Standardized catch rates of Spiny Lobster from the Puerto Rico commercial fish trap (2001-2024) and dive (2012-2024) fisheries

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Executive Summary

During the SEDAR 91 data workshop, nominal CPUE calculated by year (2014-2023) for Puerto Rico commercial spiny lobster were presented (Matos-Caraballo *et al*., 2024). The workshop panel did not recommend that the nominal series be included as an input to the stock assessment models, however. The Caribbean Fisheries Management Council during their August, 2025 meeting requested the SEFSC to explore the construction of a standardized index for Puerto Rico spiny lobster using commercial logbook data. This document describes the development of those standardized indices using data from the commercial fish trap and dive fisheries of the island. The Stephens and MacCall (2004) data subsetting method was used to identify trips in areas where spiny lobster was available to be caught. Following outlier removal and exclusion of trips with missing data, indices of abundance were constructed from fish trap and dive data. CPUE was modeled using the delta-GLM approach. Results of the analyses found increasing spiny lobster abundance since 2013 in Puerto Rico.

Caribbean Commercial Logbook Program (CCL) overview

Landings and fishing effort of commercial vessels operating in Puerto Rico are monitored by the Puerto Rico Department of Natural and Environmental Resources (PR DRNA) in collaboration with the NOAA Fisheries Southeast Fisheries Science Center through the Caribbean Commercial Logbook Program (CCL). The program includes, but is not limited to, the collection of trip-level information from commercial vessels landing species managed by the Caribbean Fishery Management Council. Data in Puerto Rico were available in electronic data bases for the years 1983-present. The option for fishers to report commercial landings using an electronic logbook application began in 2020. Approximately 40 percent of commercial fishers' report via the electronic logbook application (Matos-Caraballo, pers comm.).

For each fishing trip, the CCL and electronic logbook recorded a unique trip identifier, the landing date, fishing gear deployed, areas fished, number of days at sea, number of crew, gear-specific fishing effort, species caught, and weight of the landings by species. Fishing effort data available for fish traps included number of traps fished and the length of the fishing trip in hours. Effort data available for dive trips included the number of SCUBA tanks used and the length of the fishing trip in hours.

Background

Prior to the analyses described here, no standardized index of abundance had been constructed in the US Caribbean using commercial fishing data that was then included in an assessment model. Nominal CPUE had been calculated for the SEDAR 91 and 46 spiny lobster assessments, but no fishery dependent indices were recommended for use in the stock assessment models.

Data Description

Catch per unit effort (CPUE), defined as lobster whole weight per fish trap fished (fish trap analysis) or SCUBA tank used (dive analysis), from CCL and electronic logbook data was used to develop two indices of abundance for spiny lobster using data reported from commercial trips deploying fish traps and divers. The size range of lobsters included in the indices were, therefore, the same as the size composition of landings from the commercial fish trap and dive fleets. Those size data were available in the Trip Interview Program dataset and were included in the models developed during the assessment process.

1. *Outlier removal*
Extreme values occur more frequently in self-reported data than in scientific survey data because there are limited opportunities to validate self-reported data. Recent SEDAR stock assessments from other regions in the southeastern US mainland have removed values at the extreme tails of the distribution of effort data in self-reported fishery-dependent data sets. Values falling outside the 1st and 97.5th percentiles of the data were excluded from the analyses.

2. *Data exclusions and assumptions (multiple trips per report, multiple gears, low sample size)*
Data were restricted to include only those records with landings and effort data reported for individual trips. In some cases, fishers reported data from multiple trips within the same reporting form, particularly during the first half of the CCL time series. Use of those data would require averaging effort across the number of trips reported, thereby reducing the information content of those data. Also excluded were trips that reported use of multiple gears fished on a single trip. Such reporting prevents designating trip-level catch and effort records to specific gears. Therefore, only data records with one gear fished were included in these analyses. Fishing area has been reported in CCL since 2011, but inconsistently. Landing site has been consistently reported, however, since the inception of the CCL program. Landing site was used to assign trips to coast (Figure 1) assuming fishing occurred on the same coast as the landing site. The data were also filtered to remove those trips with insufficient effort data. Effort data were considered sufficiently detailed if the number of traps fished (fish trap data) or SCUBA tanks used (dive data) were reported for a trip. Trip hours were also reported, but were not considered informative for quantifying fishing effort as trip hours was not limited to time spent fishing.

3. *Time period*
Implemented in 1983, the CCL reporting forms were frequently incomplete for individual fishing trips. Effort data were often not reported, particularly prior to 2000. The SEDAR 91 data workshop panel recommended that the time series of landings data begin in 1985, but due to incomplete reporting of effort, the time series of data for fish traps began in 2001 and in 2012 for the dive index. The terminal year of data was updated from 2023 (used in SEDAR 91) to 2024.

Evaluation of explanatory variables

YEAR – Year was necessarily included, as standardized catch rates by year are the desired outcome. Years modeled were 2001-2024 (fish trap) and 2012-2024 (dive).
SEASON – Season included two levels: (December-April, dry season; May-November, wet season).
COAST – Coast included three levels (fish trap index: South, East, West) or four levels (dive index: North, South, East, West)
GEAR QUANTITY – Quantiles of gear quantity (number of traps fished, number of SCUBA tanks used), examined for use in the binomial model only

Subsetting trips

Effective effort was based on those trips from areas where spiny lobster was available to be caught. Without fine-scale geographic information on fishing location, trips to be included in the analysis must be inferred. This was done using the method of Stephens and MacCall (2004). The method uses multiple logistic regression to estimate a probability for each trip that spiny lobster was caught, given other species caught on that trip. As gear and coast may affect the species composition of landings, the Stephens and MacCall analyses were completed for each gear and coast combination.

A backwards stepwise AIC procedure (Venables and Ripley 1997) was then used to perform further selection among possible species as predictor variables, where the most general model included all listed species as main effects. In this procedure, a generalized linear model with Bernoulli response was used to relate presence/absence of spiny lobster in each trip to presence/absence of other species. A trip was then included if its associated probability of catching spiny lobster was higher than a threshold probability. The threshold was designed to be that which resulted in the same number of predicted and observed positive trips, as suggested by Stephens and MacCall (2004).

Standardization

CPUE was modeled using the delta-GLM approach (Lo, Jacobson, and Squire 1992; Dick 2004; Maunder and Punt 2004). This approach combines two separate generalized linear models (GLMs), one to describe presence/absence of the focal species, and one to describe catch rates of successful trips (trips that caught the focal species). Estimates of variance were based on 1000 bootstrap runs where trips were chosen randomly with replacement (Efron and Tibshirani 1993). All analyses were programmed in R, with much of the code adapted from Dick (2004).

Bernoulli submodel

The Bernoulli component of the delta-GLM is a logistic regression model designed to predict the presence/absence (i.e., availability to be caught) of spiny lobster on any given trip. Initially, all 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. The final models were:

Fish trap index

CPUE ~ YEAR + COAST + GEAR_QUANTITY

Dive index

CPUE ~ YEAR + COAST + SEASON + GEAR_QUANTITY

Positive CPUE submodel

Two parametric distributions were considered for modeling positive values of CPUE, lognormal and gamma. 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 two distributions were compared using AIC. Lognormal outperformed gamma, and was therefore applied in the final delta-GLM. The final models were:

Fish trap index

CPUE ~ YEAR + COAST

Dive index

CPUE ~ YEAR + COAST

Results and Discussion

The number of trips reporting fishing effort as lobster traps fished was very low (fewer than 50 trips per year, in many years there were no reported trips) for all coasts except the south. Due to the low sample size, lobster trap data were excluded from further analyses. Lobster trap data were not combined with fish trap data due to differences in targeting between those two gears. The number of trips reporting fish trap hauls was very low along the north coast (fewer than 50 trips per year, in many years there were no reported trips), therefore north coast data were excluded from the fish trap analysis (Figure 2a and b). Effort data were sufficient (number of SCUBA tanks used per trip) to include all coasts in the dive trip analyses (Figure 3a and b). The final data sets containing sufficient effort information needed to calculate CPUE included only 30 percent of the trips found in the full CCL data set.

Stephens and MacCall results showed several species as strong predictors of spiny lobster presence, particularly species that showed strong negative correlations with spiny lobster such as silk or yellowtail snapper, although predictor species varied among coasts (Figures 4 and 5). Residuals of the final models indicated no issues with the selected model variables in terms of skewed data or other patterns that would suggest poor model fits (Figures 6 and 7). Diagnostic plots of Log CPUE and Q-Q plots of residuals from the fitted lognormal submodels do not suggest that the data are unsuitable for the analyses (Figures 8 and 9), although data from dive trips are slightly skewed from a normal distribution.

The final gear-specific indices showed similar patterns to their respective nominal indices (Figure 10, Tables 1 and 2). Figure 11 shows both standardized indices plotted on a common scale. CV values were low, in the range of 2.6-13% in the fish trap index and 1.8-2.7% in the dive index across all years (Tables 1 and 2). The general trends were of increasing abundance since 2013, particularly for the fish trap index. There was a notable decrease in the fish trap CPUE during the years 2012-2014 that cannot be explained by low sample size. The low fish trap CPUE in 2013 is likely due to a very low proportion of fish trap trips with spiny lobster landings (0.098 proportion positive, Table 1). For both indices, the highest standardized index values have been during the final nine years of the time series of data. Those trends agree with anecdotal reports from fishers of very high spiny lobster abundance in recent years.

Development of standardized indices of abundance for Puerto Rico spiny lobster represents a significant advance in the information available to inform stock assessments in the region. By including these indices, dynamic recruitment can be incorporated into the assessment model allowing estimation of annual recruitment. Without indices as model inputs, pulses in recruitment cannot be estimated and assessment models assume constant, average recruitment across all years.

References

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Table 1. Standardized index of abundance of Puerto Rico spiny lobster using fish trap fishery reported data.

Year	N	Nominal CPUE	Relative Nominal	Standardized CPUE	Proportion Positive	CV
2001	676	0.604547	0.968523	0.528002	0.325444	0.095672
2002	655	0.641886	1.028343	0.908682	0.343511	0.088587
2003	1,159	0.377085	0.604115	0.857169	0.365833	0.055227
2004	1,457	0.397105	0.636187	0.909111	0.503089	0.03675
2005	1,384	0.311432	0.498934	0.779007	0.437861	0.042347
2006	1,300	0.390044	0.624876	0.808348	0.52	0.042094
2007	843	0.4923	0.788696	1.011721	0.641756	0.041733
2008	718	0.392455	0.628737	0.902499	0.449861	0.051986
2009	961	0.35196	0.563863	0.678186	0.476587	0.054559
2010	448	0.491246	0.787008	0.893128	0.546875	0.059738
2011	642	0.325459	0.521406	0.603209	0.521807	0.066689
2012	1,299	0.234881	0.376294	0.342771	0.327175	0.070468
2013	1,077	0.075667	0.121224	0.085201	0.098422	0.137103
2014	1,246	0.289085	0.463133	0.424685	0.26886	0.08792
2015	1,522	0.585316	0.937715	0.909352	0.586728	0.039887
2016	1,608	0.755141	1.209784	1.154824	0.705846	0.029899
2017	878	0.759094	1.216118	1.180757	0.70615	0.037282
2018	848	1.115799	1.787582	1.786447	0.73467	0.033436
2019	1,332	1.032678	1.654417	1.542397	0.780781	0.026574
2020	738	0.714294	1.144345	1.271832	0.670732	0.037241
2021	859	1.012315	1.621794	1.500071	0.799767	0.034651
2022	970	1.096799	1.757143	1.520251	0.802062	0.036188
2023	764	1.134681	1.817832	1.595873	0.812827	0.037029
2024	928	1.399402	2.241932	1.806479	0.840517	0.03453

Table 2. Standardized index of abundance of Puerto Rico spiny lobster using dive fishery reported data.

Year	N	Nominal CPUE	Relative Nominal	Standardized CPUE	Proportion Positive	CV
2012	1,648	5.182057	0.915799	0.803337	0.806432	0.027956
2013	1,686	4.267974	0.754258	0.672589	0.731317	0.026562
2014	2,172	4.898798	0.86574	0.795144	0.740331	0.024624
2015	3,198	5.415128	0.956988	0.922055	0.875547	0.018058
2016	2,669	5.387834	0.952165	0.965521	0.860247	0.018945
2017	1,519	5.760242	1.017979	1.079393	0.851876	0.026538
2018	2,490	5.74858	1.015917	1.059174	0.876707	0.02071
2019	2,968	6.282586	1.11029	1.008541	0.842992	0.019893
2020	1,308	5.877541	1.038708	1.019786	0.841743	0.025109
2021	1,332	6.367169	1.125238	1.075973	0.882883	0.025747
2022	1,764	5.635771	0.995981	1.093985	0.845805	0.023731
2023	1,317	5.689231	1.005429	1.117759	0.846621	0.024243
2024	1,490	7.047725	1.245509	1.386744	0.869128	0.022687

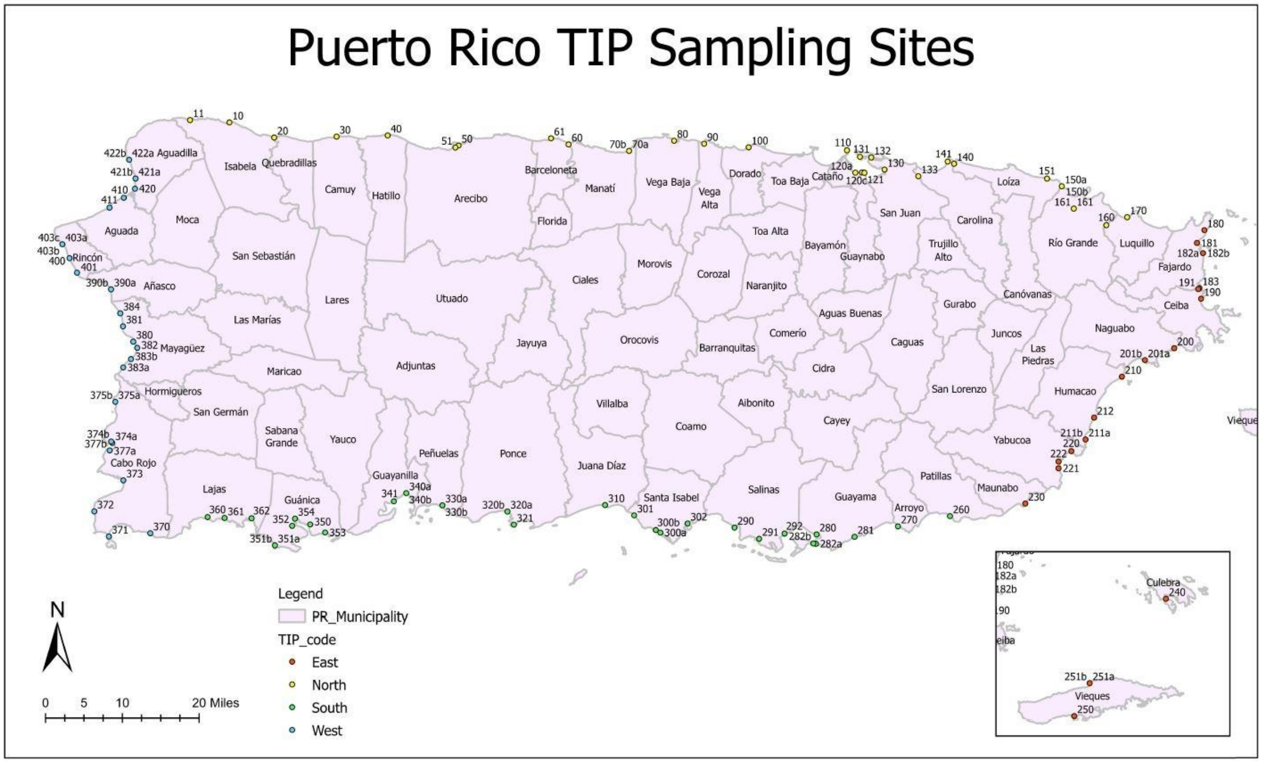
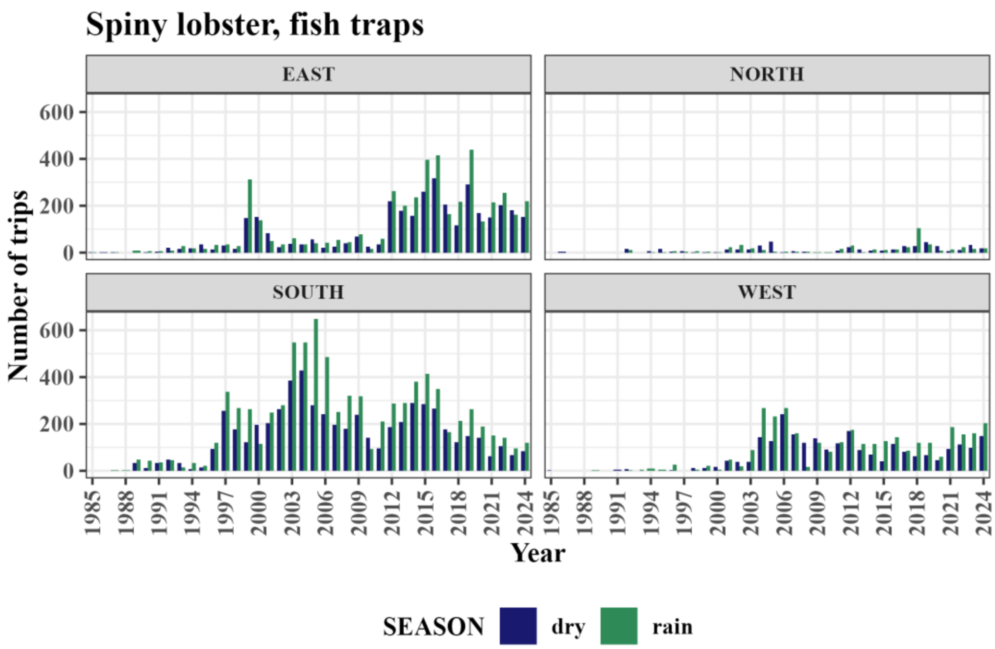


Figure 1. Map of Puerto Rico Municipalities by coast (North, South, East, West). Trips were assigned to coast by the landing site reported for each trip.

A.



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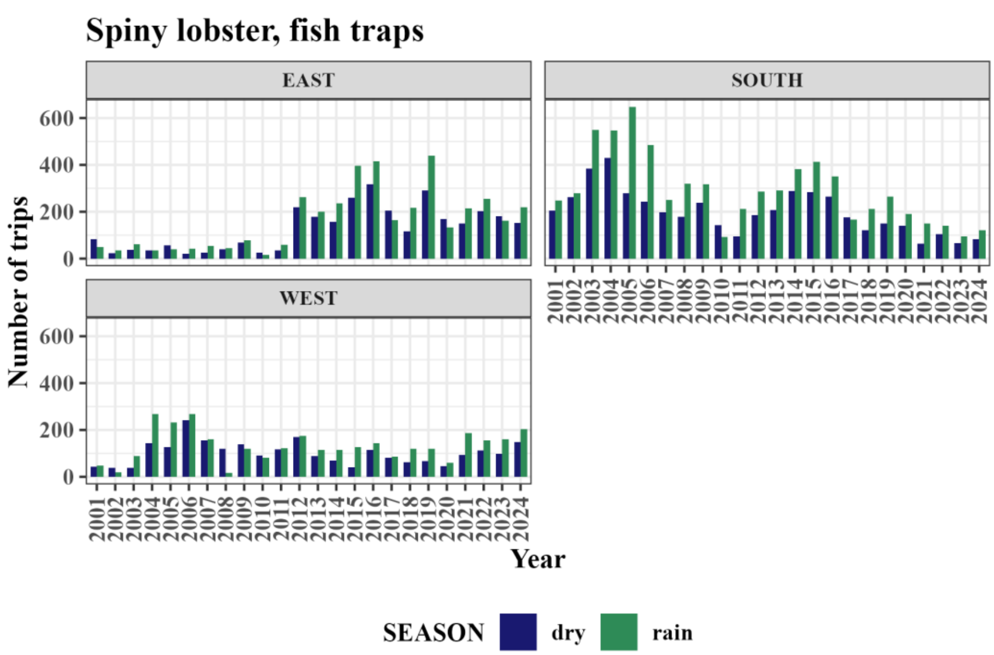
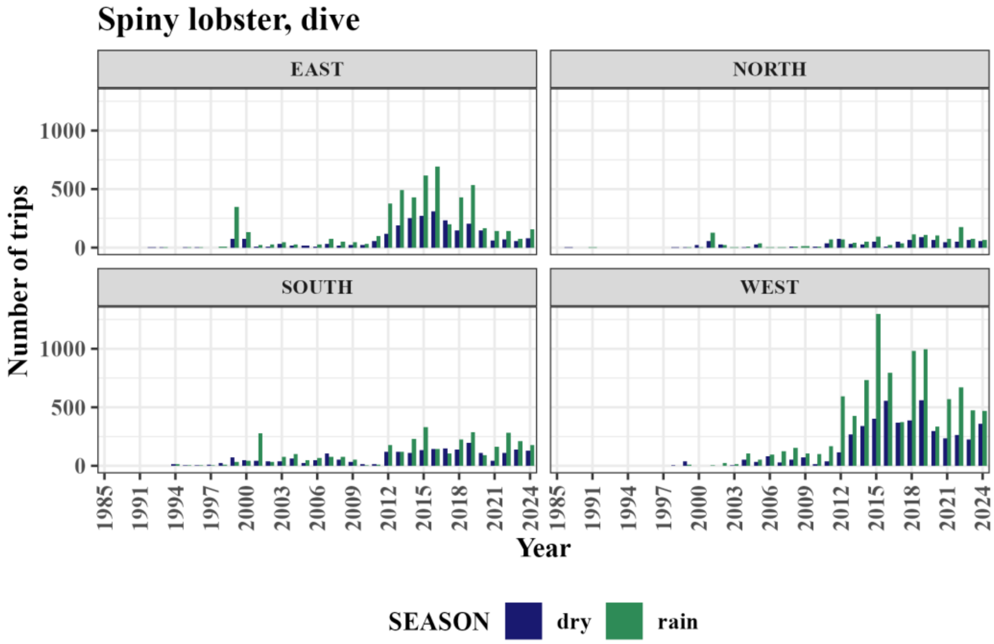


Figure 2. A) The number of fish trap trips, by year and coast, identified in the data subsetting analyses as fishing in spiny lobster habitat. B) Number of trips by year and coast for the period 2001-2024 following removal of trips missing effort data. North coast trips were removed from additional analyses due to low sample size.

A.



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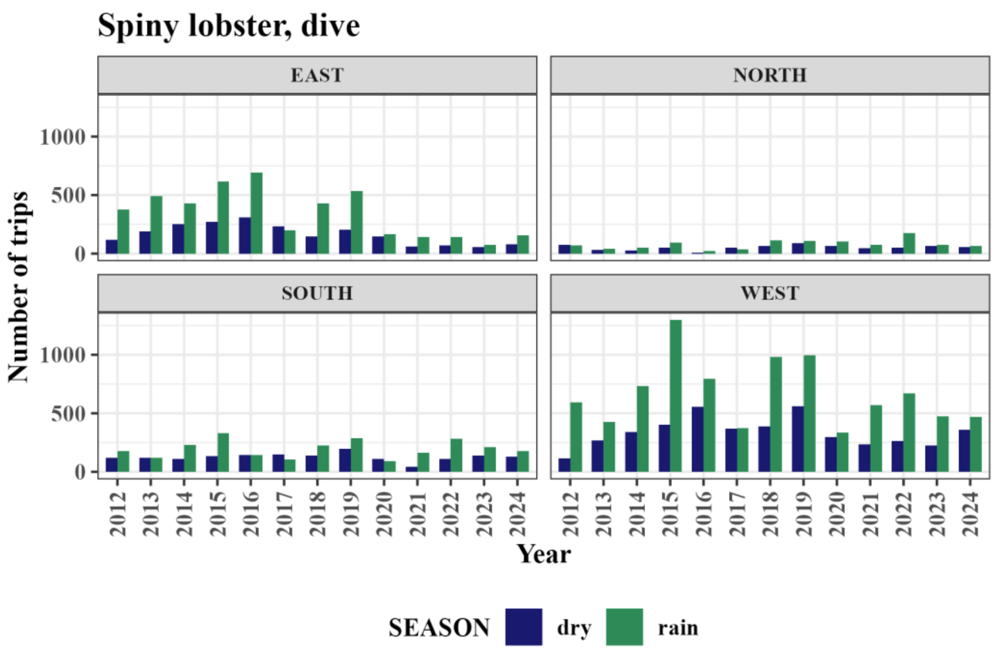


Figure 3. A) The number of dive trips, by year and coast, identified in the data subsetting analyses as fishing in Spiny lobster habitat. B) Number of trips by year and coast for the period 2001-2024 following removal of trips missing effort data.

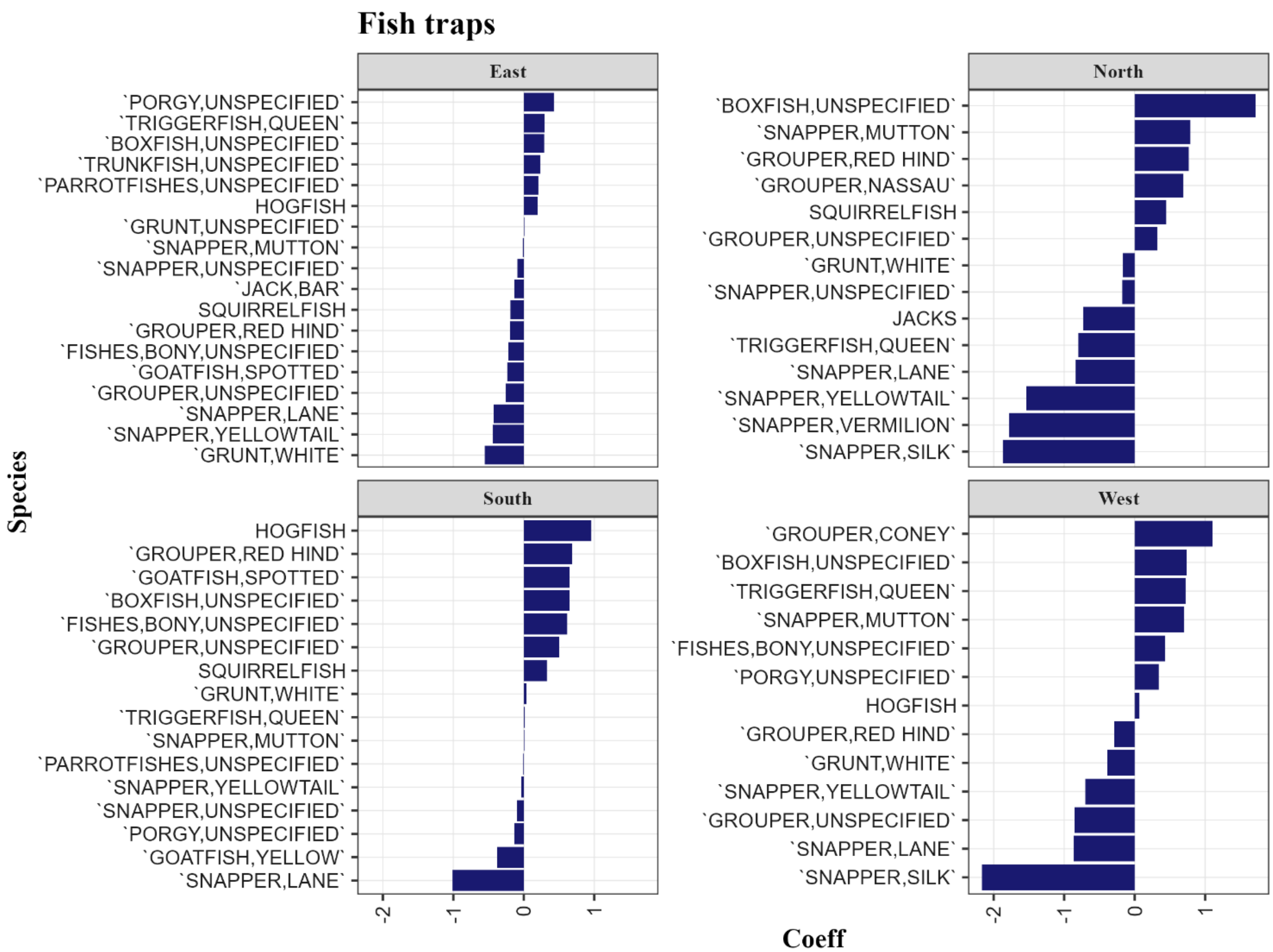


Figure 4. Estimates of species-specific regression coefficients used to predict each commercial fish trap trip's probability of catching spiny lobster. Coefficients are provided for each coast.

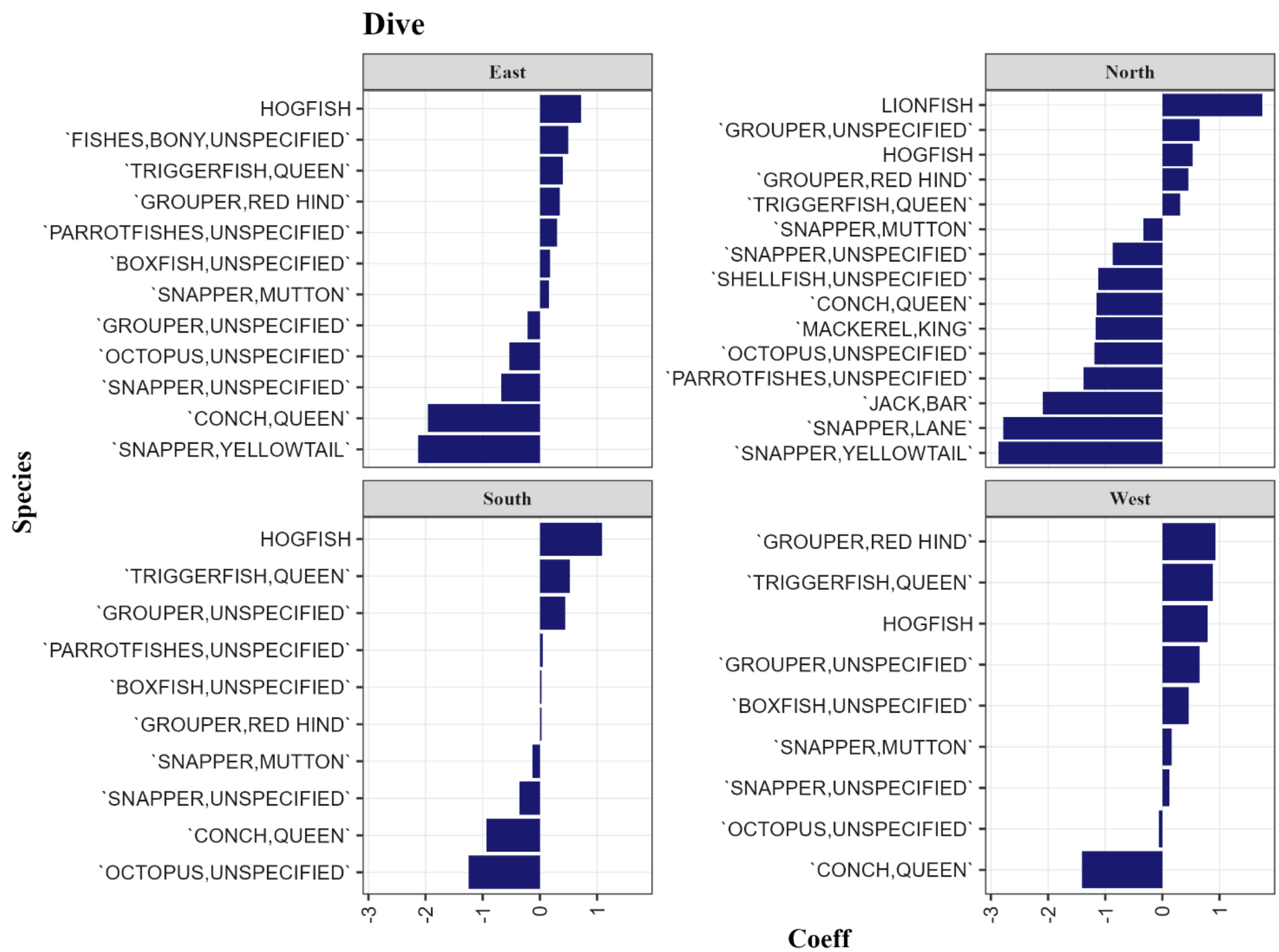


Figure 5. Estimates of species-specific regression coefficients used to predict each commercial dive trip's probability of catching spiny lobster. Coefficients are provided for each coast.

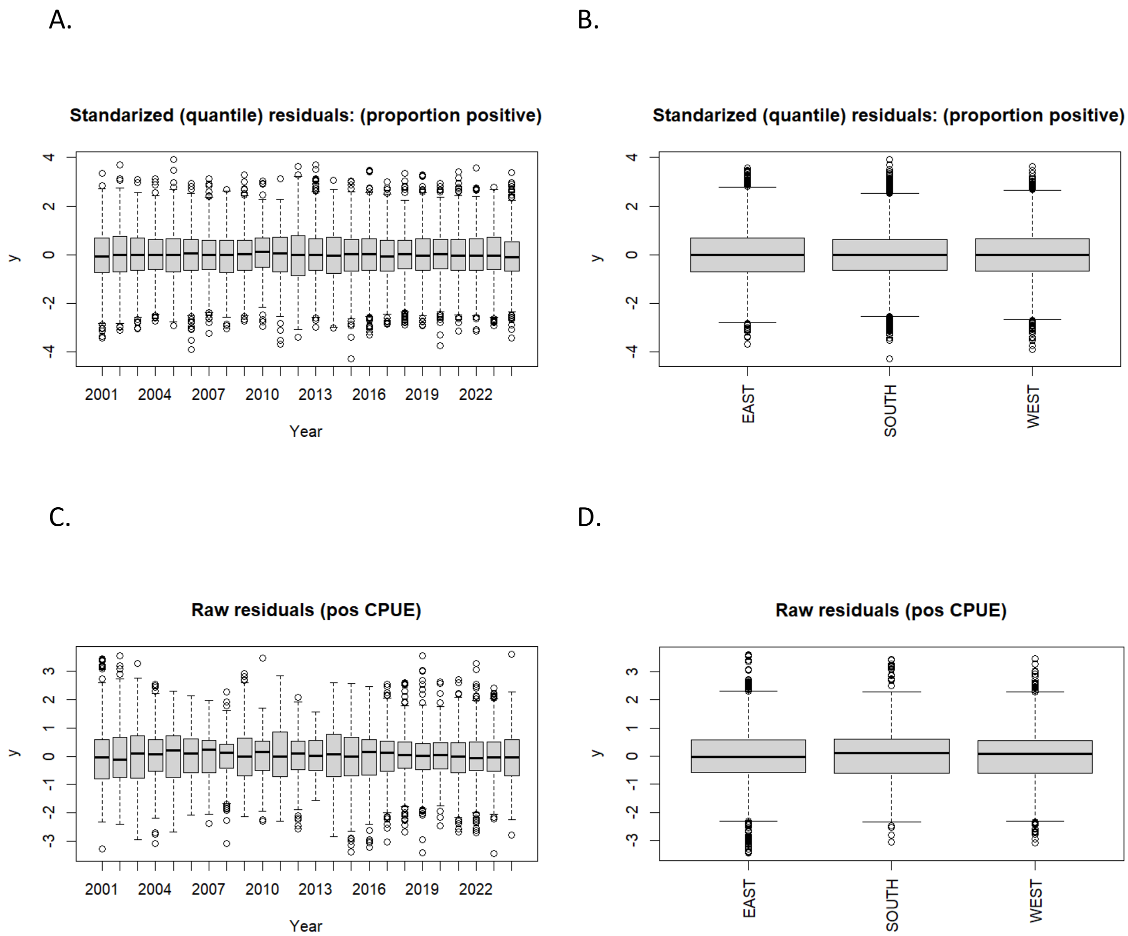


Figure 6. Fish trap index diagnostics of lognormal submodel fits to binomial data (Plots A-B). Fish trap index diagnostics of lognormal submodel fits to positive CPUE data (Plots C-D). Box and whisker plots give first, second (median) and third quartiles, as well as limbs that extend to approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs.

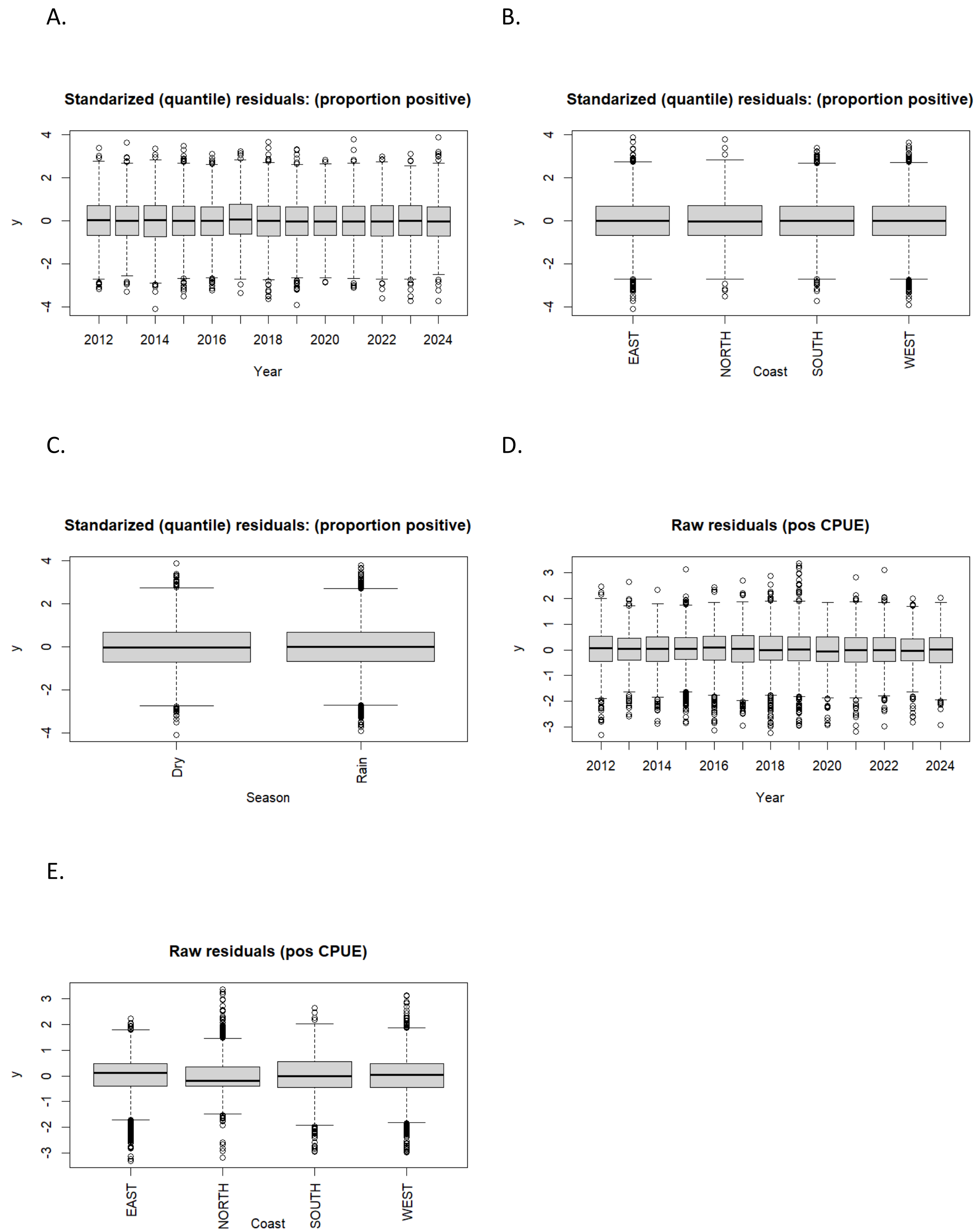


Figure 7. Dive index diagnostics of lognormal submodel fits to binomial data (Plots A-C). Dive index diagnostics of lognormal submodel fits to positive CPUE data (Plots D-E). Box and whisker plots give first, second (median) and third quartiles, as well as limbs that extend to approximately one interquartile range beyond the nearest quartile, and outliers (circles) beyond the limbs.

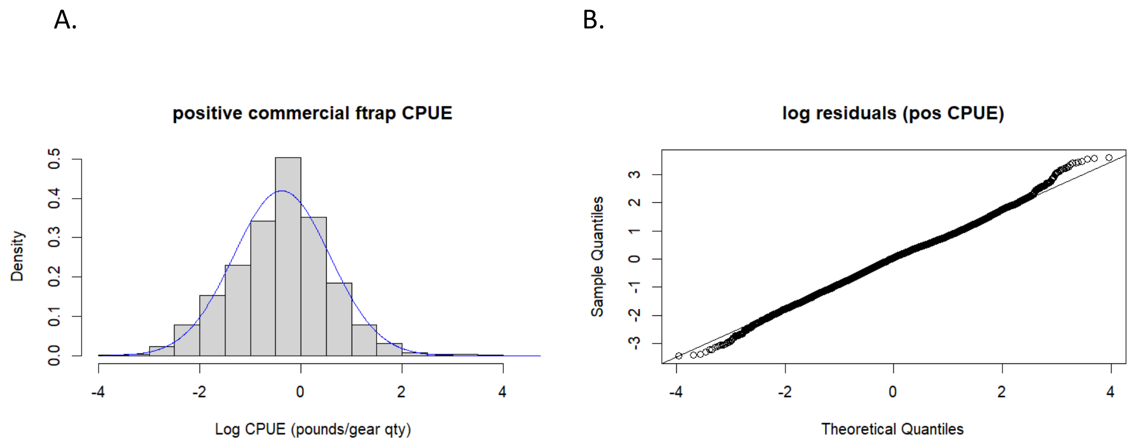


Figure 8. Histogram of empirical CPUE from the fish trap data, with the lognormal distribution overlaid. Quantile-quantile plot of residuals from the fitted lognormal submodel to the positive cpue catch.

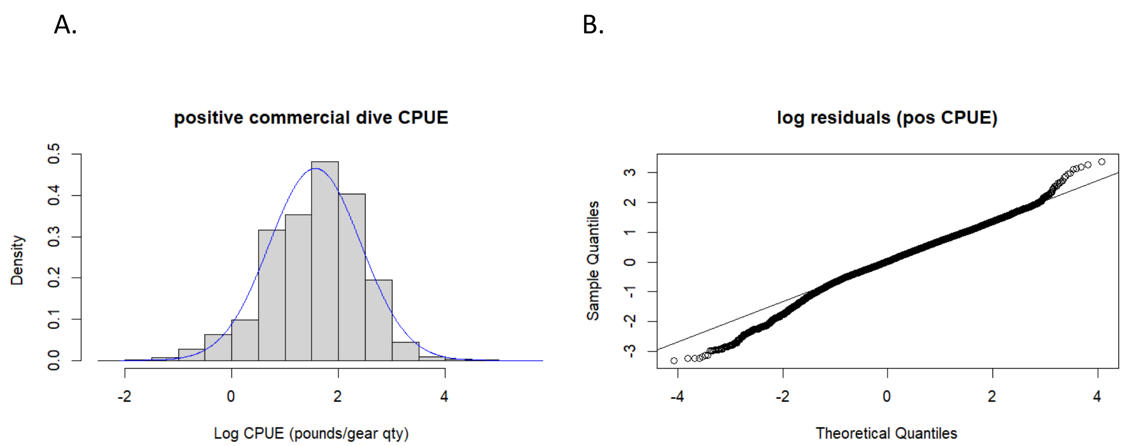
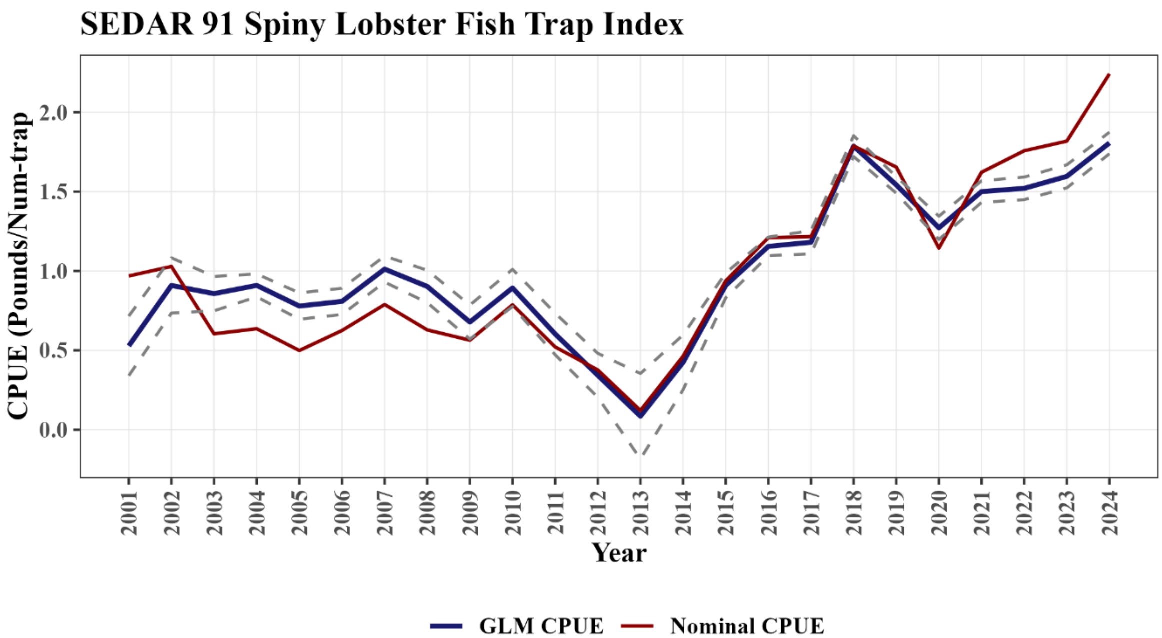


Figure 9. Histogram of empirical CPUE from the dive data, with the lognormal distribution overlaid. Quantile-quantile plot of residuals from the fitted lognormal submodel to the positive cpue catch.

A.



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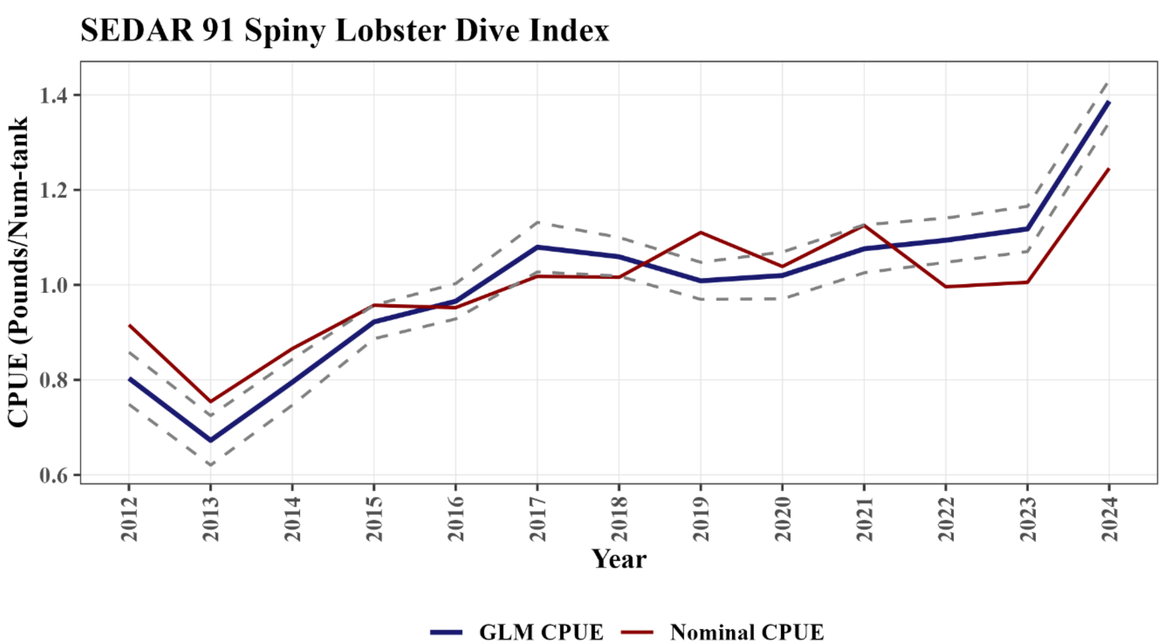

Figure 10. Standardized indices of Spiny lobster abundance in Puerto Rico from commercial fish trap (A) and dive (B) CPUE data. CPUE is pounds per trap or pounds per SCUBA tank reported, respectively. Nominal CPUE and upper and lower confidence intervals of the standardized index are also provided.

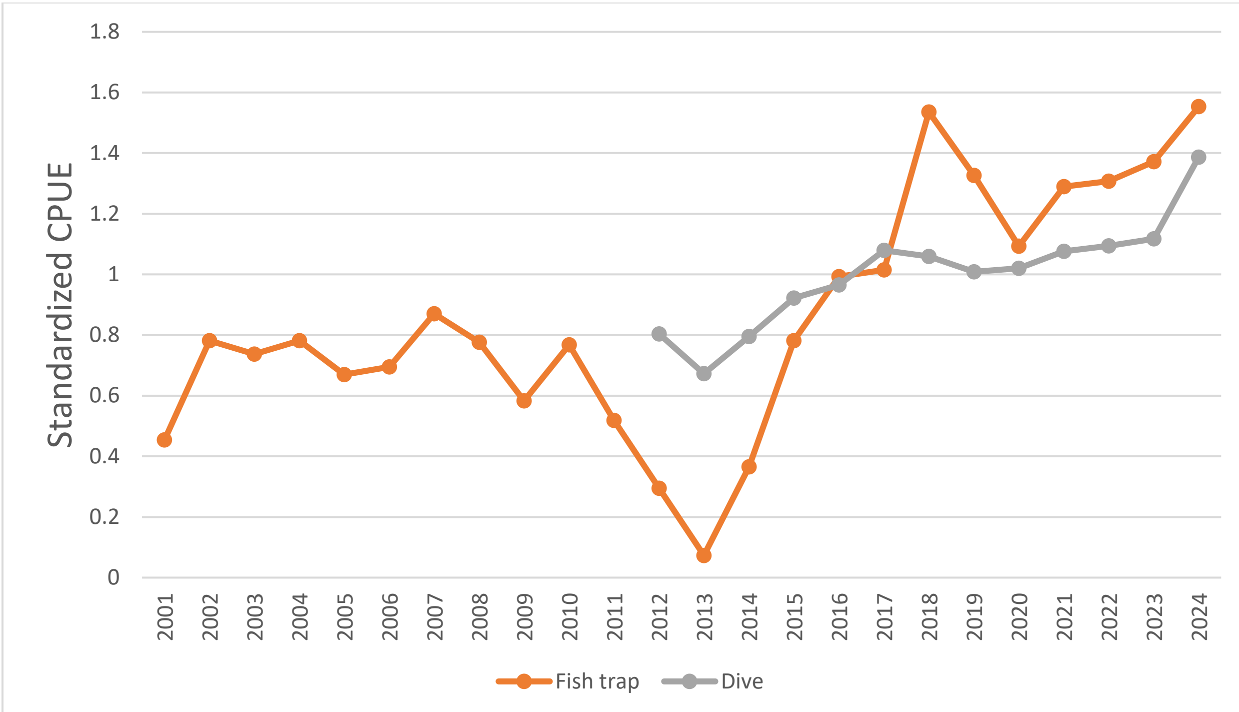

Figure 11. Standardized indices of Spiny lobster abundance in Puerto Rico from commercial fish trap and dive CPUE data. Time series are plotted on a common scale (normalized to the mean CPUE of each gear for the period 2012-2024).