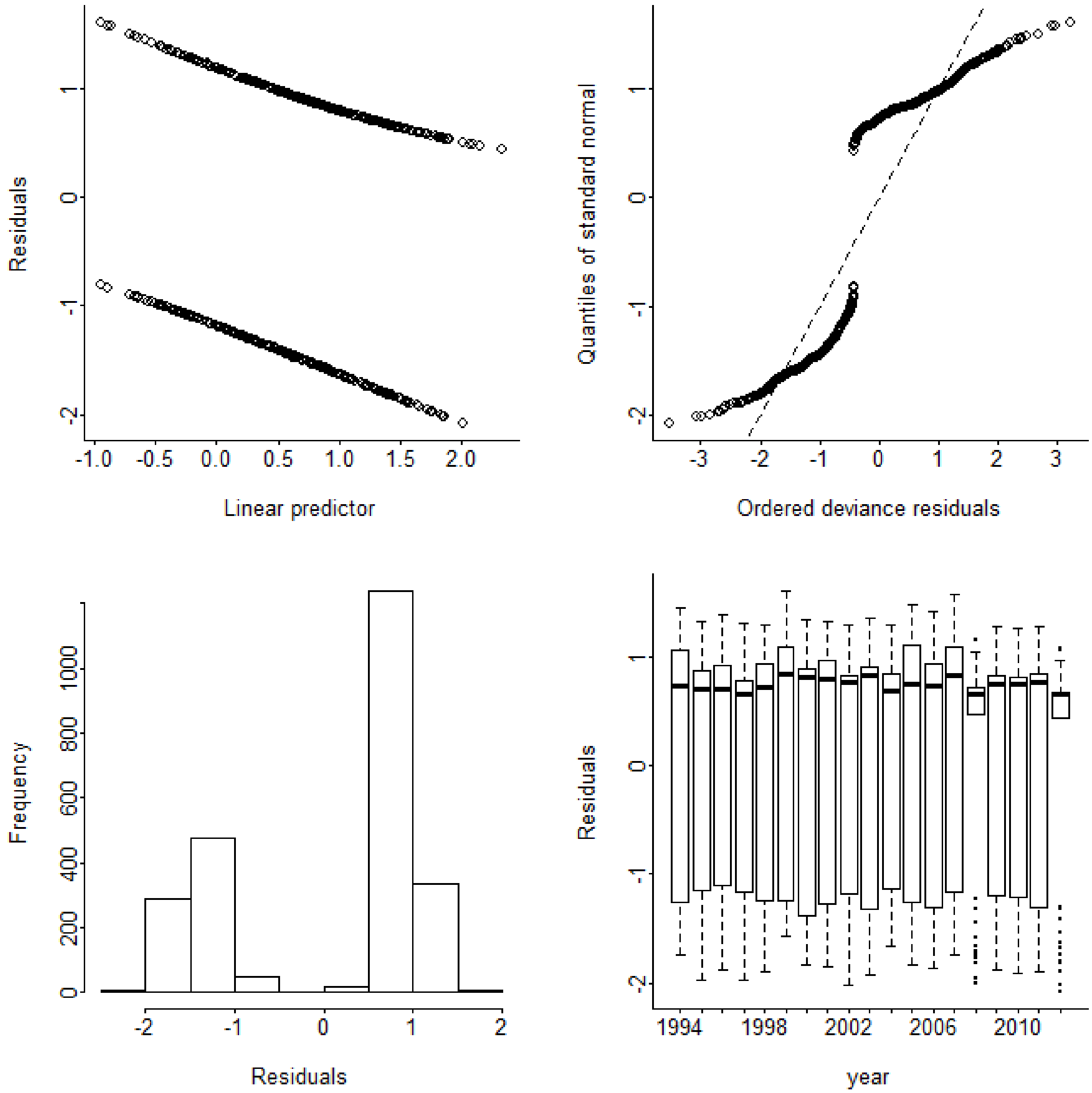

Figure 3. Diagnostic plots from the binomial component of the WFL spear model.

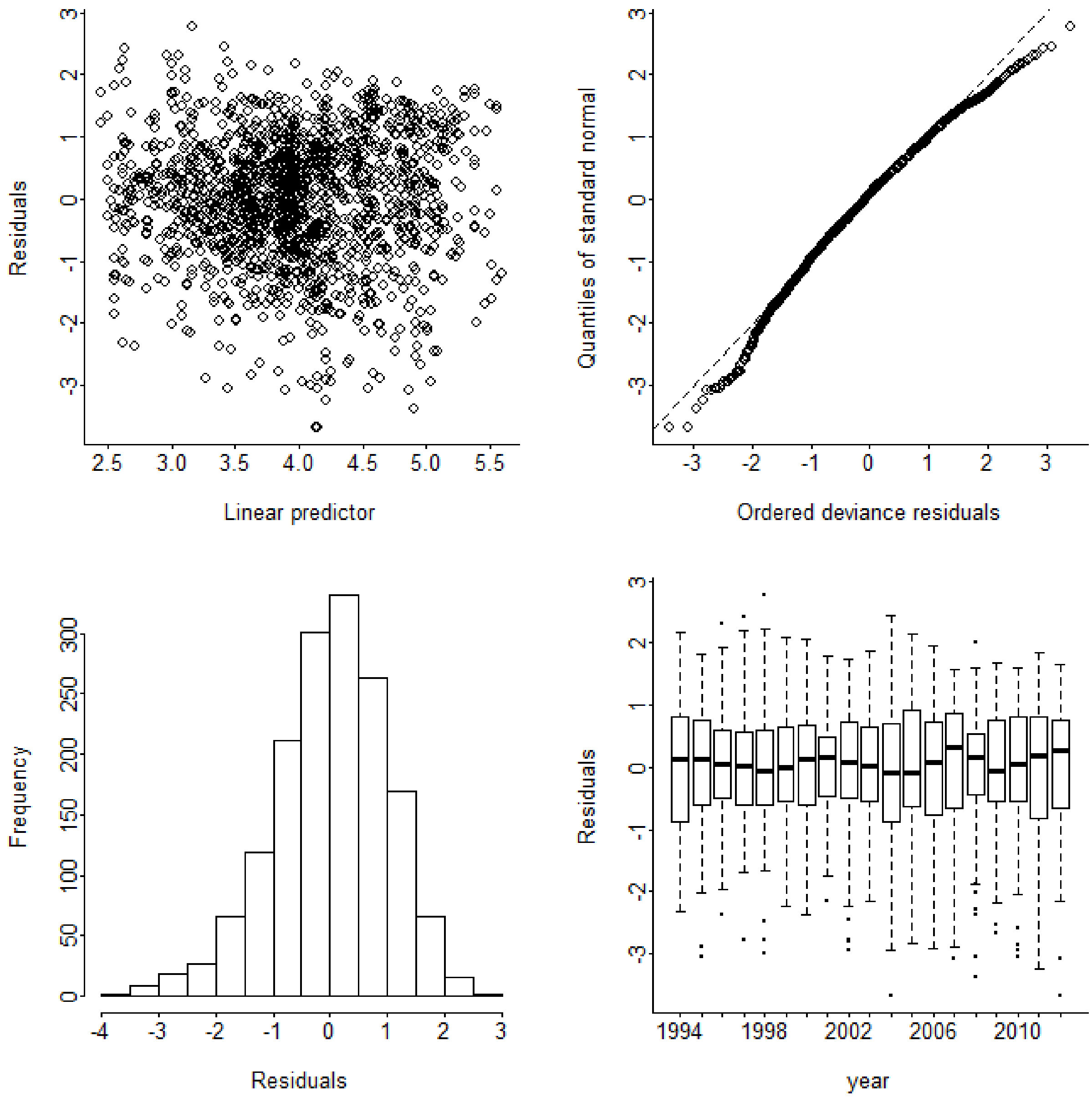

Figure 4. Diagnostic plots from the positives component of the WFL spear model.

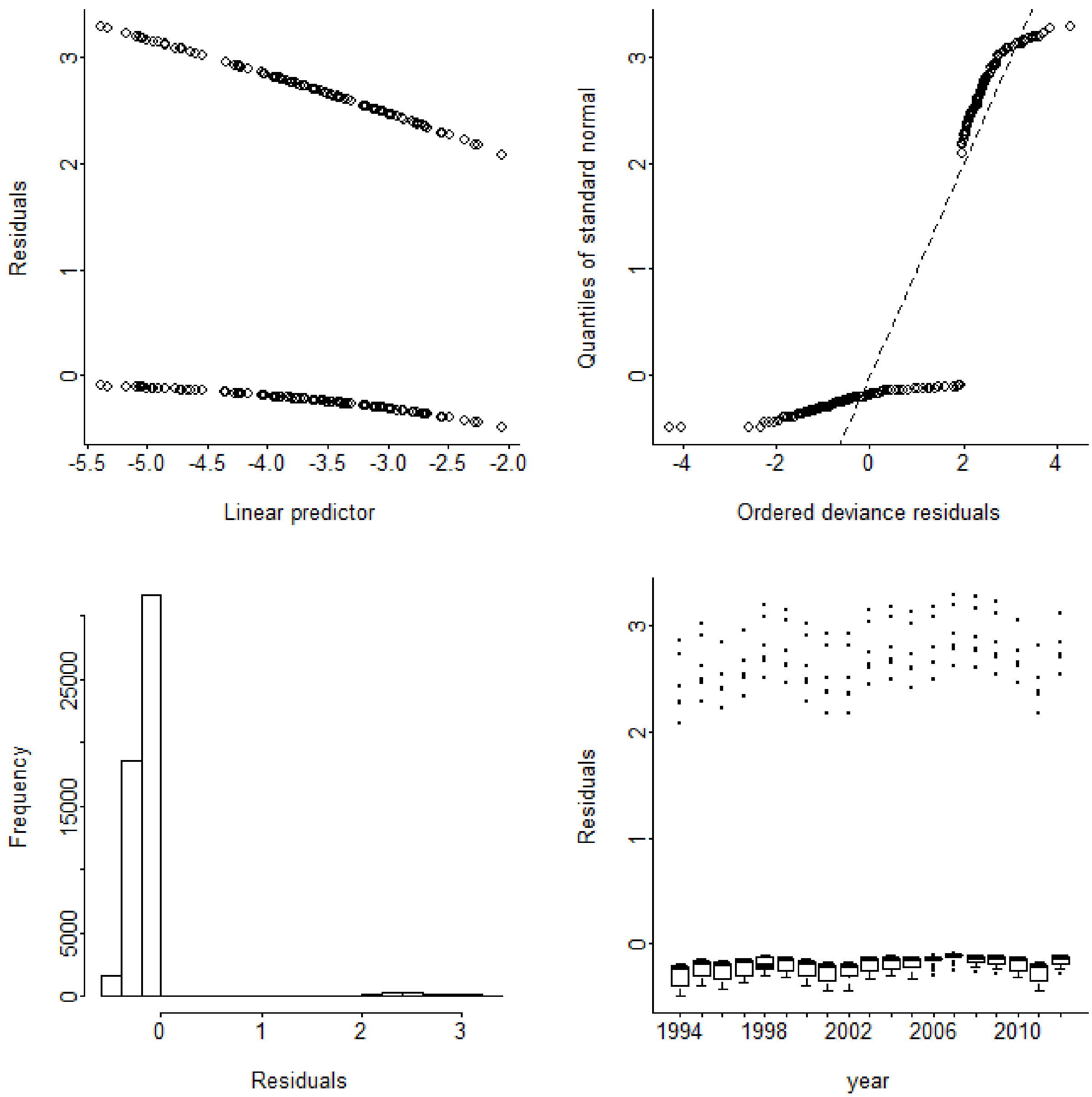

Figure 5. Diagnostic plots from the binomial component of the WFL hook-and-line model.

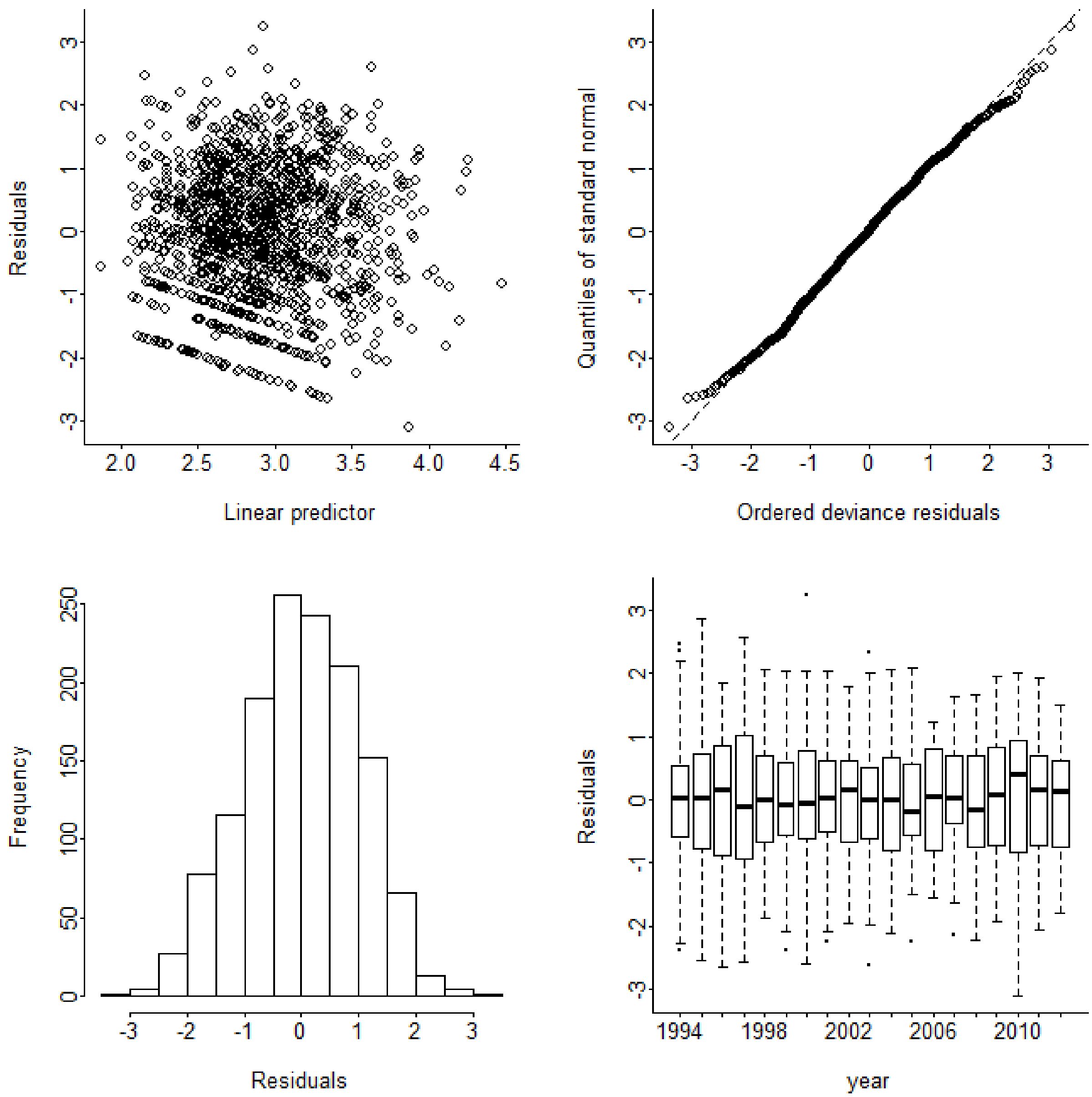

Figure 6. Diagnostic plots from the positives component of the WFL hook-and-line model.

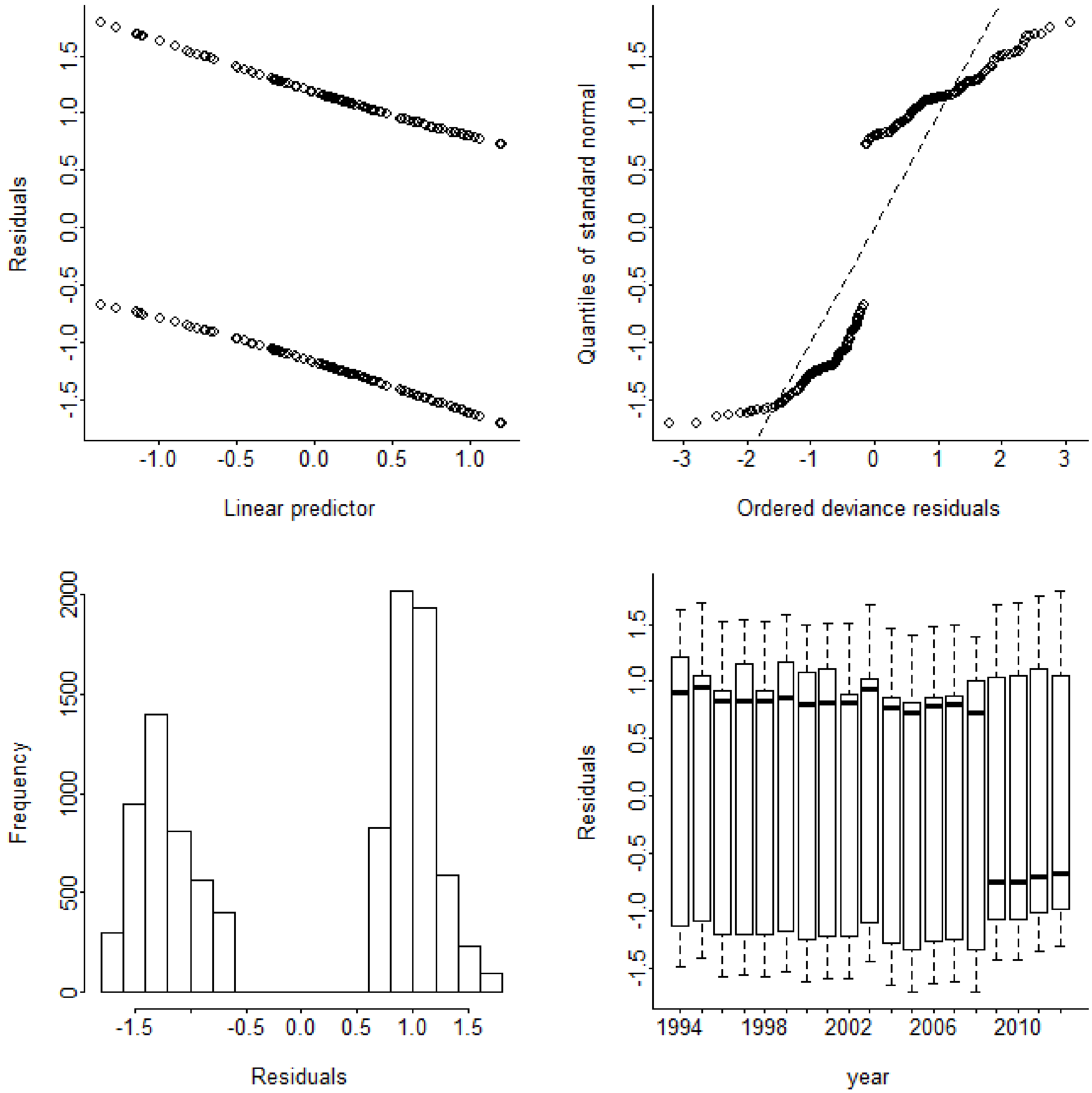

Figure 7. Diagnostic plots from the binomial component of the FLK/SEFL spear model.

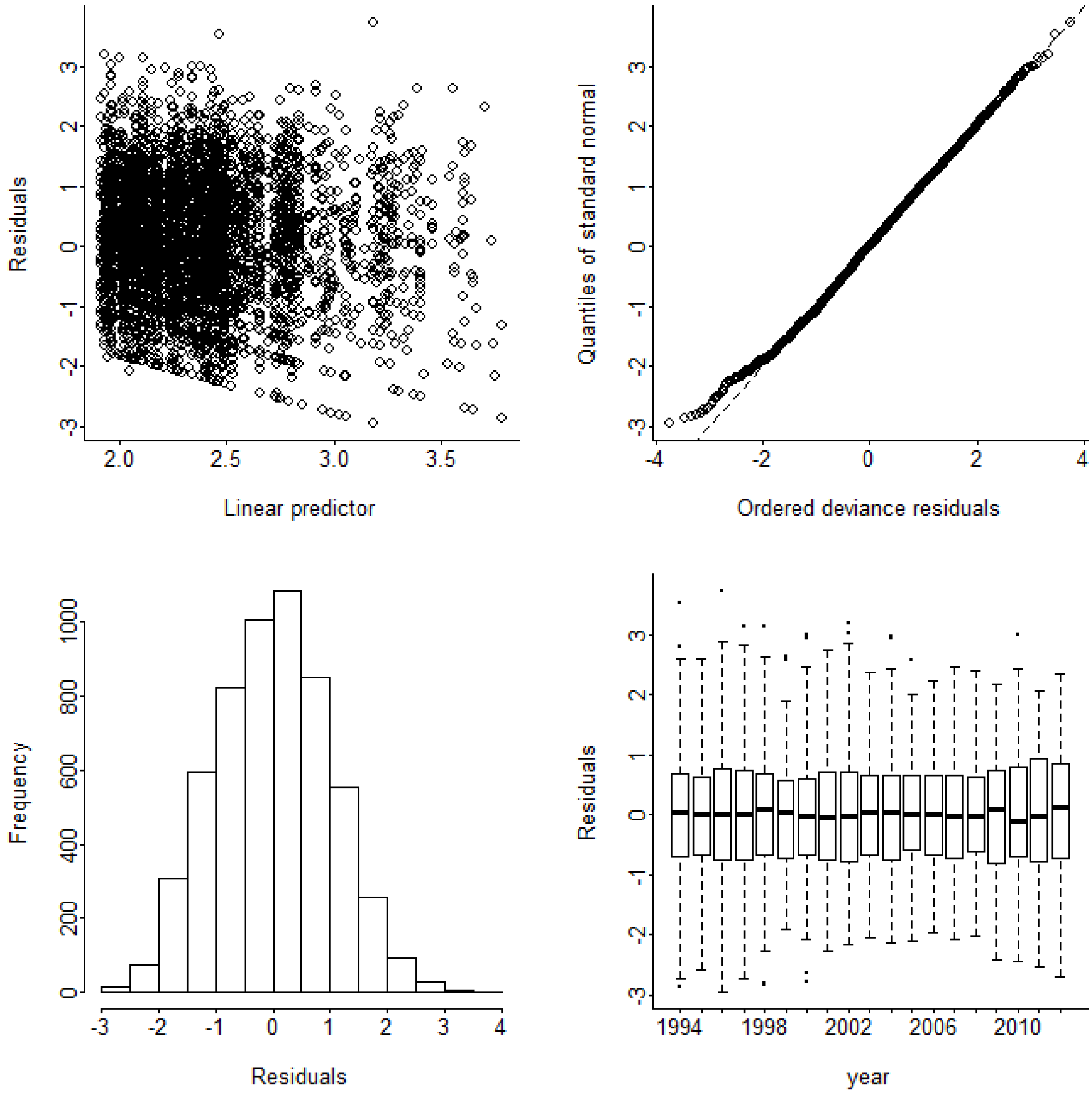

Figure 8. Diagnostic plots from the positives component of the FLK/SEFL spear model.

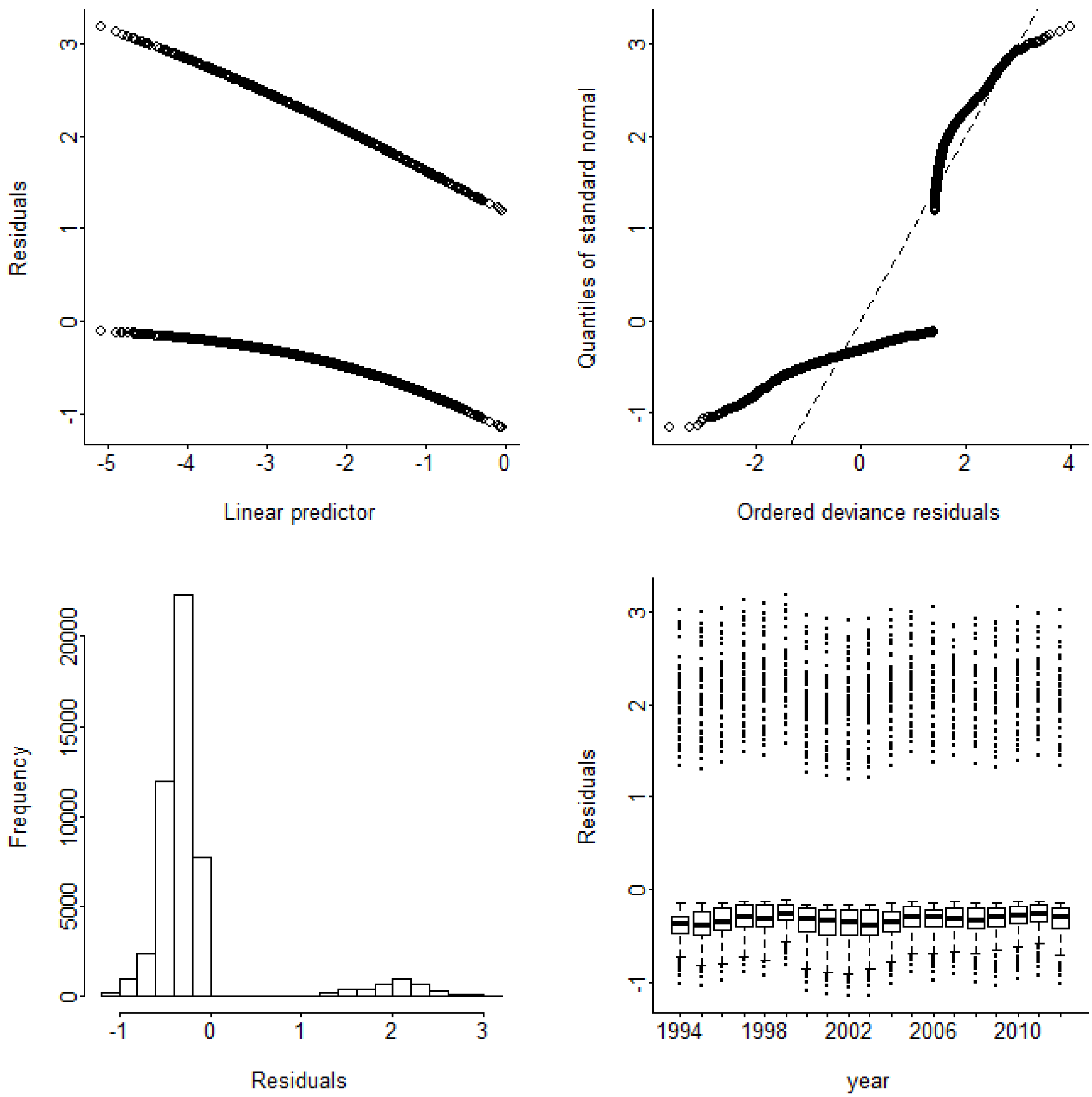

Figure 9. Diagnostic plots from the binomial component of the FLK/SEFL hook-and-line model.

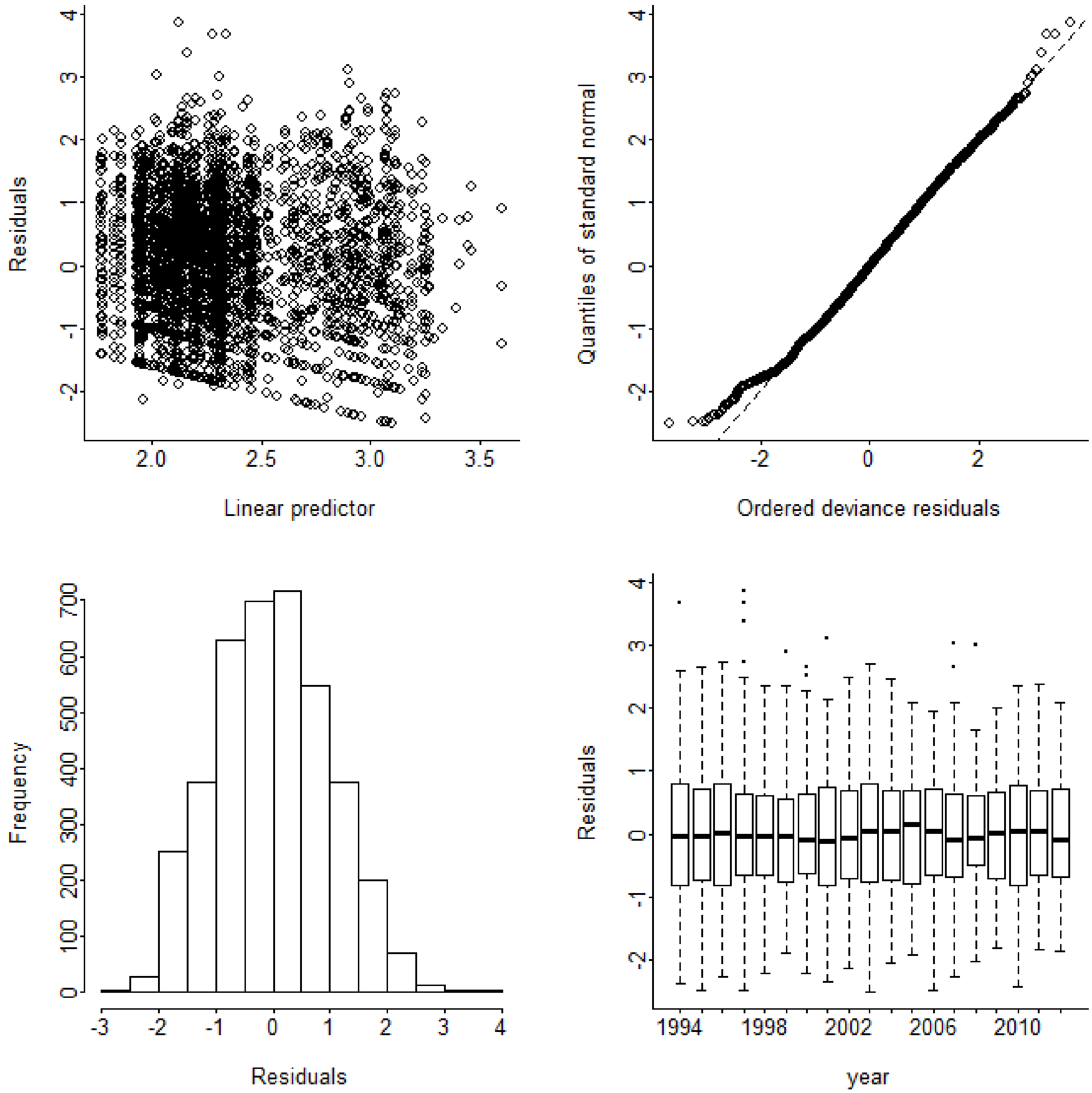

Figure 10. Diagnostic plots from the positives component of the FLK/SEFL hook-and-line model.

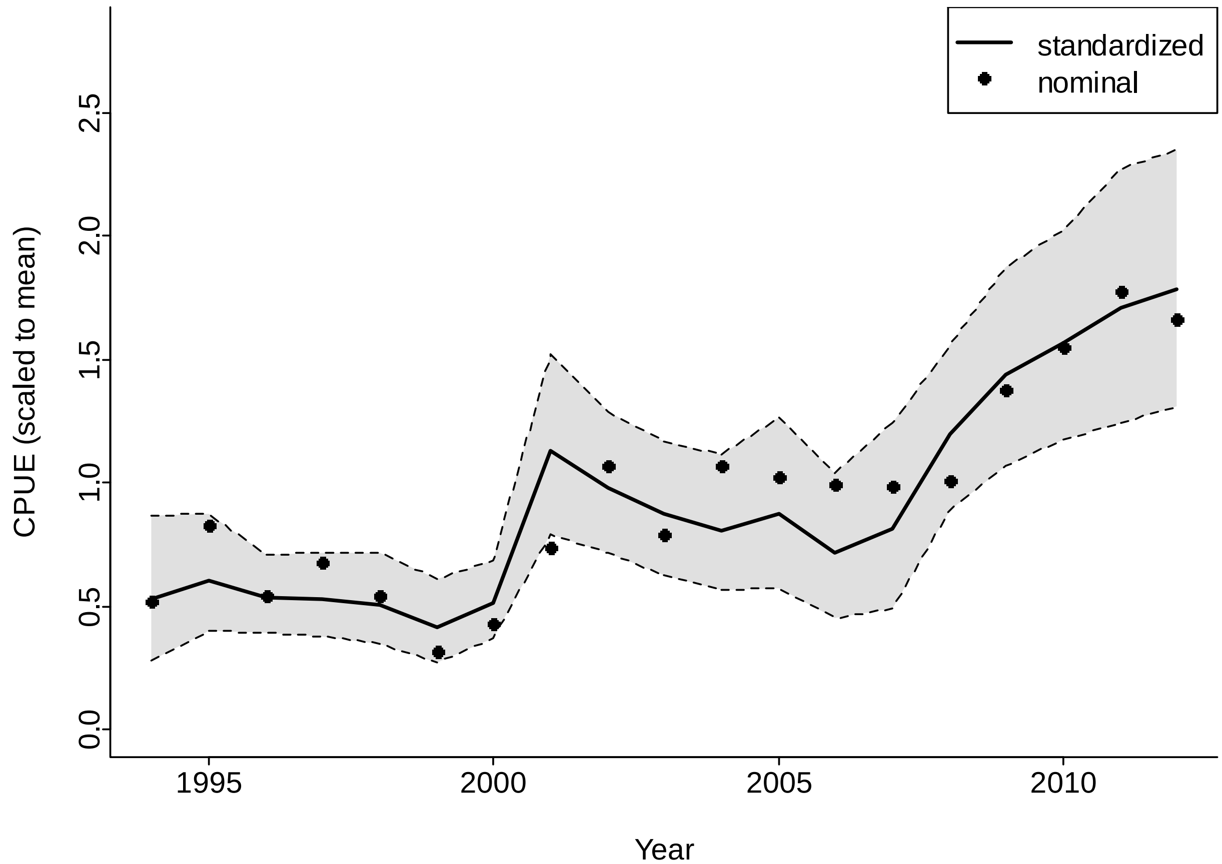

Figure 11. Standardized index of abundance for the WFL spear model.

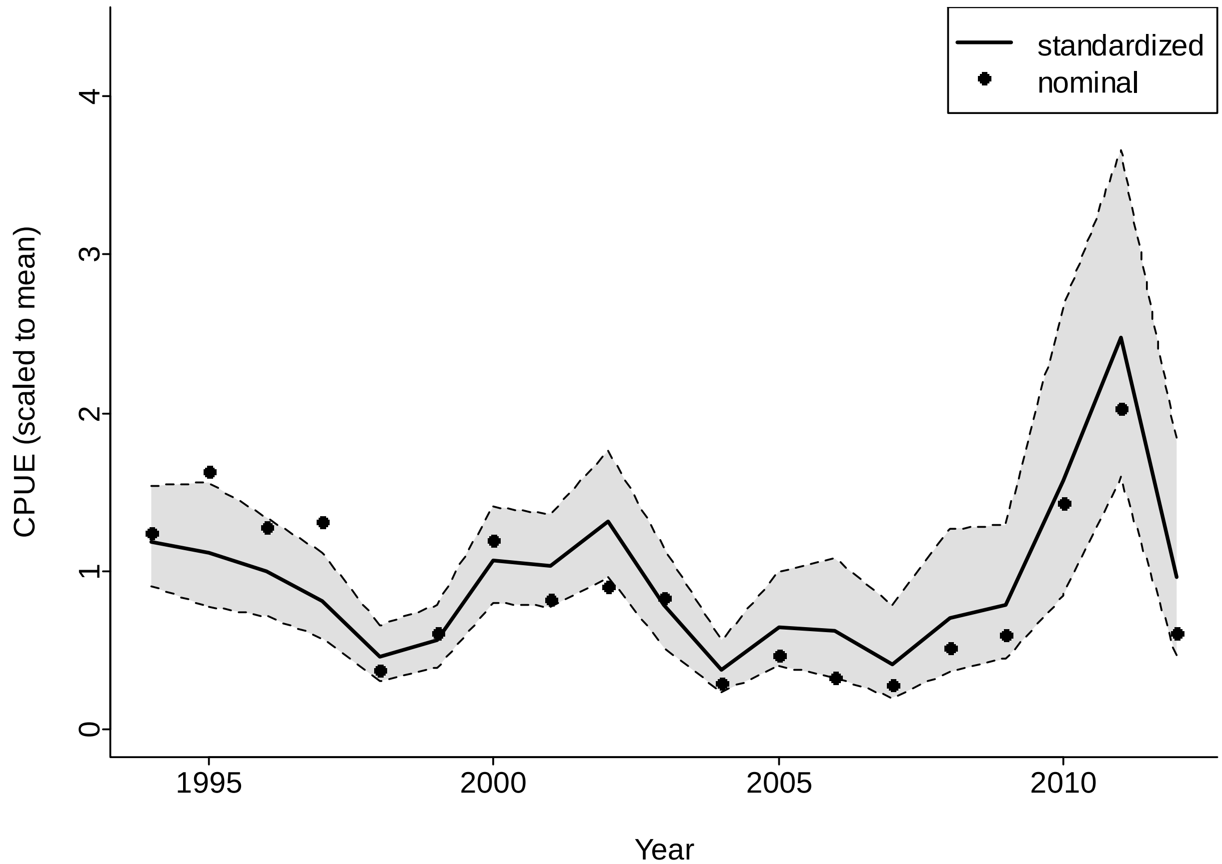

Figure 12. Standardized index of abundance for the WFL hook-and-line model.

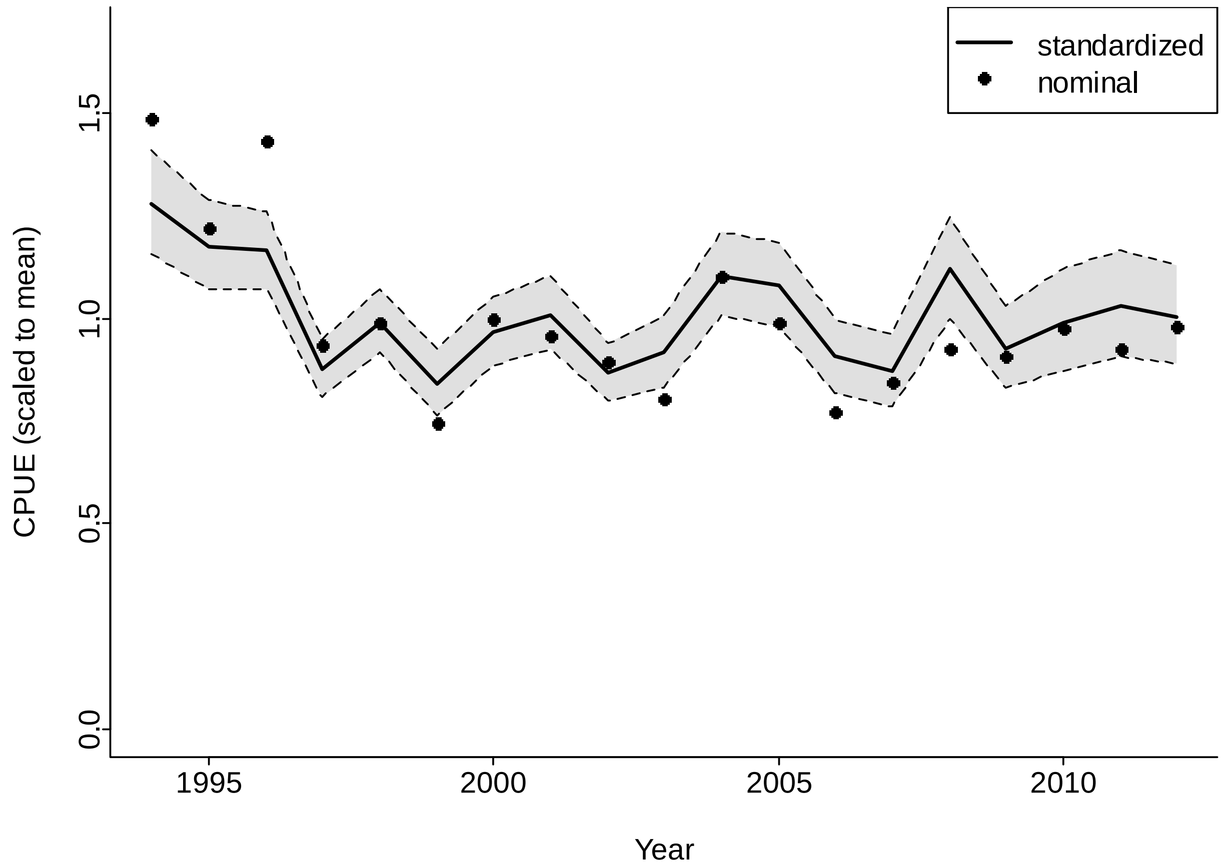

Figure 13. Standardized index of abundance for the FLK/SEFL spear model.

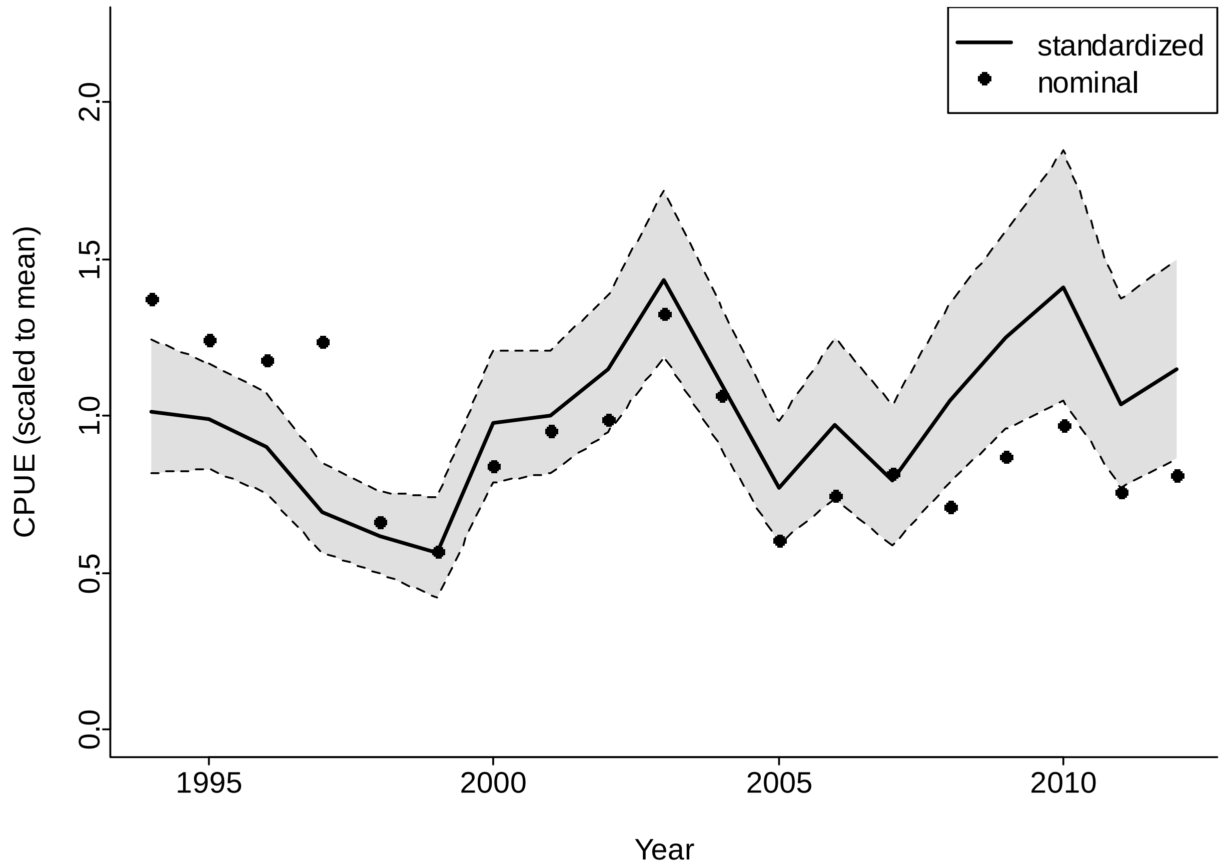

Figure 14. Standardized index of abundance for the FLK/SEFL hook-and-line model.