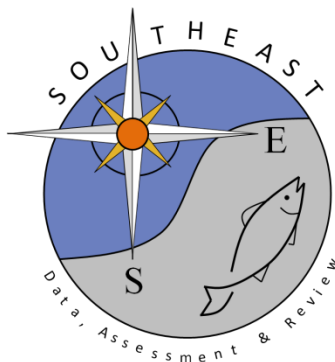


Standardized Catch per Unit Effort for US Gulf of America King Mackerel
(*Scomberomorus cavalla*) from the Southeast Region Headboat Survey

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SEDAR99-WP-10

10 April 2026



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Please cite this document as:

Nuttall, Matthew A. 2026. Standardized Catch per Unit Effort for US Gulf of America King Mackerel (*Scomberomorus cavalla*) from the Southeast Region Headboat Survey. SEDAR99-WP-10. SEDAR, North Charleston, SC. 22 pp.

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**NOAA Fisheries
Southeast Fisheries Science Center
Sustainable Fisheries Division
Data Analysis and Assessment Support Branch**

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04-10-2026

Abstract

This working paper describes a fishery-dependent index of abundance developed for the US Gulf of America King Mackerel stock in the SEDAR 99 stock assessment. This index is estimated from self-reported headboat logbook data collected by the Southeast Region Headboat Survey (SRHS) using a delta-lognormal approach. Index construction follows established procedures similar to those used in past assessments for this species (SEDAR 38 and 38U), but with the SEDAR 99 index extended through the new terminal year of 2024.

Introduction

The Southeast Region Headboat Survey (SRHS) collects catch, effort, and biological information from recreational headboats operating throughout the southeast region. As defined by SRHS, headboats are federally-permitted fishing vessels that charge anglers a per-head fee to fish for reef fish and coastal migratory pelagic species, typically over full day (8-10 hrs) or partial day trips (≈ 4 hrs) (Fitzpatrick et al. 2017). Conducted by the Beaufort Lab of the Southeast Fisheries Science Center (SEFSC), the SRHS was first implemented in the Carolinas in 1972 to provide estimates for the growing landings from this mode. The spatial extent of this survey has since grown, covering the entire South Atlantic by 1978 (NC through Monroe county, FL) and the Gulf of America by 1986 (South Padre Island, TX to Naples, FL) (SEDAR 79-DW-06).

The analysis described in this working paper is aimed at constructing an index of abundance for Gulf of America King Mackerel from SRHS headboat data. This analysis relies on industry-reported SRHS logbooks that provide trip-level data on species catch, effort, and associated catch rates. Information collected by these logbooks include vessel identification, a single fishing area for the entire trip (Figure 1), landing location and date, number of anglers, trip duration (in hours) and/or trip type (e.g., half day vs. full day).

Because the SRHS was designed to be a census, the catch records contained in these logbooks comprise the majority of headboat fishing activity across the southeast region, with compliance being near 100 percent since permits became tied to reporting requirements in 2008. Logbook catch records were submitted via paper forms until 2013, when the survey switched to electronic reporting. During this time, paper forms were largely state-specific as space constraints on the form required limiting the listed species to predominant taxa, which varied across the region. Logbook forms also tended to change over time, with most state-specific forms tending to add more species throughout the early years of the survey (SEDAR 79-DW-06, Appendix A in Fitzpatrick et al. 2017).

Methods

Catch per unit effort (CPUE) of Gulf of America King Mackerel by headboat anglers was calculated on an individual trip basis from SRHS logbook data. The CPUE for each trip was estimated as the number of King Mackerel landed on a trip divided by the fishing effort, where effort was the product of the number of anglers and total hours fished. As an estimate of total hours fished, we assumed a full-day of SRHS headboat fishing (as recorded in the trip type field) constitutes 10 hours, with all other trip types scaled proportionally (e.g., half-day = 5 hours). This decision to translate hours fished from trip type is based on the need for consistency in CPUE data, and considered a better alternative to using the trip length field (in hours) which is only available in SRHS logbook data after the switch to electronic reporting (2013+).

As described in working papers from previous assessments for this stock (SEDAR 2009, 2014), the SRHS abundance index constructed for SEDAR 99 was based on fishing year, defined as the period between July 01 to June 30 (SEDAR 16-DW-16, 38-DW-16). This is the temporal resolution at which the SEDAR 99 stock assessment model will be built, and so the associated data inputs have been adjusted accordingly.

Data Filtering

The following data preparation and filtering techniques are routinely applied to SRHS logbook data when constructing abundance indices:

- Trips with 6 or fewer anglers were excluded. It is rare for a headboat to fish with few anglers. There is anecdotal information that headboats would sometimes fish with just the crew and that logbooks for these trips were submitted. Experienced crew are likely to be more efficient at catching fish than paying customers. Captains may also limit distance to reduce fuel costs for trips with few paying customers.
- Trips with possible data errors were excluded, including trips with multiple catch records for a single species, potentially duplicated effort information, trips that report zero effort (i.e., number of anglers = 0), or trips with catch and effort values outside the 95% confidence intervals of the observed ranges.

Beyond these filters, SRHS indices for SEDAR 99 Gulf of America King Mackerel required additional decisions. In agreement with procedures followed in past SEDAR stock assessments for this species (SEDAR 16-DW-16, 38-DW-16, 2009, 2014, 2020):

- Vessels that fished for less than 10 years were excluded (SEDAR 16-DW-16). Logbooks submitted by vessels that participated infrequently in the fishery are likely to be less representative of true fishery trends. Of the 246 unique vessels in the SRHS logbook data base, this filter left catch records from 94 vessels available in developing a SRHS index for Gulf king mackerel. This filter is similar to that typically applied in constructing SRHS indices, namely to exclude vessels with fewer than 30 trips, and so was treated as its substitute.
- Observations in the Gulf of America were included from multiple headboat areas: 21 (SW Florida; 44.1%), 23 (NW FL and AL; 29.1%), 26 (Port Aransas, TX; 11.1%), 27 (Port Isabel, TX; 4.9%), 25 (NE Texas; 4.1%), 29 (Alabama; 3.4%), 24 (Louisiana; 2.4%), 28 (Mississippi; 0.9%), and 22 (FL Middle Grounds; 0%) (Figure 1). Note that observations from the winter “mixing zone” are also excluded due to an inability to distinguish trip-level catches between the South Atlantic and Gulf stocks.
- Observations were retained from half-day, three-quarter day, and full-day trips.
- Trips during the closed fishing season for King Mackerel were excluded.

Subsetting Trips: Species Associations

Because fishery-dependent data are not collected under a formal (e.g., stratified random) sampling design, the sampling intensity in any given area can vary substantially between years. In this, fishery-dependent data, by itself, may be insufficient to identify suitable habitat for the species-of-interest. In other cases, the data may allow for identification of habitat, but the associated sampling may be inconsistent or not reported at a fine enough resolution for the required analysis. Because such habitat designations are needed in controlling for absence (i.e., fish not available to be caught) when predicting the relative presence of species in trip-level catches, the construction of fishery-dependent indices requires some method to quantify effective effort and distinguish trips where a given species was present but not caught (i.e., fishing in suitable habitat) vs. trips where that species was not present (which are excluded from the analysis).

The trip selection approach applied for the SEDAR 99 SRHS index was the Stephens and MacCall (2004) method, which uses multiple logistic regression to estimate the probability of a focal species being present during a given trip based on the overall species composition of the catch and estimated associations of that focal species with any other species caught on the trip. The Stephens and MacCall (2004) approach was applied separately for the western US Gulf of America and eastern US Gulf of America due to suspected differences in species compositions between regions. Such differences have been suggested in other areas of the Gulf of America, linked to differences in habitat type between the eastern and western Gulf of America that are characterized by hard bottom habitats and less hard structure respectively (SEDAR 2011). These region-specific associations parameters are new to King Mackerel stock assessments but have been researched and applied in past SEDARs (e.g., SEDAR 68-DW-02, 68-DW-18, 88-WP-10).

Standardization

A two-stage delta-lognormal generalized linear model (GLM; Lo et al. 1992) was used to standardize catch rates from SRHS logbooks for any variability or non-randomness not caused by inter-annual fluctuations in stock abundance.

This method combines two separate generalized linear model components, one to describe the relative presence/absence of the focal species across all trips (i.e., proportion of headboat trips that caught at least one fish) and one to describe the catch rates of the focal species in those (positive) trips that successfully caught the species. In the first step, the proportion positive is modeled using a logit regression assuming a binomial error distribution of the response variable. In the second step, the logarithm of CPUE on positive trips was used as the response variable assuming a normal error distribution and an identity link function. The response variable for the lognormal model was calculated as:

$$\ln(\text{CPUE}) = \ln(\text{Catch}) / (\text{anglers} \times \text{hours fished})$$

A forward stepwise regression approach was applied to build both of these models, using the GENMOD procedure in SAS (SAS Institute 2008). In this procedure, factors were iteratively added to the base model and tested for retention (one at a time) based on the resultant percent reduction in deviance per degree of freedom. With each run of the model, the factor that caused the highest reduction in deviance was added to the base model (assuming the factor was significant based on a Chi-Square test with probability ≤ 0.05) until no factor reduced the percent deviance by the pre-specified level of 1%. Because the goal of this standardization was to model temporal trends in stock abundance, the year effect was always added as the first factor, whether it explained the most deviance or was even deemed significant. Once a set of fixed factors was identified, first level interactions were examined with significance evaluated between nested models using the likelihood ratio test. These interactions were screened and only retained if the model improvement was significant ($p < 0.0001$). All interaction terms retained in model building were treated as random effects.

Variation in catch rates by vessel was examined using a 'repeated measures' approach (Littell et al. 1998), which is the same approach taken in SEDAR 38 (SEDAR 38-DW-16) and followed in the SEDAR 38 Update (SEDAR 2020). The term repeated measures refers to multiple measurements taken over time on the same experimental unit (i.e. vessel). Specifying the repeated measure "VESSEL" and the subject "VESSEL(YEAR)" allows PROC MIXED to model the covariance structure of the data. This is particularly important because catch rates may vary by vessel and because catch rates by a given vessel that are close in time can have a higher correlation than those far apart in time (Littell et al. 1998).

Once constructed, the binomial and lognormal models were then combined to provide a single standardized index of abundance for SEDAR 99 Gulf of America King Mackerel. Predictions from the binomial (proportion positive) and lognormal (mean CPUE from positive trips) models were calculated from the estimated year effects and multiplied together to produce annual estimates of catch rate. This final delta-lognormal model was fit using the SAS GLIMMIX macro (glmm800MaOB.sas: Russ Wolfinger, SAS Institute) and the PROC MIXED procedure in SAS, which follows the procedures of Lo et al. (1992).

Results and Discussion

Trip Selection - Stephens and MacCall (2004) Approach - western US Gulf of America

The minimum difference between the predicted and the observed number of trips that reported King Mackerel occurred at the probability threshold of 0.48 (Figure 2A-A). The number of trips that observed and expected to catch a King Mackerel were largely consistent throughout the time series, with a noted increase in the early 1990s, but showed a consistent decline after ~2013 (Figure 2A-B). Nominal CPUE was relatively similar before and after applying the Stephens and MacCall (2004) approach (Figure 2A-C). The Stephens and MacCall (2004) trip subsetting approach identified 37 fish species that were positively/negatively associated with King Mackerel in the western US Gulf of America: Dolphin, Little Tunny, Cobia, and Spanish Mackerel were positively correlated to King Mackerel whereas Gafftopsail Catfish, Southern Kingfish, Red Drum, and Red Snapper were negatively correlated (Figure 3). Generally speaking, these interactions seem reasonable ecologically with western King Mackerel predicted to have the strongest positive interactions with other pelagics and strongest negative interactions with demersals.

Trip Selection - Stephens and MacCall (2004) Approach - eastern US Gulf of America

The minimum difference between the predicted and the observed number of trips that reported King Mackerel occurred at the probability threshold of 0.23 (Figure 2B-A). The number of trips that observed and expected to catch a King Mackerel were largely consistent throughout the time series, with a noted increase in the early 1990s and maybe an increase after ~2010, but both show a consistent decline after ~2015. Predicted trips appear overestimated in the first few years of the time series, and underestimated in the late 2010s (Figure 2B-B). Nominal CPUE was relatively similar before and after applying the Stephens and MacCall (2004) approach (Figure 2B-C). The Stephens and MacCall (2004) trip subsetting approach identified 35 fish species that were positively/negatively associated with King Mackerel in the eastern US Gulf of America: Spanish Mackerel, Little Tunny, Cobia, and Red Snapper were positively correlated to King Mackerel whereas White Grunt, Tomtate, Whitebone Porgy, and Pigfish were negatively correlated (Figure 3). Generally speaking, these interactions seem reasonable ecologically with eastern King Mackerel predicted to have the strongest positive interactions with other pelagics and strongest negative interactions with demersals.

Variable Selection

The following factors were treated as fixed effects and examined for possible influence on the proportion of positive trips and on catch rates of positive trips:

Name	DF	Details
(Fishing) Year	39	1986-2024
Area	9	21-29 (see also Figure 1)
Season	4	Jan-Mar, Apr-Jun, Jul-Oct, Nov-Dec
Month	12	1-12
Trip Type	3	Full day , Half day , Three quarter day
day/night	2	day, mixed
Red Snapper Season	2	Closed, Open
King Mack Size Limit	4	None, 12, 20, 24
King Mack Bag Limit	3	None, 2, 3

Concerns with Overfitting

Following the approaches applied in previous assessments for this stock (S16-DW-16, S38-DW-16), the SRHS abundance index constructed during SEDAR 99 model building initially included vessel effects as a 'repeated measure', allowing catch rates to vary by vessel. However, this treatment resulted in excess variability in the final standardized index and clear undesirable patterns in the residuals of the variables selected in the lognormal model, suggesting the model structure of the current 'repeated measure' approach is inappropriate for this dataset, and to which the model may be overfitting. Additionally, there remains concern as to whether a vessel effect is needed or even estimable for the SRHS headboat fleet. The vast majority of fishing on a headboat is conducted by the general public, whose experience and skillset may vary drastically across anglers within a given trip and across trips for a given vessel. Decisions on the type and location of fishing are often made by trip, and not always consistent for a given vessel. Given the aforementioned modeling issues with vessel effects, as noted in past SRHS data provisions (SEDAR 43-WP-06, SEDAR 62-WP-03), *a priori* concerns in the inherent variability of this factor and what driver(s) are truly being captured by a vessel effect, and in agreement with standard practices for other fishery-dependent indices (SEDAR 99-WP-07), the decision for SEDAR 99 was to exclude vessel from consideration during model building. Future research may focus on evaluating alternative parameterizations of the 'repeated measure' approach, including alternative structures of the associated covariance matrix.

Similar concerns with overfitting were noted when allowing for fixed effects from a month variable and multiple interaction terms in the standardization. Indices in previous King Mackerel assessments tested for (and retained) effects from a seasonal variable, but month was not mentioned as a candidate predictor variable despite season being defined from month (S16-DW-16, S38-DW-16). Believing the additional flexibility in monthly parameters were contributing to overfitting, and possibly their omission from past indices, the month variable was dropped from consideration in SEDAR 99 in favor of season. Additionally, variable selection in SEDAR 99 tended to retain most/all of the interactions tested in stepwise model building. In particular, based on the 1% deviance-explained criteria, both the binomial and lognormal components each retained three fixed factors and the three associated interaction terms. Concerned with overfitting, given the resultant residual patterns and fluctuations in the final index, model building in SEDAR 99 was limited to retention of a single interaction term in both components, resulting in exclusion of additional interactions that explained no more than 2% of the remaining deviance.

Annual Abundance Indices

Final deviance tables for the Gulf of America index are included in Table 1.

The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive trips) models were:

$$\textit{ProportionPositive} = \textit{Year} + \textit{Area} + \textit{Season} + \textit{Year} * \textit{Area}$$

$$\ln(\textit{CPUE}) = \textit{Year} + \textit{Area} + \textit{Season} + \textit{Year} * \textit{Area}$$

Diagnostics for each of these GLMs are provided in Figures 3 and 4, respectively, and the resultant annual index is summarized in Table 2. The dispersion parameter for the binomial component was estimated at 3.76, indicating some overdispersion in the data with respect to the specified model distribution. Predictions for proportion positive ranged between 0.05 and 0.46, but generally remained between 0.24 and 0.38 with a mean of 0.29 (Figure 3A). The binomial model consistently underestimated the proportion of positive trips, but no noticeable pattern was seen in the residuals (Figure 3B-3D). The lognormal model results suggest a good fit to the data and indicated that the assumption of a lognormal distribution for positive catch rates was appropriate for the data. Residual analysis of the lognormal model also showed no obvious patterns in residuals across factors (Figure 4).

The variables selected in the binomial and lognormal models for SEDAR 99 are generally similar to those in past assessments. The same set of fixed effects was retained in SEDAR 38 for both the binomial and lognormal components (SEDAR 38-DW-16), and in SEDAR 16 for the binomial component but not in the lognormal component which did not include season, although two interaction terms with season were retained (SEDAR 16-DW-16). The interaction terms also differed, with SEDAR 99 showing a larger effect from Year*Area interactions than in previous assessments. This may be a function of the general decline in

SRHS headboat catch rates over the last decade (Figure 5), in that these interactions may be capturing localized depletion of King Mackerel in certain headboat areas. Conversely, the relative importance of the Area effects in the SEDAR 99 index may also be a function of the decision to exclude random vessel effects, in that the two variables are likely correlated if certain headboat vessels have a tendency to fish in particular areas.

Figure 5 summarizes the standardized index, corresponding lower and upper 95% confidence limits, and nominal CPUE for the Gulf of America King Mackerel abundance index. Nominal CPUE values fell within the 95% confidence interval of the standardized index, with the exception of the years 1996 and from 2019-2021. Relative abundance peaked in 1996 (at 2.33) and was at the lowest value in 2022 (at 0.05). In the standardized index, relative abundance remained below the time series mean over the first few years (1986-1990), remained relatively high over the next twenty years (1991-2009), and show a general decline over the last ~15 years (2010+).

This index largely follows those provided for previous SEDAR stock assessments of Gulf of America King Mackerel (Figure 6). The general trends in these indices largely agree, but the overall magnitude of fluctuations tends to be higher in the SEDAR 99 index. This is likely due to inclusion of catch rates from the most recent years, which show a fairly drastic reduction in King Mackerel catch which increases earlier peaks due to the relativization of the index (to the global mean).

Comments on Adequacy for Assessment

The SRHS index provides one of the longest time series (1986+) and has widespread spatial coverage compared to other indices, and was selected for use in the final models of past assessments for this stock (SEDAR 2009, 2014, 2020). For SEDAR 99, it was constructed stepwise, starting with a continuity that used the same assumptions but into which different methodological improvements have been incorporated (i.e., exclusion of vessel effects, region-specific estimates of Stephens and MacCall species-association parameters). It predicts the same general trends as in past assessments, but with scale differing as a function of the relatively low catch rates observed over the most recent time period (Table 2, Figure 5).

Part of a fishery-dependent survey, SRHS data is not collected under a formal (e.g., stratified random) survey design and so can be influenced by any number of processes for which sampling does not control. Of particular concern, there have been multiple changes to management regulations over the last couple of decades in the Gulf of America, any of which may cause spatiotemporal shifts in fishing effort or changes to angler behavior, influencing catchability, selectivity, and associated catch rates. As such, more recent SRHS indices provided for SEDAR stock assessments (SEDAR 88-WP-10, 100-DW-09) have truncated this index at an earlier terminal year to exclude more recent years from the standardization.

With regards to SEDAR 99, the SRHS abundance index shows a fairly drastic drop in King Mackerel catch rates over the last 10-20 years, bottoming out at ~ 0.1 over the most recent years (Figure 5). This trend is seen in both the nominal and standardized catch rates, and so is a characteristic of the SRHS headboat data and not due to modeling decisions or methods. However, it remains unclear whether it is indicative of a real reduction in stock abundance or some other mechanism effecting angler behavior. Attempts were made to control for such effects in the standardization, but testing was largely limited to those restrictions aimed directly at King Mackerel (i.e., size and bag limits), neither of which were retained as significant variables in the final standardized index (Table 1). Naturally, regulations aimed at other stocks could also be tested, but it is not currently feasible to compile such a dataset given the complexities of regional management actions (e.g., aimed at different species or complexes, different restrictions between state vs. federal waters). It is also statistically indefensible, as the probability of retaining a spurious effect increases with the number of candidate predictor variables tested, in that some *a priori* hypothesis of a possible cause-and-effect relationship should be developed first. With this in mind, the standardized SRHS index for SEDAR 99 is being provided through the terminal year (i.e., fishing year of 2024) as requested by assessment analysts and encouraged in the Terms of Reference. However, there are concerns that the submitted trends in the SRHS index may be confounded by drivers other than population abundance, which hopefully can be relieved through comparison to other data sources as they become available (e.g., fishery-independent indices).

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Table 1. Deviance tables for the generalized linear models for King Mackerel in the Gulf of America. The table shows the order of the factors as they were sequentially added stepwise to each model. Fit diagnostics listed for each factor represent diagnostics from a model with that factor and all other factors listed above it. Although summarized below, variables in the filled cells were not ultimately retained in the final standardized index.

Binomial

Factor	DF	Deviance	Residual Df	Residual Deviance	AIC	% Deviance Reduced	log likelihood	Likelihood Ratio Test
Null	1	64,855.3	46,992	64,855.3	64,857.2		-32,427.6	
Year	40	63,064.7	46,953	1,790.6	63,146.6	2.68	-31,532.3	1,790.6
Area	9	57,336.7	46,945	5,728.0	57,436.8	9.07	-28,668.4	5,727.8
Season	4	55,462.5	46,942	1,874.2	55,570.6	3.26	-27,731.3	1,874.2
Year*Area	215	54,334.4	46,728	1,128.1	54,872.4	1.59	-27,167.2	1,128.2
Year*Season	107	53,406.2	46,622	928.2	54,158.2	1.48	-26,703.1	928.2

Lognormal

Factor	DF	Deviance	Residual Df	Residual Deviance	AIC	% Deviance Reduced	log likelihood	Likelihood Ratio Test
Null	1	49,779.3	25,343	49,779.3	89,033.8		-44,515.9	
Year	40	48,889.6	25,304	889.7	88,656.8	1.64	-44,287.4	457.0
Area	9	34,709.3	25,296	14,180.3	79,993.0	28.98	-39,946.5	8,681.8
Season	4	33,922.8	25,293	786.5	79,420.2	2.25	-39,656.1	580.8
Year*Area	195	32,453.2	25,099	1,469.6	78,687.6	3.59	-39,094.8	1,122.6
Year*Season	105	31,702.4	24,995	750.8	78,304.4	1.91	-38,798.2	593.2
Area*Season	20	31,276.1	24,976	426.3	78,001.4	1.27	-38,626.7	343.0

Table 2. Summary of the annual SRHS abundance index constructed for Gulf of America King Mackerel (stdCPUE) and the data used to inform it, including the total number of trips (N), those positive with King Mackerel catch (Npos), proportion of positive trips (PPT), and the relative nominal (nomCPUE) and standardized CPUE (stdCPUE). Uncertainty estimates are provided as the coefficient of variation (CV), and the upper (UCI) and lower (LCI) 95% confidence intervals.

Year	N	Npos	PPT	nomCPUE	stdCPUE	LCI	UCI	CV
1986	901	412	0.4573	0.7320	0.5481	0.2535	1.1853	0.4004
1987	592	368	0.6216	1.1122	0.8223	0.3810	1.7747	0.3993
1988	694	379	0.5461	1.0179	0.7641	0.3505	1.6655	0.4049
1989	916	426	0.4651	0.8820	0.6982	0.3187	1.5297	0.4077
1990	812	439	0.5406	0.9447	0.6577	0.3237	1.3367	0.3660
1991	859	571	0.6647	0.9485	1.6015	0.8347	3.0727	0.3347
1992	1,362	803	0.5896	1.1081	1.5939	0.8250	3.0794	0.3384
1993	1,459	847	0.5805	1.0158	1.5892	0.8178	3.0883	0.3416
1994	1,802	1,135	0.6299	1.0086	1.8342	0.9731	3.4570	0.3250
1995	1,477	905	0.6127	1.2142	1.8074	0.9311	3.5087	0.3410
1996	1,540	905	0.5877	1.1796	2.3298	1.2316	4.4071	0.3270
1997	1,756	1,036	0.5900	1.2334	1.3531	0.6894	2.6560	0.3470
1998	1,326	704	0.5309	1.1334	1.4787	0.7271	3.0072	0.3664
1999	1,242	635	0.5113	0.9189	1.3960	0.6845	2.8469	0.3679
2000	1,389	692	0.4982	0.9543	1.0284	0.4994	2.1180	0.3733
2001	1,510	686	0.4543	0.8771	0.8883	0.4199	1.8789	0.3881
2002	1,667	939	0.5633	1.3254	1.0780	0.5352	2.1712	0.3611
2003	1,335	654	0.4899	0.8338	0.8717	0.4136	1.8371	0.3861
2004	1,506	835	0.5544	1.3826	1.0731	0.5236	2.1996	0.3707
2005	1,376	896	0.6512	1.8429	1.9343	1.0114	3.6992	0.3329
2006	1,438	865	0.6015	1.5023	1.5279	0.7876	2.9641	0.3406
2007	1,127	588	0.5217	0.9850	1.1032	0.5564	2.1877	0.3526
2008	1,311	724	0.5523	1.2728	1.5195	0.7743	2.9817	0.3469

Year	N	Npos	PPT	nomCPUE	stdCPUE	LCI	UCI	CV
2009	1,358	938	0.6907	1.5756	1.8953	0.9997	3.5933	0.3282
2010	1,143	686	0.6002	1.6838	1.0063	0.5058	2.0020	0.3544
2011	1,577	969	0.6145	1.3851	1.1859	0.6232	2.2568	0.3302
2012	1,710	1,055	0.6170	1.0594	0.8589	0.4472	1.6500	0.3353
2013	1,579	822	0.5206	0.8047	0.4972	0.2449	1.0091	0.3653
2014	1,602	852	0.5318	0.9679	0.6851	0.3496	1.3429	0.3462
2015	1,574	790	0.5019	0.7265	0.5151	0.2581	1.0279	0.3560
2016	1,379	716	0.5192	1.0639	0.7230	0.3625	1.4419	0.3557
2017	1,016	510	0.5020	0.7719	0.5854	0.2898	1.1825	0.3627
2018	900	435	0.4833	0.8142	0.4471	0.2123	0.9416	0.3857
2019	705	318	0.4511	0.9017	0.3779	0.1664	0.8584	0.4280
2020	715	265	0.3706	0.7763	0.3395	0.1500	0.7685	0.4262
2021	754	196	0.2599	0.5238	0.1564	0.0658	0.3718	0.4541
2022	658	104	0.1581	0.0857	0.0548	0.0205	0.1467	0.5238
2023	435	74	0.1701	0.1361	0.0633	0.0219	0.1826	0.5691
2024	394	79	0.2005	0.2977	0.1103	0.0367	0.3309	0.5937

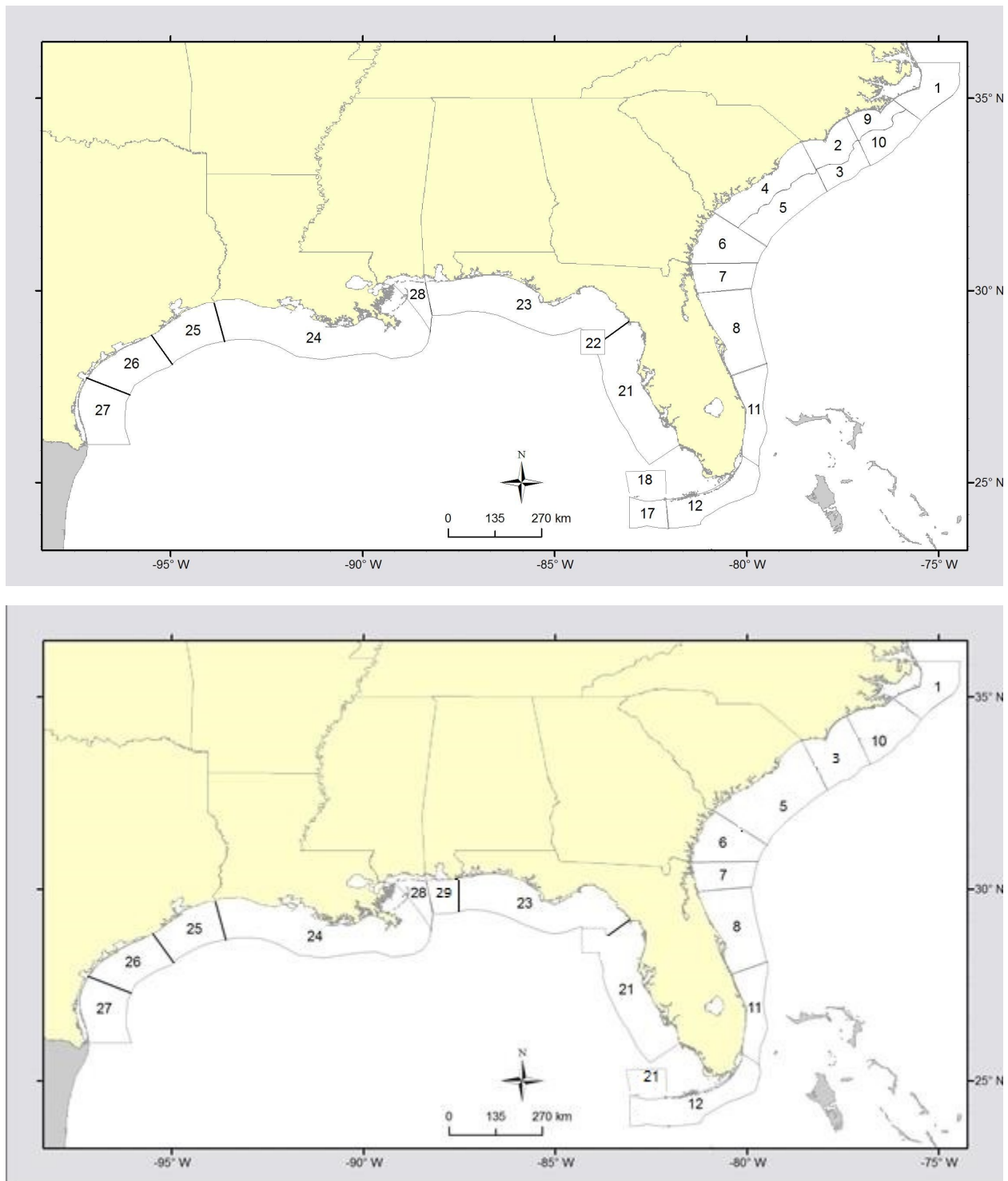


Figure 1. Headboat sampling areas for years prior to 2013 (top) and from 2013 to present (bottom).

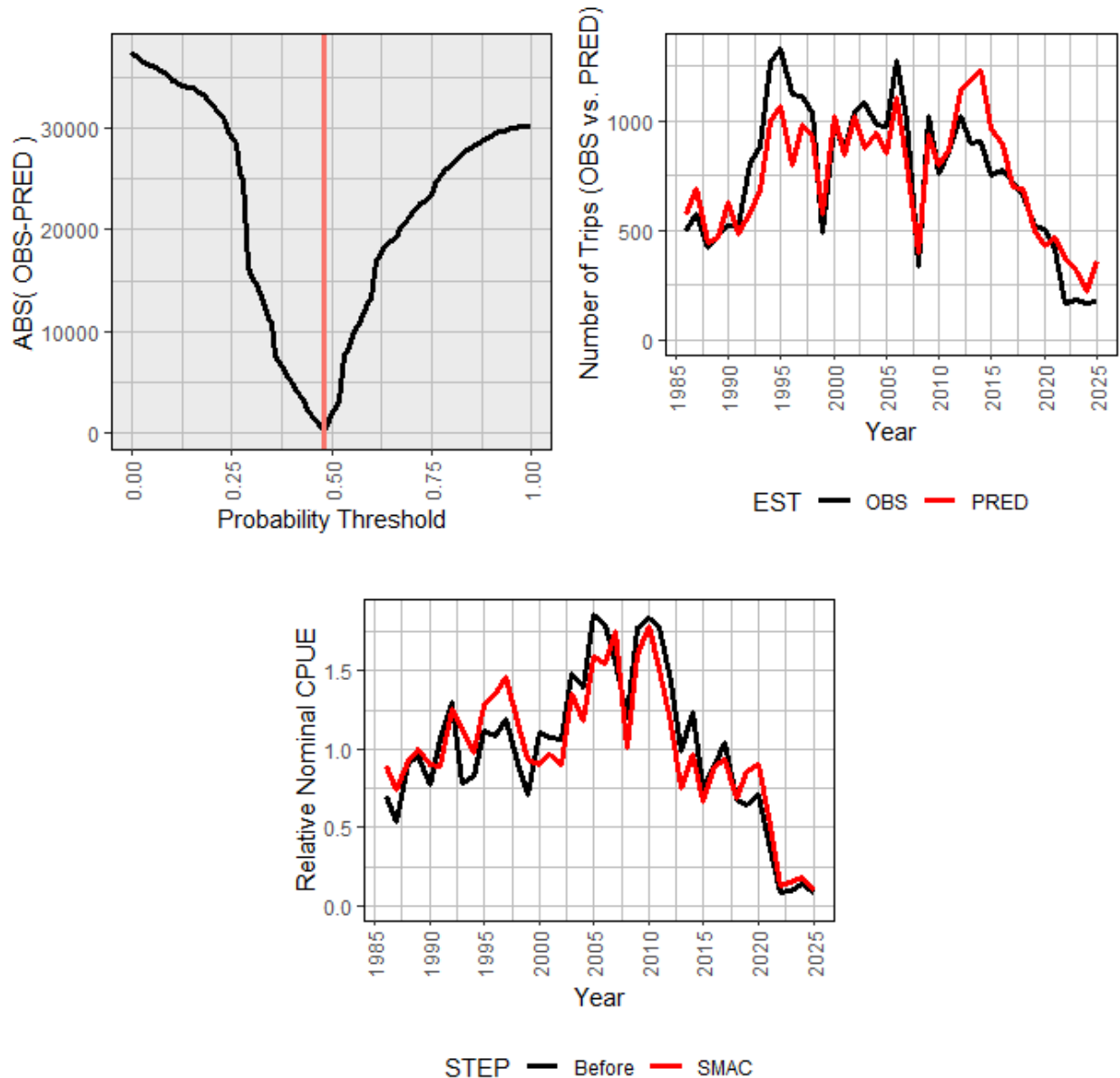


Figure 2A. Diagnostic Plots for Stephens and MacCall (2004) trip selection for the western US Gulf of America to include (A) the absolute difference in number of trips with observed King Mackerel catch versus that predicted for each probability threshold, (B) the associated annual time series for numbers of trips with observed and predicted King Mackerel catch, and (C) nominal catch rates “Before” and after “SMAC” Trip Selection. As illustrated by panel (A), the Stephens and MacCall (2004) approach minimizes the number of incorrect predictions (both false positives and negatives) by applying a probability threshold as a **critical value** to minimize errors, below which individual trips are excluded. This critical value (0.48) is highlighted as a red vertical line in panel (A).

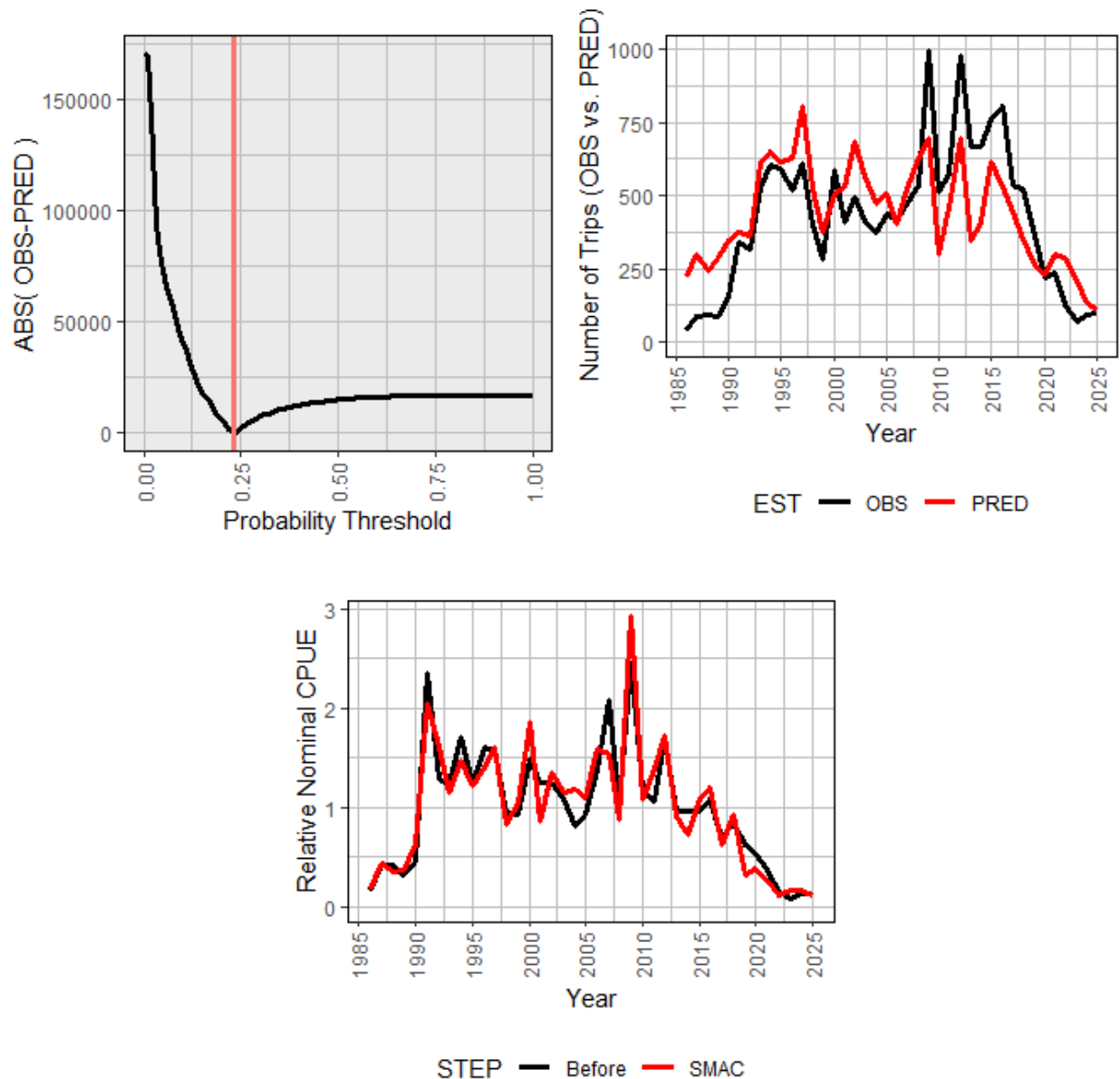


Figure 2B. Diagnostic Plots for Stephens and MacCall (2004) trip selection for the eastern US Gulf of America to include (A) the absolute difference in number of trips with observed King Mackerel catch versus that predicted for each probability threshold, (B) the associated annual time series for numbers of trips with observed and predicted King Mackerel catch, and (C) nominal catch rates “Before” and after “SMAC” Trip Selection. As illustrated by panel (A), the Stephens and MacCall (2004) approach minimizes the number of incorrect predictions (both false positives and negatives) by applying a probability threshold as a **critical value** to minimize errors, below which individual trips are excluded. This critical value (0.23) is highlighted as a red vertical line in panel (A).

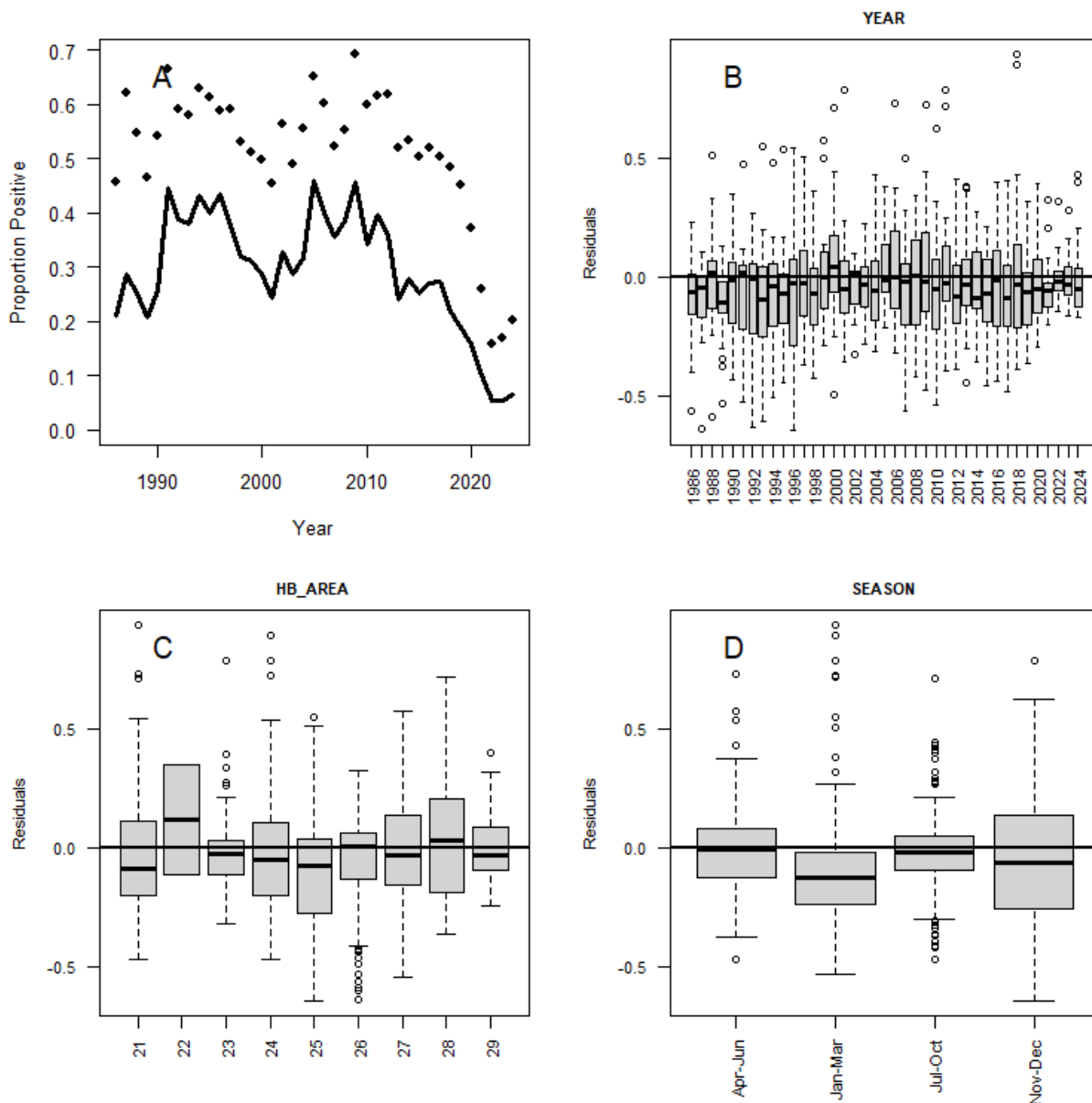


Figure 3. Diagnostic plots for the Binomial component (i.e., proportion positive) of the final delta-lognormal GLM, including the (A) comparison of observed (solid circles) vs. predicted (solid line) proportion of positive trips (i.e., with King Mackerel catch) by year, and the distribution of residuals by (B) YEAR, (C) HB_AREA, (D) SEASON.

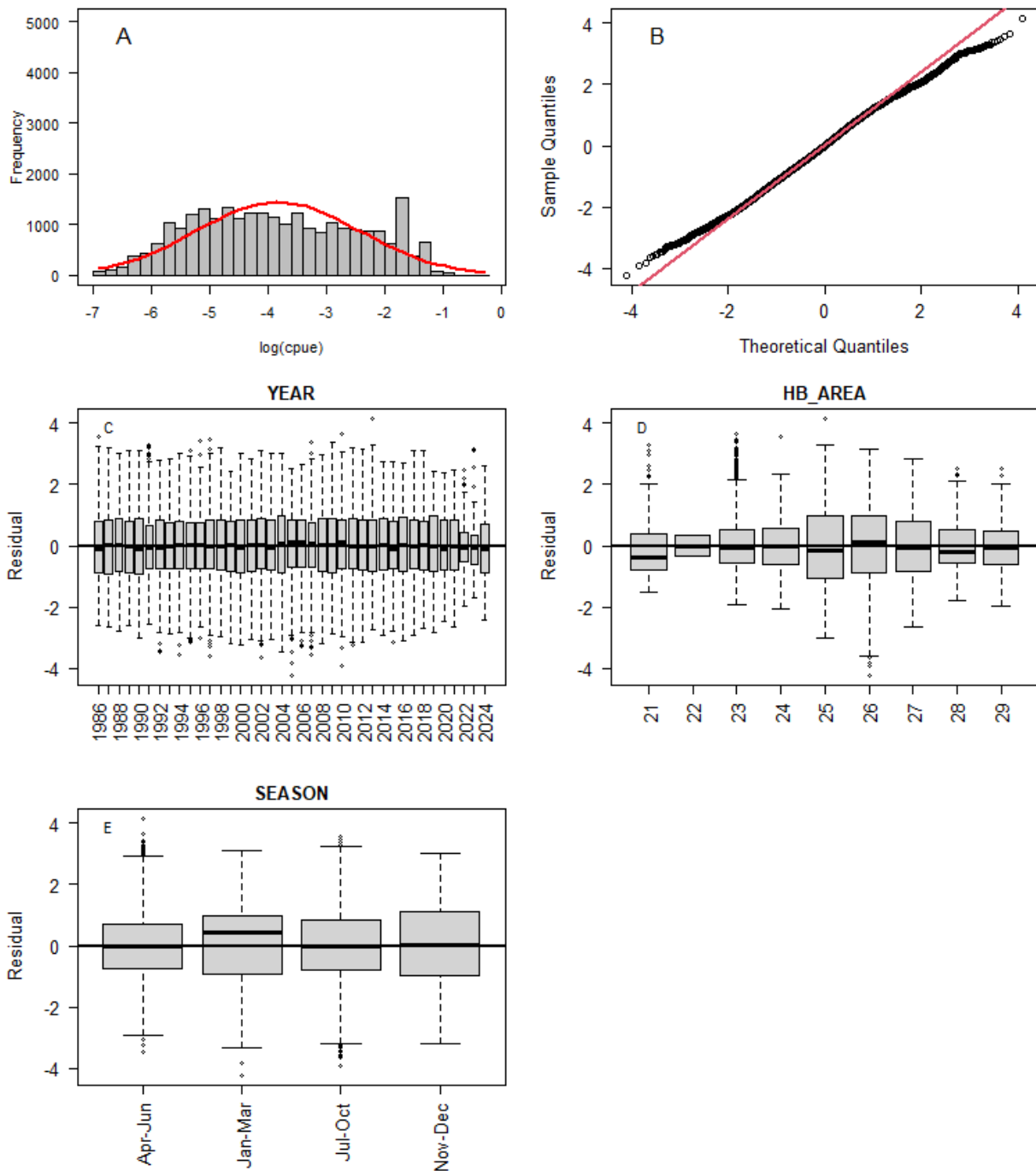


Figure 4. Diagnostic plots for the Lognormal component (i.e., catch rates of King Mackerel from positive trips) of the final delta-lognormal GLM, including (A) frequency distribution of log-transformed catch rates, (B) cumulative normalized residuals, and the distribution of residuals by (C) YEAR, (D) HB_AREA, (E) SEASON. The red lines represent the expected normal distribution.

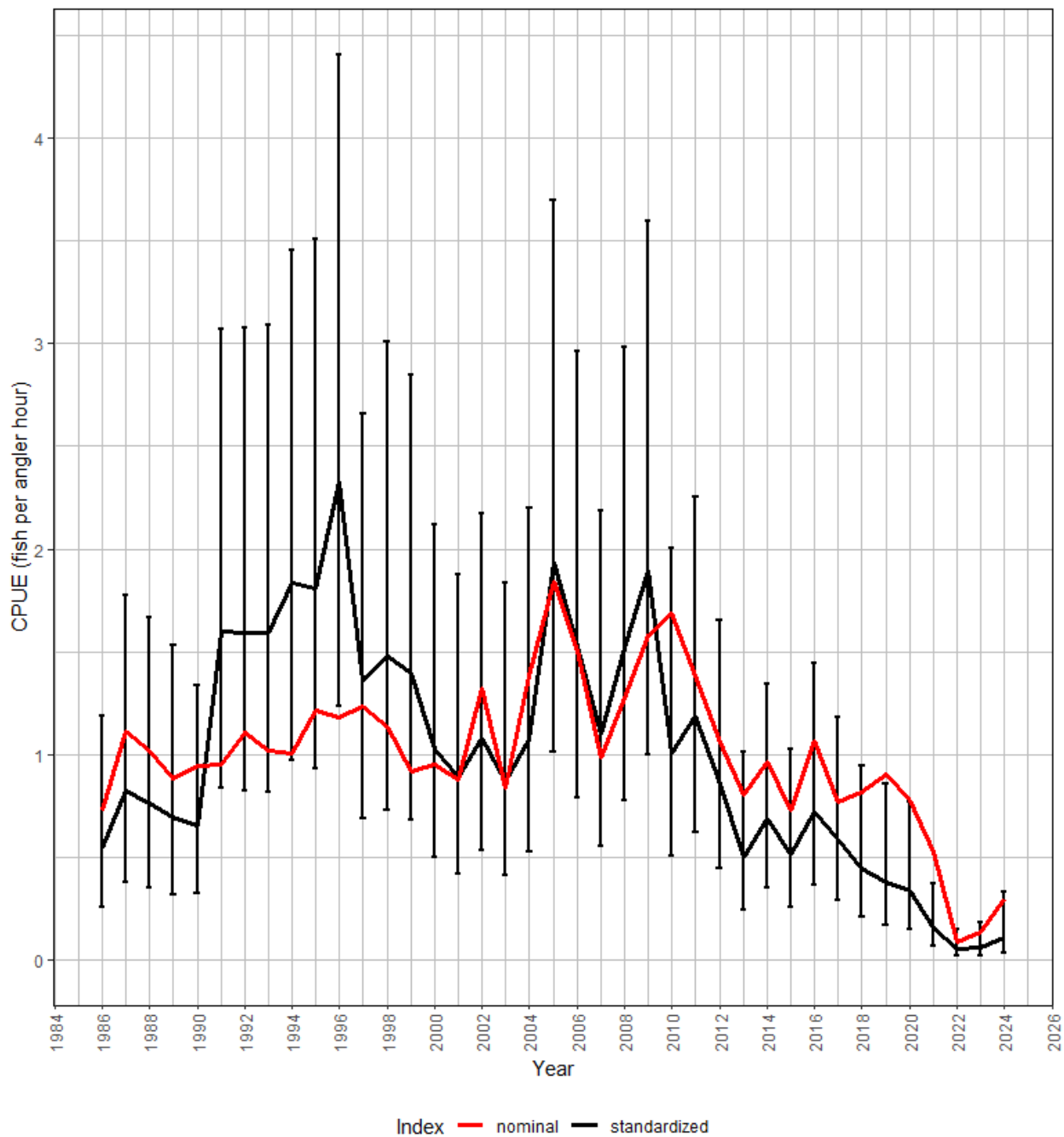


Figure 5. Standardized abundance index (black line), with 95% confidence interval (bars), for SEDAR 99 Gulf of America King Mackerel as compared to the associated nominal rates (red line), both of which have been rescaled to the mean values of their respective timeseries.

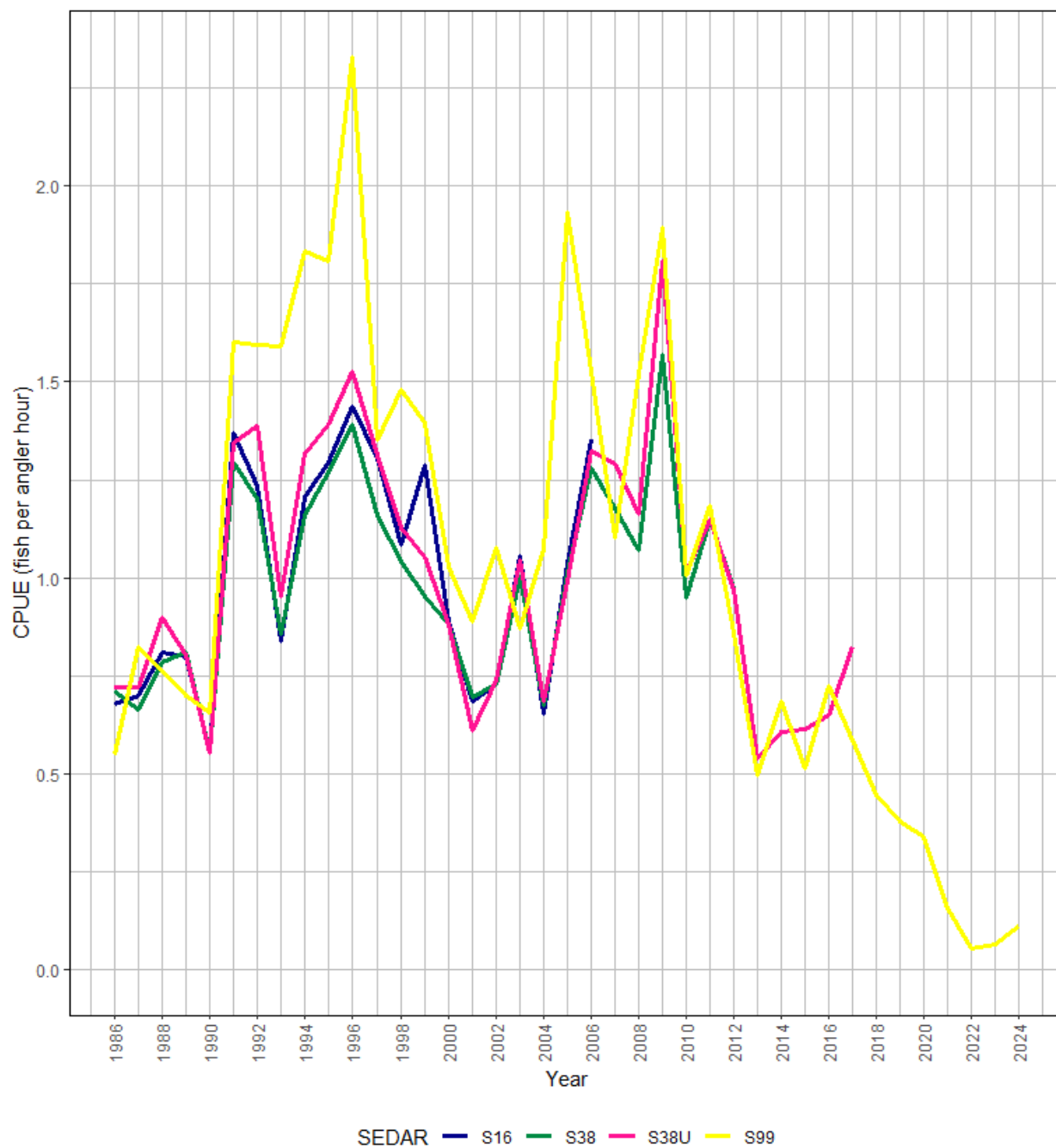


Figure 6. Comparison of standardized abundance indices between SEDAR 99 and SEDAR 38U, the terminal years of which are 2024 and 2012 and 2006 respectively.