# Red Snapper Abundance Indices from Combined Bottom Trawl Surveys in the Eastern Gulf of Mexico

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# Red Snapper Abundance Indices from Combined Bottom Trawl Surveys in the Eastern Gulf of Mexico

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**Abstract**

*The Southeast Area Monitoring and Assessment Program (SEAMAP) has been conducting standardized groundfish trawls in the Gulf of Mexico since 1972. In 1987, an area off the coast of Alabama, designated the Alabama Artificial Reef Permit Area (AARPA), was established to provide habitat for commercially and recreationally important fish. With the establishment and expansion of the AARPA, trawling in this area became increasingly difficult and led to the exclusion of the AARPA from the SEAMAP sampling universe. Dauphin Island Sea Lab (DISL) has recently undertaken a multifaceted approach to sample within the AARPA and with the help of side scan sonar, conducted bottom trawls. Relative abundance indices for red snapper using the combined SEAMAP and DISL survey data were estimated using delta-lognormal modeling for age 0 (fall survey) and age 1 (summer survey) red snapper.*

## Introduction

At the red snapper (*Lutjanus campechanus*) Data Workshop (DW) for Southeast Data Assessment and Review (SEDAR 31), a question was raised about incorporating data collected during the Southeast Area Monitoring and Assessment Program (SEAMAP) Groundfish Survey with bottom trawl data collected by Dauphin Island Sea Lab (DISL). The DISL survey data focuses on an area off the coast of Alabama designated as the Alabama Artificial Reef Permit Area (AARPA) (Figure 1). Historically, the AARPA and surrounding areas (located mainly in shrimp statistical zone 10) were sampled under SEAMAP until 1989 and sporadically thereafter (Tables 1 and 2) due to the increasing number of artificial reefs in the area and large amount of hangs in shrimp statistical zone 10 which made it difficult to find suitable bottom for trawling operations. Currently, the AARPA (roughly 3,263 $km^2$) is not included in the sampling universe due to the large number of artificial reefs and the difficulty in finding suitable area to set gear. The DISL survey was able to sample in the area primarily because they used side scan sonar to map the sea floor and identify paths to pull the trawl gear.

The SEAMAP Groundfish Survey has been used in previous stock assessments, not only for red snapper, but for other key species. This fishery independent survey provides a long time series (1982 and 1972 for the summer and fall surveys, respectively) for age 0 (fall survey) and age 1 (summer survey) red snapper. The primary objective of the SEAMAP survey was to collect data on the abundance and distribution of demersal organisms in the northern Gulf of Mexico (GOM). This survey, which was conducted semi-annually (summer and fall), provided an important source of fisheries independent information on many commercially and recreationally important species throughout the GOM. The purpose of this document was to provide abundance indices for red snapper and serves as an extension to the work presented by Pollack *et al.* (2012) at the DW for SEDAR 31.

## Methodology

### *Survey Design*

The survey methodologies and descriptions of the SEAMAP datasets used herein have been presented in detail by Nichols (2004) and Pollack *et al.* (2012). The methodology for the DISL data has been presented in Gregalis *et al*. (2012). The majority of the methodology for the DISL survey follows standardized SEAMAP protocols concerning the trawling operations and processing of the catch. The main difference was how the stations are selected during each survey, as part of the overall survey design.

### *Data*

A total of 1,401 and 2,587 stations were sampled during the summer (1982-2011) and fall (1972-2011), respectively under SEAMAP and DISL (Table 1 and Table 2). Data from SEAMAP was limited to shrimp statistical zones 10 and 11 because of the limited recent sampling that has taken place in shrimp statistical zones 3-9. Trawl data was obtained from the Gulf States Marine Fisheries Commission database from Alabama, Florida, Louisiana and Mississippi state agencies and other state partners and incorporated with data collected by the SEFSC. Data from DISL was provided by Marcus Drymon and limited to the timeframe of the SEAMAP survey during the summer (May-July) and fall (October-November). Spatial coverage of both surveys was shown in Figure 2 and Figure 3 for 2010 and 2011, respectively.

### *Index Construction*

Delta-lognormal modeling methods were used to estimate relative abundance indices for red snapper (Lo *et al*. 1992). The main advantage of using this method was allowance for the probability of zero catch (Ortiz *et al.* 2000). The index computed by this method was a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which described the proportion of positive abundance values (i.e. presence/absence) and a lognormal model which described variability in only the nonzero abundance data (Lo *et al*. 1992).

The delta-lognormal index of relative abundance ($I_y$) as described by Lo *et al*. (1992) was estimated as:

(2) $$I_y = c_y p_y,$$

where $c_y$ was the estimate of mean CPUE for positive catches only for year $y$, and $p_y$ was the estimate of mean probability of occurrence during year $y$. Both $c_y$ and $p_y$ were estimated using generalized linear models. Data used to estimate abundance for positive catches ($c$) and probability of occurrence ($p$) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(3) $$\ln(c) = X\beta + \varepsilon$$

and

(4) $$p = \frac{e^{\mathbf{X\beta}+\boldsymbol{\varepsilon}}}{1+e^{\mathbf{X\beta}+\boldsymbol{\varepsilon}}},$$

respectively, where *c* was a vector of the positive catch data, *p* was a vector of the presence/absence data, *X* was the design matrix for main effects, $\beta$ was the parameter vector for main effects, and ε was a vector of independent normally distributed errors with expectation zero and variance $\sigma^2$. Therefore, $c_y$ and $p_y$ were estimated as least-squares means for each year along with their corresponding standard errors, SE($c_y$) and SE($p_y$), respectively. From these estimates, $I_y$ was calculated, as in equation (1), and its variance calculated as:

(5) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where:

(6) $$\mathrm{Cov}(c, p) \approx \rho_{\mathrm{c,p}}\left[\mathrm{SE}(c_y)\mathrm{SE}(p_y)\right],$$

and $\rho_{c,p}$ denoted correlation of *c* and *p* among years.

The submodels of the delta-lognormal model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.05$. Binomial submodel performance was evaluated using Akaike's Information Criteria (AIC), while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC. Variables that could be included in the submodels were:

**Submodel Variables (Summer Survey)**

Year: 1982-2011
Depth Zone: <10 fathoms, 10-30 fathoms, >30 fathoms
Time of Day: Day, Night
Survey: SEAMAP, DISL

**Submodel Variables (Fall Survey)**

Year: 1972-2011
Depth Zone: <10 fathoms, 10-30 fathoms, >30 fathoms
Time of Day: Day, Night
Survey: SEAMAP, DISL

Depth was compiled into zones following the same zones used to calculate effort from the commercial shrimp fleet. The survey variable was based solely on the source of the data. While there are some SEAMAP stations that fall within the AARPA, this was mainly before the vast deployment of artificial reefs in the area.

**Results and Discussion**

For the EGOM abundance index for red snapper (summer survey), the nominal CPUE and number of stations with a positive catch are presented in Figure 4. Year, time of day and depth zone were retained in both the binomial and lognormal submodels. Table 3 summarizes backward selection procedure used to select the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 6,633.9 and 1,067.1, respectively. There was a slight increase in AIC (1,066.8 to 1,067.1) in the lognormal submodel when survey was dropped; however, this was acceptable since the p-value (0.6667) indicated survey was insignificant. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 5-7 and indicated the distribution of the residuals was approximately normal. Annual abundance indices are presented in Table 4 and Figure 8.

For the EGOM abundance index for red snapper (fall survey), the nominal CPUE and number of stations with a positive catch are presented in Figure 9. Year, time of day and depth zone were retained in both the binomial and lognormal submodels. Table 5 summarizes backward selection procedure used to select the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 11,864.3 and 4,121.8, respectively. There was a slight increase in AIC in both the binomial (1,066.8 to 1,067.1) and lognormal (4,120.9 to 4,121.8) submodels when survey was dropped; however, this was acceptable since the p-value (0.3948 and 0.8392, respectively) indicated survey was insignificant. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 10-12 and indicated the distribution of the residuals was approximately normal. Annual abundance indices are presented in Table 6 and Figure 13.

Comparisons between the indices produced from the SEAMAP summer survey and the combined SEAMAP/DISL summer surveys are presented in Figure 14, as well as the annual abundance indices from just the SEAMAP summer survey (Table 7). The higher peak in red snapper abundance in summer 2010 may be attributed to the location of all the DISL samples, which were concentrated in the northeastern corner of the AARPA, which appears to be a productive area for red snapper as evidenced by the high catch rates in the area from the SEAMAP summer survey (Figure 2). This is also evidenced by the lack of difference in abundance indices in fall 2010 (Figure 14 and Table 8) and summer 2011, when a wide range of areas were sampled in the AARPA (Figures 2 and 3). There was an increase in AIC for the binomial submodel when the DISL summer data was appended to the SEAMAP summer data (6,477.5 to 6,633.9); however, there was a decrease in AIC for the lognormal submodel (1,067.1 to 1,018.4). When the DISL fall data was appended to the SEAMAP fall data there were increases in AIC for both the binomial (11,674.6 to 11,864.3) and lognormal (4,108.1 to 4,121.8) submodels.

Overall, we have some reservations about the combined index presented herein. Primarily, we question whether it is useful to maintain a time series for trawl data for an area where the habitat has been altered. If the area changes from trawlable shrimp/groundfish habitat to untrawlable artificial reef habitat, catches will change accordingly. These changes are related to habitat alteration and not changes in the relative abundance of red snapper on trawlable bottom. If artificial habitat has been created, the only logical reason for “before and after” comparisons would be to document the effects of habitat alterations.  That is not the purpose of this analysis, and in our opinion, incorporating the DISL data is of questionable scientific merit.

## Literature Cited


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Table 1. Number of stations sampled by Southeast Area Monitoring and Assessment Program (SEAMAP) during the annual summer groundfish survey and Dauphin Island Sea Lab (DISL) in the Alabama Artificial Reef Permit Area (AARPA).

| | SEAMAP Survey | | | DISL Survey | |
|---|---|---|---|---|---|
| | Shrimp Statistical Zone | | | | |
| Year | 10 | 11 | Total | AARPA | Total |
| 1982 | 14 | 22 | 36 | | 36 |
| 1983 | 8 | 13 | 21 | | 21 |
| 1984 | 13 | 16 | 29 | | 29 |
| 1985 | 10 | 26 | 36 | | 36 |
| 1986 | 14 | 21 | 35 | | 35 |
| 1987 | 30 | 66 | 96 | | 96 |
| 1988 | 19 | 49 | 68 | | 68 |
| 1989 | 23 | 30 | 53 | | 53 |
| 1990 | | 68 | 68 | | 68 |
| 1991 | | 46 | 46 | | 46 |
| 1992 | 1 | 45 | 46 | | 46 |
| 1993 | | 45 | 45 | | 45 |
| 1994 | | 61 | 61 | | 61 |
| 1995 | | 44 | 44 | | 44 |
| 1996 | | 46 | 46 | | 46 |
| 1997 | | 44 | 44 | | 44 |
| 1998 | | 35 | 35 | | 35 |
| 1999 | | 44 | 44 | | 44 |
| 2000 | | 45 | 45 | | 45 |
| 2001 | | 36 | 36 | | 36 |
| 2002 | | 44 | 44 | | 44 |
| 2003 | | 44 | 44 | | 44 |
| 2004 | | 39 | 39 | | 39 |
| 2005 | | 32 | 32 | | 32 |
| 2006 | | 45 | 45 | | 45 |
| 2007 | | 41 | 41 | | 41 |
| 2008 | 11 | 43 | 54 | | 54 |
| 2009 | 24 | 67 | 91 | | 91 |
| 2010 | 14 | 22 | 36 | 6 | 42 |
| 2011 | 8 | 16 | 24 | 12 | 36 |
| *Total* | *189* | *1195* | *1384* | *18* | *1401* |

Table 2. Number of stations sampled by Southeast Area Monitoring and Assessment Program (SEAMAP) during the annual fall groundfish survey and Dauphin Island Sea Lab (DISL) in the Alabama Artificial Reef Permit Area (AARPA).

| | SEAMAP Survey | | | DISL Survey | |
|---|---|---|---|---|---|
| | Shrimp Statistical Zone | | | | |
| Year | 10 | 11 | Total | AARPA | Total |
| 1972 | 10 | 55 | 65 | | 65 |
| 1973 | 17 | 98 | 115 | | 115 |
| 1974 | 12 | 92 | 104 | | 104 |
| 1975 | | 93 | 93 | | 93 |
| 1976 | | 108 | 108 | | 108 |
| 1977 | | 97 | 97 | | 97 |
| 1978 | 36 | 101 | 137 | | 137 |
| 1979 | | 109 | 109 | | 109 |
| 1980 | 24 | 85 | 109 | | 109 |
| 1981 | 21 | 85 | 106 | | 106 |
| 1982 | 21 | 102 | 123 | | 123 |
| 1983 | 17 | 82 | 99 | | 99 |
| 1984 | | 82 | 82 | | 82 |
| 1985 | 30 | 59 | 89 | | 89 |
| 1986 | 21 | 19 | 40 | | 40 |
| 1987 | 16 | 28 | 44 | | 44 |
| 1988 | 8 | 28 | 36 | | 36 |
| 1989 | | 43 | 43 | | 43 |
| 1990 | | 52 | 52 | | 52 |
| 1991 | | 46 | 46 | | 46 |
| 1992 | | 33 | 33 | | 33 |
| 1993 | | 72 | 72 | | 72 |
| 1994 | | 50 | 50 | | 50 |
| 1995 | | 40 | 40 | | 40 |
| 1996 | | 45 | 45 | | 45 |
| 1997 | | 44 | 44 | | 44 |
| 1998 | | 44 | 44 | | 44 |
| 1999 | | 42 | 42 | | 42 |
| 2000 | | 43 | 43 | | 43 |
| 2001 | | 21 | 21 | | 21 |
| 2002 | 1 | 51 | 52 | | 52 |
| 2003 | 1 | 76 | 77 | | 77 |
| 2004 | | 43 | 43 | | 43 |
| 2005 | | 44 | 44 | | 44 |
| 2006 | 1 | 47 | 48 | | 48 |
| 2007 | | 31 | 31 | | 31 |
| 2008 | 4 | 35 | 39 | | 39 |
| 2009 | 12 | 48 | 60 | | 60 |
| 2010 | 14 | 16 | 30 | 12 | 42 |
| 2011 | 6 | 14 | 20 | | 20 |
| Total | *272* | *2303* | 2575 | *12* | *2587* |

Table 3. Summary of backward selection procedure for building delta-lognormal submodels for red snapper (EGOM / Summer) index of relative abundance from 1982 to 2011.

| ***Model Run #1*** | *Binomial Submodel Type 3 Tests (AIC 6635.2)* | | | | | | *Lognormal Submodel Type 3 Tests (AIC 1066.8)* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Effect* | *Num DF* | *Den DF* | *Chi-Square* | *F Value* | *Pr > ChiSq* | *Pr > F* | *Num DF* | *Den DF* | *F Value* | *Pr > F* |
| *Year* | 29 | 416 | 75.31 | 2.49 | <.0001 | <.0001 | 29 | 326 | 2.60 | <.0001 |
| *Depth Zone* | 1 | 1195 | 6.24 | 6.24 | 0.0125 | 0.0126 | 1 | 326 | 13.34 | 0.0003 |
| *Time of Day* | 2 | 1160 | 31.99 | 15.99 | <.0001 | <.0001 | 2 | 326 | 4.15 | 0.0166 |
| *Survey* | 1 | 71.9 | 0.97 | 0.97 | 0.3237 | 0.3270 | 1 | 326 | 0.19 | 0.6667 |
| ***Model Run #2*** | *Binomial Submodel Type 3 Tests (AIC 6633.9)* | | | | | | *Lognormal Submodel Type 3 Tests (AIC 1067.1)* | | | |
| *Effect* | *Num DF* | *Den DF* | *Chi-Square* | *F Value* | *Pr > ChiSq* | *Pr > F* | *Num DF* | *Den DF* | *F Value* | *Pr > F* |
| *Year* | 29 | 414 | 75.93 | 2.51 | <.0001 | <.0001 | 29 | 327 | 2.60 | <.0001 |
| *Depth Zone* | 1 | 1203 | 5.99 | 5.99 | 0.0144 | 0.0145 | 1 | 327 | 13.18 | 0.0003 |
| *Time of Day* | 2 | 1163 | 32.64 | 16.32 | <.0001 | <.0001 | 2 | 327 | 4.27 | 0.0147 |
| *Survey* | dropped | | | | | | dropped | | | |

Table 4. Indices of red snapper (EGOM / Summer) abundance developed using the delta-lognormal model for 1982-2011 for combined SEAMAP and DISL surveys. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

| Survey Year | Frequency | *N* | DL Index | Scaled Index | CV | LCL | UCL |
|---|---|---|---|---|---|---|---|
| 1982 | 0.19444 | 36 | 3.5828 | 1.27947 | 0.60275 | 0.42023 | 3.89559 |
| 1983 | 0.28571 | 21 | 2.9352 | 1.04821 | 0.71166 | 0.29137 | 3.77103 |
| 1984 | 0.06897 | 29 | 0.1495 | 0.05338 | 0.96877 | 0.01049 | 0.27166 |
| 1985 | 0.27778 | 36 | 1.0919 | 0.38993 | 0.41543 | 0.17555 | 0.86608 |
| 1986 | 0.05714 | 35 | 0.1288 | 0.04600 | 1.15197 | 0.00732 | 0.28910 |
| 1987 | 0.21875 | 96 | 1.6382 | 0.58503 | 0.27915 | 0.33826 | 1.01185 |
| 1988 | 0.16176 | 68 | 1.9154 | 0.68402 | 0.49514 | 0.26813 | 1.74499 |
| 1989 | 0.26415 | 53 | 6.8573 | 2.44888 | 0.47669 | 0.99067 | 6.05349 |
| 1990 | 0.38235 | 68 | 3.0580 | 1.09206 | 0.27422 | 0.63733 | 1.87123 |
| 1991 | 0.34783 | 46 | 3.1846 | 1.13728 | 0.35009 | 0.57614 | 2.24497 |
| 1992 | 0.28261 | 46 | 8.6160 | 3.07693 | 0.44060 | 1.32515 | 7.14449 |
| 1993 | 0.20000 | 45 | 0.9848 | 0.35169 | 0.50567 | 0.13542 | 0.91334 |
| 1994 | 0.32787 | 61 | 2.6549 | 0.94812 | 0.32106 | 0.50677 | 1.77385 |
| 1995 | 0.18182 | 44 | 1.0061 | 0.35928 | 0.54013 | 0.13061 | 0.98832 |
| 1996 | 0.26087 | 46 | 1.5216 | 0.54340 | 0.36283 | 0.26894 | 1.09794 |
| 1997 | 0.34091 | 44 | 2.0731 | 0.74034 | 0.35627 | 0.37083 | 1.47804 |
| 1998 | 0.08571 | 35 | 0.8725 | 0.31160 | 1.02071 | 0.05751 | 1.68836 |
| 1999 | 0.11364 | 44 | 0.3877 | 0.13846 | 0.61191 | 0.04482 | 0.42773 |
| 2000 | 0.31111 | 45 | 1.7113 | 0.61112 | 0.34519 | 0.31239 | 1.19554 |
| 2001 | 0.13889 | 36 | 0.6520 | 0.23284 | 0.57557 | 0.07988 | 0.67872 |
| 2002 | 0.11364 | 44 | 0.5711 | 0.20396 | 0.55054 | 0.07288 | 0.57077 |
| 2003 | 0.20455 | 44 | 2.1328 | 0.76165 | 0.53066 | 0.28126 | 2.06256 |
| 2004 | 0.23077 | 39 | 1.9495 | 0.69620 | 0.47398 | 0.28295 | 1.71299 |
| 2005 | 0.28125 | 32 | 4.5529 | 1.62592 | 0.50540 | 0.62637 | 4.22051 |
| 2006 | 0.22222 | 45 | 0.9172 | 0.32753 | 0.38335 | 0.15618 | 0.68688 |
| 2007 | 0.56098 | 41 | 8.3094 | 2.96745 | 0.28602 | 1.69363 | 5.19937 |
| 2008 | 0.42593 | 54 | 10.6405 | 3.79993 | 0.27102 | 2.23114 | 6.47180 |
| 2009 | 0.27473 | 91 | 1.5407 | 0.55020 | 0.26528 | 0.32660 | 0.92691 |
| 2010 | 0.42857 | 42 | 6.9046 | 2.46576 | 0.37685 | 1.18968 | 5.11063 |
| 2011 | 0.27778 | 36 | 1.4654 | 0.52333 | 0.39956 | 0.24238 | 1.12996 |

Table 5. Summary of backward selection procedure for building delta-lognormal submodels for red snapper (EGOM / Fall) index of relative abundance from 1972 to 2011.

| ***Model Run #1*** | *Binomial Submodel Type 3 Tests (AIC 11862.3)* | | | | | | *Lognormal Submodel Type 3 Tests (AIC 4120.9)* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Effect* | *Num DF* | *Den DF* | *Chi-Square* | *F Value* | *Pr > ChiSq* | *Pr > F* | *Num DF* | *Den DF* | *F Value* | *Pr > F* |
| *Year* | 39 | 659 | 220.64 | 5.45 | <.0001 | <.0001 | 39 | 1288 | 6.60 | <.0001 |
| *Depth Zone* | 1 | 2444 | 23.04 | 23.04 | <.0001 | <.0001 | 1 | 1288 | 20.81 | <.0001 |
| *Time of Day* | 2 | 2325 | 309.54 | 154.77 | <.0001 | <.0001 | 2 | 1288 | 41.85 | <.0001 |
| *Survey* | 1 | 40.1 | 0.74 | 0.74 | 0.3897 | 0.3948 | 1 | 1288 | 0.04 | 0.8392 |
| ***Model Run #2*** | *Binomial Submodel Type 3 Tests (AIC 11864.3)* | | | | | | *Lognormal Submodel Type 3 Tests (AIC 4121.8)* | | | |
| *Effect* | *Num DF* | *Den DF* | *Chi-Square* | *F Value* | *Pr > ChiSq* | *Pr > F* | *Num DF* | *Den DF* | *F Value* | *Pr > F* |
| *Year* | 39 | 659 | 221.37 | 5.47 | <.0001 | <.0001 | 39 | 1289 | 6.61 | <.0001 |
| *Depth Zone* | 1 | 2449 | 23.58 | 23.58 | <.0001 | <.0001 | 1 | 1289 | 20.76 | <.0001 |
| *Time of Day* | 2 | 2325 | 309.35 | 154.67 | <.0001 | <.0001 | 2 | 1289 | 41.97 | <.0001 |
| *Survey* | | | | dropped | | | | dropped | | |

Table 6. Indices of red snapper (EGOM / Fall) abundance developed using the delta-lognormal model for 1972-2011 for combined SEAMAP and DISL surveys. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed. With DISL

| Survey Year | Frequency | *N* | DL Index | Scaled Index | CV | LCL | UCL |
|---|---|---|---|---|---|---|---|
| 1972 | 0.67692 | 65 | 43.3523 | 3.27897 | 0.23093 | 2.07851 | 5.17278 |
| 1973 | 0.51304 | 115 | 7.0478 | 0.53307 | 0.19107 | 0.36501 | 0.77850 |
| 1974 | 0.40385 | 104 | 8.1696 | 0.61791 | 0.24465 | 0.38151 | 1.00080 |
| 1975 | 0.44086 | 93 | 6.7982 | 0.51418 | 0.23532 | 0.32320 | 0.81803 |
| 1976 | 0.45370 | 108 | 8.2338 | 0.62277 | 0.21350 | 0.40827 | 0.94997 |
| 1977 | 0.43299 | 97 | 11.3475 | 0.85827 | 0.24609 | 0.52846 | 1.39393 |
| 1978 | 0.45985 | 137 | 5.1218 | 0.38739 | 0.19216 | 0.26470 | 0.56695 |
| 1979 | 0.39450 | 109 | 4.0739 | 0.30813 | 0.21378 | 0.20189 | 0.47027 |
| 1980 | 0.49541 | 109 | 7.6000 | 0.57483 | 0.19526 | 0.39041 | 0.84635 |
| 1981 | 0.59434 | 106 | 26.4207 | 1.99834 | 0.19802 | 1.34996 | 2.95814 |
| 1982 | 0.71545 | 123 | 29.7164 | 2.24761 | 0.15322 | 1.65733 | 3.04812 |
| 1983 | 0.50505 | 99 | 4.2067 | 0.31818 | 0.20415 | 0.21240 | 0.47664 |
| 1984 | 0.34146 | 82 | 3.4199 | 0.25867 | 0.29101 | 0.14625 | 0.45750 |
| 1985 | 0.21348 | 89 | 1.5642 | 0.11831 | 0.30863 | 0.06472 | 0.21628 |
| 1986 | 0.12500 | 40 | 1.4497 | 0.10965 | 0.63114 | 0.03444 | 0.34910 |
| 1987 | 0.25000 | 44 | 2.4484 | 0.18518 | 0.42288 | 0.08228 | 0.41678 |
| 1988 | 0.36111 | 36 | 3.2428 | 0.24527 | 0.36379 | 0.12118 | 0.49644 |
| 1989 | 0.67442 | 43 | 49.7588 | 3.76353 | 0.28811 | 2.13953 | 6.62023 |
| 1990 | 0.73077 | 52 | 28.3171 | 2.14178 | 0.25793 | 1.28925 | 3.55806 |
| 1991 | 0.76087 | 46 | 31.7676 | 2.40276 | 0.22098 | 1.55259 | 3.71847 |
| 1992 | 0.42424 | 33 | 2.5540 | 0.19317 | 0.36027 | 0.09605 | 0.38848 |
| 1993 | 0.50000 | 72 | 18.3964 | 1.39142 | 0.29236 | 0.78470 | 2.46725 |
| 1994 | 0.52000 | 50 | 4.5464 | 0.34387 | 0.24324 | 0.21289 | 0.55544 |
| 1995 | 0.62500 | 40 | 9.5341 | 0.72112 | 0.23486 | 0.45367 | 1.14623 |
| 1996 | 0.53333 | 45 | 7.3352 | 0.55480 | 0.29347 | 0.31223 | 0.98581 |
| 1997 | 0.50000 | 44 | 12.2921 | 0.92972 | 0.30562 | 0.51144 | 1.69007 |
| 1998 | 0.45455 | 44 | 2.9233 | 0.22110 | 0.31707 | 0.11906 | 0.41061 |
| 1999 | 0.54762 | 42 | 8.0347 | 0.60771 | 0.30472 | 0.33487 | 1.10287 |
| 2000 | 0.67442 | 43 | 22.1992 | 1.67905 | 0.24100 | 1.04395 | 2.70050 |
| 2001 | 0.61905 | 21 | 6.8943 | 0.52145 | 0.39074 | 0.24536 | 1.10822 |
| 2002 | 0.44231 | 52 | 5.4839 | 0.41478 | 0.30300 | 0.22929 | 0.75031 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2003 | 0.64935 | 77 | 16.2343 | 1.22789 | 0.22031 | 0.79444 | 1.89782 |
| 2004 | 0.41860 | 43 | 4.3589 | 0.32969 | 0.33160 | 0.17281 | 0.62900 |
| 2005 | 0.68182 | 44 | 9.6825 | 0.73234 | 0.26418 | 0.43563 | 1.23117 |
| 2006 | 0.89583 | 48 | 37.9349 | 2.86922 | 0.18689 | 1.98075 | 4.15623 |
| 2007 | 0.77419 | 31 | 24.2815 | 1.83655 | 0.23559 | 1.15379 | 2.92333 |
| 2008 | 0.51282 | 39 | 4.9385 | 0.37353 | 0.30064 | 0.20740 | 0.67271 |
| 2009 | 0.80000 | 60 | 40.2090 | 3.04123 | 0.24815 | 1.86519 | 4.95879 |
| 2010 | 0.47619 | 42 | 4.2921 | 0.32464 | 0.36737 | 0.15935 | 0.66137 |
| 2011 | 0.40000 | 20 | 2.6697 | 0.20193 | 0.42128 | 0.08997 | 0.45318 |

Table 7. Indices of red snapper (EGOM / Summer) abundance developed using the delta-lognormal model for 1982-2011 from the SEAMAP survey. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

| Survey Year | Frequency | *N* | DL Index | Scaled Index | CV | LCL | UCL |
|---|---|---|---|---|---|---|---|
| 1982 | 0.19444 | 36 | 2.8888 | 1.09250 | 0.54008 | 0.39718 | 3.00503 |
| 1983 | 0.28571 | 21 | 2.1433 | 0.81056 | 0.58033 | 0.27594 | 2.38097 |
| 1984 | 0.06897 | 29 | 0.2171 | 0.08210 | 1.16402 | 0.01290 | 0.52262 |
| 1985 | 0.27778 | 36 | 1.4967 | 0.56601 | 0.46155 | 0.23503 | 1.36310 |
| 1986 | 0.05714 | 35 | 0.1757 | 0.06645 | 1.20597 | 0.00999 | 0.44213 |
| 1987 | 0.21875 | 96 | 2.0033 | 0.75761 | 0.31616 | 0.40865 | 1.40459 |
| 1988 | 0.16176 | 68 | 1.5787 | 0.59705 | 0.44054 | 0.25716 | 1.38619 |
| 1989 | 0.26415 | 53 | 4.1722 | 1.57783 | 0.37850 | 0.75899 | 3.28007 |
| 1990 | 0.38235 | 68 | 3.2224 | 1.21863 | 0.27355 | 0.71210 | 2.08546 |
| 1991 | 0.34783 | 46 | 3.3646 | 1.27244 | 0.34726 | 0.64797 | 2.49872 |
| 1992 | 0.28261 | 46 | 7.0297 | 2.65851 | 0.38679 | 1.25984 | 5.60995 |
| 1993 | 0.20000 | 45 | 1.1508 | 0.43519 | 0.48819 | 0.17262 | 1.09715 |
| 1994 | 0.32787 | 61 | 2.6490 | 1.00182 | 0.31533 | 0.54120 | 1.85445 |
| 1995 | 0.18182 | 44 | 1.0238 | 0.38718 | 0.51995 | 0.14555 | 1.02992 |
| 1996 | 0.26087 | 46 | 1.9485 | 0.73688 | 0.41160 | 0.33403 | 1.62560 |
| 1997 | 0.34091 | 44 | 2.0989 | 0.79375 | 0.36108 | 0.39411 | 1.59867 |
| 1998 | 0.08571 | 35 | 0.6920 | 0.26170 | 0.85004 | 0.05988 | 1.14377 |
| 1999 | 0.11364 | 44 | 0.5000 | 0.18907 | 0.68469 | 0.05471 | 0.65341 |
| 2000 | 0.31111 | 45 | 2.0417 | 0.77212 | 0.37570 | 0.37331 | 1.59700 |
| 2001 | 0.13889 | 36 | 0.8554 | 0.32350 | 0.65950 | 0.09725 | 1.07606 |
| 2002 | 0.11364 | 44 | 0.8130 | 0.30746 | 0.66342 | 0.09188 | 1.02885 |
| 2003 | 0.20455 | 44 | 1.8220 | 0.68906 | 0.47948 | 0.27742 | 1.71150 |
| 2004 | 0.23077 | 39 | 1.9260 | 0.72836 | 0.47421 | 0.29591 | 1.79280 |
| 2005 | 0.30303 | 33 | 4.5320 | 1.71392 | 0.43577 | 0.74441 | 3.94612 |
| 2006 | 0.22222 | 45 | 1.2538 | 0.47415 | 0.45943 | 0.19761 | 1.13769 |
| 2007 | 0.56098 | 41 | 7.5152 | 2.84208 | 0.26799 | 1.67837 | 4.81268 |
| 2008 | 0.42593 | 54 | 11.7878 | 4.45790 | 0.28388 | 2.55457 | 7.77933 |
| 2009 | 0.27473 | 91 | 1.8817 | 0.71162 | 0.28979 | 0.40327 | 1.25575 |
| 2010 | 0.37838 | 37 | 4.6645 | 1.76404 | 0.36729 | 0.86601 | 3.59328 |
| 2011 | 0.29167 | 24 | 1.8788 | 0.71051 | 0.52792 | 0.26357 | 1.91531 |

Table 8. Indices of red snapper (EGOM / Fall) abundance developed using the delta-lognormal model for 1972-2011 from the SEAMAP survey. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

| Survey Year | Frequency | *N* | DL Index | Scaled Index | CV | LCL | UCL |
|---|---|---|---|---|---|---|---|
| 1972 | 0.67692 | 65 | 43.6574 | 3.27439 | 0.22927 | 2.08227 | 5.14903 |
| 1973 | 0.51304 | 115 | 7.1767 | 0.53826 | 0.18783 | 0.37090 | 0.78114 |
| 1974 | 0.40385 | 104 | 8.4347 | 0.63262 | 0.24490 | 0.39040 | 1.02512 |
| 1975 | 0.44086 | 93 | 6.9768 | 0.52328 | 0.22225 | 0.33729 | 0.81181 |
| 1976 | 0.45370 | 108 | 8.4324 | 0.63245 | 0.20645 | 0.42032 | 0.95164 |
| 1977 | 0.43299 | 97 | 11.6354 | 0.87268 | 0.24406 | 0.53942 | 1.41182 |
| 1978 | 0.45985 | 137 | 5.2682 | 0.39512 | 0.18587 | 0.27331 | 0.57123 |
| 1979 | 0.39450 | 109 | 4.1681 | 0.31261 | 0.21558 | 0.20412 | 0.47878 |
| 1980 | 0.49541 | 109 | 7.7914 | 0.58437 | 0.19938 | 0.39373 | 0.86733 |
| 1981 | 0.59434 | 106 | 26.9305 | 2.01984 | 0.19221 | 1.38000 | 2.95634 |
| 1982 | 0.71545 | 123 | 29.9358 | 2.24525 | 0.15134 | 1.66170 | 3.03372 |
| 1983 | 0.50505 | 99 | 4.3068 | 0.32302 | 0.19694 | 0.21867 | 0.47716 |
| 1984 | 0.34146 | 82 | 3.5334 | 0.26501 | 0.29985 | 0.14737 | 0.47657 |
| 1985 | 0.21348 | 89 | 1.6241 | 0.12181 | 0.30546 | 0.06703 | 0.22137 |
| 1986 | 0.12500 | 40 | 1.5295 | 0.11472 | 0.66374 | 0.03427 | 0.38407 |
| 1987 | 0.25000 | 44 | 2.5507 | 0.19130 | 0.43068 | 0.08384 | 0.43653 |
| 1988 | 0.36111 | 36 | 3.3413 | 0.25060 | 0.37730 | 0.12081 | 0.51983 |
| 1989 | 0.67442 | 43 | 49.8205 | 3.73664 | 0.28304 | 2.14463 | 6.51041 |
| 1990 | 0.71698 | 53 | 27.7674 | 2.08261 | 0.26237 | 1.24307 | 3.48916 |
| 1991 | 0.76087 | 46 | 31.7855 | 2.38397 | 0.22842 | 1.51852 | 3.74269 |
| 1992 | 0.42424 | 33 | 2.5964 | 0.19473 | 0.33867 | 0.10074 | 0.37641 |
| 1993 | 0.50000 | 72 | 18.8373 | 1.41283 | 0.29898 | 0.78693 | 2.53656 |
| 1994 | 0.52000 | 50 | 4.6211 | 0.34659 | 0.24565 | 0.21358 | 0.56242 |
| 1995 | 0.62500 | 40 | 9.6240 | 0.72182 | 0.24339 | 0.44675 | 1.16627 |
| 1996 | 0.52174 | 46 | 7.3109 | 0.54834 | 0.28379 | 0.31427 | 0.95672 |
| 1997 | 0.48889 | 45 | 12.2807 | 0.92108 | 0.30546 | 0.50684 | 1.67387 |
| 1998 | 0.45455 | 44 | 2.9987 | 0.22491 | 0.30515 | 0.12383 | 0.40848 |
| 1999 | 0.53488 | 43 | 7.9702 | 0.59778 | 0.28922 | 0.33912 | 1.05372 |
| 2000 | 0.65909 | 44 | 21.8594 | 1.63950 | 0.23221 | 1.03672 | 2.59275 |
| 2001 | 0.61905 | 21 | 6.8914 | 0.51687 | 0.38283 | 0.24669 | 1.08292 |
| 2002 | 0.44231 | 52 | 5.6057 | 0.42044 | 0.30216 | 0.23279 | 0.75935 |
| 2003 | 0.64935 | 77 | 16.4241 | 1.23184 | 0.22272 | 0.79331 | 1.91280 |
| 2004 | 0.41860 | 43 | 4.4729 | 0.33548 | 0.31992 | 0.17969 | 0.62634 |
| 2005 | 0.68182 | 44 | 9.7321 | 0.72993 | 0.24780 | 0.44796 | 1.18938 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2006 | 0.89583 | 48 | 37.8969 | 2.84234 | 0.18441 | 1.97167 | 4.09750 |
| 2007 | 0.77419 | 31 | 24.5363 | 1.84027 | 0.24935 | 1.12604 | 3.00753 |
| 2008 | 0.51282 | 39 | 4.9821 | 0.37367 | 0.27418 | 0.21809 | 0.64023 |
| 2009 | 0.80000 | 60 | 40.5835 | 3.04384 | 0.23536 | 1.91311 | 4.84287 |
| 2010 | 0.53333 | 30 | 4.7111 | 0.35335 | 0.36541 | 0.17406 | 0.71730 |
| 2011 | 0.40000 | 20 | 2.7178 | 0.20384 | 0.44724 | 0.08677 | 0.47884 |

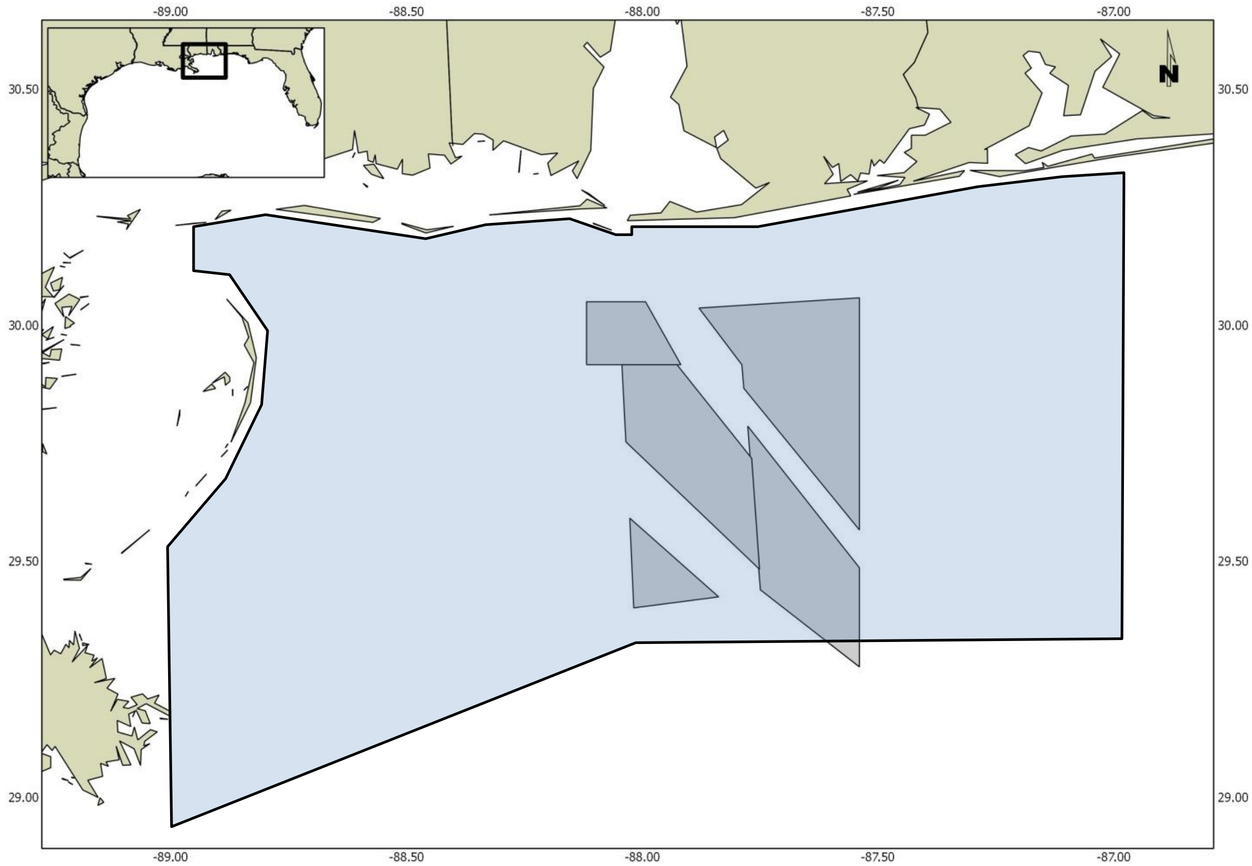


Figure 1. Alabama Artificial Reef Permit Area (gray area) located off the coast of Alabama in relation to the rest of the area sampled under the SEAMAP summer and fall groundfish surveys (blue area). Note that the current SEAMAP universe excludes the Alabama Artificial Reef Permit Area from its sampling universe.

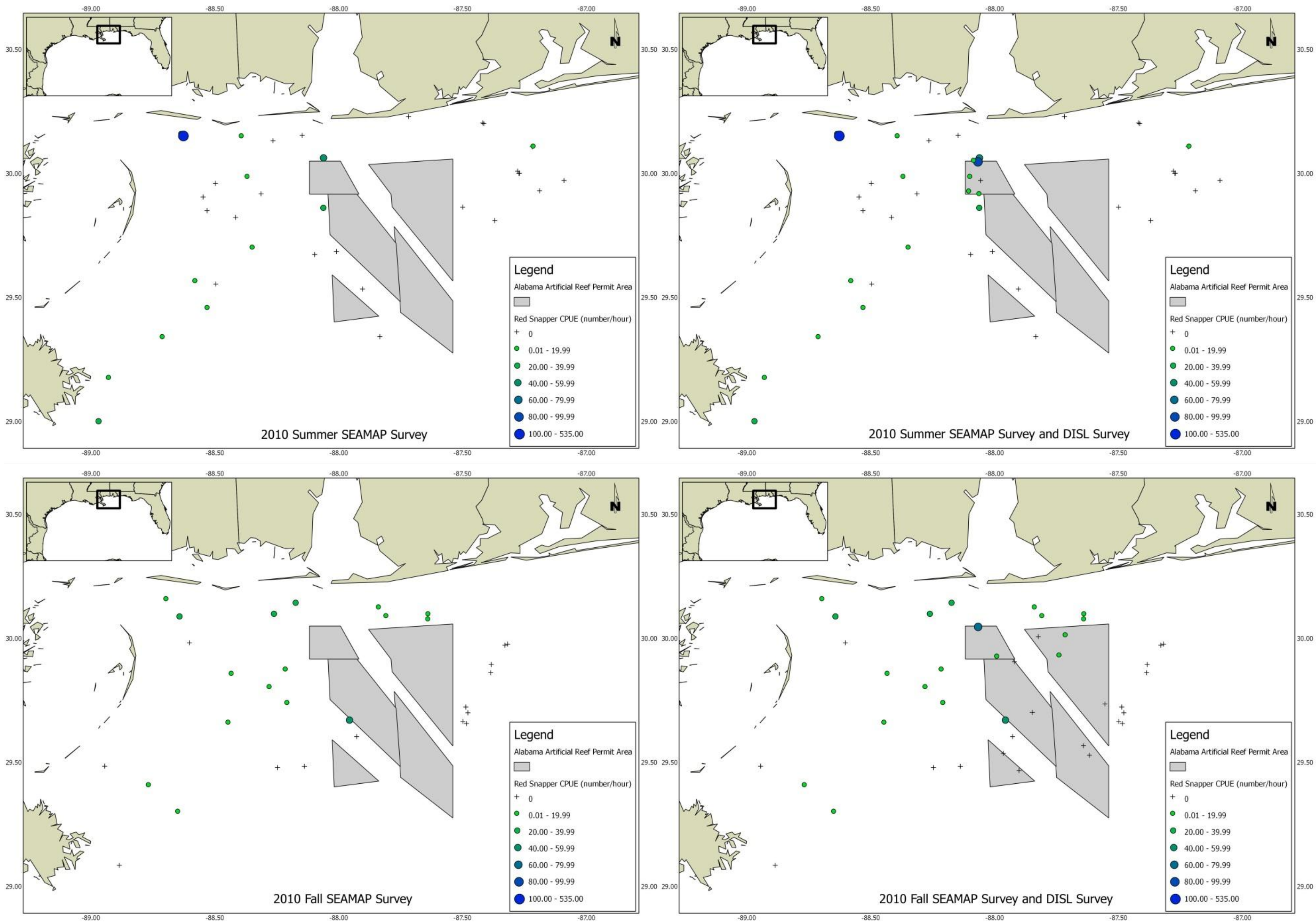


Figure 2. Spatial coverage and red snapper catch rates for the Summer and Fall SEAMAP Bottom Trawl Survey and the DISL Bottom Trawl Survey for 2010.

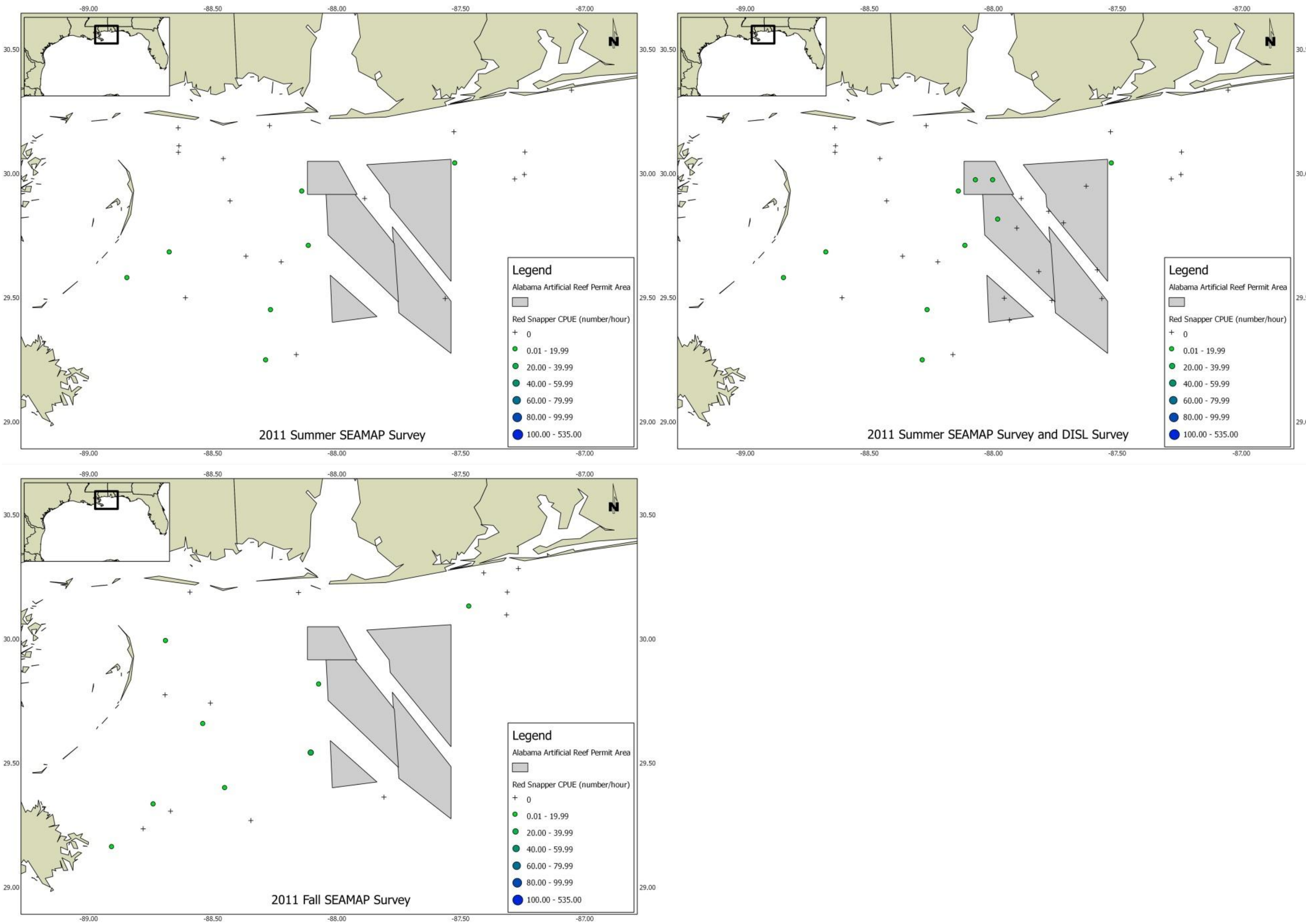


Figure 3. Spatial coverage and red snapper catch rates for the Summer and Fall SEAMAP Bottom Trawl Survey and the DISL Bottom Trawl Survey for 2011. Note that there were no stations from DISL in the fall.

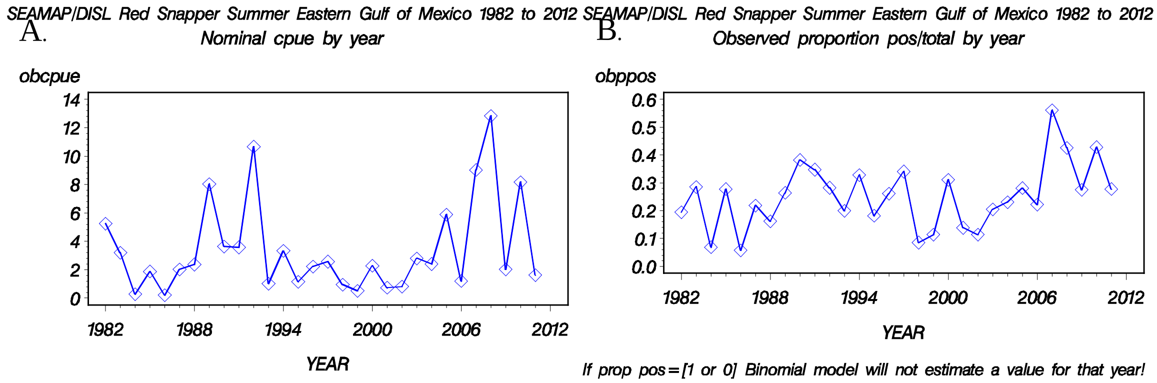


Figure 4. Annual trends for red snapper (EGOM / Summer) captured during Summer SEAMAP Groundfish Surveys from 1982 to 2011 in **A.** nominal CPUE and **B.** proportion of positive stations.

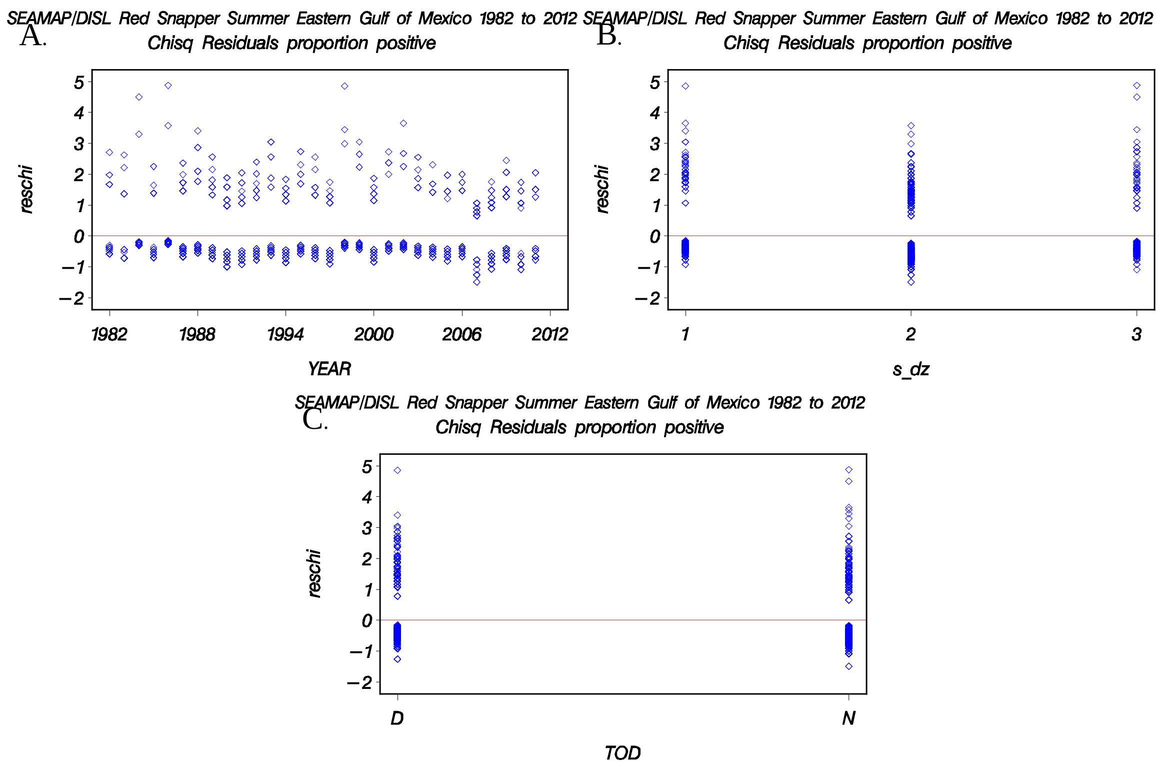


Figure 5. Diagnostic plots for binomial component of the red snapper SEAMAP Groundfish Survey (EGOM / Summer) model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by depth zone and **C.** the Chi-Square residuals by time of day.

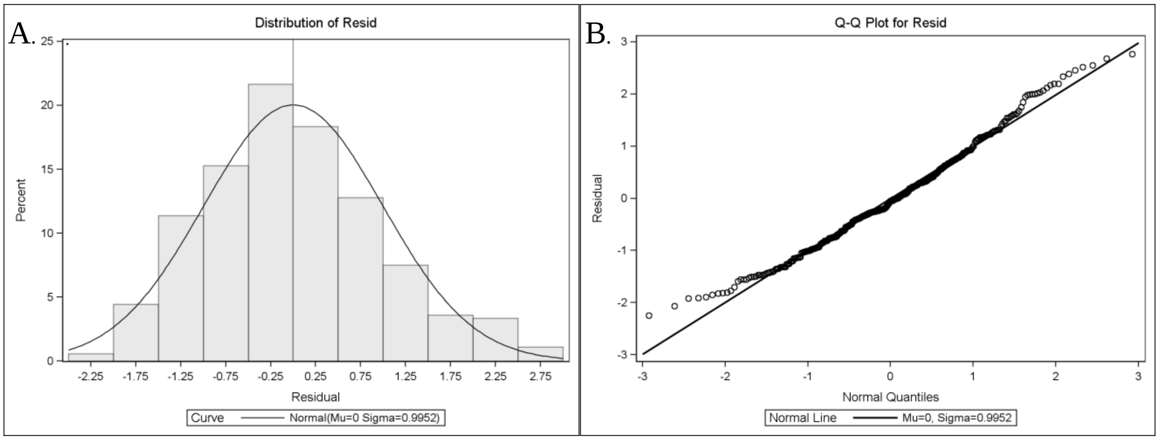


Figure 6. Diagnostic plots for lognormal component of the red snapper SEAMAP Groundfish Survey (EGOM / Summer) model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

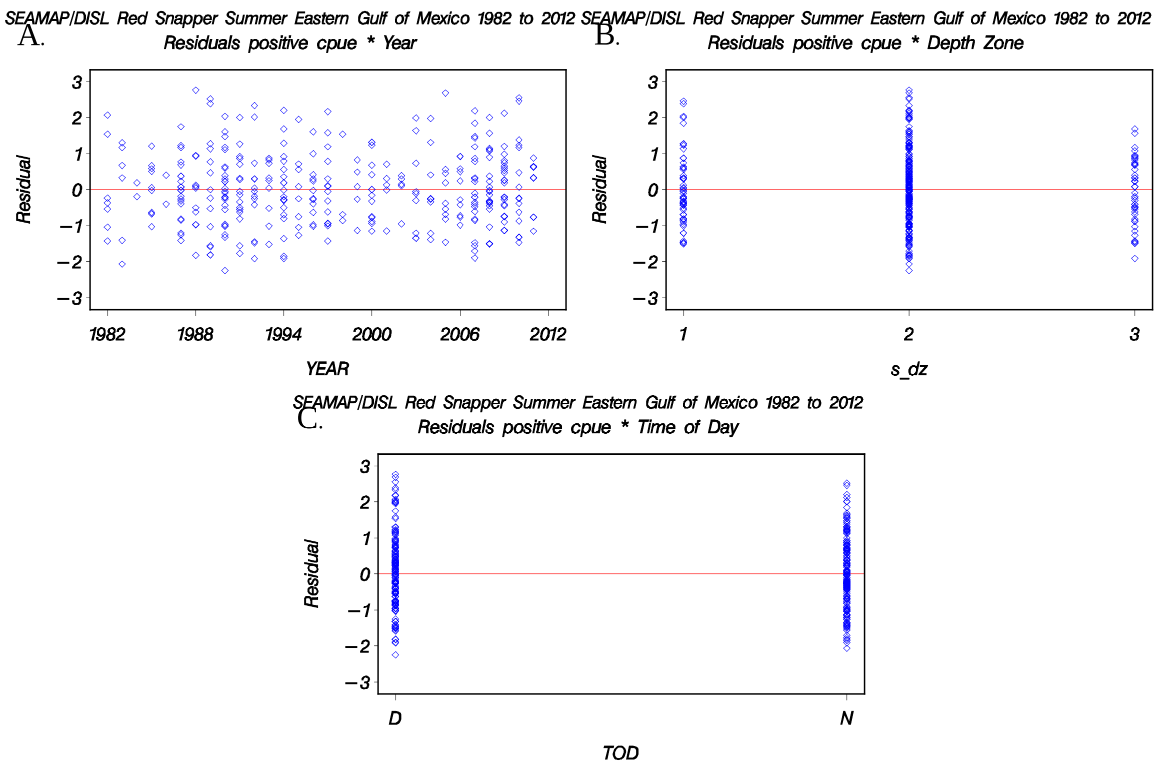


Figure 7. Diagnostic plots for lognormal component of the red snapper SEAMAP Groundfish Survey (EGOM / Summer) model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by depth zone and **C.** the Chi-Square residuals by time of day.

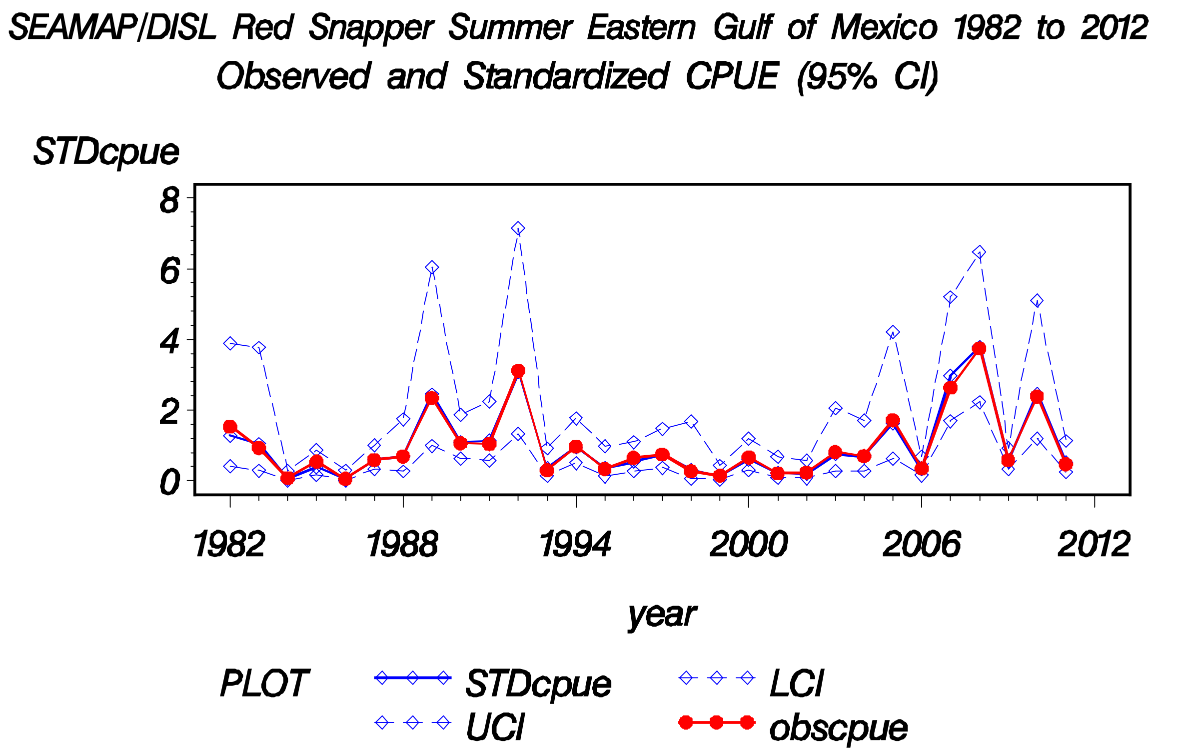


Figure 8. Annual index of abundance for red snapper (EGOM / Summer) from the SEAMAP Groundfish Survey from 1982 – 2011.

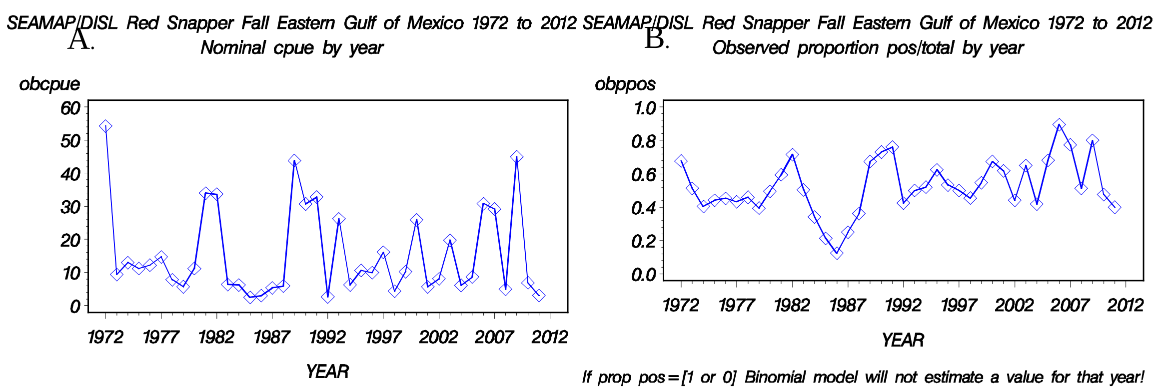


Figure 9. Annual trends for red snapper (EGOM / Fall) captured during Fall SEAMAP Groundfish Surveys from 1972 to 2011 in **A.** nominal CPUE and **B.** proportion of positive stations.

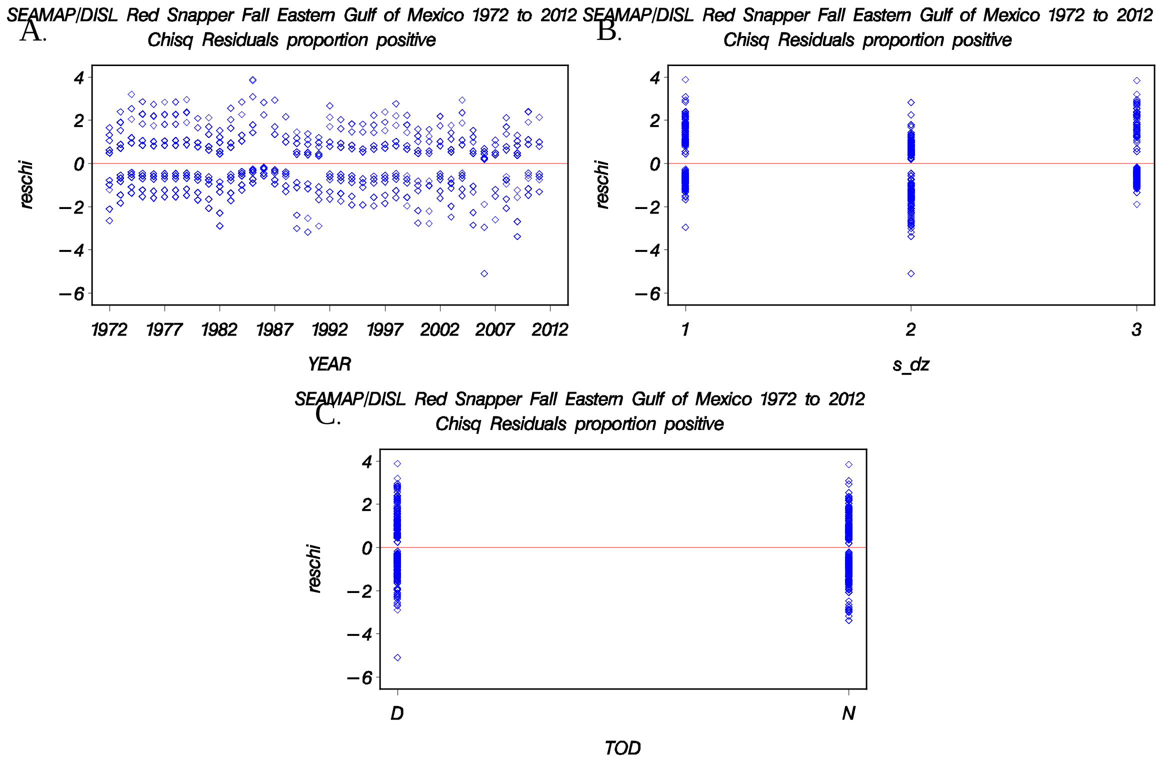


Figure 10. Diagnostic plots for binomial component of the red snapper SEAMAP Groundfish Survey (EGOM / Fall) model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by depth zone and **C.** the Chi-Square residuals by time of day.

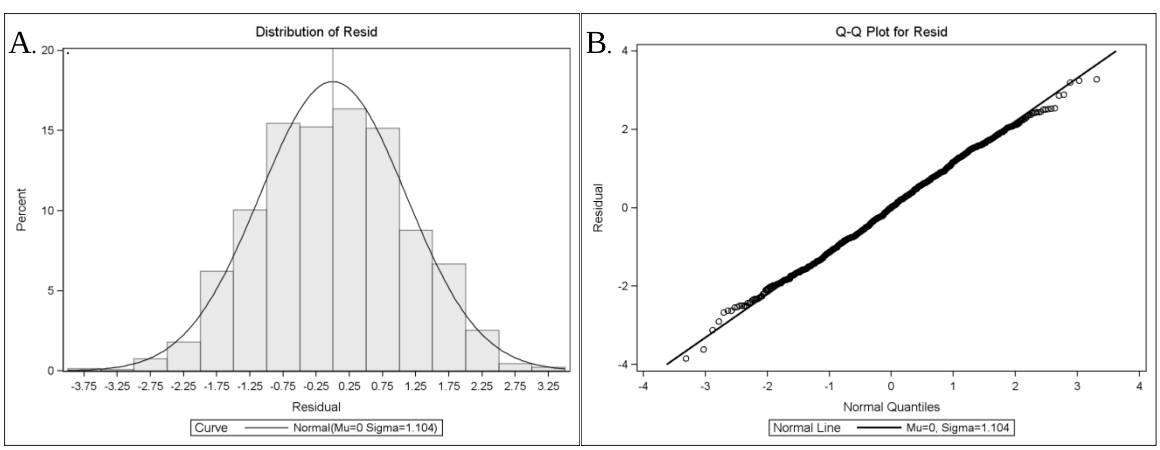


Figure 11. Diagnostic plots for lognormal component of the red snapper SEAMAP Groundfish Survey (EGOM / Fall) model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

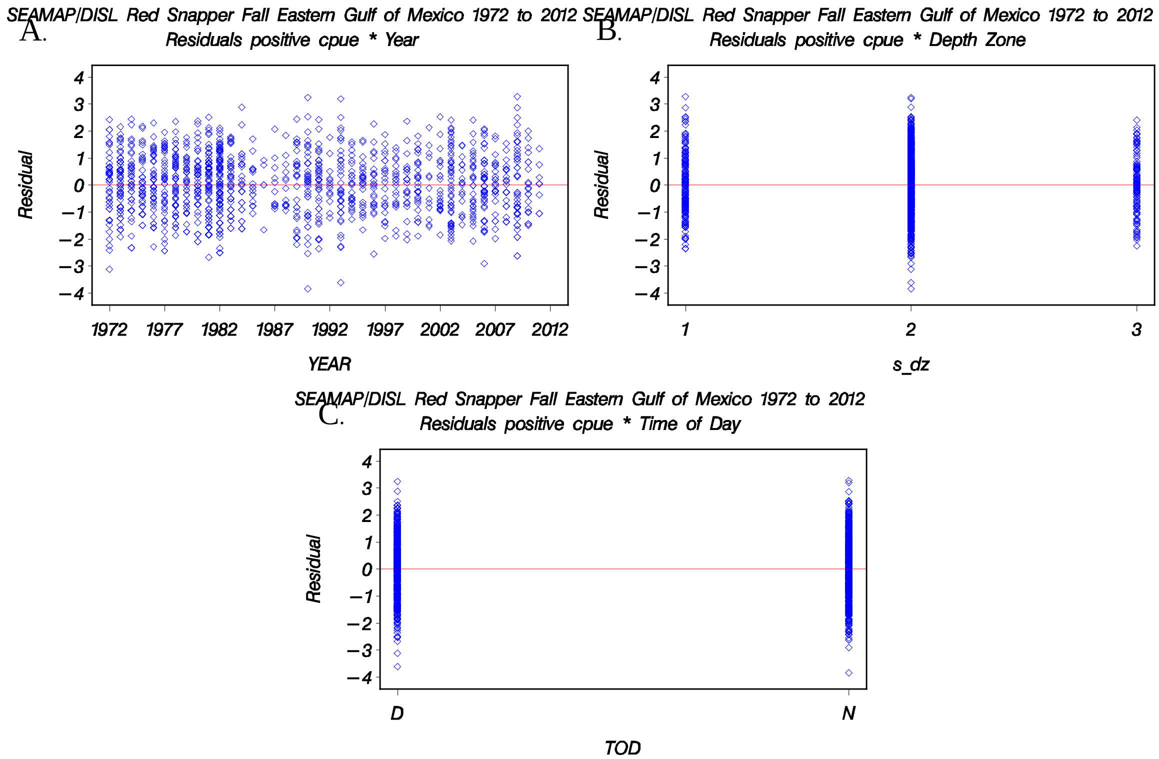


Figure 12. Diagnostic plots for lognormal component of the red snapper SEAMAP Groundfish Survey (EGOM / Fall) model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by depth zone and **C.** the Chi-Square residuals by time of day.

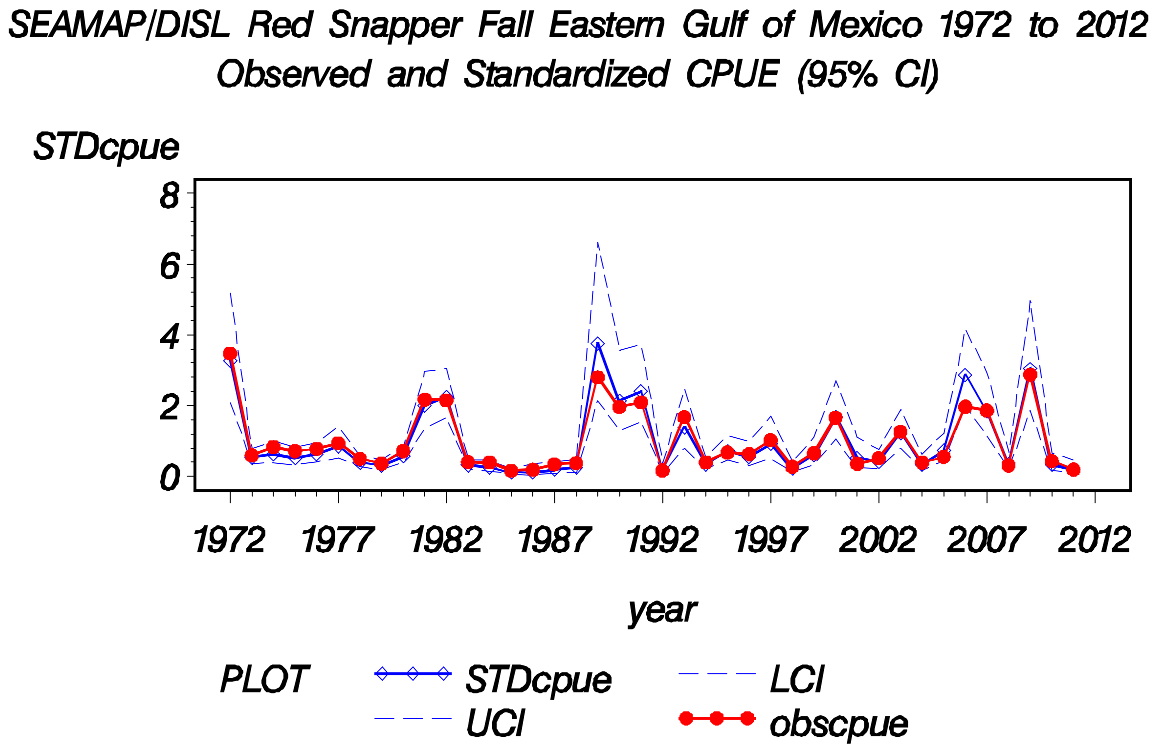


Figure 13. Annual index of abundance for red snapper (EGOM / Fall) from the SEAMAP Groundfish Survey from 1972 – 2011.

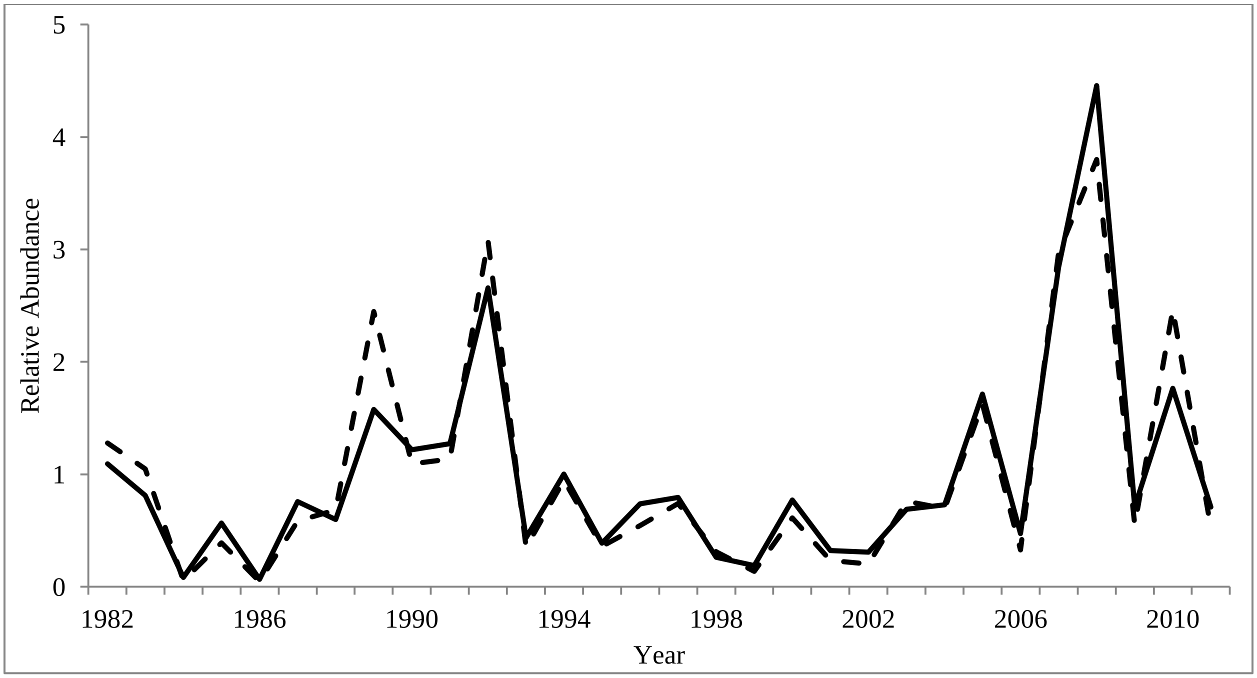


Figure 14. Comparison of relative abundance indices for red snapper from the summer SEAMAP (solid line) and combined SEAMAP/DISL (dashed line) surveys.

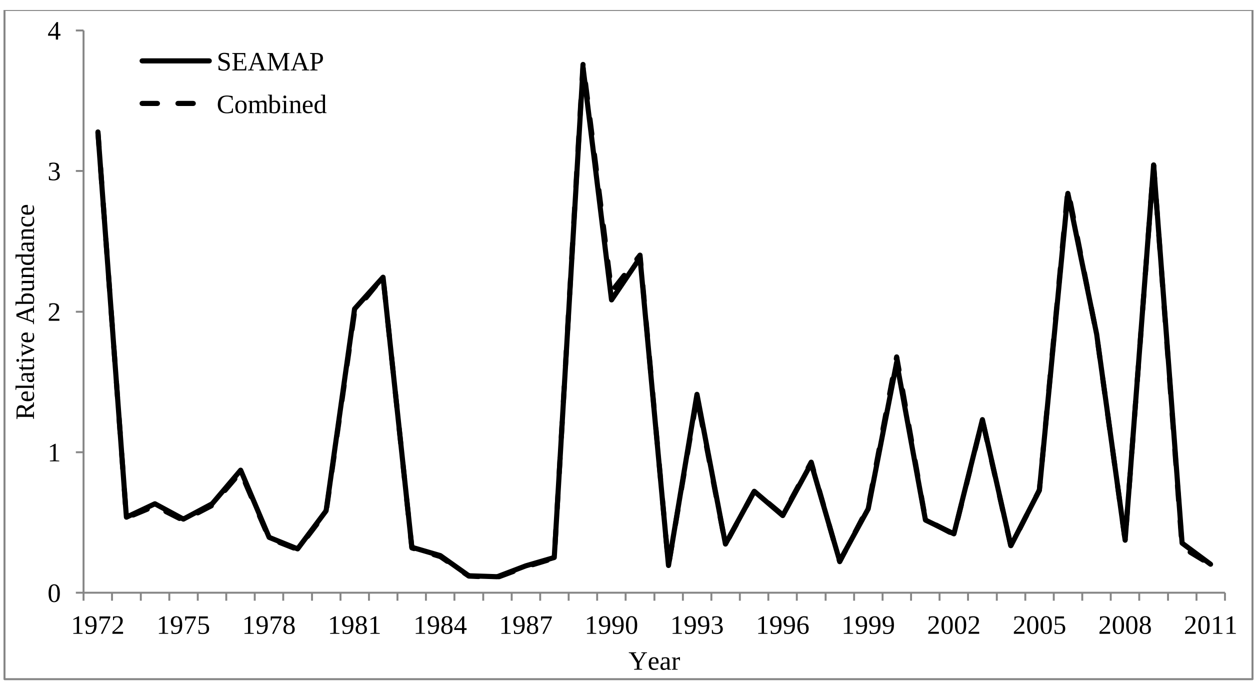


Figure 15. Comparison of relative abundance indices for red snapper from the fall SEAMAP (solid line) and combined SEAMAP/DISL (dashed line) surveys.