Fishery-dependent CPUE index for Spanish mackerel derived from MRIP data

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Summary

The Marine Recreational Information Program (MRIP) dockside intercept program dataset was used to develop recreational catch per unit effort (CPUE) as an index of abundance for Spanish mackerel. Two methods of sub-setting the data were explored: a species guild approach, where "Spanish mackerel trips" were identified on the basis of what species were caught most frequently with Spanish mackerel, and a directed trips approach, where "Spanish mackerel trips" were identified as trips where the anglers reported targeting Spanish mackerel. These two methods produced indices with generally similar trends except for the most recent few years, where the guild approach showed a strong, rapid increase while the directed trips approach showed a more modest uptick. This difference was likely due to the recent significant decline in the number of trips that caught bluefish, one of the most commonly co-occurring species with Spanish mackerel. This resulted in an increase in the proportion of positive trips and overall CPUE from the guild approach at the end of the time series. As a result, the directed trips method was recommended to develop the index for this assessment. The directed trips index generally varied without trend across the time series (Table 1, Figure 1).

Guild Approach

Because MRIP is not designed to track effort for any one species, it can be hard to determine which of the intercepted trips should be considered a "Spanish mackerel trip" (i.e., a trip that would be expected to catch Spanish mackerel and should be included to track abundance) and which trips are not expected to catch Spanish mackerel and thus should be excluded from the analysis. One way of identifying Spanish mackerel trips is to identify the species that are most commonly caught with Spanish mackerel and assume that any trips that caught one of those co-occurring (aka guild) species also could have caught Spanish mackerel.

To identify the guild species, the Jaccard coefficient was calculated for the more commonly caught species in the south Atlantic. This was done on a state by state basis for Florida, Georgia, South Carolina, and North Carolina, as species associations may change from north to south. The Jaccard coefficient for species *j* is defined as:

$$S_j = \frac{a}{a + b + c}$$

Where

a = number of trips that caught both Spanish mackerel AND species *j*
b = number of trips that caught Spanish mackerel but NOT species *j*
c = number of trips that caught species *j* but NOT Spanish mackerel

The three species with the highest Jaccard coefficients for each state are shown in Table 1. Bluefish was one of the top 3 species in all states; other commonly co-occurring species

included king mackerel and great barracuda. However, these species associations were not particularly strong, with Jaccard coefficients of all species being 0.11 or lower. Each guild species was caught on 20% or less of the trips that caught Spanish mackerel (with the exception of bluefish in North Carolina, which was caught on 38% of trips that caught Spanish mackerel) (Tables 2).

A trip was defined as a Spanish mackerel trip for a given state if it caught either Spanish mackerel or the species with the highest Jaccard coefficient for that state. The final subset of the MRIP data used to develop the CPUE index was compiled from the Spanish mackerel trips identified for each state (NC-FL). As dockside sampling was limited in 2020 due to COVID-19, MRIP used imputed records to calculate total recreational catch for 2020. Those imputed records were excluded from the CPUE calculations.

Directed Trips Approach

Because the guild approach was sensitive to trends in the associated species, the directed trips approach was developed as an alternative. When anglers are intercepted at the dock after a fishing trip, they are asked what two species or species groups they were targeting on that trip. A directed Spanish mackerel trip was defined as a trip where the angler reported targeting Spanish mackerel as their primary or secondary target. About 40% of trips that reported targeting Spanish mackerel caught Spanish mackerel. However, about 56% of trips that caught Spanish mackerel did not report targeting Spanish mackerel.

Because of an increasing number of positive intercepts in trips outside the management area for Spanish mackerel (i.e., in the north and mid- Atlantic, Figure 2 and Figure 3), records from all states from eastern Florida to Maine were used in the subset of directed Spanish mackerel trips. The total number of positive trips increased significantly in 2018-2020 (Figure 2), and the proportion of directed trips that were positive increased somewhat as well (Figure 4), although both metrics have generally fluctuated without trend for most of the time series.

As with the guild approach, the imputed records for 2020 were excluded from the CPUE calculations.

Index Standardization

The CPUE index for the directed trips dataset was standardized using a negative binomial model using the glm.nb() function from the R package MASS. The distribution of catch per trip skewed towards zero, but had a long tail (Figure 4). The factors included in the model were year, region, wave, mode of fishing, area fished, kind of day (weekend vs. weekday), and avidity (the number of days the angler reported fishing in the previous year). The log of angler-hours (the number of anglers that contributed to the catch multiplied by the hours they reported fishing) was used as an effort offset. The negative binomial model was slightly over dispersed (dispersion=1.3) but comparable zero-inflated and zero-altered models had higher AIC values and did not significantly improve the dispersion. AIC and the lrtest() from the R package lmtest were used to select factors. The R package DHARMa was used to examine residual patterns for the final fitted model (Figures 6-13). Although DHARMa flagged some deviations from uniformity as

significant, visual inspection of residual patterns indicated no major problems; the statistical significance was most likely due to the very large sample size (over 28,000 observations over the time series).

The CPUE index for the guild approach was standardized with a similar approach; the same factors were selected as significant, but AIC testing indicated a zero-altered model (fit using the hurdle() function from the R package pscl) performed the best.

Index Comparison

Generally, the guild trips and directed trips approaches produced similar indices (Figure 15), increasing form low levels at the beginning of the time series and peaking in the late 1980s to early 1990s, before declining slightly and varying without trend for the rest of the time series. The directed trips index peaked earlier than the guild trips, but the main difference was that the guild trips index increased rapidly from 2018-2020, reaching time series highs in 2019 and 2020, while the direct trips index showed a more modest increase over that time period, and declined from 2019 to 2020 (Figure 15).

The discrepancy was mostly likely due to the rapid decline in trips that caught bluefish and king mackerel, the top two guild species, in the MRIP dataset from 2018-2020 at the same time there was an increase in the number of positive Spanish mackerel trips (Figure 16). This caused a decline in the number of zero trips (trips that were identified as a guild trip but did not catch Spanish mackerel) that went into the index and a rapid increase in the overall catch per trip. The directed trips index did pick up the increase in the number of positive trips but the increase in the index was not as significant.

The directed trips approach has some limitations, in that anglers are asked about their target species after they have completed their trip and many anglers do not have a specific target in mind when they fish (about one third of the trips that caught Spanish mackerel did not report a target species), which is why the guild approach was investigated. However, the guild approach can be influenced by changes in the regulations or abundance for those co-occurring species, as was the case here. Because of this sensitivity, the directed trips approach was recommended to form the final index.

Table 1. MRIP CPUE index for Spanish mackerel from directed trips approach.

Year	CPUE	SE	CV
1982	1.307	0.30	0.23
1983	0.150	0.06	0.40
1984	0.452	0.12	0.27
1985	1.334	0.30	0.22
1986	2.820	0.54	0.19
1987	1.499	0.21	0.14
1988	1.493	0.28	0.19
1989	1.751	0.23	0.13
1990	1.603	0.21	0.13
1991	1.515	0.18	0.12
1992	1.238	0.15	0.12
1993	0.999	0.13	0.13
1994	1.596	0.20	0.12
1995	1.182	0.15	0.13
1996	1.540	0.20	0.13
1997	1.844	0.25	0.14
1998	1.010	0.14	0.14
1999	1.911	0.25	0.13
2000	1.547	0.20	0.13
2001	1.450	0.19	0.13
2002	1.835	0.24	0.13
2003	1.923	0.25	0.13
2004	1.526	0.21	0.14
2005	1.515	0.21	0.14
2006	1.179	0.18	0.15
2007	1.267	0.18	0.14
2008	2.152	0.28	0.13
2009	1.506	0.20	0.13
2010	1.462	0.18	0.12
2011	1.516	0.19	0.13
2012	1.684	0.21	0.12
2013	1.763	0.24	0.13
2014	1.631	0.21	0.13
2015	1.245	0.16	0.13
2016	1.272	0.16	0.13
2017	1.355	0.18	0.13
2018	1.550	0.19	0.12
2019	2.187	0.26	0.12
2020	1.661	0.20	0.12

Table 2. Top three species ("guild species") associated with Spanish mackerel by state.

North Carolina

Guild Species	Trip that caught both species	Trips that caught only Sp. Mackerel	Trips that caught only the guild species	Jaccard Coefficient	Percent of Spanish mackerel trips that caught guild species	Percent of guild species trips that caught Spanish mackerel
BLUEFISH	6,742	11,085	44,018	0.109	38%	13%
KING MACKEREL	1,660	16,167	6,253	0.069	9%	21%
LITTLE TUNNY	1,036	16,791	5,745	0.044	6%	15%

South Carolina

Guild Species	Trip that caught both species	Trips that caught only Sp. Mackerel	Trips that caught only the guild species	Jaccard Coefficient	Percent of Spanish mackerel trips that caught guild species	Percent of guild species trips that caught Spanish mackerel
KING MACKEREL	307	2,180	1,785	0.072	12%	15%
BLUEFISH	559	1,928	5,701	0.068	22%	9%
GREAT BARRACUDA	104	2,383	628	0.033	4%	14%

Georgia

Guild Species	Trip that caught both species	Trips that caught only Sp. Mackerel	Trips that caught only the guild species	Jaccard Coefficient	Percent of Spanish mackerel trips that caught guild species	Percent of guild species trips that caught Spanish mackerel
KING MACKEREL	111	596	443	0.097	16%	20%
GREAT BARRACUDA	81	626	342	0.077	11%	19%
BLUEFISH	76	631	2,738	0.022	11%	3%

Florida

Guild Species	Trip that caught both species	Trips that caught only Sp. Mackerel	Trips that caught only the guild species	Jaccard Coefficient	Percent of Spanish mackerel trips that caught guild species	Percent of guild species trips that caught Spanish mackerel
BLUEFISH	1,259	5,584	13,365	0.062	18%	9%
BLUE RUNNER	960	5,883	14,433	0.045	14%	6%
CREVALLE JACK	1,135	5,708	23,491	0.037	17%	5%

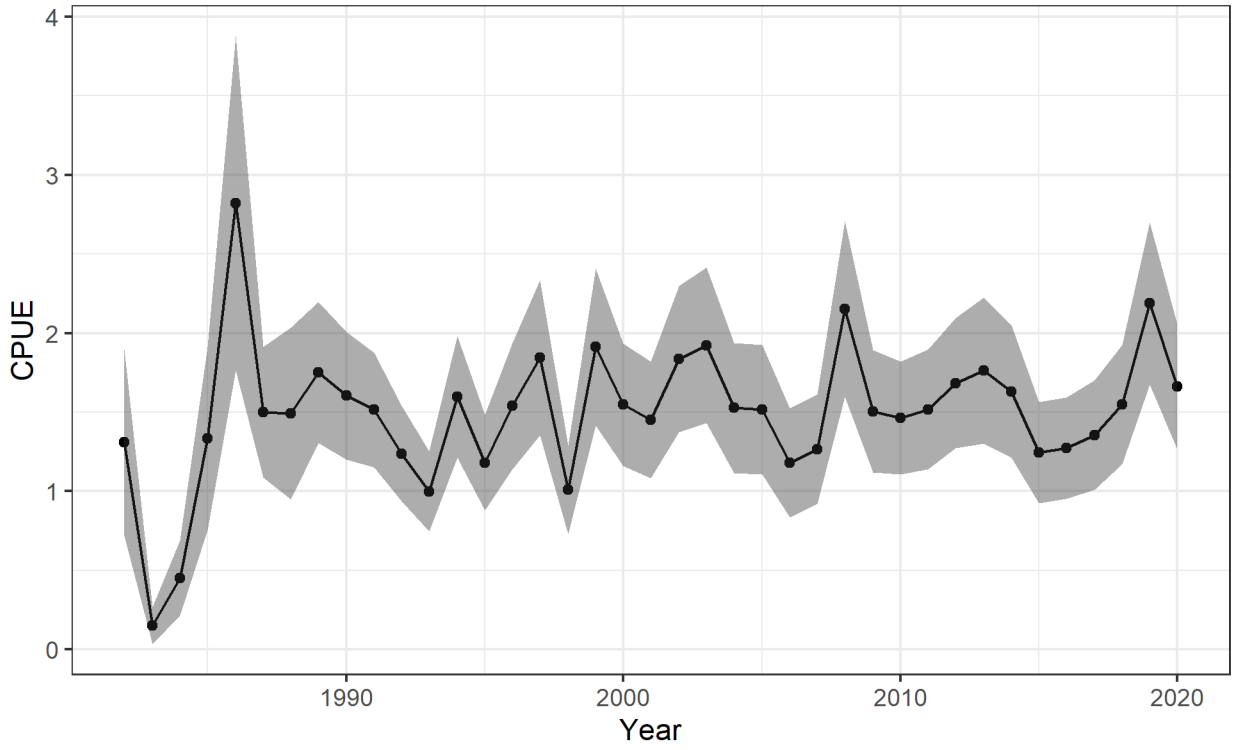

Figure 1. MRIP CPUE index for Spanish mackerel from directed trips approach. Shaded area indicates 95% confidence intervals.

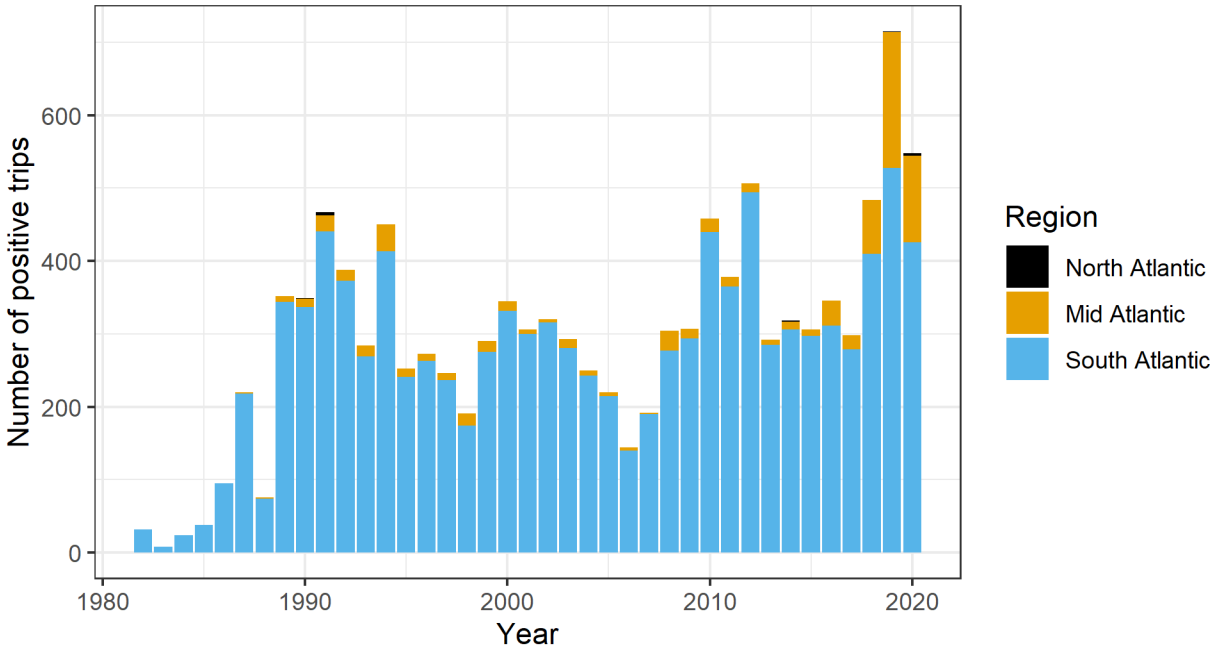

Figure 2. Number of intercepted trips that caught Spanish mackerel by year and region.

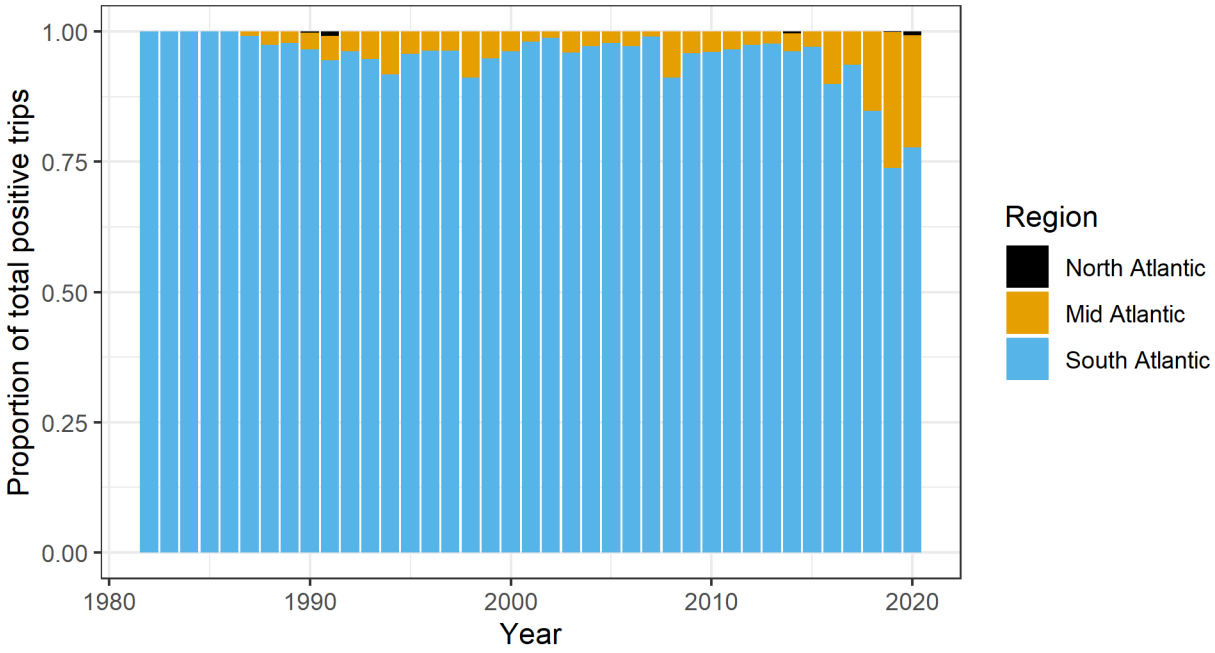

Figure 3. Proportion of total positive trips that occurred in each region over time.

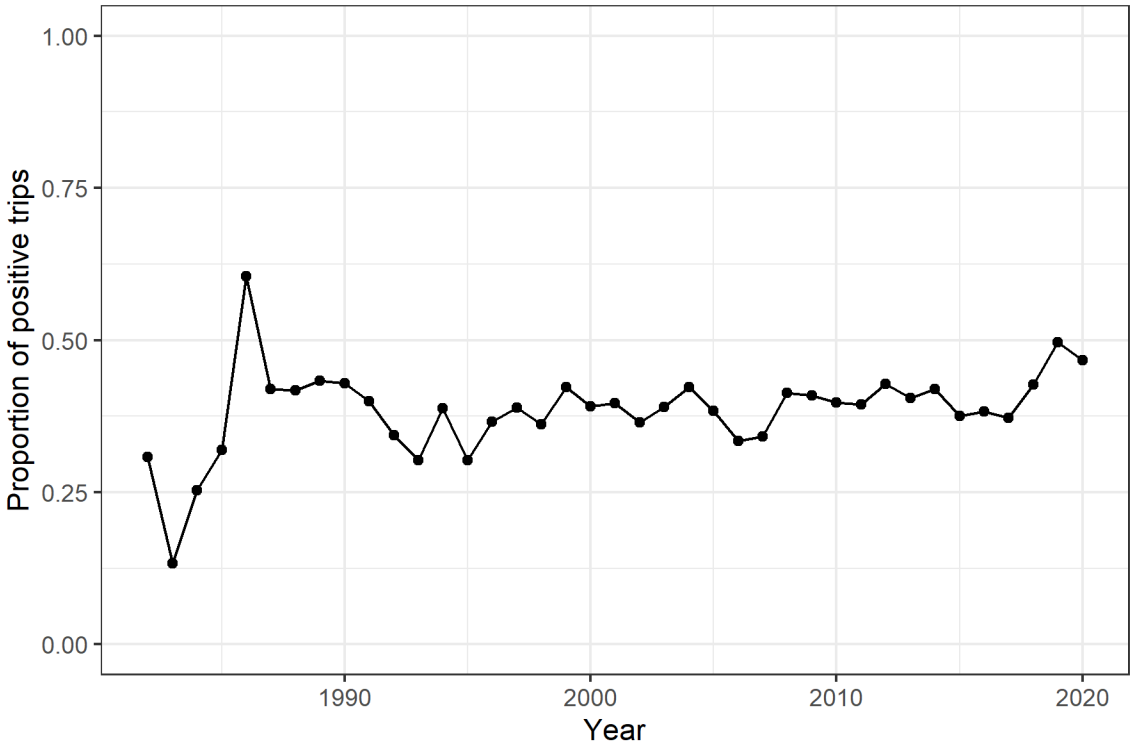

Figure 4. Proportion of directed trips that caught Spanish mackerel by year.

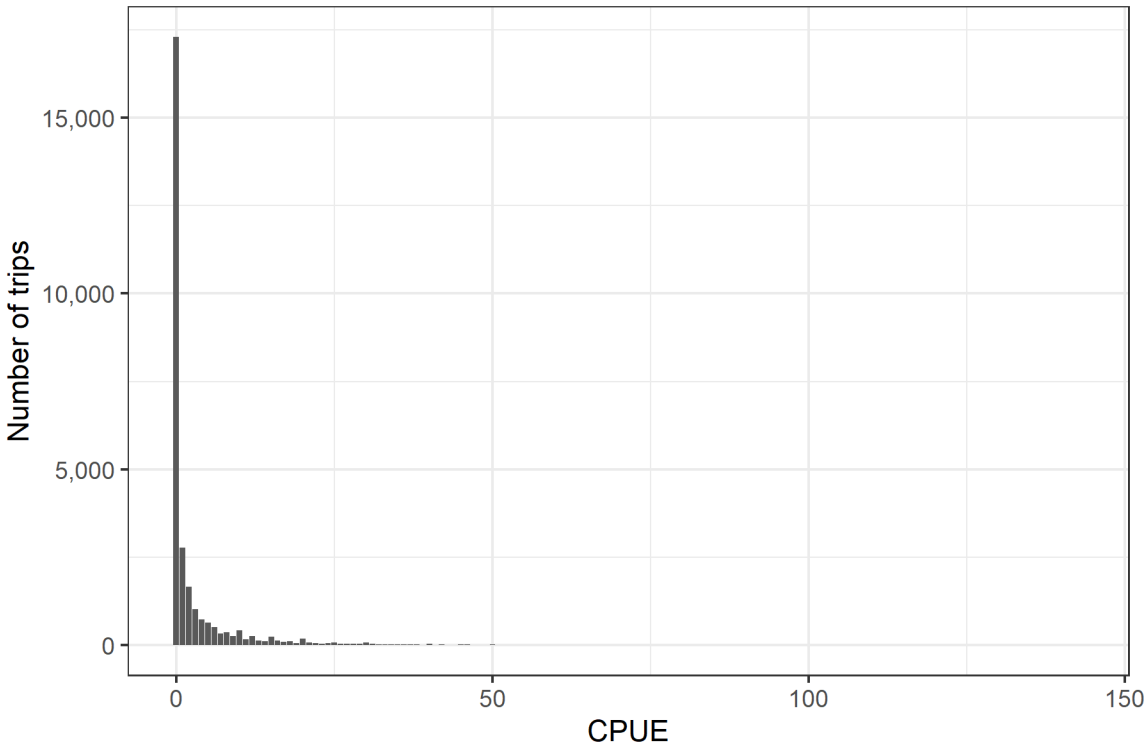

Figure 5. Histogram of catch per directed trip (CPUE in numbers of fish).

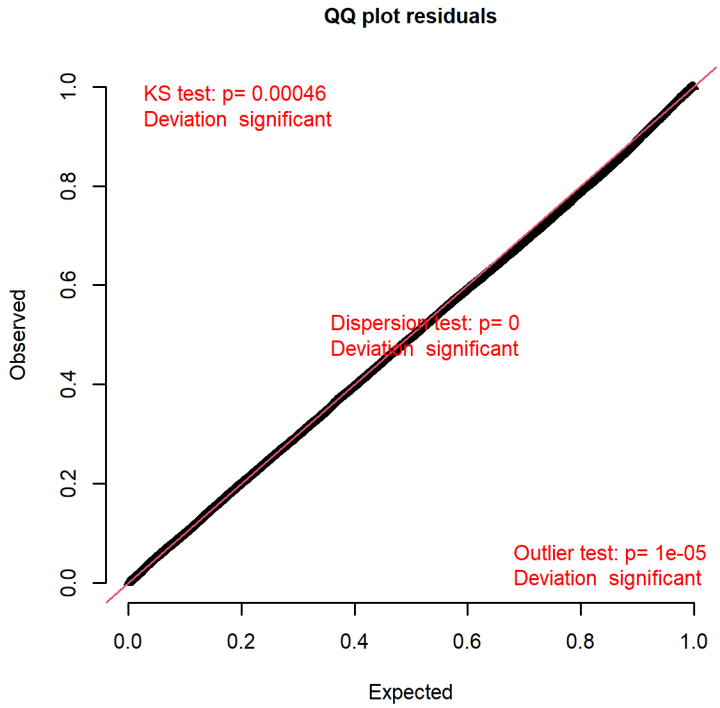

Figure 6. QQ-plot of fitted vs. simulated residuals for the directed trips negative binomial model.

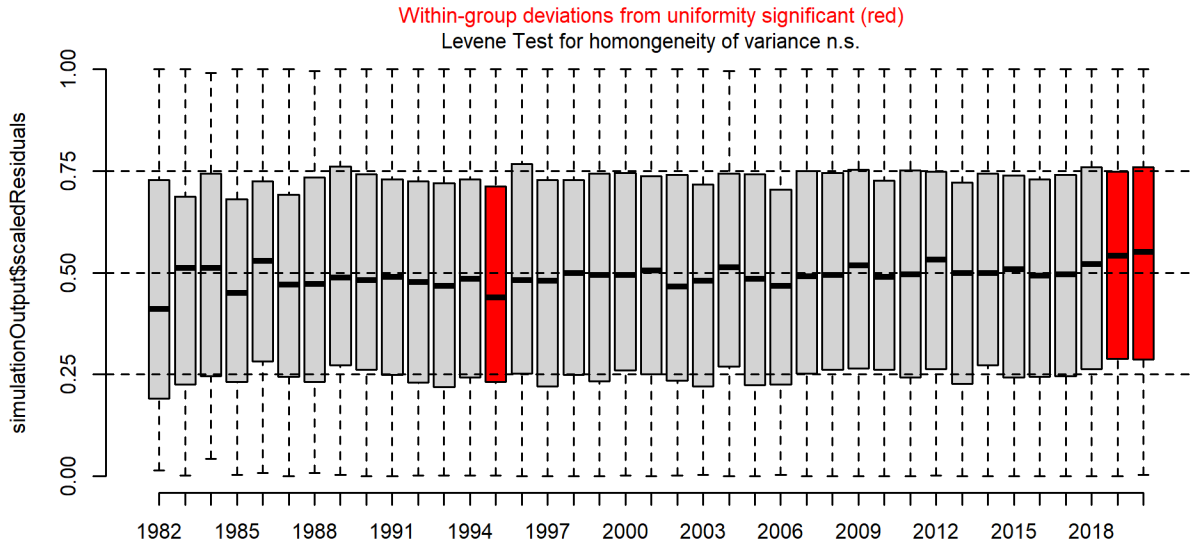

Figure 7. Scaled residuals vs. year for the directed trips negative binomial model.

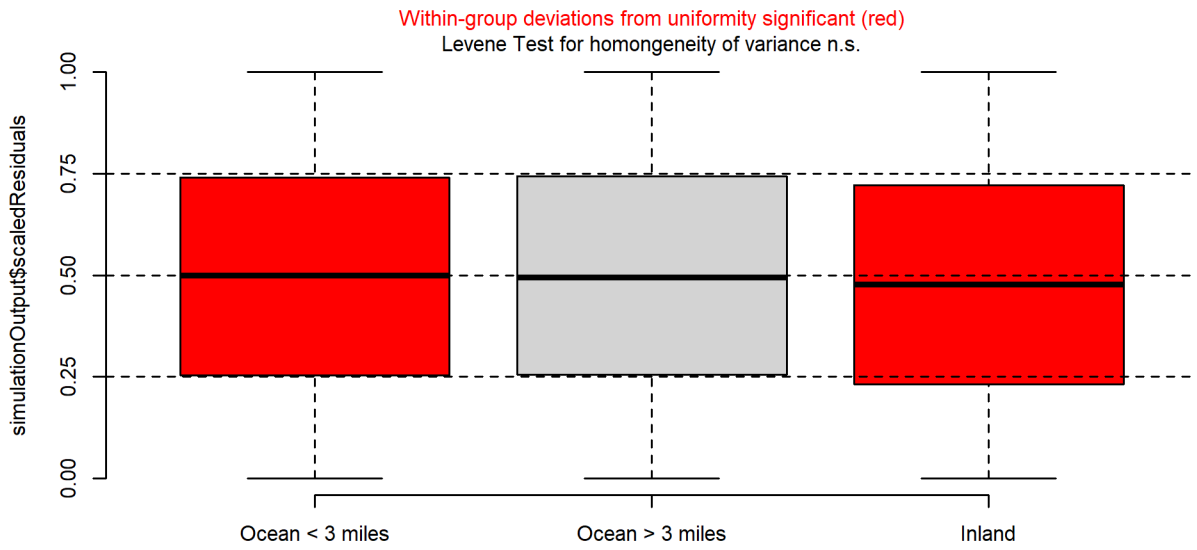

Figure 8. Scaled residuals vs. area fished for the directed trips negative binomial model.

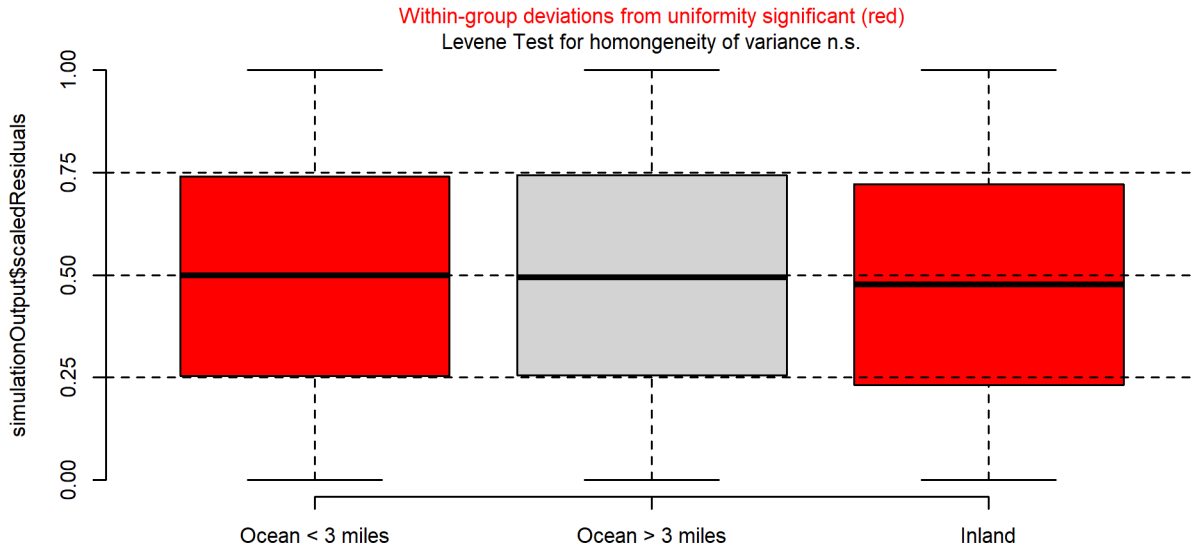

Figure 9. Scaled residuals vs. kind of day for the directed trips negative binomial model.

Figure 10. Scaled residuals vs. mode of fishing for the directed trips negative binomial model.

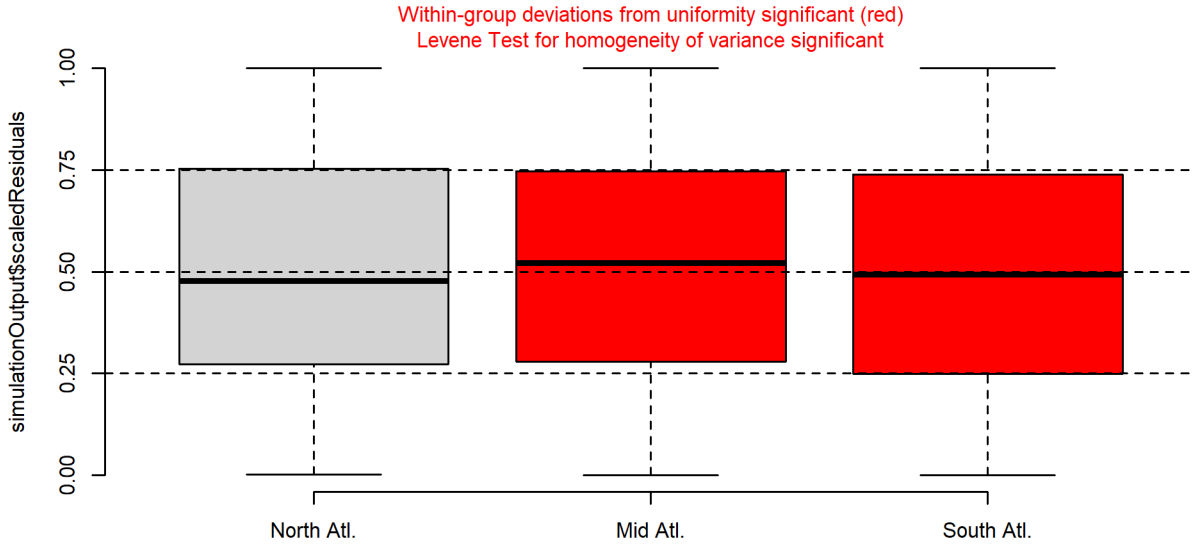

Figure 11. Scaled residuals vs. region for the directed trips negative binomial model.

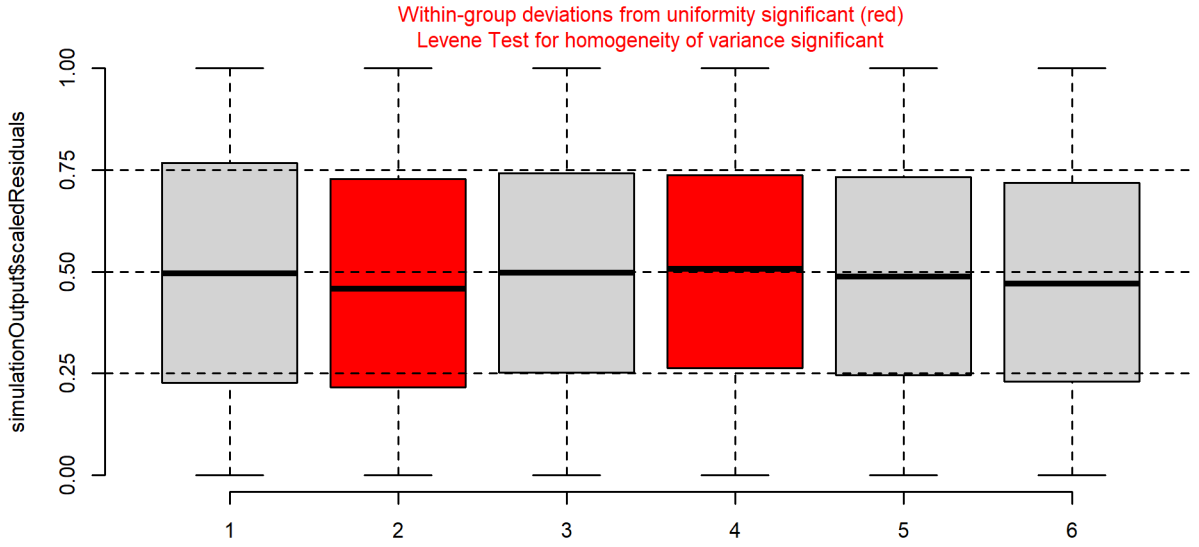

Figure 12. Scaled residuals vs. wave for the directed trips negative binomial model.

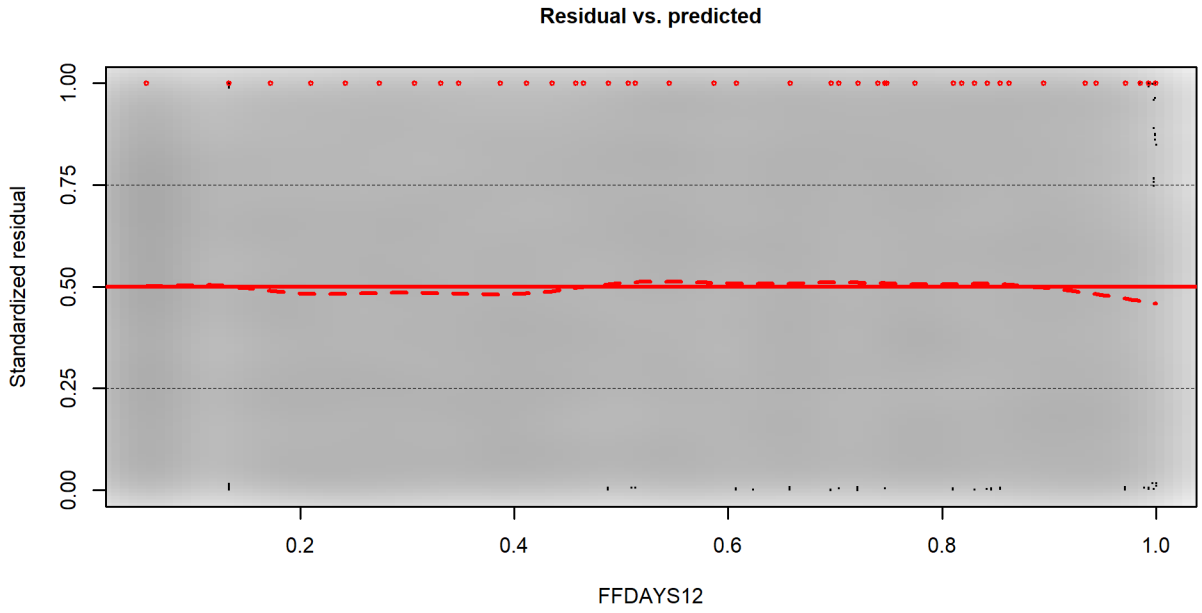

Figure 13. Scaled residuals vs. avidity for the directed trips negative binomial model.

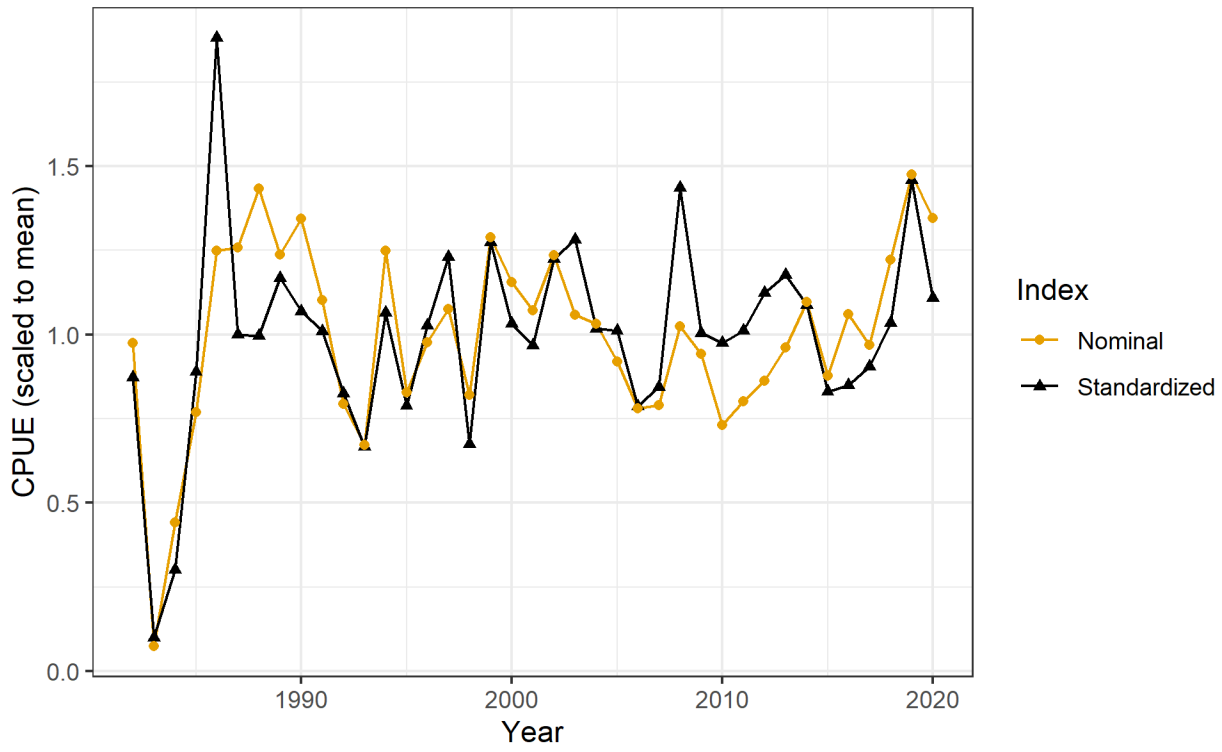

Figure 14. Standardized MRIP index plotted with the nominal, unstandardized CPUE from the directed trips approach. Both indices are scaled to their time-series mean.

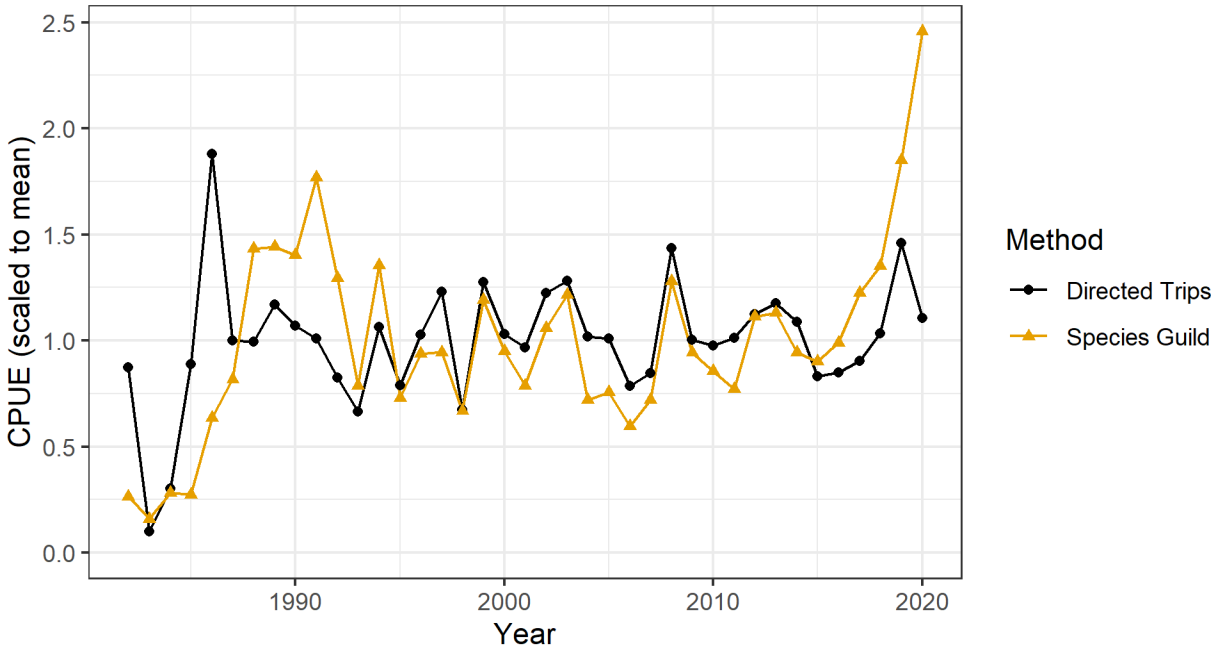

Figure 15. Standardized MRIP index plotted with the nominal, unstandardized CPUE from the directed trips approach. Both indices are scaled to their time-series mean.

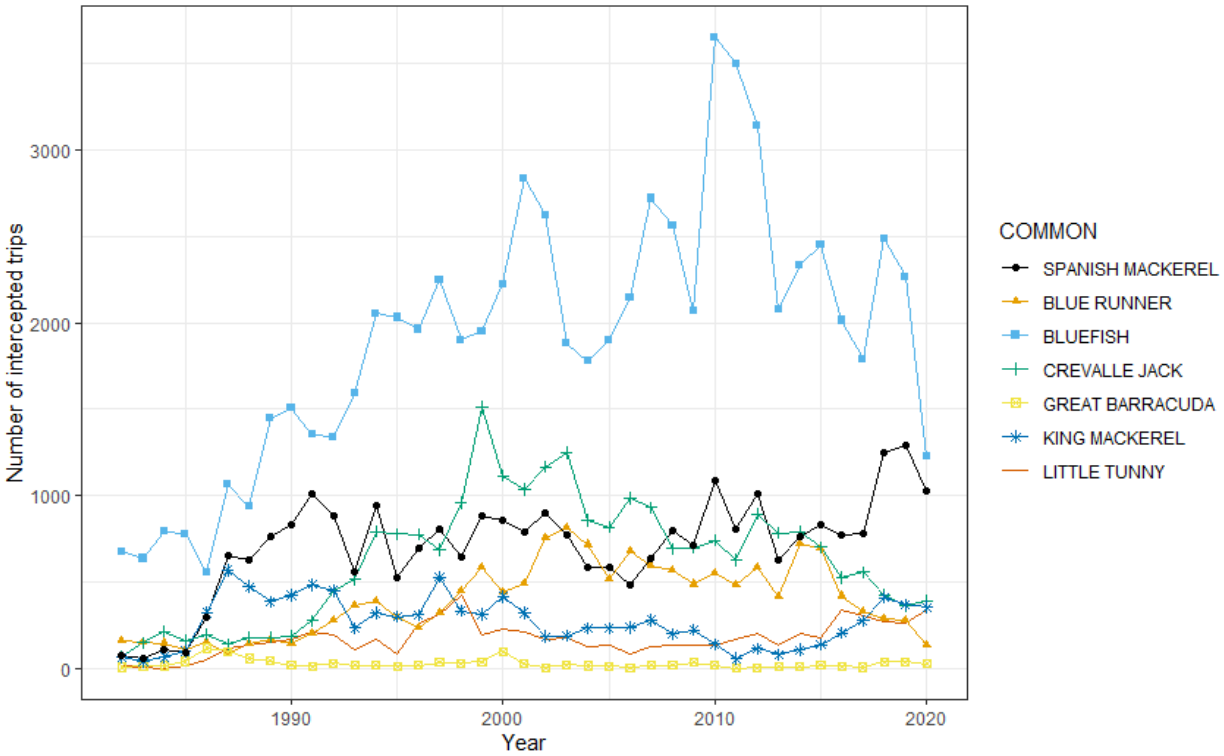

Figure 16. Number of intercepted trips by year for the most commonly co-occurring species for the guild approach.