Standardized CPUE of black sea bass (*Centropristis striata*) caught in blackfish and Florida snapper traps deployed by MARMAP

Nathan Bacheler and Kyle Shertzer
National Marine Fisheries Service, Southeast Fisheries Science Center, 101 Pivers Island Road, Beaufort, NC 28516

Marcel Reichert, Jessica Stephen, and Michelle Pate
Marine Resources Monitoring, Assessment, and Prediction Program, Marine Resources Research Institute, South Carolina Department of Natural Resources, 217 Fort Johnson Road, Charleston, SC 29412

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1. Abstract

An index of abundance was developed for black sea bass caught in blackfish and Florida snapper traps deployed by MARMAP in 1981–1987. Sampling occurred from North Carolina to Georgia, but most effort was concentrated off South Carolina. To estimate fewer parameters in the assessment model, these two trap gears were combined into a single index of abundance, and a 'gear' variable was included in the model to account for differences in CPUE between trap types. The index of abundance standardized catch-per-unit-effort (CPUE; number of fish caught per hour of soak time) of black sea bass using a delta-GLM model. Four categorical predictor variables were included in the delta-GLM model (year, gear, latitude, and depth), and a gamma rather than lognormal distribution was chosen by AIC. Standard model diagnostics suggested reasonable fit of both the Bernouilli (presence-absence) and positive CPUE submodels. Relative nominal CPUE fell within the 95% confidence interval of the standardized index in all seven years of the index, and indicated a general decline was observed from 1982–1987.

2. Introduction

For over thirty years, fishery-independent sampling for reef fishes in the southeast USA has been conducted by the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program of the South Carolina Department of Natural Resources. The overall mission of MARMAP has been to determine the distribution, relative abundance, and critical habitat of economically and ecologically important reef fishes between Cape Hatteras, NC, and St. Lucie Inlet, FL.

MARMAP has historically used a variety of gears to sample reef fishes, but the focus of this paper is on blackfish and Florida snapper (i.e., Antillean) traps. Trapping with blackfish traps occurred from 1977–1989, and trapping with Florida snapper traps occurred from 1980–1989. In 1977–1980, traps were fished while connected together, and from 1988 – 1989 traps were fished while anchored to a research vessel, so data from these years were excluded because MARMAP personnel believe they represent a significant methodological change. Thus, the time series used for construction of a black sea bass index of abundance spanned 1981–1987. During this reduced time series, both trap types were deployed from a research vessel and soaked for approximately 90 minutes using cut clupeids as bait. Traps were deployed during daylight hours on hardbottom sampling stations randomly selected from a database of approximately 2,200 potential stations; thus, sampling was accomplished using a simple random sampling design. Sampling occurred between spring and fall each year, with most sampling in summer months. MARMAP trapping targets a wide variety of species in the snapper-grouper complex, and both trap types caught substantial numbers of black sea bass. All trapping by MARMAP from 1981–1987 occurred aboard the R/V *Oregon I*, a 105' research vessel.

3. Data and treatment

3.1 Available data

For each trap fished, the MARMAP database used here included a unique collection number, date, soak time (provided in minutes), latitude, longitude, bottom depth (m), number of black sea bass caught, and collective weight of black sea bass caught. We used numbers instead of weight of black sea bass caught for all analyses. Catch-per-unit-effort (CPUE) was standardized to the number of black sea bass caught per hour of soak time. Trap samples that lacked soak time were excluded (< 0.2% of the full data set). There were no obvious CPUE outliers in the database, so no trap samples were excluded based on unusual CPUE.

3.2 Combining blackfish and Florida snapper trap samples

A comparison of length and age distributions from blackfish and Florida snapper traps is shown in Figure 1. To estimate fewer parameters in the assessment model, these two trap gears were combined into a single index of abundance. A 'gear' variable was included in the model to account for differences in CPUE between trap types (see *4. Standardization* below).

3.3 Subsetting

Effective effort was based on the traps deployed from areas where black sea bass were available to be caught. Catches of black sea bass were extremely low in waters greater than 44 m deep (Figure 2), so all trap sets deployed in water deeper than 44 m were excluded (21.2% of the full data set).

3.4 Data set after exclusions and subsetting

After subsetting and data exclusions, 3037 blackfish and Florida snapper traps were deployed between 1981 and 1987 (mean = 434; range = 238–641 per year; Table 1). Blackfish/Florida snapper traps were deployed in depths ranging from 15–44 m deep (annual mean ranged from 25.9 to 28.7 m deep; Table 1). Sampling occurred from as far south as Georgia (30.74° N) to as far north as Onslow Bay, North Carolina (34.39° N); annual mean latitude sampled ranged from 32.24 – 32.95° N (Table 1). Trapping with blackfish and Florida snapper traps occurred from April to September, and mean date sampled each year ranged from as early as 10 April to as late as 4 August (Table 1).

Blackfish and Florida snapper trapping consistently occurred between North Carolina and Georgia, with the exception of 1987 when no sampling occurred in North Carolina (Figure 3).

4. Standardization

Black sea bass CPUE from MARMAP blackfish and Florida snapper trapping was modeled using the delta-GLM approach (Lo et al. 1992; Dick 2004; Maunder and Punt 2004). The delta-GLM approach combines two separate generalized linear models (GLMs), one that describes the presence/absence of the focal species and one that describes the catch rates from samples with positive CPUE of the focal species. The response variable was black sea bass CPUE, calculated as the number of black sea bass caught in traps per hour of soak time. All explanatory variables were included as categorical variables (see below), and estimates of variance were based on the jackknife "leave one out" estimator. All analyses were performed in R, based primarily on code adapted from Dick (2004).

4.1 Explanatory variables considered

YEAR – Year was necessarily included because standardized catch rates by year are the desired outcome of the delta-GLM model. Years modeled were 1981–1987. The total number of traps deployed each year, as well as the proportion of traps with positive catch, are available in Table 2.

DEPTH – Black sea bass CPUE was influenced by depth (Figure 2). We excluded all traps deployed in water greater than 44 m because black sea bass were rarely captured deeper than this depth. Depth was pooled into two remaining levels: < 30 m deep or 30 – 44 m deep. The total number of traps deployed in each depth zone, the proportion of traps with positive catch, and the nominal CPUE within each depth zone is provided in Figure 4.

LATITUDE – Latitudes reported in the MARMAP database were pooled into three levels for analysis in the delta-GLM model: > 33° N, 32–33° N, and < 32° N. The total number of traps deployed in each latitudinal zone, the proportion of traps with positive catch in each latitudinal zone, and the nominal CPUE within each latitudinal zone is provided in Figure 5.

GEAR – Because the ages of black sea bass caught by blackfish and Florida snapper traps were similar (Figure 1), catches from each trap type were combined into a single analysis. To account for differences in black sea bass CPUE that may have occurred between trap types, a gear variable with two levels (blackfish = "BL"; Florida snapper = "FS") was included in the delta-GLM model. The total number of traps deployed for each trap type, the proportion of traps with positive catch for each trap type, and the nominal CPUE for each trap type is provided in Figure 6.

A season variable was also considered for inclusion in the delta-GLM model. A season variable was tested, but AIC (Akaike Information Criterion) excluded the season variable in both submodels when it was tested with only two levels (March – June, July – November). A season variable with three levels (March – May, June – August, September – November) was also considered, but the number of traps deployed in some levels in some years was zero, which caused problems for the delta-GLM model. Therefore, a season variable was excluded from the delta-GLM model.

4.2 Bernoulli submodel
The Bernoulli submodel of the delta-GLM is a logistic regression that attempts to explain why individual trap sets may or may not catch black sea bass (presence/absence data). All four explanatory variables were included in the model as main effects, and then stepwise AIC (Venables and Ripley 1997) with a backwards selection algorithm was used to eliminate those variables that did not improve model fit. For black sea bass caught in blackfish and Florida snapper traps, the stepwise AIC procedure did not remove any explanatory variables (Table 3A). Diagnostics based on randomized quantile residuals (Dunn and Smyth 1996) suggested reasonable fits of the Bernoulli submodel (Figure 7).

4.3 Positive CPUE submodel
Both lognormal and gamma distributions were considered for modeling positive CPUE values. For both distributions, all explanatory variables were initially included as main effects, and then stepwise AIC (Venables and Ripley 1997) with a backwards selection algorithm was used to eliminate those variables that did not improve model fit. The best model fit for both distributions (gamma and lognormal) was a model with all explanatory variables included (Table 3B). The two distributions, each with all explanatory variables included, were compared using AIC. The gamma distribution outperformed the lognormal distribution (ΔAIC > 80), so the gamma distribution was used in the final delta-GLM model. Diagnostics suggested reasonable fits of the gamma submodel (Figures 8 and 9).

5. Results

Relative nominal CPUE fell within the 95% confidence interval of the standardized index in all seven years of the index (Figure 10). There was a general decline after 1982 in both the nominal and standardized indices.

6. Literature cited

Dick, E.J. 2004. Beyond ‘lognormal versus gamma’: discrimination among error distributions for generalized linear models. Fish. Res. 70:351-366.

Dunn, K.P., Smyth, G.K. 1996. Randomized quantile residuals. J. Comp. Graph. Stat. 5:1-10.

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

Maunder, M.N., Punt, A.E. 2004. Standardizing catch and effort data: a review of recent approaches. Fish. Res. 70:141-159.

Venables, W.N., Ripley, B.D. 1997. Modern Applied Statistics with S-Plus, 2nd Edition. Springer-Verlag, New York.

Table 1. Information associated with blackfish (BF) and Florida snapper trap (FS) sets in the subsetted MARMAP database, 1981–1987.

Year	Total *N*	BF *N*	FS *N*	Mean depth (m)	Depth range (m)	Mean latitude (° N)	Latitude range (° N)	Mean date	Date range
1981	462	343	119	28.1	16-44	32.90	31.67-34.28	7/31	6/22-9/13
1982	375	259	116	26.6	16-43	32.66	31.68-33.48	6/21	6/8-7/14
1983	511	429	82	25.9	15-44	32.95	31.68-34.33	5/2	4/13-8/4
1984	641	491	150	26.8	15-42	32.82	31.68-34.39	8/4	7/12-8/30
1985	473	372	101	27.7	16-44	32.69	30.74-34.32	6/3	5/11-8/14
1986	337	252	85	28.7	16-44	32.24	30.89-33.28	4/30	4/12-6/22
1987	238	180	58	28.5	15-42	32.31	31.68-32.79	4/10	4/7-4/13

Table 2. Relative nominal CPUE and relative standardized index of black sea bass abundance from MARMAP blackfish and Florida snapper trapping data, 1981–1987.

Year	Number of trap sets	Proportion *N* Positive	Relative nominal CPUE	Relative standardized index	CV (index)
1981	462	0.79	0.99	1.07	0.06
1982	375	0.84	1.42	1.21	0.08
1983	511	0.90	0.97	1.10	0.06
1984	641	0.86	0.91	0.94	0.05
1985	473	0.81	1.08	1.09	0.06
1986	337	0.77	0.80	0.78	0.07
1987	238	0.82	0.84	0.81	0.09

Table 3. Model selection results from the delta-GLM model for black sea bass caught in MARMAP blackfish and Florida snapper traps, 1981–1987.

A. Bernoulli submodel

Removed	Df	Deviance	AIC
<none>		2539.1	2561
- gear	1	2549.3	2569
- year	6	2560.8	2571
- latitude	2	2603.8	2622
- depth	1	2660.3	2680

B. Gamma submodel

Removed	Df	Deviance	AIC
<none>		2163.4	16028
- depth	1	2181.2	16046
- year	6	2214.1	16074
- latitude	2	2241.5	16114
- gear	1	2292.5	16175

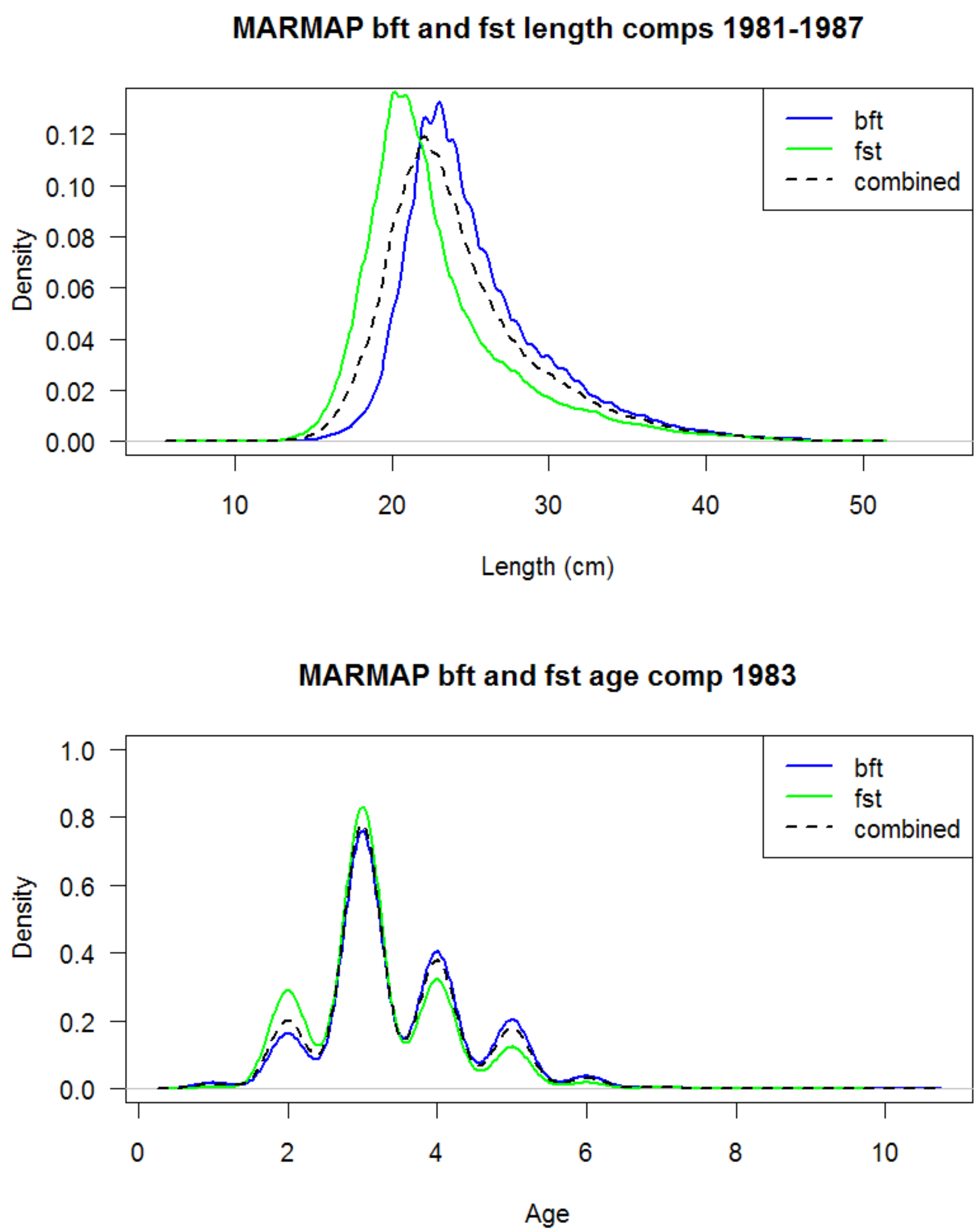

Figure 1. Top panel: Length distributions (cm total length) of black sea bass from blackfish traps (blue line), Florida snapper traps (green line), or both traps combined (black dotted line), 1981–1987, from MARMAP sampling. A total of 20,545 black sea bass were measured from blackfish traps, and a total of 13,633 black sea bass were measured from Florida snapper traps. Bottom panel: Age distributions of black sea bass from blackfish traps (blue line), Florida snapper traps (green line), or both traps combined (black dashed lines) from MARMAP sampling in 2003, a year when most captured black sea bass were aged.

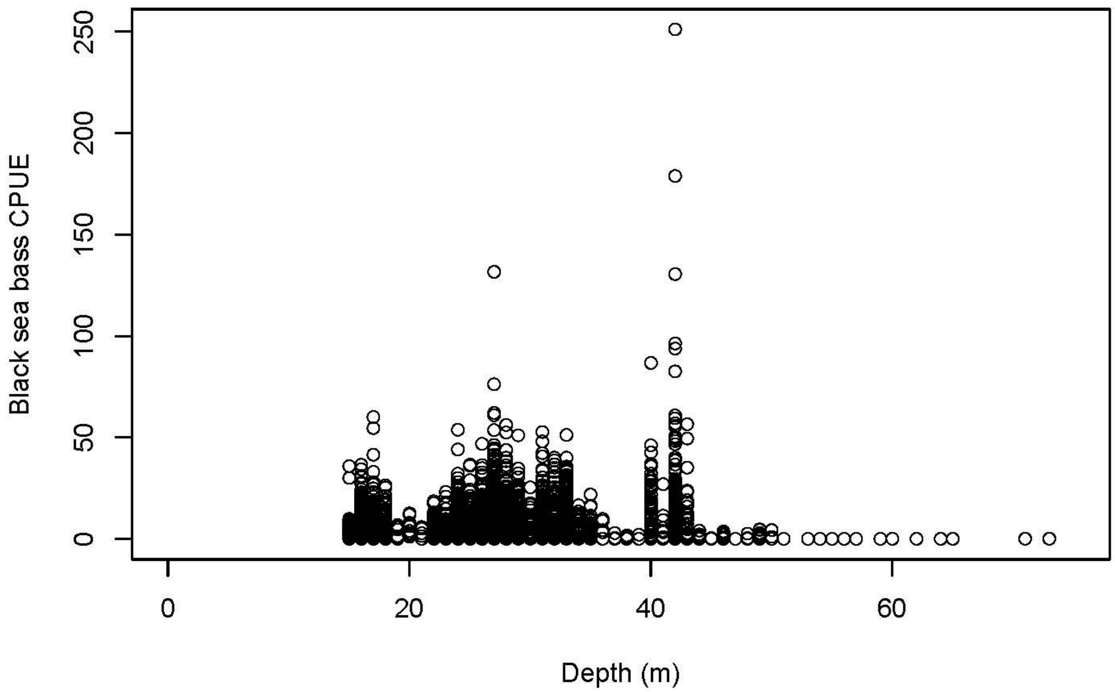

Figure 2. Relationship between catch-per-unit-effort of black sea bass (numbers per hour soak time) to bottom depth (m) from blackfish and Florida snapper traps deployed by MARMAP, 1981–1987.

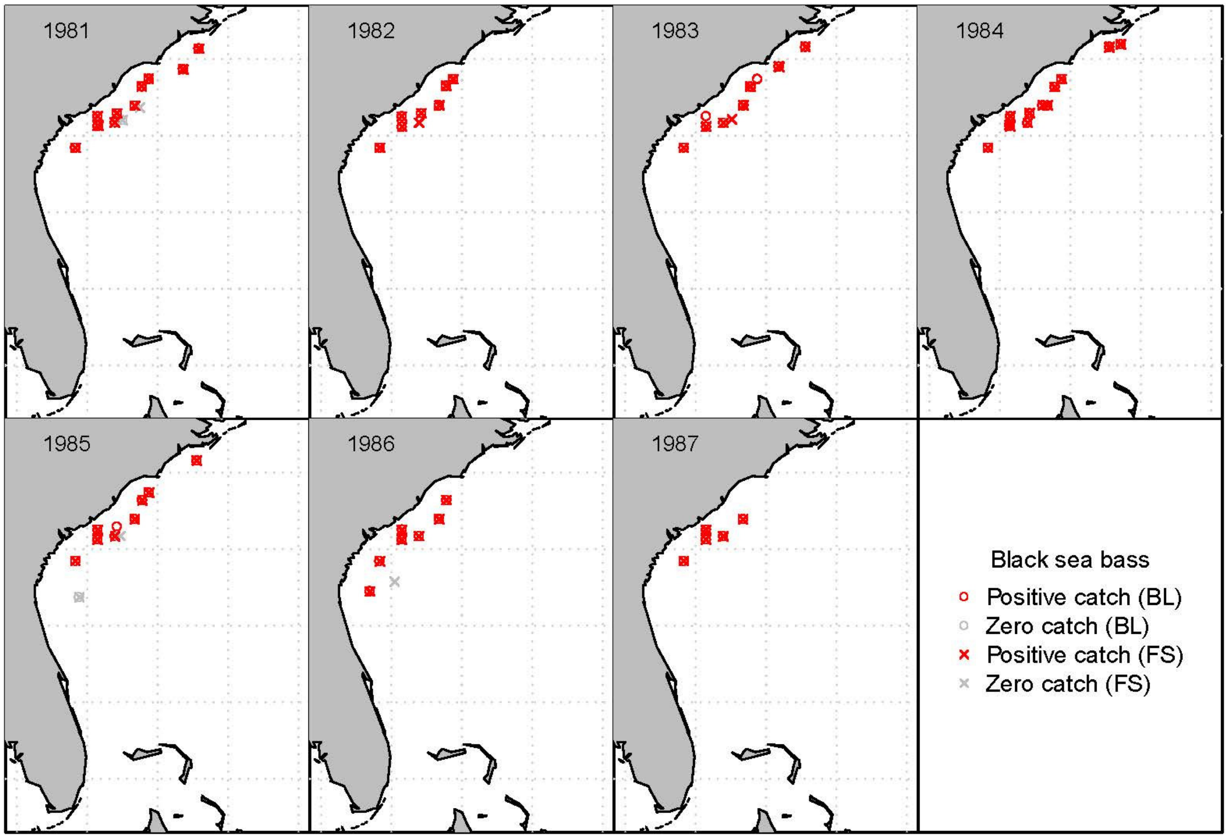

Figure 3. Map of blackfish (BL) and Florida snapper (FS) trap catches of black sea bass by MARMAP, 1981–1987. Red symbols denote positive catch of black sea bass and gray symbols denote zero catch of black sea bass, while circles represent blackfish trap sets and "×" represents Florida snapper trap sets. Note that symbols overlap substantially, so a single symbol may represent multiple trap deployments.

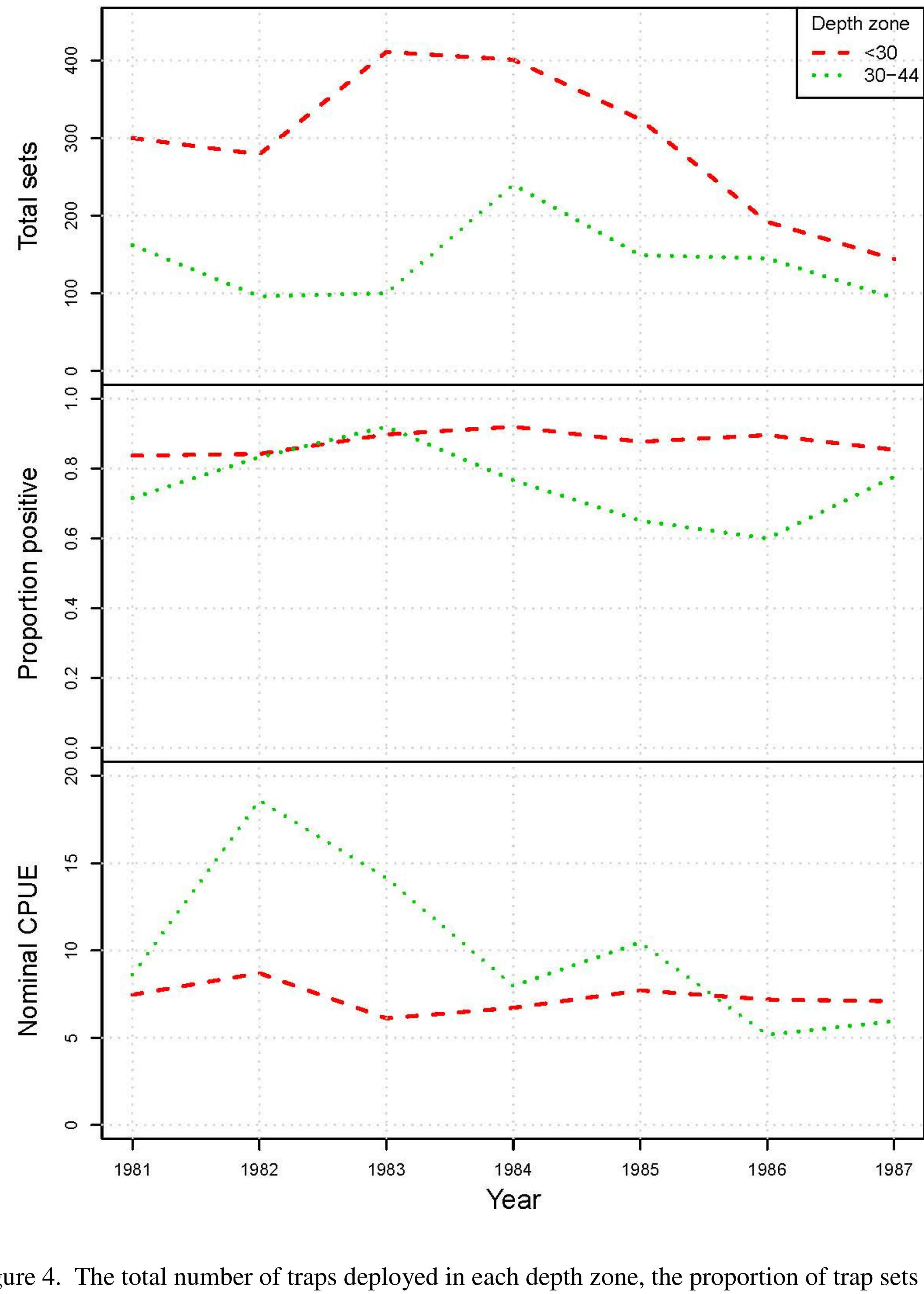

Figure 4. The total number of traps deployed in each depth zone, the proportion of trap sets with positive black sea bass catch in each depth zone, and the nominal CPUE within each depth zone based on MARMAP blackfish and Florida snapper trapping, 1981–1987.

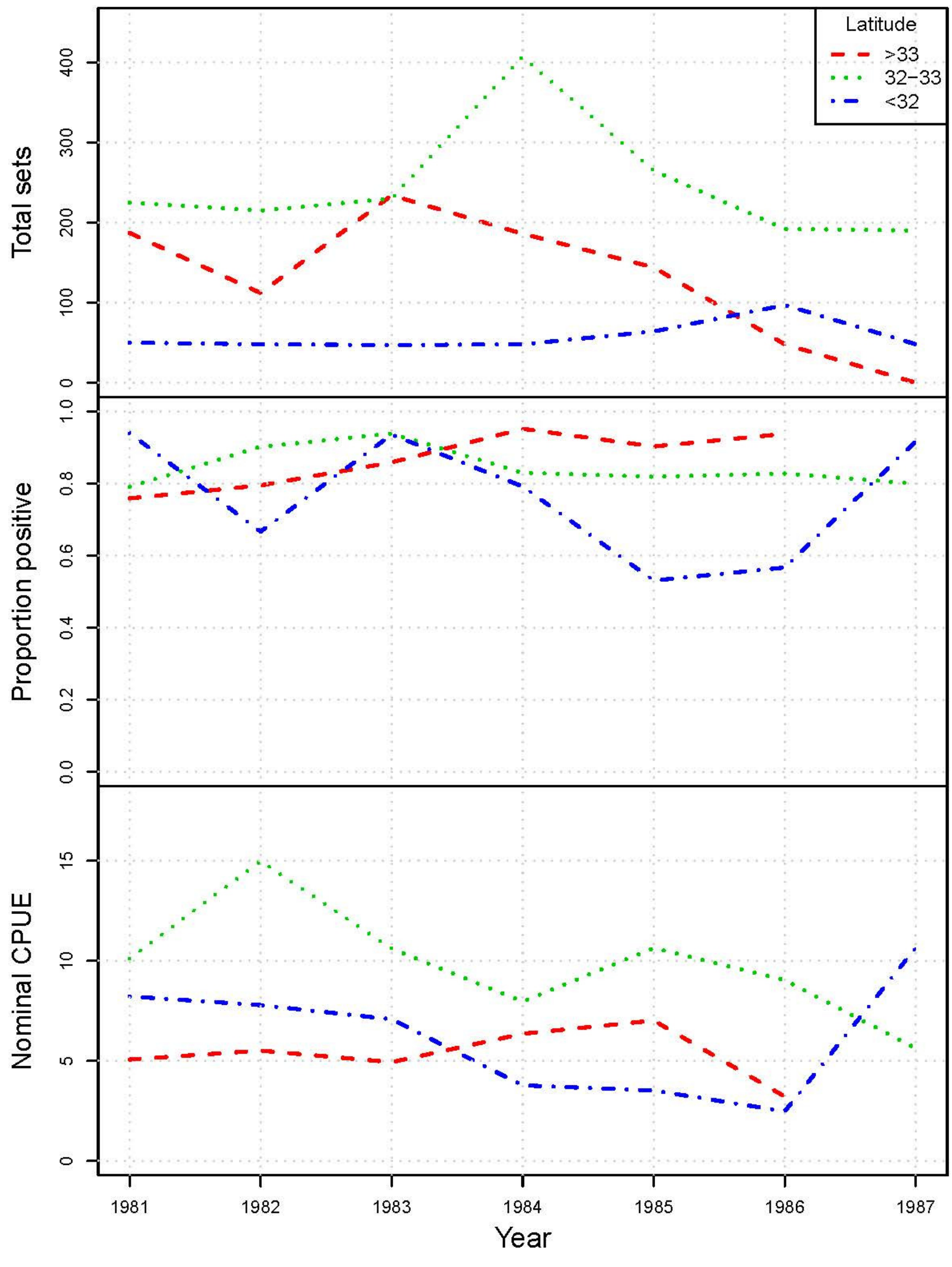

Figure 5. The total number of traps deployed in each latitudinal zone, the proportion of trap sets with positive black sea bass catch in each latitudinal zone, and the nominal CPUE within each latitudinal zone based on MARMAP blackfish and Florida snapper trap sets, 1981–1987. Note that zero trap sets were made north of 33° N latitude in 1987.

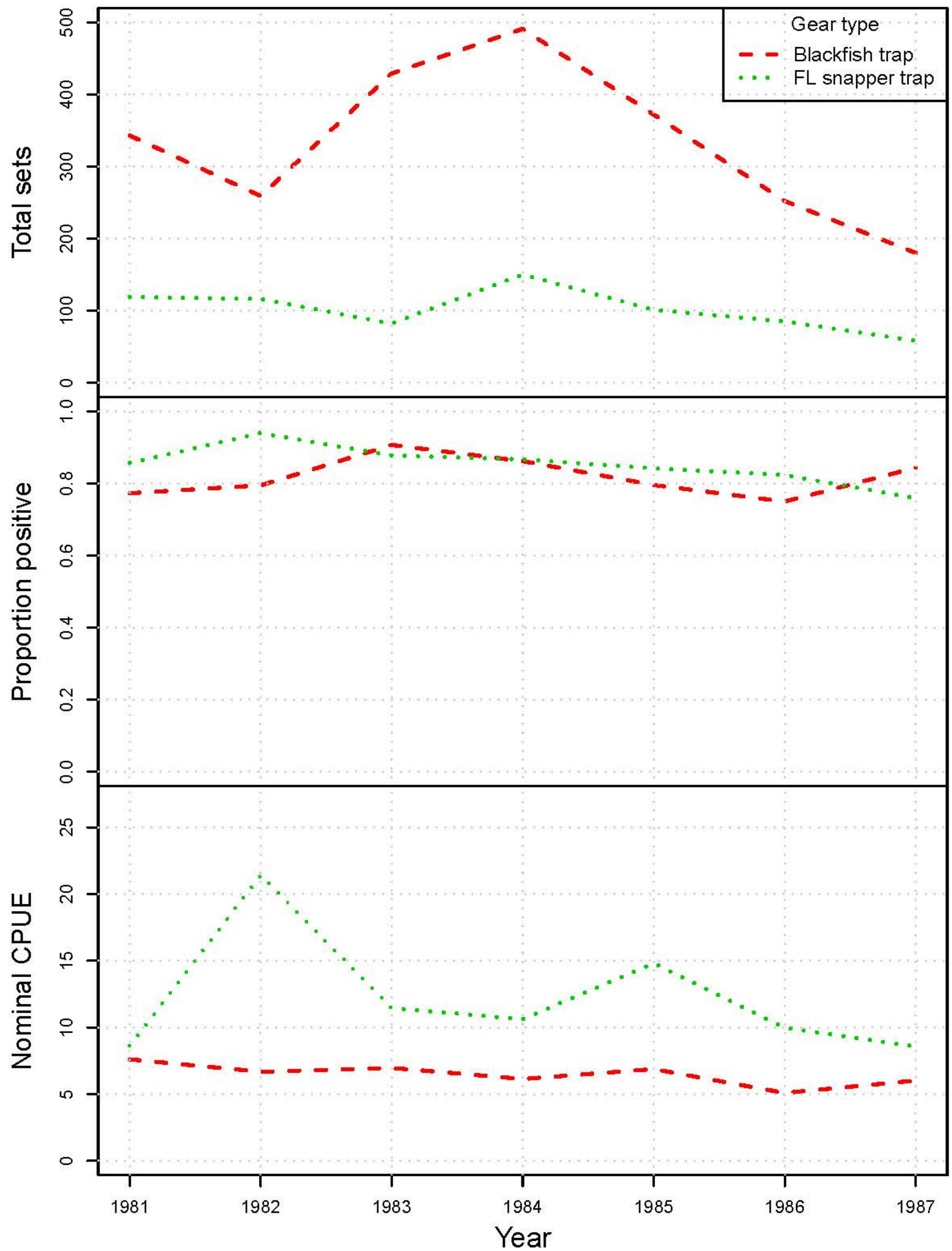

Figure 6. The total number of traps deployed with each gear type, the proportion of trap sets with positive black sea bass catch for each gear type, and the nominal CPUE for each gear type based on MARMAP blackfish and Florida snapper trapping, 1981–1987.

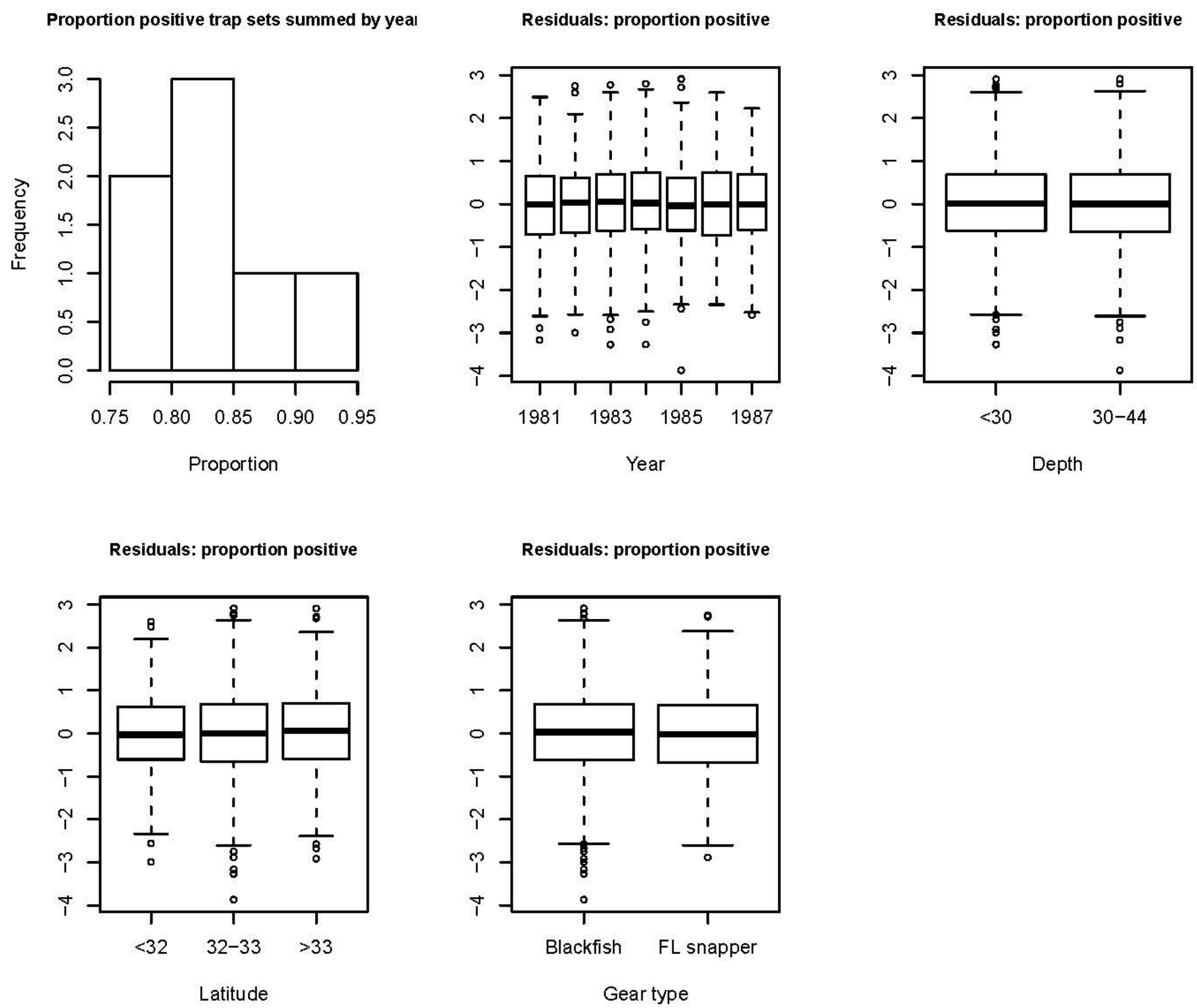

Figure 7. Diagnostics of Bernoulli submodel fits to positive versus zero black sea bass CPUE data in MARMAP blackfish and Florida snapper traps, 1981–1987. Box-and-whisker plots give first, second (median), and third quartiles, as well as limbs that extend approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are randomized quantile residuals.

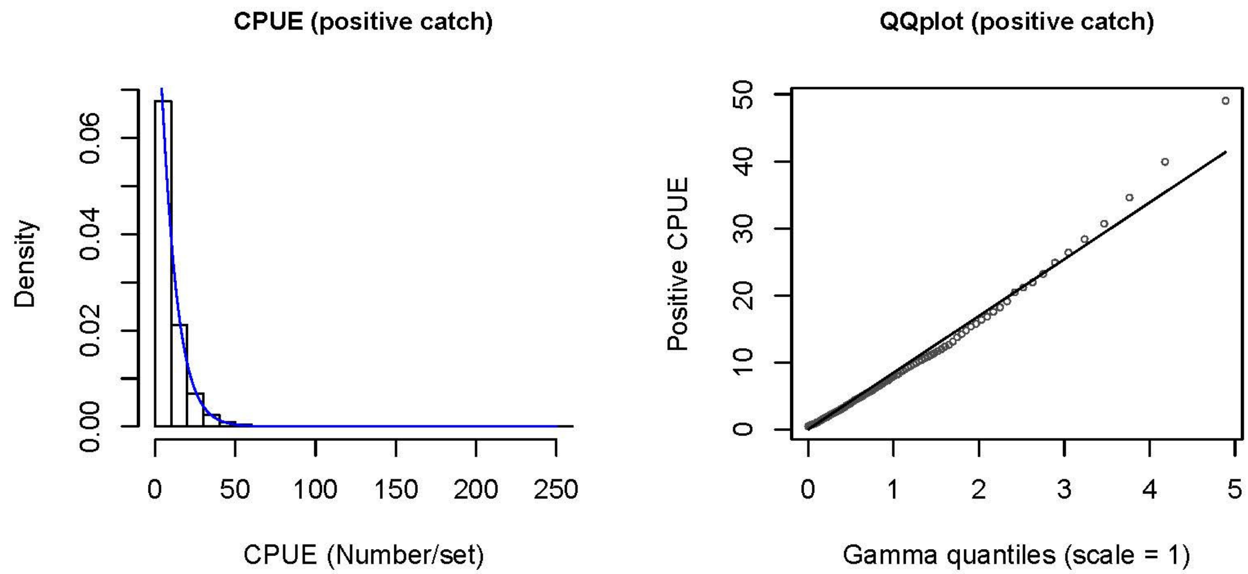

Figure 8. Diagnostics of the gamma submodel fit to positive CPUE data in MARMAP blackfish and Florida snapper traps, 1981–1987. Left panel shows the histogram of black sea bass CPUE with the gamma distribution overlaid (line). Right panel shows the quantile-quantile plot of positive CPUE data from the fitted model.

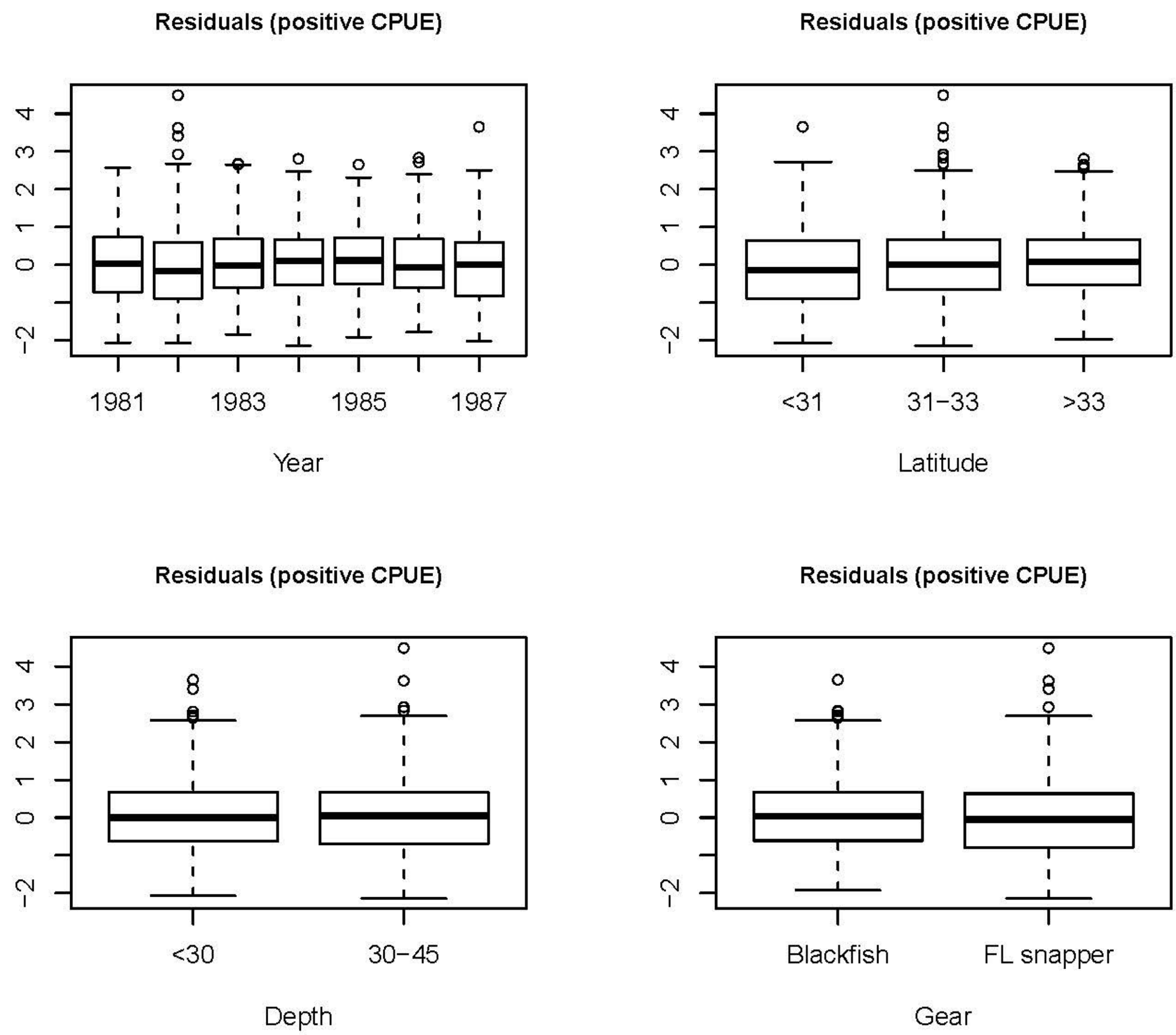

Figure 9. Diagnostics of the gamma submodel fit to positive CPUE data in MARMAP blackfish and Florida snapper traps, 1981–1987. Box-and-whisker plots give first, second (median), and third quartiles, as well as limbs that extend approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs.

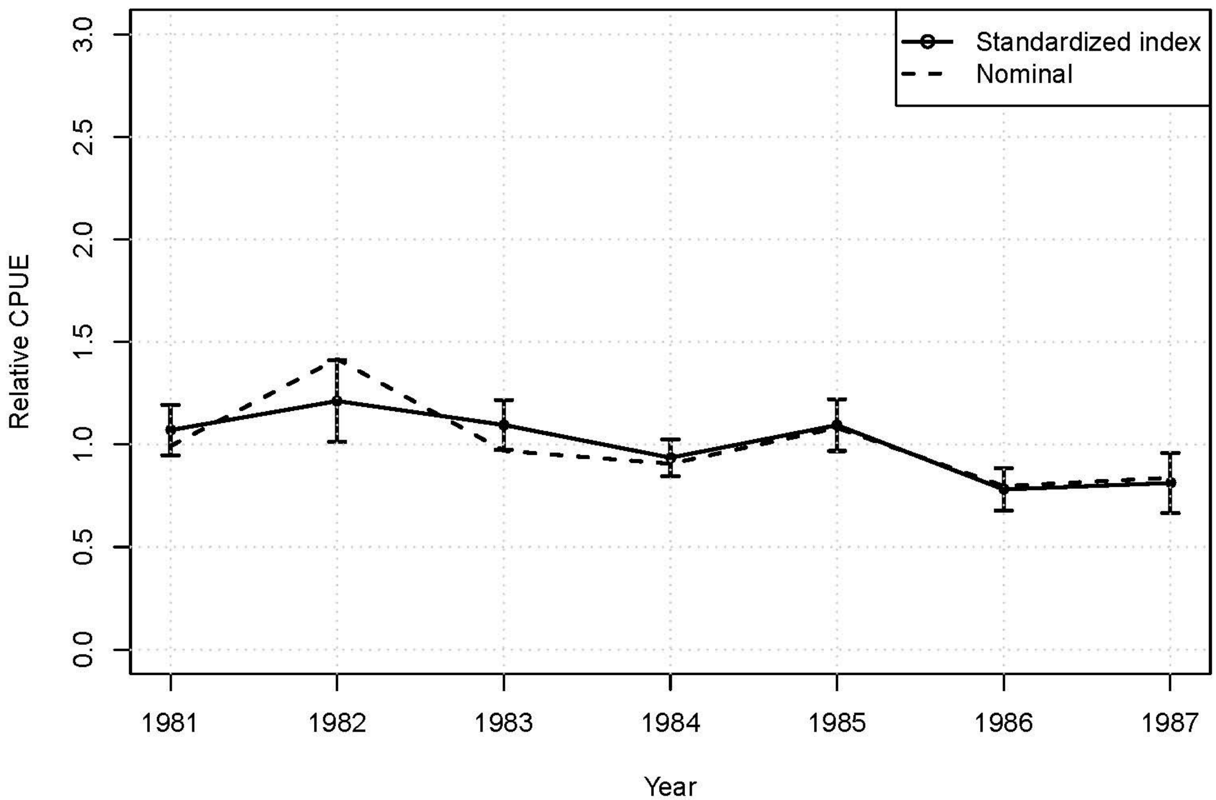

Figure 10. Relative standardized index (solid line, open circles, 95% error bars) and relative nominal index (dashed) of black sea bass CPUE in MARMAP blackfish and Florida snapper traps, 1981–1987.