Standardized CPUE of black sea bass (*Centropristis striata*) from chevron trapping by MARMAP

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1. Abstract

An index of abundance was developed for black sea bass caught in chevron traps deployed by MARMAP in 1990–2010. Sampling occurred from North Carolina to Florida, but most effort was concentrated off of South Carolina. 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. Three categorical predictor variables were included in the delta-GLM model (year, 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 years except 1999. Generally, there was a decline in nominal and standardized CPUE in the early 1990s, followed by an increase in the late 1990s. Since 2000, black sea bass CPUE has been somewhat variable, with no obvious increasing or decreasing trend.

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 chevron trapping. Chevron trapping has occurred since 1988, but data before 1990 were excluded because traps were anchored to a research vessel in 1988–1989. From 1990–2010, chevron traps were deployed from a research vessel and soaked for approximately 90 minutes using cut clupeids as bait. Chevron traps were deployed during daylight hours on 300–500 hardbottom sampling stations randomly selected from a database of approximately 1800 potential stations; thus, sampling was accomplished using a simple random sampling design.

Sampling typically occurred between spring and fall each year, with most sampling in summer months. MARMAP chevron trapping targets a wide variety of species in the snapper-grouper complex, and catches of black sea bass have been substantial. All chevron trapping since 1990 has been aboard the R/V *Palmetto*, a 110' 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), bottom temperature (° C), 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) for each trap was standardized to the number of black sea bass caught per hour of soak time. Trap samples that lacked soak time were excluded (< 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.

Concerns were raised at the data workshop that individual trap samples may not be spatially independent. We examined the influence of potentially non-independent trap samples by developing nominal CPUE in two ways. The first treated each trap sample as independent, and the second combined individual trap samples into a single value for the group of traps deployed in an area (treating each trap sample as a subsample). The nominal CPUE values for each method were nearly identical, so all following analyses considered the trap sample to be the experimental unit.

3.2 Subsetting

Effective effort was based on the traps deployed from areas where black sea bass were available to be caught. Catch of black sea bass was extremely low in waters greater than 44 m deep (Figures 1 and 2), so all trap sets deployed in water deeper than 44 m were excluded (33.5% of the full data set). An additional 0.5% of the records were excluded because they lacked information on latitude.

3.3 Data set after exclusions and subsetting

After subsetting and data exclusions, 4975 chevron traps were deployed between 1990 and 2010 (mean = 237; range = 109 – 416 per year; Table 1). Chevron traps were deployed in depths ranging from 13 to 44 m deep (annual mean ranged from 24.7 to 30.7 m deep). Sampling occurred from North Carolina to Florida, and mean latitude sampled each year ranged from 32.10 to 32.88° N (Table 1). Chevron trapping has occurred from March to November, and mean date sampled each year ranged from as early as 26 May to as late as 24 August (Table 1).

Chevron trapping consistently occurred between North Carolina and Georgia, but only in 12 of 21 years did sampling occur south of 30° N, which is near Jacksonville, Florida (Figure 3).

4. Standardization

Black sea bass CPUE from MARMAP chevron 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 chevron 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 coded 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 1990–2010. The total number of chevron traps deployed each year, as well as the proportion of traps with positive catch, is available in Table 2.

DEPTH – Black sea bass CPUE was influenced by depth (Figure 1). We excluded all chevron traps deployed in water greater than 44 m because black sea bass were rarely captured deeper than this depth (Figures 1 and 2). Depth was pooled into two remaining levels: < 30 m deep or 30 – 44 m deep. The total number of chevron traps deployed in each depth zone, the proportion of traps with positive black sea bass 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 chevron 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.

Two additional variables were considered for inclusion. 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.

Water temperature was also considered for inclusion in the delta-GLM model. However, preliminary tests using both linear and nonlinear models excluded water temperature (based on AIC scores) as a predictor variable for explaining black sea bass CPUE. Therefore, a water temperature 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 chevron traps may or may not catch black sea bass (presence/absence data). All three 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 chevron 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 6).

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 > 200), so the gamma distribution was used in the final delta-GLM model. Diagnostics suggested reasonable fits of the gamma submodel (Figures 7 and 8).

5. Results

Relative nominal CPUE fell within the 95% confidence interval of the standardized index in all years except 1999 (Figure 9). Generally, there was a decline in nominal and standardized CPUE in the early 1990s, followed by an increase in the late 1990s. Since 2000, black sea bass CPUE has been somewhat variable, with no obvious increasing or decreasing trend.

The ages of black sea bass collected by MARMAP chevron traps (1990–2010) ranged from 0 to 10 years (median = 2, N = 71,989 individual ages; Figure 10).

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 chevron trap sets in the subsetted MARMAP database, 1990–2010.

Year	Number of trap sets	Mean depth (m)	Depth range (m)	Mean latitude (° N)	Latitude range (° N)	Mean date	Date range
1990	274	28.9	17-44	32.65	30.74-33.86	5/26	4/23-8/9
1991	222	28.7	17-44	32.70	30.75-34.61	8/8	6/11-9/24
1992	253	29.5	17-44	32.88	30.74-34.32	6/3	3/31-8/13
1993	285	27.8	16-44	32.41	30.74-34.32	7/2	5/10-8/13
1994	292	27.2	16-44	32.18	30.74-33.82	7/22	5/9-10/26
1995	416	25.1	16-44	32.26	31.35-33.92	8/4	4/17-10/26
1996	331	30.7	14-44	32.65	30.75-34.32	8/4	4/29-10/17
1997	264	29.1	15-44	32.21	27.87-34.59	7/9	4/21-9/29
1998	290	28.9	14-44	32.42	27.44-34.59	6/29	3/31-8/18
1999	218	24.7	15-44	32.10	27.27-34.59	7/11	5/18-10/6
2000	217	27.5	15-44	32.64	31.38-34.28	7/25	5/16-10/19
2001	163	26.5	14-44	32.25	27.87-34.28	8/7	5/23-10/24
2002	183	25.2	13-44	32.14	27.86-33.94	8/24	6/17-11/5
2003	109	28.4	16-44	32.34	27.43-34.33	7/19	6/4-9/22
2004	167	29.3	14-44	32.69	30.51-33.97	7/5	5/5-10/28
2005	182	29.5	15-44	32.34	27.33-34.32	6/29	5/3-9/23
2006	196	28.0	15-44	32.25	27.27-34.39	8/1	6/6-10/19
2007	203	28.9	15-44	32.43	27.33-34.33	7/23	5/21-9/24
2008	186	29.2	15-44	32.38	27.27-34.59	7/3	5/5-9/11
2009	272	27.7	14-44	32.55	27.27-34.60	7/21	5/6-10/8
2010	252	27.9	14-44	32.61	27.34-34.59	7/8	5/4-10/13

Table 2. Relative nominal CPUE and relative standardized index of black sea bass abundance from MARMAP chevron trapping data, 1990–2010.

Year	Number of trap sets	Proportion *N* Positive	Relative nominal CPUE	Relative standardized index	CV (index)
1990	274	0.80	1.37	1.59	0.08
1991	222	0.73	1.18	1.09	0.10
1992	253	0.76	1.07	1.26	0.09
1993	285	0.70	0.65	0.71	0.09
1994	292	0.58	0.70	0.68	0.10
1995	416	0.42	0.48	0.37	0.10
1996	331	0.49	0.59	0.72	0.12
1997	264	0.61	0.90	1.03	0.10
1998	290	0.59	0.92	1.05	0.09
1999	218	0.48	1.16	0.72	0.13
2000	217	0.52	1.17	1.04	0.11
2001	163	0.53	1.37	1.30	0.15
2002	183	0.48	0.80	0.69	0.13
2003	109	0.60	0.95	0.97	0.13
2004	167	0.58	1.62	1.78	0.12
2005	182	0.60	1.05	1.04	0.11
2006	196	0.62	1.30	1.12	0.11
2007	203	0.57	0.94	0.88	0.11
2008	186	0.59	0.85	0.88	0.11
2009	272	0.59	0.79	0.83	0.11
2010	252	0.73	1.14	1.24	0.08

Table 3. Model selection results from the delta-GLM model for black sea bass caught in MARMAP chevron traps, 1990–2010.

A. Bernoulli submodel

Removed	Df	Deviance	AIC
<none>		5899.0	5947
- latitude	2	6037.7	6082
- year	20	6175.9	6183
- depth	1	6434.0	6480

B. Gamma submodel

Removed	Df	Deviance	AIC
<none>		3270.7	22054
- year	20	3420.7	22169
- latitude	2	3587.2	22376
- depth	1	3617.2	22409

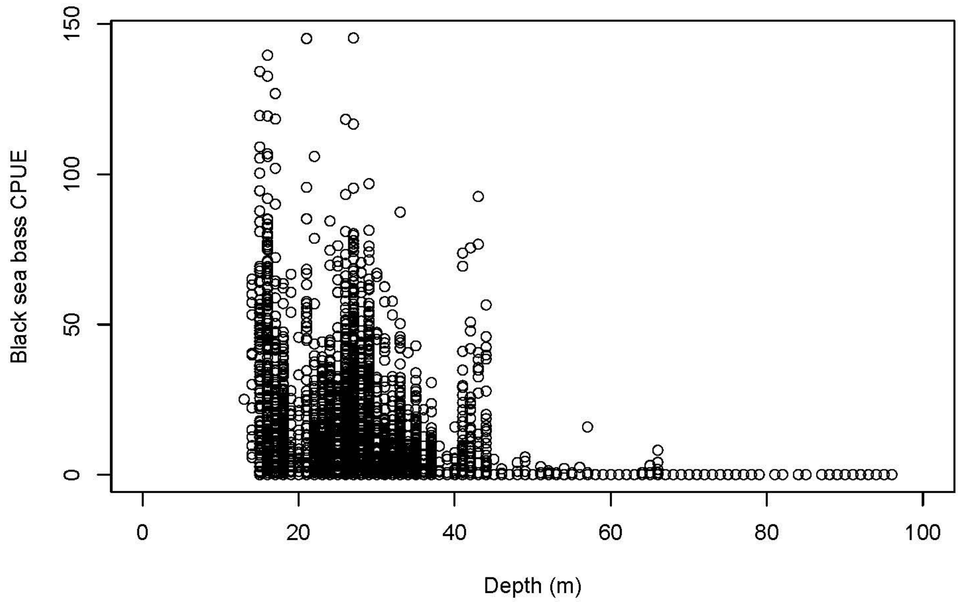

Figure 1. Relationship between catch-per-unit-effort of black sea bass (numbers per hour soak time) to bottom depth (m) from chevron trapping by MARMAP, 1990–2010.

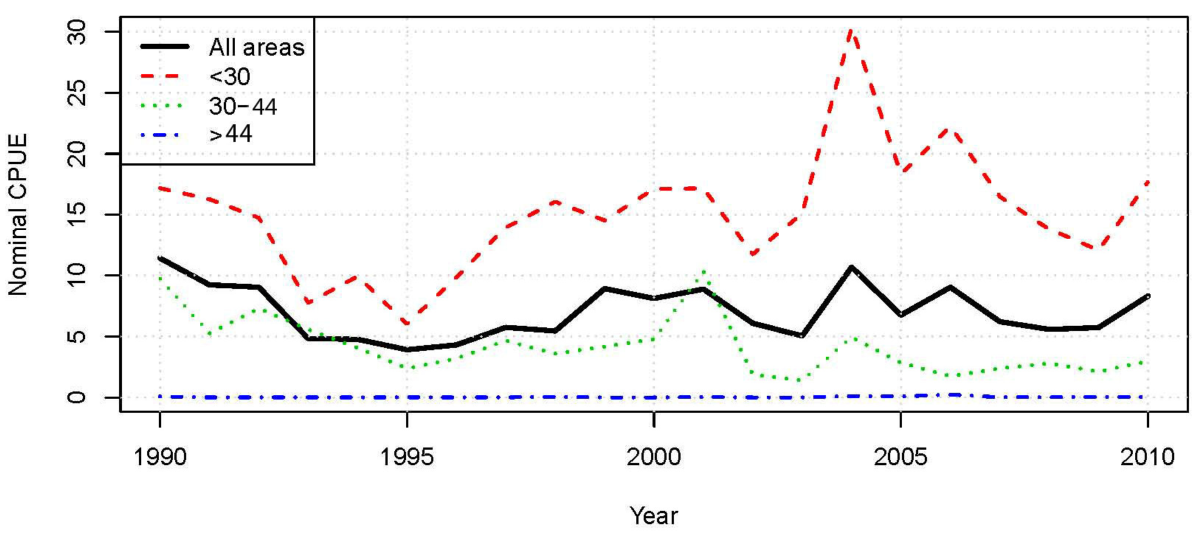

Figure 2. Nominal catch-per-unit-effort (numbers per hour soak time) of black sea bass caught in MARMAP chevron traps within each of three depth zones: < 30m, 30–44 m, and > 44 m.

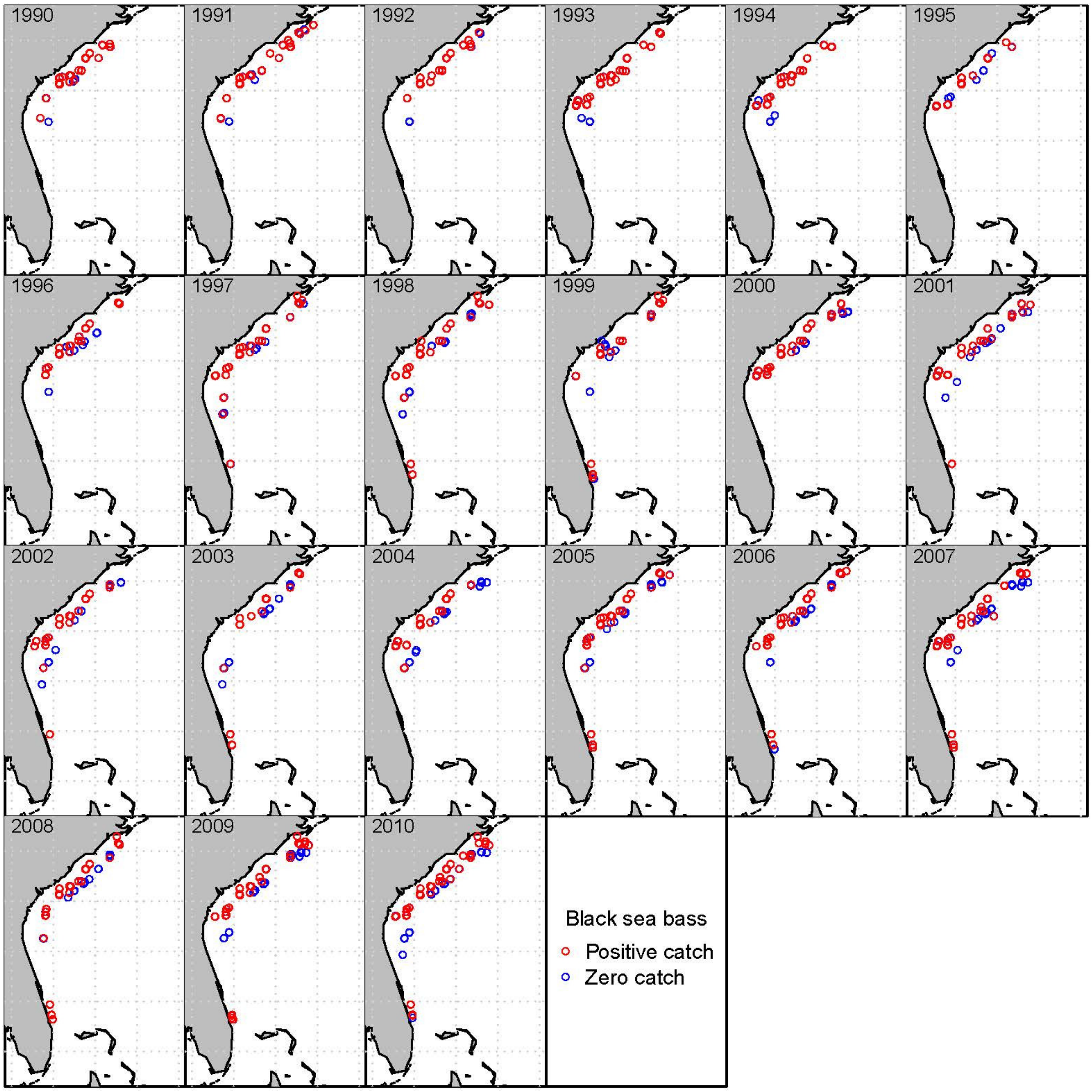

Figure 3. Map of chevron trap catches of black sea bass by MARMAP, 1990–2010. Red circles denote positive catch of black sea bass and blue circles denote zero catch of black sea bass. Note that bubbles overlap substantially, so a single bubble may represent multiple trap deployments.

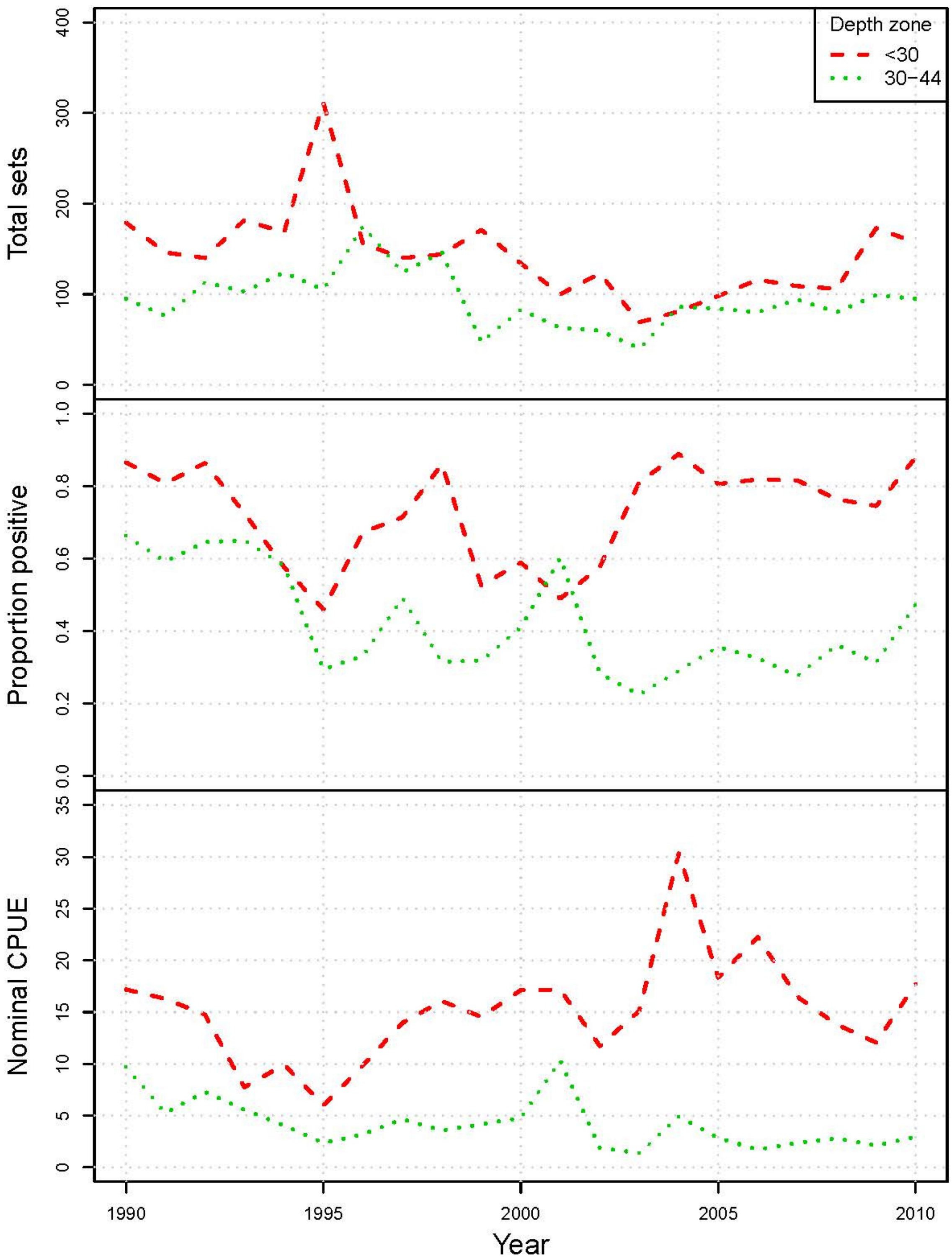

Figure 4. The total number of chevron traps deployed in each depth zone, the proportion of trap sets positive in each depth zone, and the nominal CPUE within each depth zone based on MARMAP chevron trapping, 1990–2010.

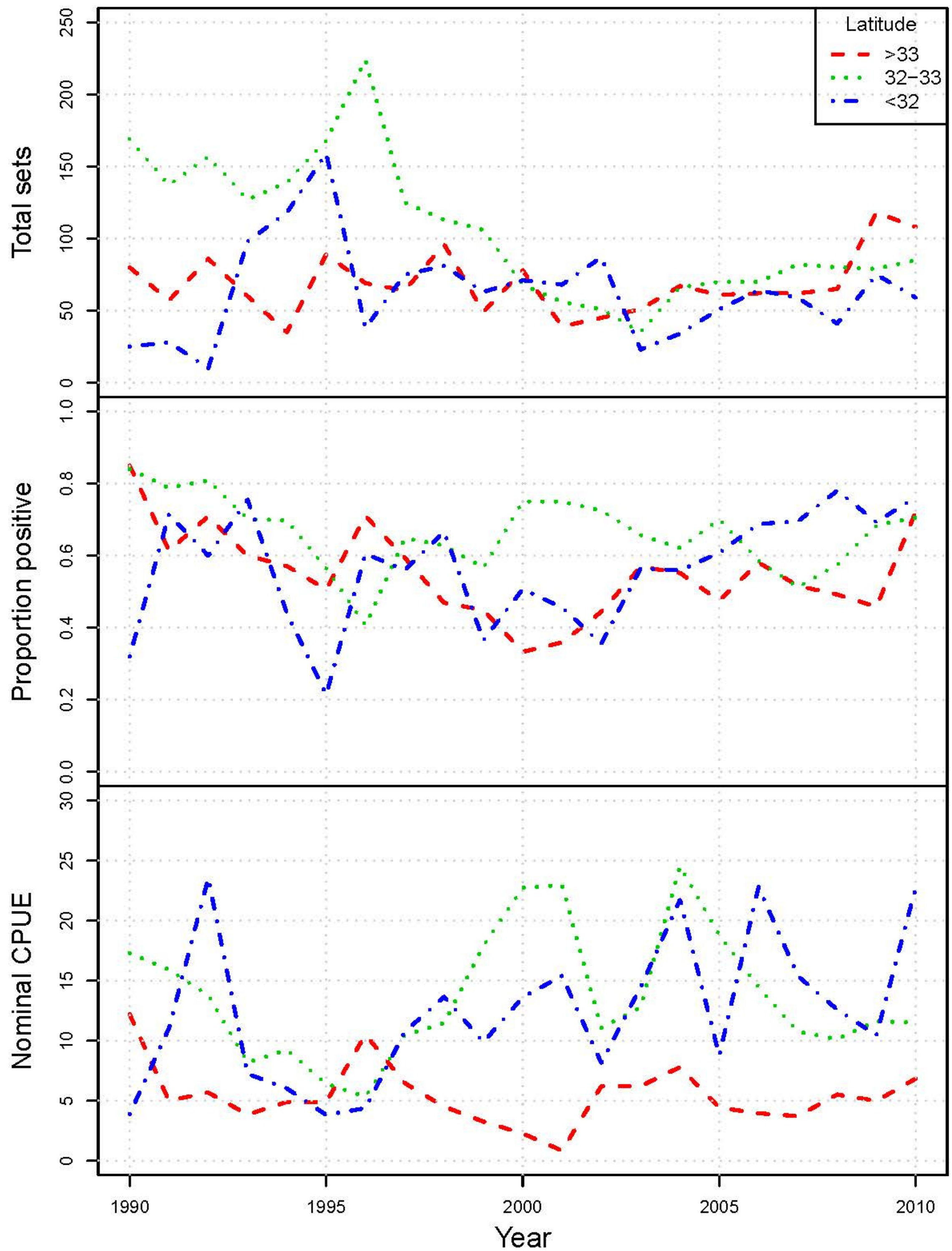

Figure 5. The total number of chevron traps deployed in each latitudinal zone, the proportion of trap sets positive in each latitudinal zone, and the nominal CPUE within each latitudinal zone based on MARMAP chevron trapping, 1990–2010.

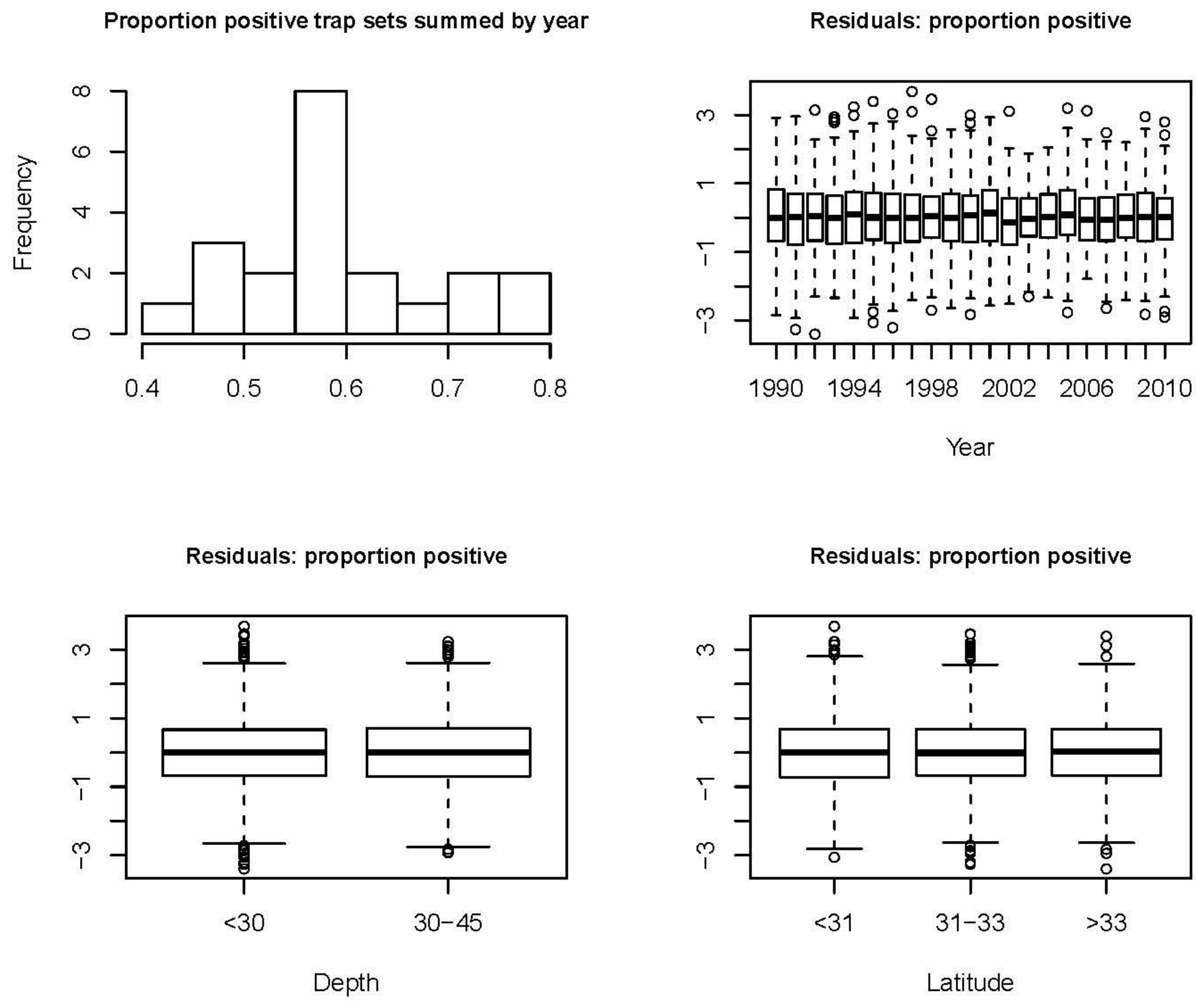

Figure 6. Diagnostics of Bernoulli submodel fits to positive versus zero black sea bass CPUE data from MARMAP chevron trapping, 1990–2010. Box-and-whisker plots give first, second (median), and third quartiles, as well as limbs that extend approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs. Residuals are randomized quantile residuals.

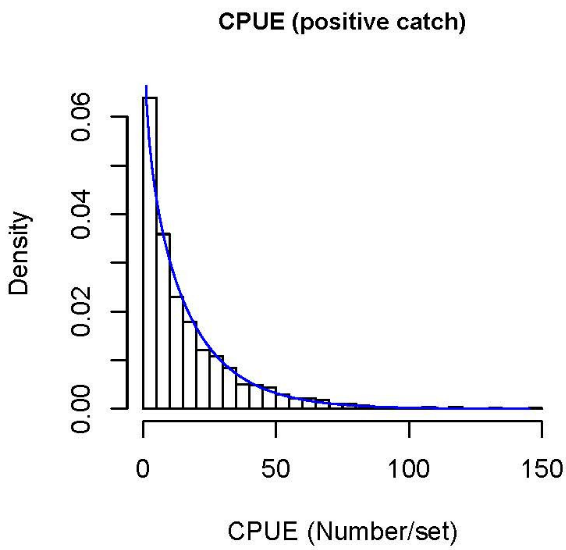

Figure 7. Diagnostics of the gamma submodel fit to positive CPUE data from MARMAP chevron trapping, 1990–2010. Left panel shows the histogram of black sea bass CPUE with the gamma distribution overlaid (line). Right panel shows the quantile-quantile plot of positive CPUE data from the fitted model.

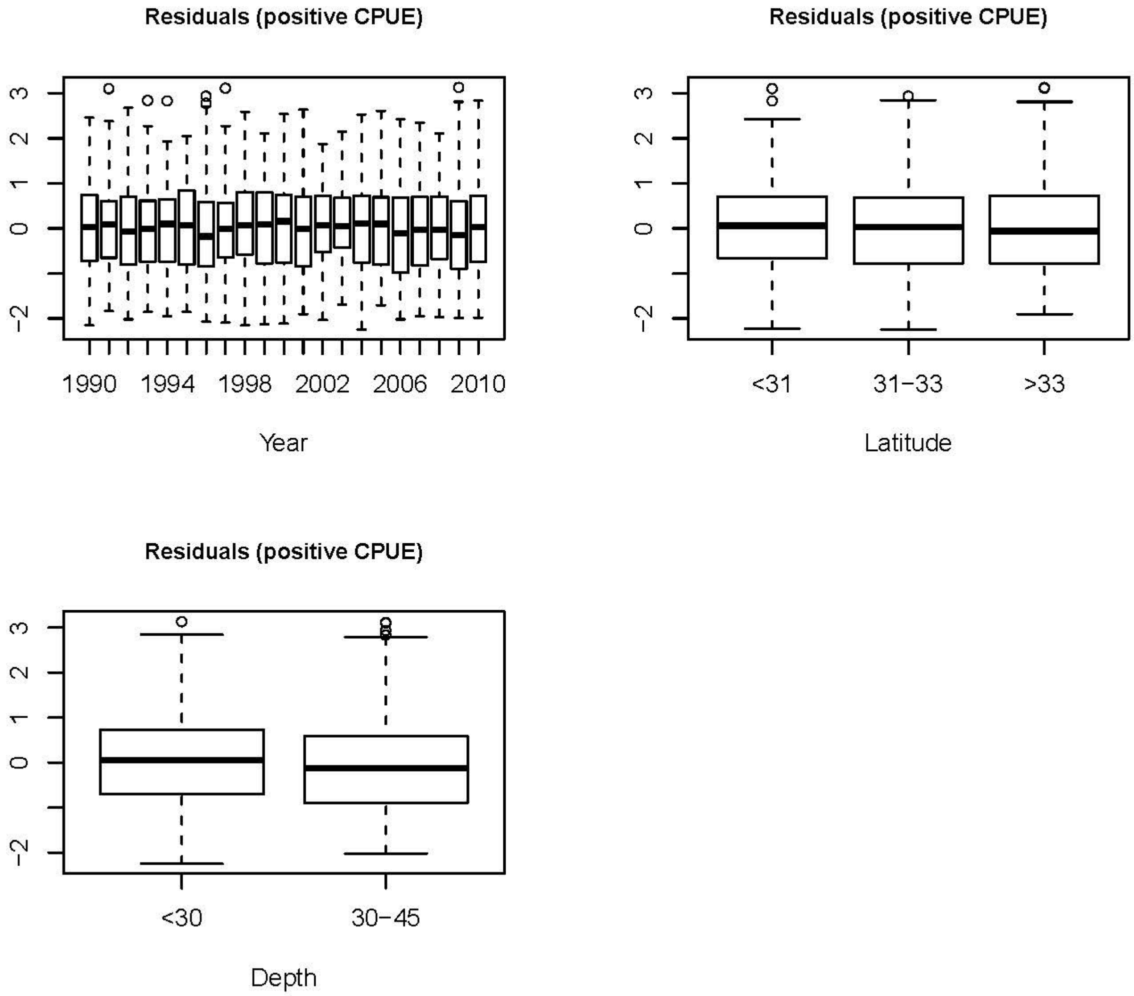

Figure 8. Diagnostics of the gamma submodel fit to positive CPUE data from MARMAP chevron trapping, 1990–2010. Box-and-whisker plots give first, second (median), and third quartiles, as well as limbs that extend approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs.

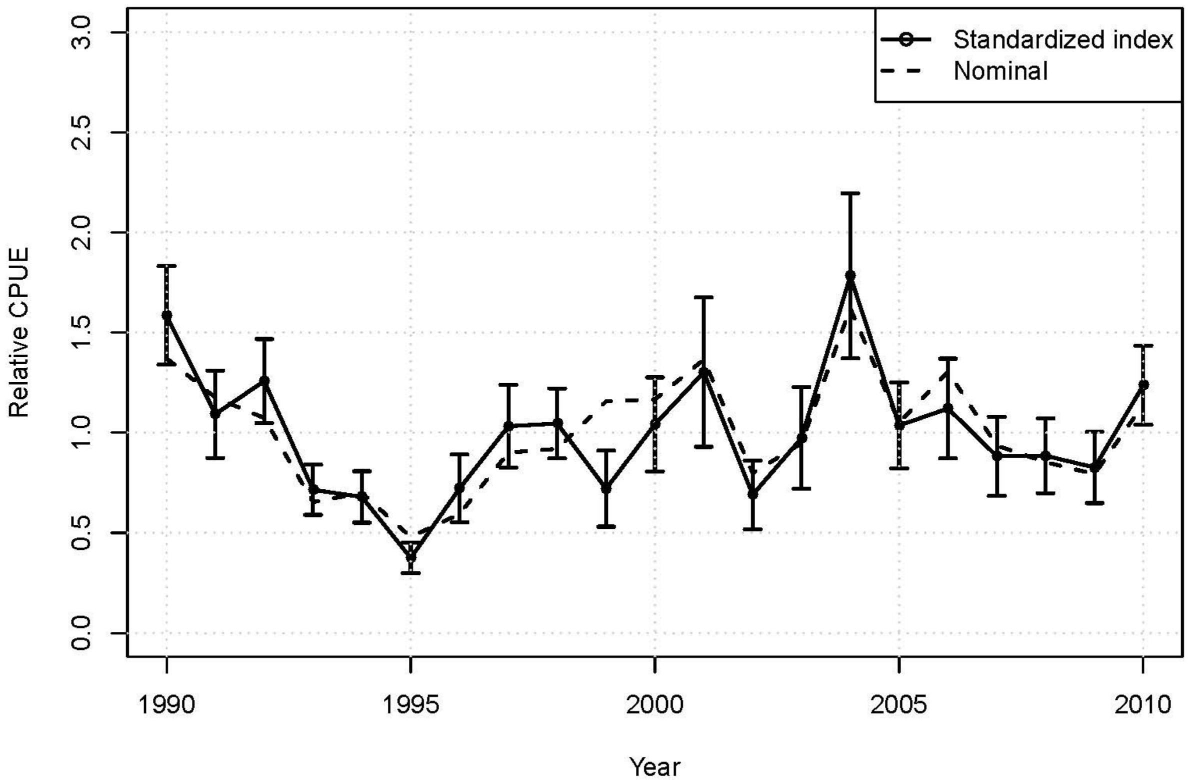

Figure 9. Relative standardized index (solid line, filled circles, 95% error bars) and relative nominal index (dashed) of black sea bass CPUE from MARMAP chevron trapping, 1990–2010.

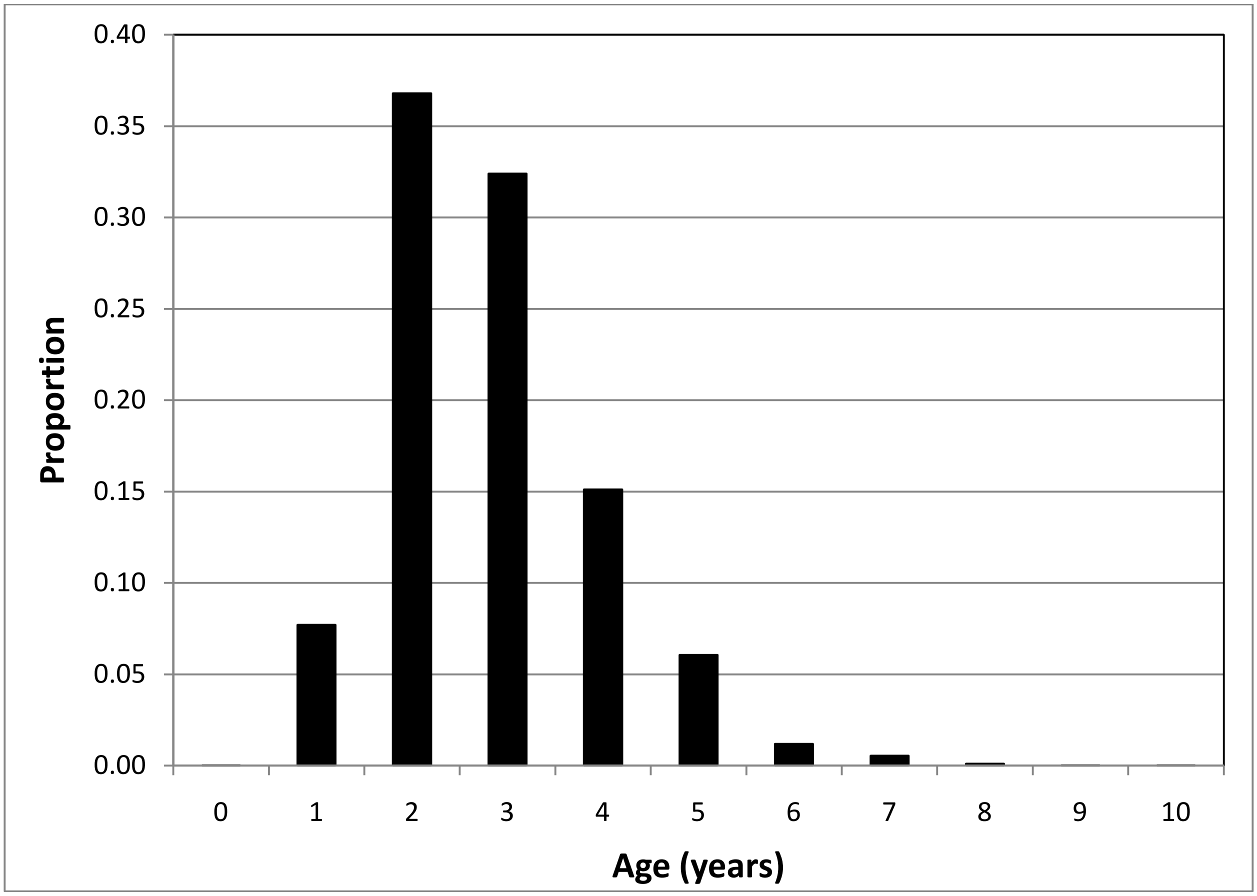

Figure 10. Ages of black sea bass collected by MARMAP chevron traps, 1990–2010 (N = 71,989).