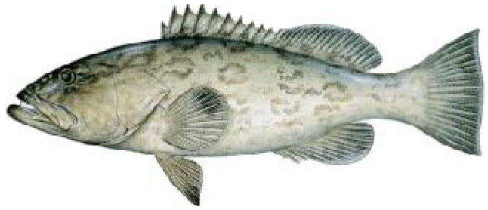

Interim Analysis for Gulf of Mexico Gag Grouper

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Keywords

Interim Analysis, Health Check, Index of Abundance, Gag Grouper, Gulf of Mexico

Abstract

Interim analyses (IA) are designed to occur between regular stock assessments conducted through the Southeast Data Assessment and Review process (SEDAR) to provide a health check on current stock conditions, or an opportunity to adjust harvest recommendations prior to the next assessment (Huynh et al. 2020). In the case of Gulf of Mexico Gag Grouper, the two candidate indices for the IA (from the Panama City Laboratory Camera Fishery-Independent Survey and the SEAMAP Reef Fish Video Survey) were updated to 2021, which does not provide a long enough time series to conduct a proper IA following the methods of Huynh et al. (2020). As such, a simple health check is conducted. Both indices show a downward trend from 2019 (terminal year of the assessment) to 2020 followed by a slight uptick in 2021. The Age-0 Survey index was updated to 2022. That index tracks young-of-the-year Gag Grouper and shows an uptick in recruitment in 2020 followed by a downward trend from 2020 to 2022, with the 2022 index value being among the lowest in the time series.

Introduction

The Gulf of Mexico Gag Grouper stock was last assessed in 2021/2022 (SEDAR 72; Operational assessment with terminal year 2019) and was determined to be overfished and undergoing overfishing (SEDAR 2022). As a result, NOAA Fisheries implemented a Temporary Rule (88 FR 27701) that intended to reduce overfishing of Gag during the 2023 fishing year. These interim measures reduced the total stock ACL from 3,120,000 lb gutted weight (gw) (MRIP-CHTS units) to 661,901 lb gw (MRIP-FES units), and brought modifications to the recreational fishing season. In June 2023, the Gulf of Mexico Fishery Management Council took final action on Reef Fish Amendment 56: Modification to Catch Limits, Sector Allocation, and Recreational Fishing Seasons for Gulf of Mexico Gag (GMFMC 2023). This Amendment established a rebuilding timeline of 18 years and set corresponding annual catch limits at 75% of the fishing mortality associated with a 40% spawning potential ratio (75% of F40%SPR). The resulting total ACL for 2024 was set to 444,000 lb gw (SRFS units). Recent trends in catches compared with the quotas are depicted in **Figure 1**.

For this IA, indices of abundance from all three fishery independent surveys included in the SEDAR 72 Base Model SRFS Run (SEDAR 2022) were updated. The Panama City Laboratory Camera Fishery-Independent Survey index and SEAMAP Reef Fish Video Survey index were updated through 2021, and the Age-0 Survey index through 2022. This document describes recent index trends since 2019, the terminal year of the assessment.

Materials and Methods

Index Selection Process

Three fishery independent survey indices were used in SEDAR 72: 1. the Panama City Laboratory Camera Fishery-Independent Survey, 2. the SEAMAP Reef Fish Video Survey, and 3. the Age-0 Survey (combined Florida State University Estuarine Gag Survey, NMFS PC Lab St. Andrew Bay Survey, and State of Florida FWC Estuarine (FIM) Survey).

The prediction skill of the SEDAR 72 Base Model SRFS Run for each of these CPUE series was tested using the hindcasting cross-validation approach of Kell et al. (2021). In this approach, recent CPUE data are sequentially removed, and the assessment model is refitted with the remaining data. Known values (observations) are then compared to model estimates (calculated by multiplying catchability and vulnerable biomass obtained from the stock assessment model). The mean absolute scaled error (MASE; Hyndman and Koehler 2006) is calculated for a 5-year period for each data input where available. The MASE scales the mean absolute error (MAE) of forecasts (i.e., prediction residuals) to the MAE of a naïve in-sample prediction (i.e. random walk using the last year's survey value) (Carvahlo et al. 2021). A skilled model would improve the model forecast compared to the baseline. A MASE value of 0.5 indicates that the forecast is twice as accurate as the baseline and values >1 indicate that the average model forecasts are worse than the baseline (Carvahlo et al. 2021; Kell et al. 2021).

All MASE scores for the fishery independent indices used in SEDAR 72 were below 1 (**Figure 2**), indicating that the base model is predicting the indices more accurately than the naïve prediction. Most accurate predictions are observed for the Panama City Laboratory Camera Fishery-Independent Survey index with a MASE of 0.47, followed by the Age-0 Survey index (MASE=0.84) and the SEAMAP Reef Fish Video Survey index (MASE=0.96).

Indices Update

Indices were updated following the same methodology used during SEDAR 72; see Gardner et al. (2020) for the Panama City Laboratory Camera Fishery-Independent Survey, Campbell et al. (2020) for the SEAMAP Reef Fish Video Survey, and Ingram (2021) for the Age-0 Survey. Additional details on survey design, data filtering and exclusions, modeling approach and results are provided in the Appendix.

Starting in 2020, the stand-alone PC and SEAMAP surveys ceased and were replaced by a combined survey (G-FISHER; Gulf Fishery Independent Survey of Habitat and Ecosystem Resources), which combines data collected through PC, the Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute (FWRI), and the NMFS Pascagoula Laboratory. To update the Panama City Laboratory Camera Fishery-Independent Survey and SEAMAP Reef Fish Video Survey indices, post-2020 G-FISHER data were limited to the historical survey design footprints to match the indices used in SEDAR 72.

For the Panama City Laboratory Camera Fishery-Independent Survey, during SEDAR 72, the year 2005 was dropped from the index because video sampling was only completed in Apalachee Bay (East of Cape San Blas) in that year. The same decision was applied to this interim analysis.

The three indices differ in target population. The primary objective of the PC survey was establishing an annual index of abundance for young (age 0-3), pre-recruit gag, scamp, and red grouper (Gardner et al. (2020), and Appendix). The SEAMAP Reef Fish Video Survey collects data on mostly larger/older individuals (SEDAR 2022, see Appendix). And the Age-0 Survey, as its name indicates, provides an index of young-of-the-year Gag grouper.

Interim Approach

Interim approaches conducted for past SEDAR assessments (e.g. red grouper) typically seek to quantify a target ABC adjustment through the use of a harvest control rule that utilizes recent trends in observed indices of abundance following the general methodology proposed by Huynh et al. (2020). The harvest control rule takes the following forms depending on the number of years used in the moving average:

3-year moving average: $C_{y+1} = C_{ref} * \left(\frac{1}{3}\sum_{k=y-2}^{y} I_k\right) / \left(\frac{1}{3}\sum_{ref=yref-1}^{yref+1} I_{ref}\right)$ (Equation 1)

5-year moving average: $C_{y+1} = C_{ref} * \left(\frac{1}{5}\sum_{k=y-4}^{y} I_k\right) / \left(\frac{1}{5}\sum_{ref=yref-3}^{yref+1} I_{ref}\right)$ (Equation 2)

where:

C_{y+1} = adjusted catch recommendation for year $y+1$.

C_{ref} = reference catch level to be adjusted (Y_{ref} = 2020).

I_k = average of the observed index values during the recent period (3-year 2019-2021 or 5-year 2017-2021).

I_{ref} = average of the observed index values during the reference period (3-year 2019-2021 or 5-year 2017-2021).

This approach could not be applied to Gulf of Mexico Gag Grouper because the two preferred indices for the IA (i.e., the Panama City Laboratory Camera Fishery-Independent Survey index and the SEAMAP Reef Fish Video Survey index) could only be updated to 2021. As such, both I_k and I_{ref} were equal and the analysis could not yield usable results. Those two indices are preferred over the Age-0 Survey index given that they each track a portion of the exploitable population. In contrast, the Age-0 Survey, which was updated to 2022, is not a good candidate for adjusting catch since that index is an index of recruitment.

As such, this IA is intended as a simple health check on the current condition of the stock. Index trends since the terminal year of the assessment (2019) are described in more detail below.

Results

Figure 3-Figure 5 provide a comparison of the updated indices through 2021/2022 with the indices used in SEDAR 72. Updated indices fell within the confidence interval of the SEDAR 72 time series for the Panama City Laboratory Camera Fishery-Independent Survey and SEAMAP

Reef Fish Video Survey indices. Larger differences were observed for the Age-0 Survey index but trends between indices were similar (**Figure 5**).

For the Panama City Laboratory Camera Fishery-Independent Survey index, relative abundance peaked in 2006, was lowest in 2020, and has remained low in recent years. Index values for 2020 and 2021 were among the lowest in the time series (**Figure 3**). The 2020 index value was 85% lower than the 2019 value and the 2021 index value was 73% lower than the 2019 value (**Table 1**). A total of 5 and 11 fish were measured in the survey in 2020 and 2021 (**Figure 6**) with mean fork length (FL) 45 cm (SD=11cm) and 44cm FL (SD=22cm), respectively.

For the SEAMAP Reef Fish Video Survey index, relative abundance peaked in 2005, was lowest in 1994, and has remained low in recent years. The 2020 index value was 69% lower than the 2019 value and the 2021 index value was 11% higher than the 2019 value (**Table 1**). A single fish was measured in the survey in 2021 (67cm FL).

For the Age-0 Survey index, relative abundance peaked in 2006, was lowest in 2011, and has remained low in recent years. The 2020 index value was 103% higher than the 2019 value, while the 2021 and 2022 index values were 55% and 77% lower than the 2019 value, respectively (**Table 1**).

Discussion

On average, recent index values show a declining trend since 2019, with little sign of improvement in stock condition. The recruitment index does show signs of a potentially strong 2020 year class. It remains to be seen what impact that year class will have on the overall stock, and whether its magnitude will be large enough to improve stock conditions into the future. The 2020 year class would be expected to enter the recreational fishery (private mode) in 2022 and be fully selected by 2023 – yet catches for 2022 remain low (**Figure 1**).

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Gardner, C.L., K.E. Overly, and A.G. Pollack. 2020. Gag Mycteroperca microlepis Findings from the NMFS Panama City Laboratory Trap & Camera Fishery-Independent Survey – 20052019 . SEDAR72-WP-06. SEDAR, North Charleston, SC. 12 pp.

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Tables

Table 1. Recent index values (2019 on) and associated differences in annual index values compared to the terminal year of the SEDAR 72 assessment (2019).

Year	PC Index	% difference from 2019	SEAMAP Index	% difference from 2019	Age-0 Index	% difference from 2019
2019	1.41	0	0.77	0	0.71	0
2020	0.21	-85	0.24	-69	1.45	103
2021	0.38	-73	0.86	11	0.32	-55
2022					0.17	-77

Figures

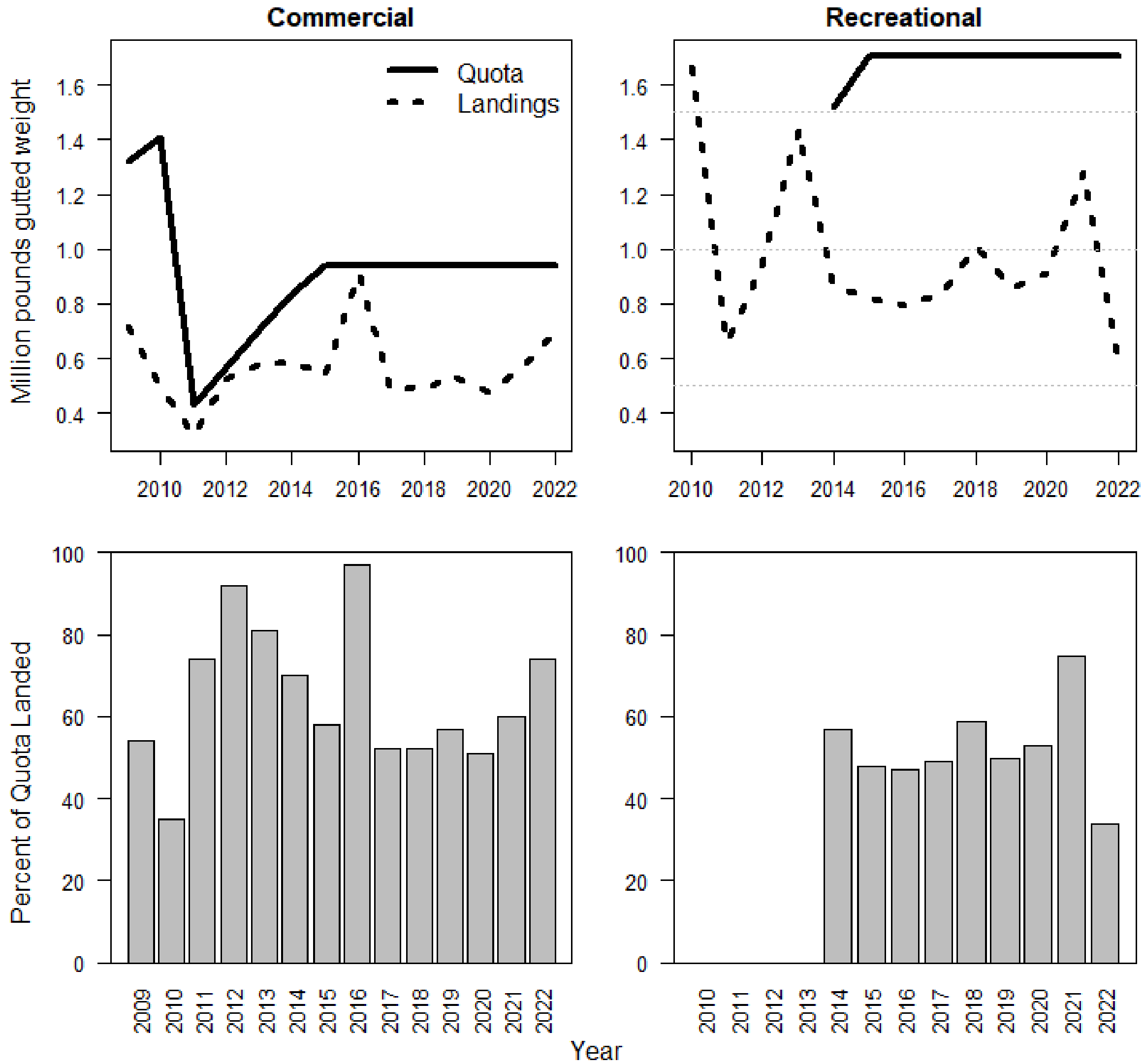

Figure 1. Commercial and recreational landings (dashed line) and Annual Catch Targets (ACT; thick line) for Gulf of Mexico Gag Grouper. Bars represent the percent of quota landed. Commercial data from 2010 to 2022 were obtained from the Quotas and Catch Allowances, accessed September 7, 2023 (*https://secatchshares.fisheries.noaa.gov/additionalInformation* [select Commercial Quotas/Catch Allowances (all years)]), remaining years were obtained from the Gulf of Mexico Historical Commercial Landings and Annual Catch Limits (ACLs), updated January 20, 2023 (*https://www.fisheries.noaa.gov/southeast/gulf-mexico-historical-commercial-landings-and-annual-catch-limit-monitoring*). Recreational data from 2010 through 2021 were obtained from recreational historical landings, accessed September 7, 2023 (*https://www.fisheries.noaa.gov/southeast/recreational-fishing-data/gulf-mexico-historical-recreational-landings-and-annual-catch*), data for 2022 were obtained September 7, 2023 from *https://www.fisheries.noaa.gov/southeast/recreational-fishing/2022-and-2023-gulf-mexico-recreational-landings-and-annual-catch*. **All recreational data are in MRIP-CHTS units.**

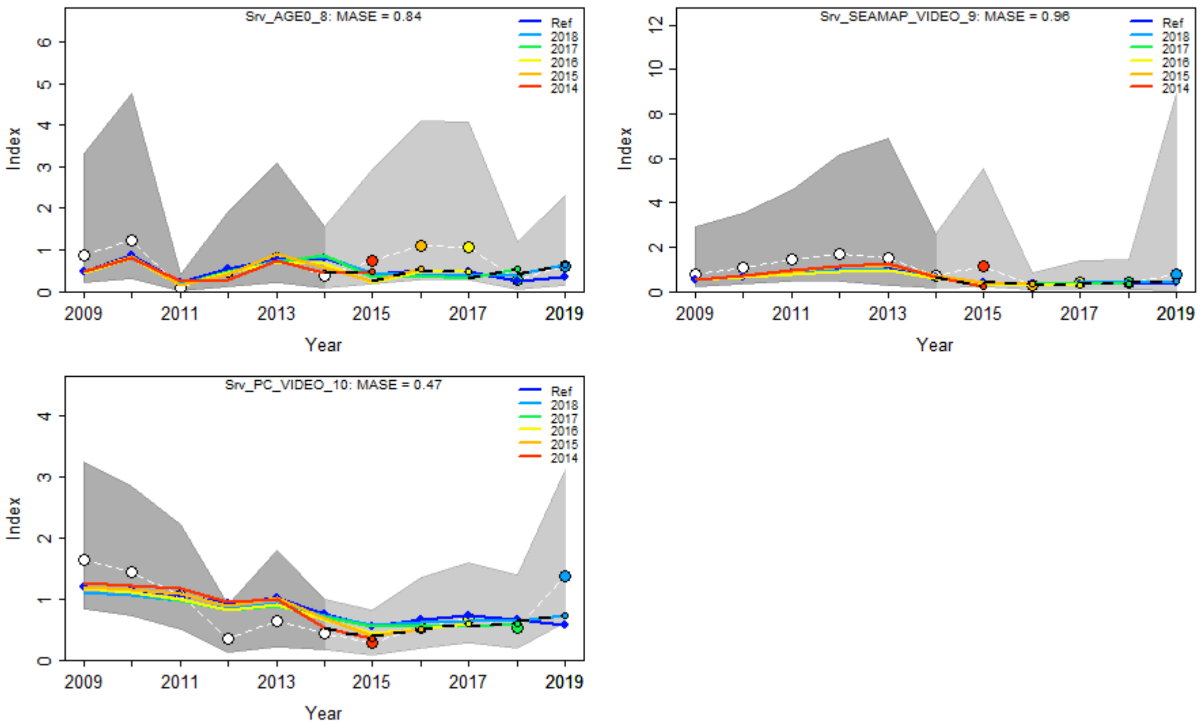

Figure 2. Hindcasting cross-validation (HCxval) results for fishery independent indices (the Age-0 Survey, the SEAMAP Reef Fish Video Survey, and the Panama City Laboratory Camera Fishery-Independent Survey) from the Gag Grouper SEDAR 72 Base Model SRFS Run (SEDAR 2022), showing observed (large points connected with dashed line), fitted (solid lines) and one-year-ahead forecast values (small terminal points). HCxval was performed using one reference model (Ref) and five hindcast model runs (solid lines) relative to the expected catch-per-unit-effort (CPUE). The observations used for cross-validation are highlighted as color-coded solid circles with associated 95 % confidence intervals (light-gray shading). The model reference year refers to the endpoints of each one-year-ahead forecast and the corresponding observation (i. e., year of peel + 1). The mean absolute scaled error (MASE) score associated with each CPUE time series is denoted in each panel.

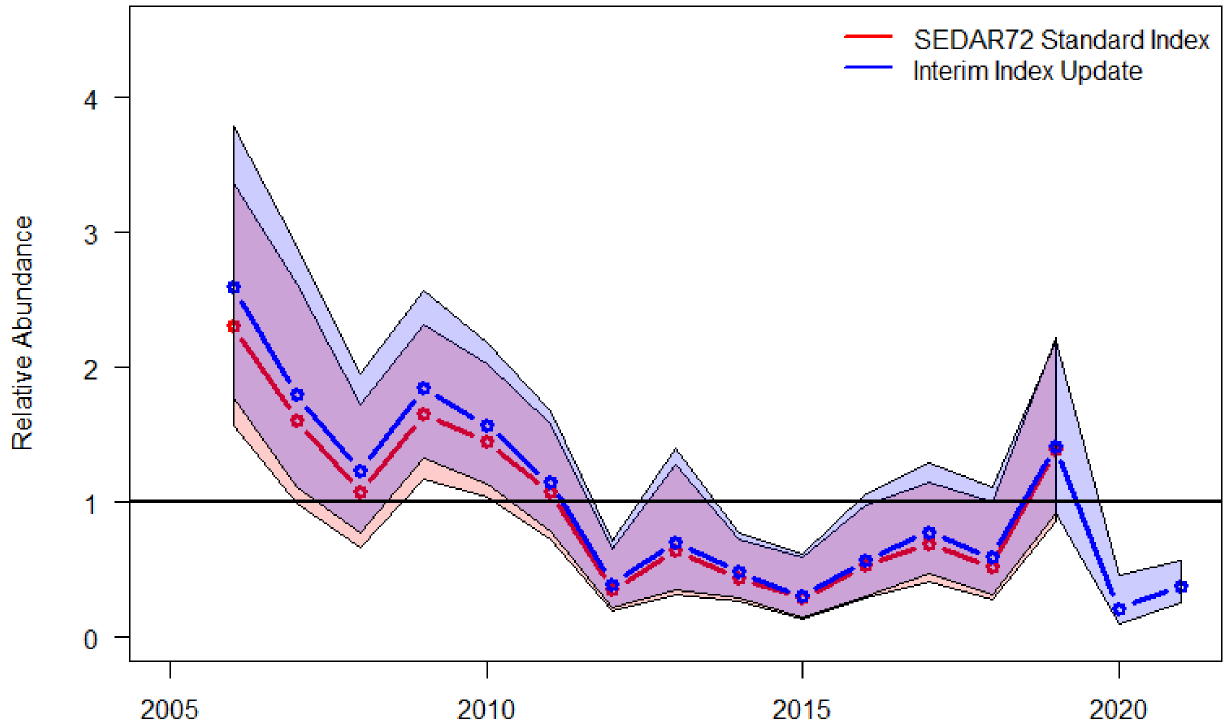

Figure 3. Comparison of Panama City Laboratory Camera Fishery-Independent Survey index of abundance derived for Gag Grouper in the Gulf of Mexico for SEDAR 72 compared to the index updated through 2021 with confidence intervals. All indices have been standardized to a mean of 1.

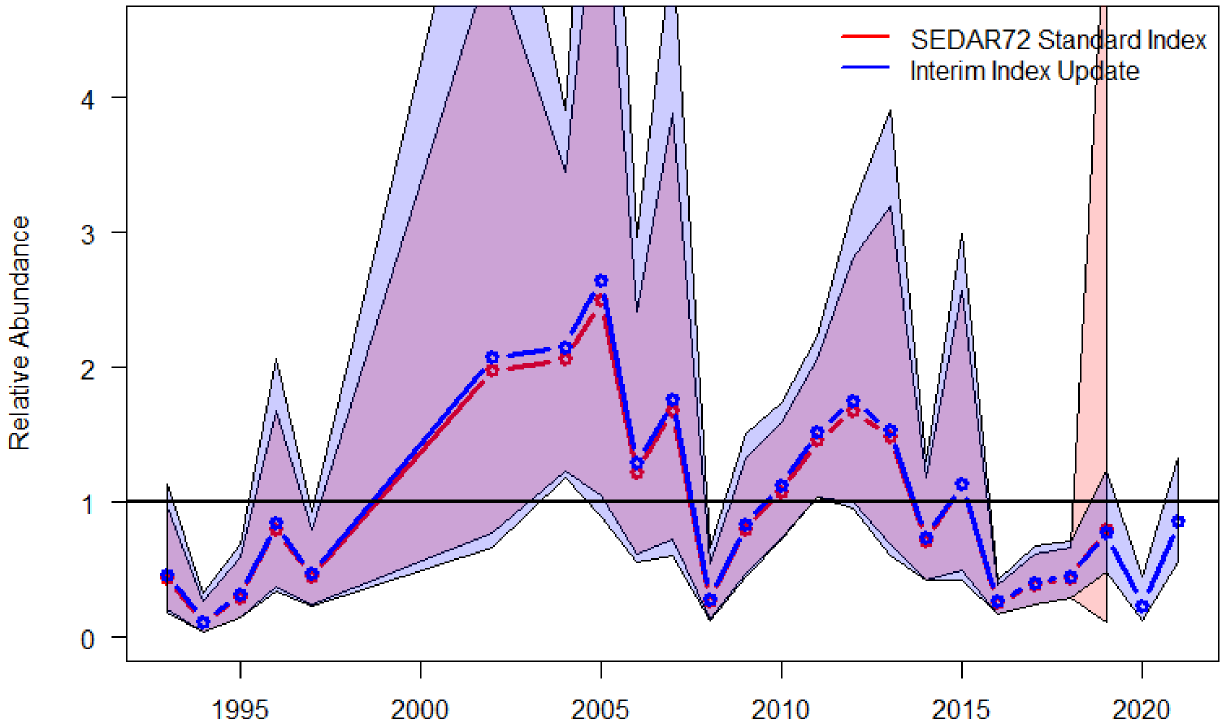

Figure 4. Comparison of SEAMAP Reef Fish Video Survey index of abundance derived for Gag Grouper in the Gulf of Mexico for SEDAR 72 compared to the index updated through 2021 with confidence intervals. All indices have been standardized to a mean of 1.

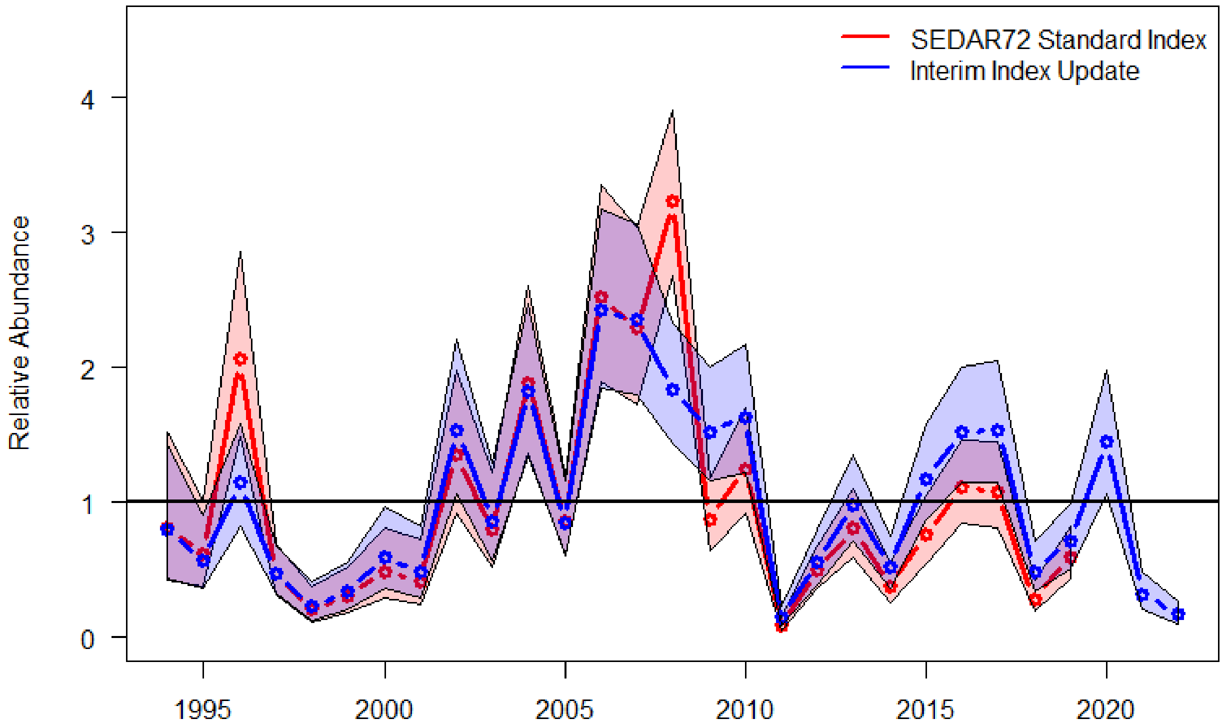

Figure 5. Comparison of Age-0 Survey index of abundance derived for Gag Grouper in the Gulf of Mexico for SEDAR 72 compared to the index updated through 2021 with confidence intervals. All indices have been standardized to a mean of 1.

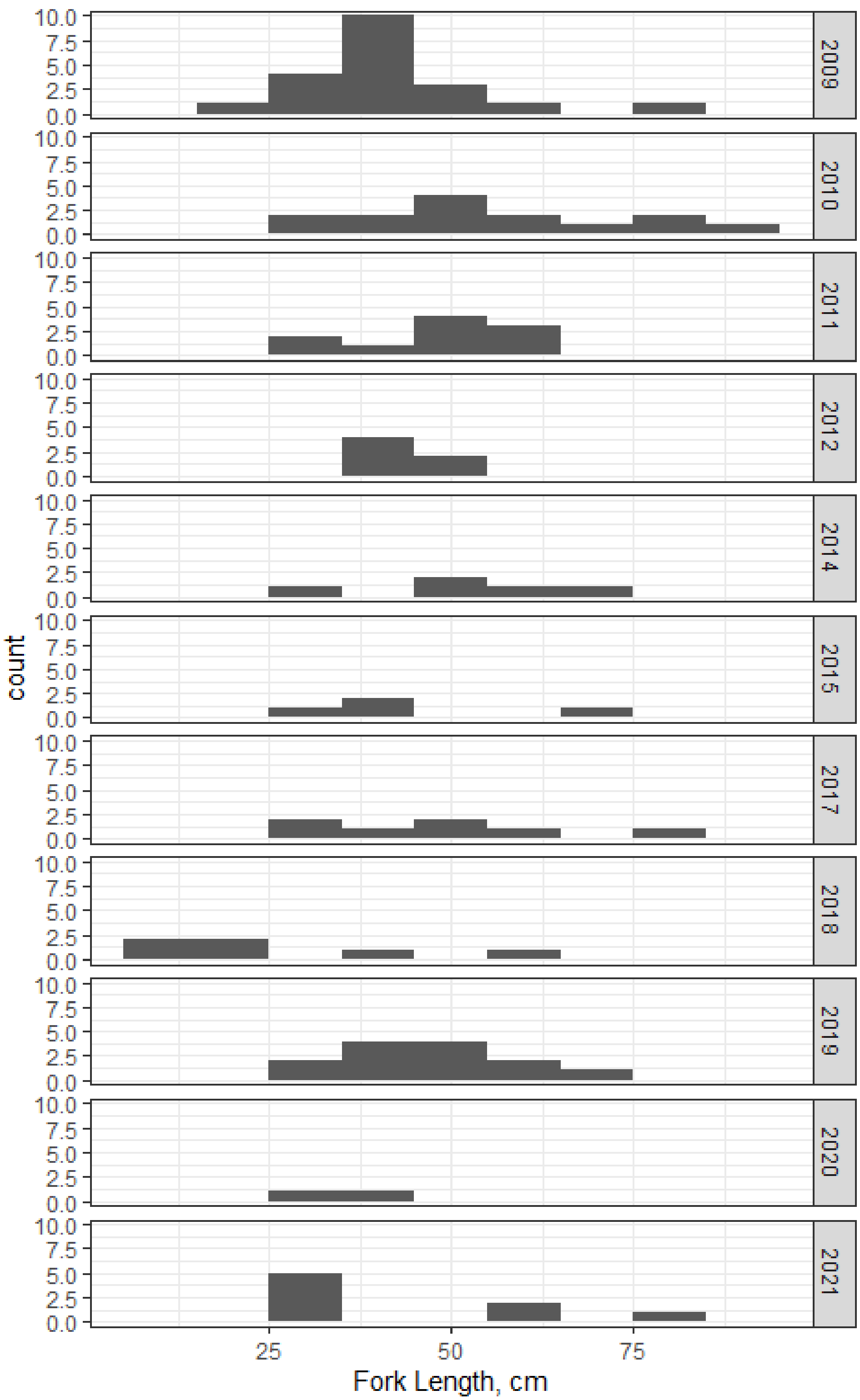

Figure 6. Lengths collected during the Panama City Laboratory Camera Fishery-Independent Survey.

APPENDIX

An Updated Index of Relative Abundance for Gag *Mycteroperca microlepis* Findings from the NMFS Panama City Laboratory Fishery-Independent Video Survey– 2005-2021

Katherine E. Overly and Adam G. Pollack

This document serves to update the index of relative abundance for gag grouper (*Mycteroperca microlepis*) sampled during the NMFS Panama City Laboratory Fishery-Independent Video Survey in the Gulf of Mexico (GOM) through 2021. Data were limited to the historical sampling frame with stations completed east 87.5° W and north of 28.3° N and at depths less than 60 m (Figure 1).

The final delta-lognormal NMFS Panama City Laboratory Fishery-Independent Video Survey index of gag grouper abundance retained year (2005 – 2021), depth (6 – 58 m, continuous), month (May – November), and region (East of Cape San Blas and West of Cap San Blas) in the binomial submodel, and year and region in the lognormal submodel. The updated annual abundance index is shown in Table 1 and Figure 2. The diagnostic plots for the lognormal submodel are shown in Figure 2.

Although sample sizes were small in the stereo camera data, patterns of periodic strong cohorts moving through the population were present. This is observed as the occasional influx of smaller and younger fish driving the mean size down and increasing over the next few years. The survey often observes pre-recruit gag - about 76% were below the recreational minimum legal size limit of ~610 mm FL. Summaries of the size composition are displayed in Table 2 and Figure 4.

Table 1: Indices of gag abundance developed using the delta-lognormal (DL) model for NMFS Panama City Video Survey from 2005 - 2021 in the eastern Gulf of Mexico. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per video-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.

NominalFrequency	*N*	*DL Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
0.2439	41	0.3329	0.69566	0.3862	0.33004	1.4663
0.4	90	1.26331	2.63988	0.1918	1.80493	3.8611
0.41509	53	0.8747	1.82783	0.2422	1.13377	2.9468
0.3012	83	0.59989	1.25356	0.2352	0.78812	1.9939
0.45283	106	0.90096	1.8827	0.166	1.35387	2.6181
0.33824	136	0.76792	1.60468	0.1651	1.156	2.2275
0.26582	158	0.55846	1.16699	0.1915	0.79838	1.7058
0.10884	147	0.1916	0.40038	0.3058	0.22019	0.728
0.12941	85	0.3432	0.71717	0.3539	0.36079	1.4256
0.15625	160	0.23338	0.48768	0.2468	0.29989	0.7931
0.06707	164	0.14654	0.30621	0.3664	0.15058	0.6227
0.09036	166	0.27822	0.58139	0.3162	0.31356	1.078
0.14094	149	0.37955	0.79313	0.258	0.47736	1.3178
0.15385	91	0.2873	0.60035	0.3238	0.31924	1.129
0.26168	107	0.6899	1.44165	0.2215	0.9307	2.2331
0.06569	137	0.10283	0.21489	0.4002	0.09942	0.4645
0.13699	292	0.18464	0.38584	0.2036	0.25785	0.5774

Table 2. Gag lengths (FL mm) observed from the NMFS Panama City Lab Video Survey 2009-2021.

Year	n	Mean FL (mm)	SD	Min FL (mm)	Max FL (mm)
2009	33	460	156.3	245	913
2010	22	527	157.0	334	909
2011	22	598	180.3	299	987
2012	13	506	107.8	362	698
2014	6	507	126.2	308	657
2015	6	527	149.1	333	672
2017	7	492	178.5	304	833
2018	6	259	179.6	111	566
2019	16	475	143.2	278	736
2020	5	451	112.6	308	611
2021	11	442	219.9	143	806
Total	147	493	169.3	111	987

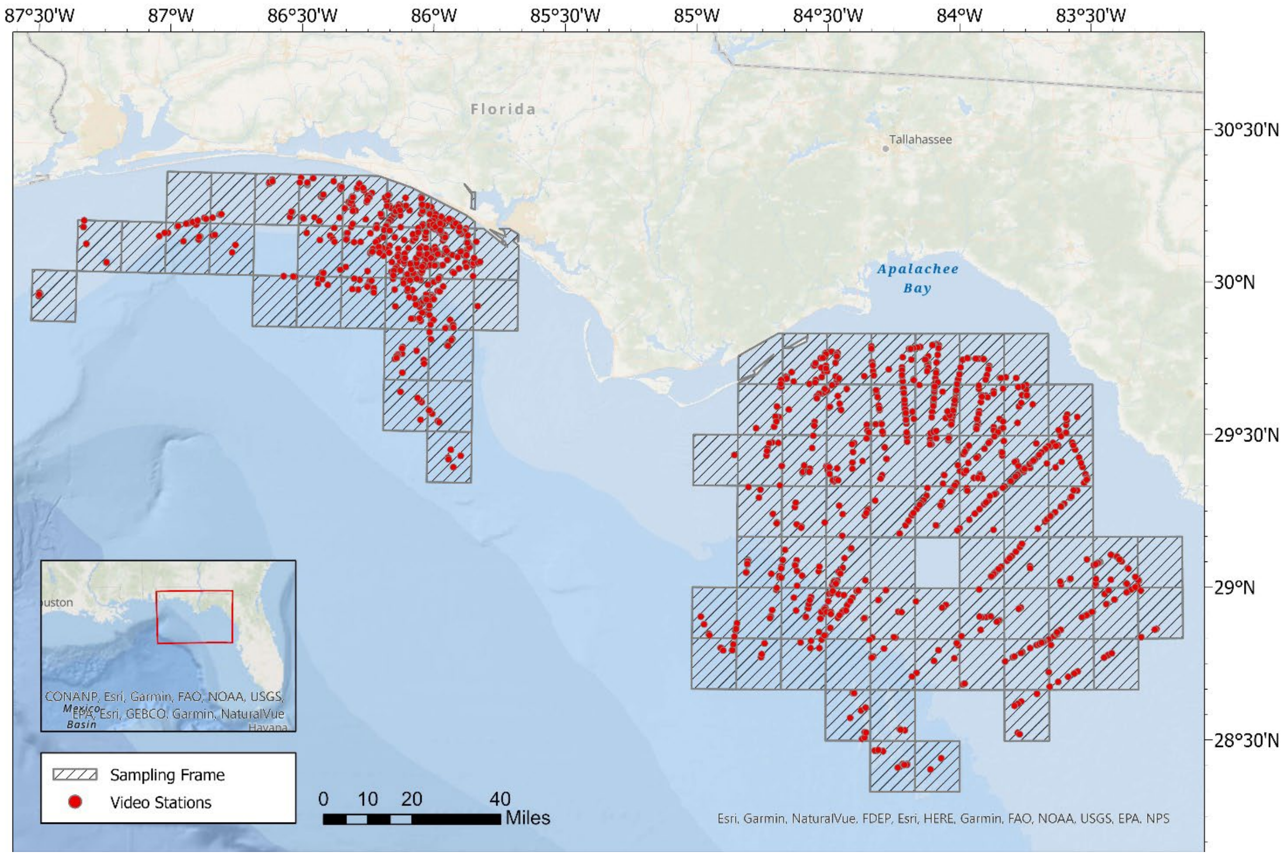

Figure 1. Video sampling locations 2005 - 2021.

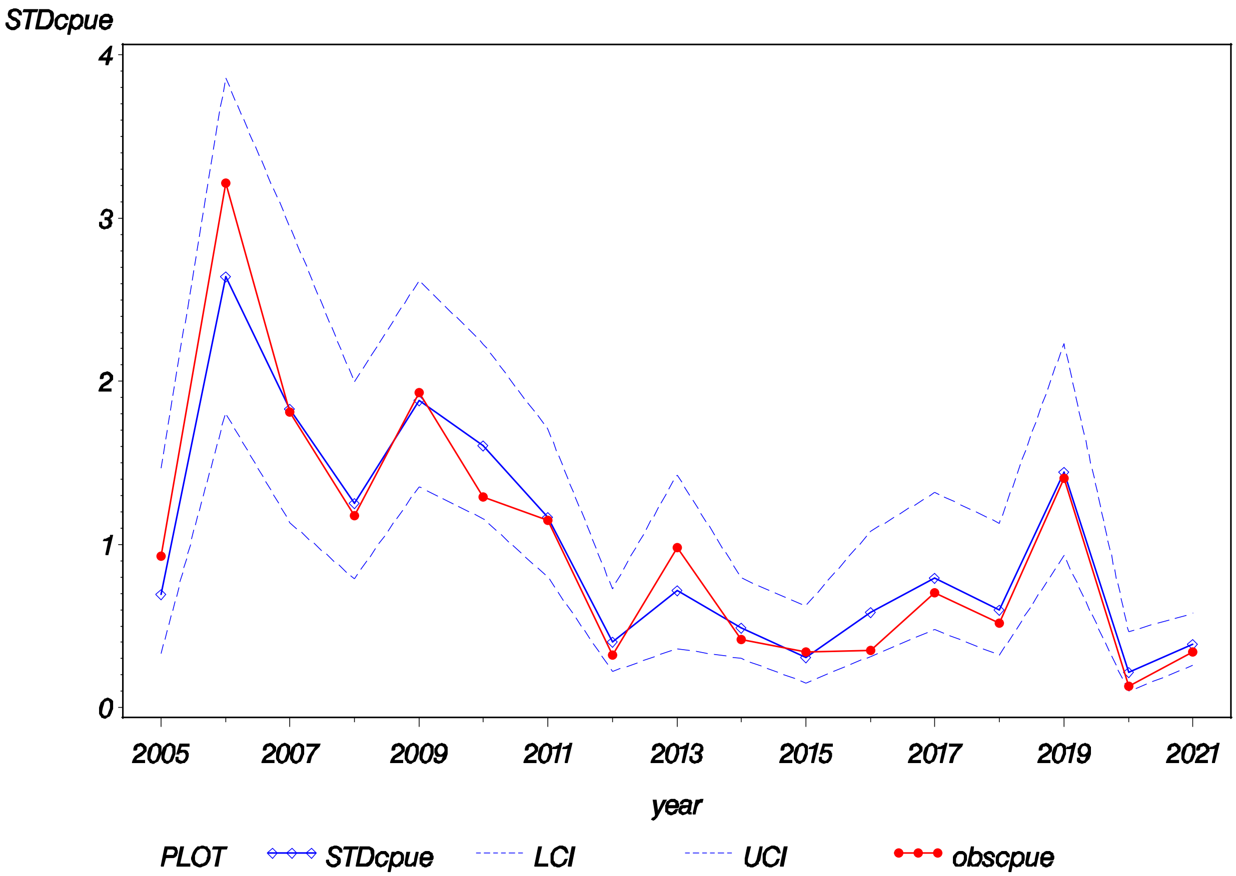

Figure 2. Annual index of abundance for gag from the NMFS Panama City Video Survey from 2005 – 2021.

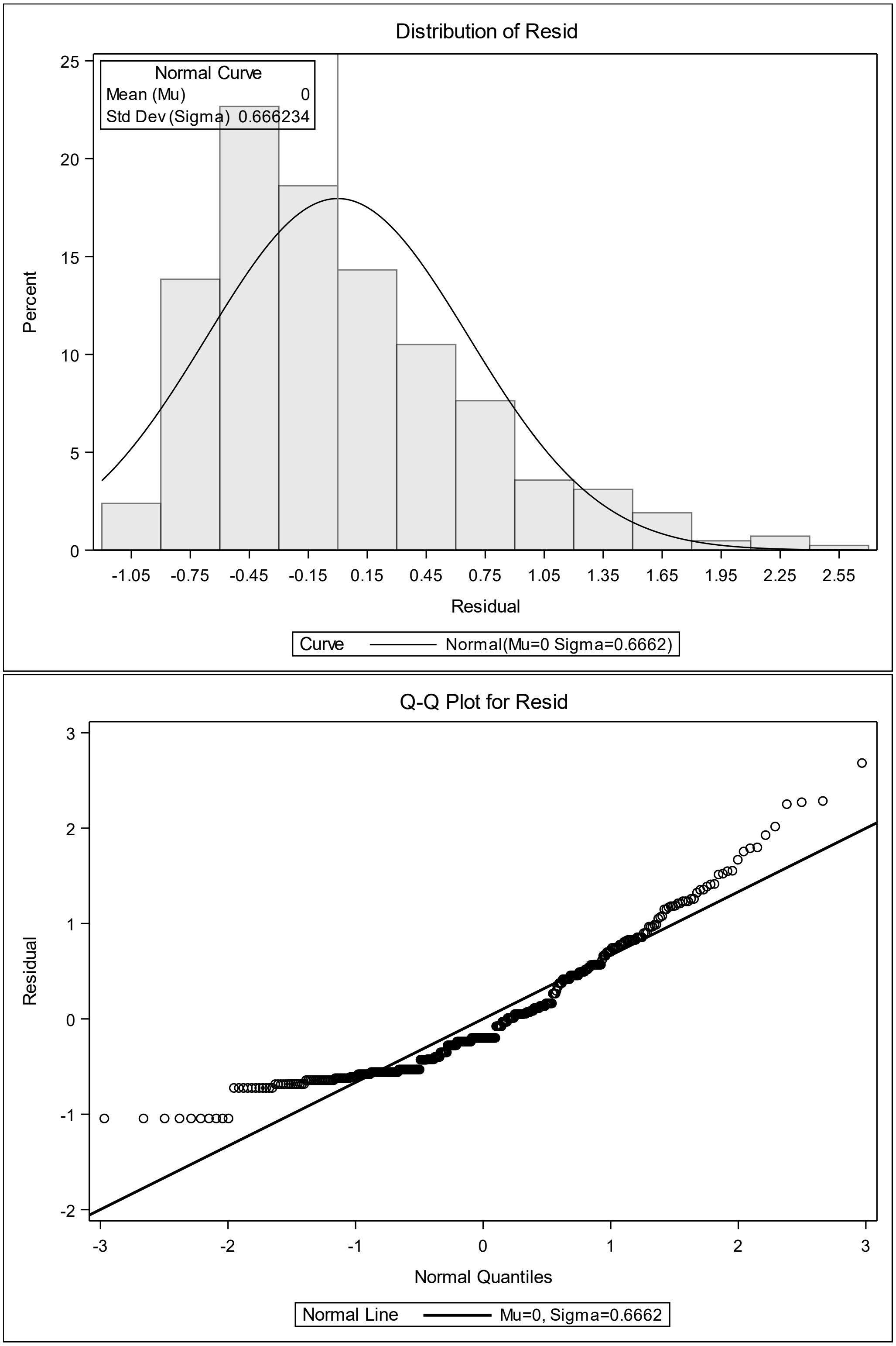

Figure 3. Diagnostic plots for lognormal component of the gag NMFS Panama City Video Survey model: **A)** the frequency distribution of log (CPUE) on positive stations, and **B)** the cumulative normalized residuals (QQ plot).

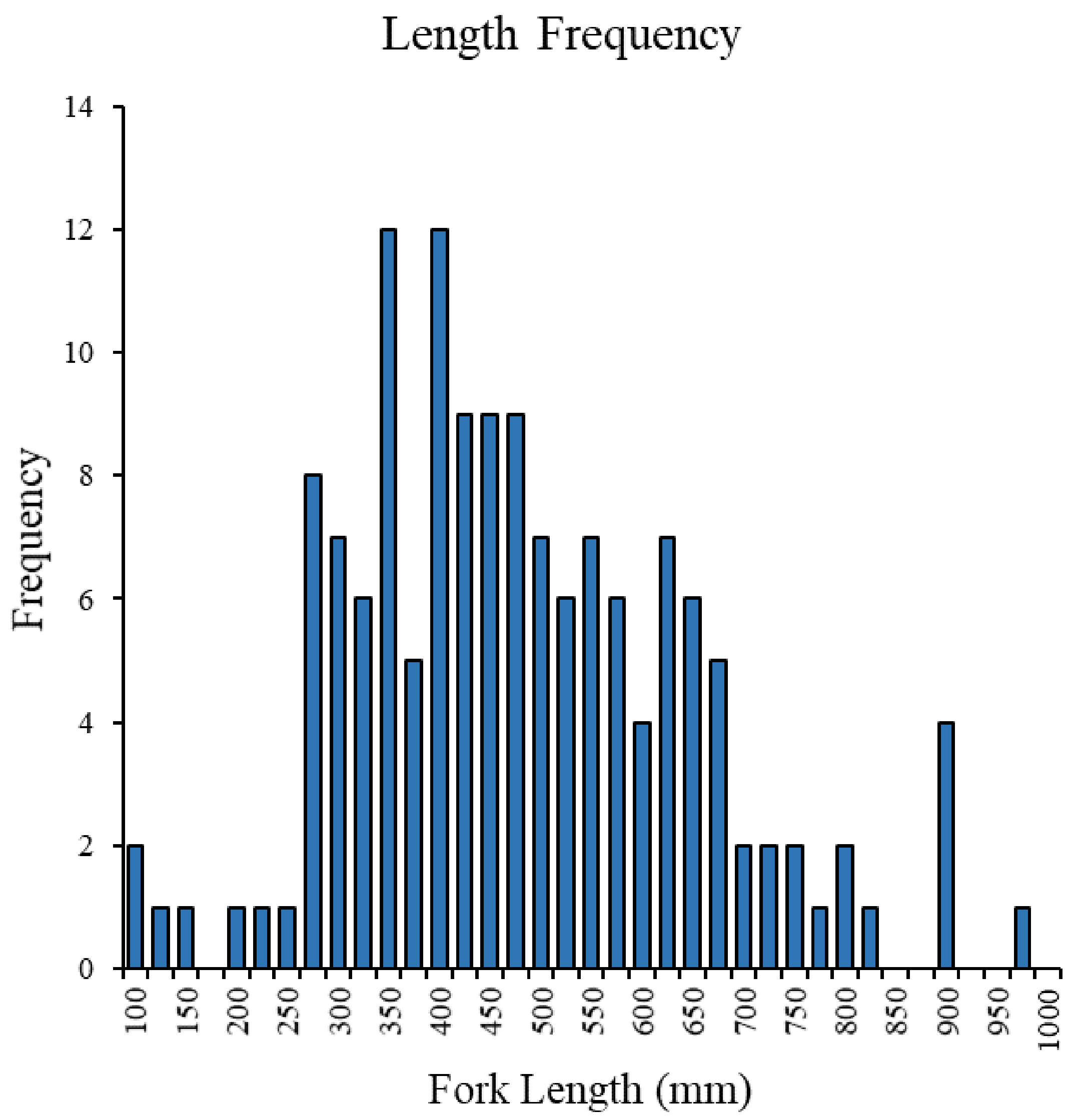

Figure 4. Overall size distribution of gag (25 mm bins) observed on stereo cameras: 2009 - 2021.

SEAMAP Reef Fish Video Survey:
Relative Indices of Abundance of Gag

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September 2023

This document serves to update the index of relative abundance for gag (*Mycteroperca microlepis*) observed during the SEAMAP Reef Fish Video survey conducted in the Gulf of Mexico (GOM) through 2021. Data were limited to those stations completed in the eastern GOM (east of 87° W) as many years there are zero observations of gag from the west Gulf and they tend to be at very low abundance (i.e. model mostly do not converge). Additionally we exclude sites that had average relief smaller than 0.15 m (same data treatment from SEDAR 72). This filter is applied to the data because gag are significantly associated with high relief features on sampled reefs and thus very low relief features is habitat that gag do not occupy.

In most years the SEAMAP Reef Fish Video survey shows good coverage in the defined sampling universe, and coverage improved through time as the sampling universe expanded and more sites were added to the survey. As this is an update assessment we apply the same model and used the same variables as were applied in SEDAR 72. In the east Gulf analysis variables retained in the negative-binomial model included year, reef, and maxrelief (Table 1). General trends reflect outcomes from SEDAR 72, with most recent years showing increasing standardized MaxN values from 2016-2021 with a dip in 2020 (Figure 1, Table 2). Proportion positives and standardized index values indicate a consistent increase since a recent low point observed in 2016, having tripled standardized index mincount over those years. Despite the recent increases estimated MaxN counts are still significantly lower than peaks observed in the early 2000's and 2010's. Because there is insufficient data to create west and GOM wide population models, it is safe to say that gag population trends are primarily driven by eastern populations. Despite this eastern trend in the spatial data western population do exist in low abundance and frequency and are commonly but inconsistently observed on the high-relief Louisiana banks.

Length frequency histograms show that most of the measurements were captured from east populations with few coming from the west GOM (Table 3, Figure 2). Regional size trends should be treated carefully due to the lack of sample in the west. East gulf Gag were 100 mm shorter than the west Gulf wide average however sample sizes in the west are small. In most years this trend holds true. Both regions showed a general trend of increasing total length of gag over the course of the survey with some inter-annual variability. We were unable to provide length data from 2020 as FWC conducted all of those surveys and video reads.

Campbell, Matthew, D., Kevin R. Rademacher, Paul Felts, Brandi Noble, Joseph Salisbury, and John Moser. 2020. SEAMAP Reef Fish Video Survey: Relative Indices of Abundance of Gag SEDAR72-WP-03. SEDAR, North Charleston, SC. 26 pp.

Table 1. Type III fixed effects output from the negative binomial model for east Gulf Gag showing significant variables year and maximum relief, and marginally significant 'reef' variable indicating if a camera observed reef directly.

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
year	23	2608	3.60	<.0001
REEF	1	2608	3.32	0.0684
MREL	1	2608	13.41	0.0003

Table 2. Output for the negative binomial index of relative abundance of Gag by year, east Gulf negative binomial model run.

Year	N	Proportion Positive	MaxN	Index	CV
1993	99	0.061	0.071	0.070	45.751
1994	61	0.016	0.016	0.017	54.959
1995	45	0.022	0.044	0.047	40.404
1996	100	0.100	0.120	0.127	45.741
1997	131	0.069	0.069	0.070	34.848
2002	118	0.212	0.331	0.312	57.977
2004	103	0.223	0.320	0.324	30.368
2005	140	0.193	0.379	0.398	54.989
2006	149	0.121	0.181	0.194	42.566
2007	153	0.176	0.261	0.265	54.462
2008	97	0.041	0.041	0.042	44.187
2009	134	0.082	0.127	0.125	30.781
2010	127	0.142	0.173	0.169	22.237
2011	182	0.159	0.225	0.230	19.528
2012	131	0.160	0.260	0.264	30.767
2013	79	0.152	0.253	0.231	47.753
2014	112	0.080	0.116	0.111	28.986
2015	60	0.133	0.167	0.171	49.496
2016	97	0.041	0.041	0.040	23.751
2017	118	0.059	0.059	0.060	26.592
2018	88	0.045	0.068	0.068	23.280
2019	138	0.065	0.109	0.116	24.041
2020	83	0.036	0.036	0.036	33.002
2021	89	0.079	0.135	0.129	22.203

Figure 1. Plot of the standardized indices for Gag, for the east Gulf wide negative binomial model run. Standardized MaxN values are shown with associated standard deviation.

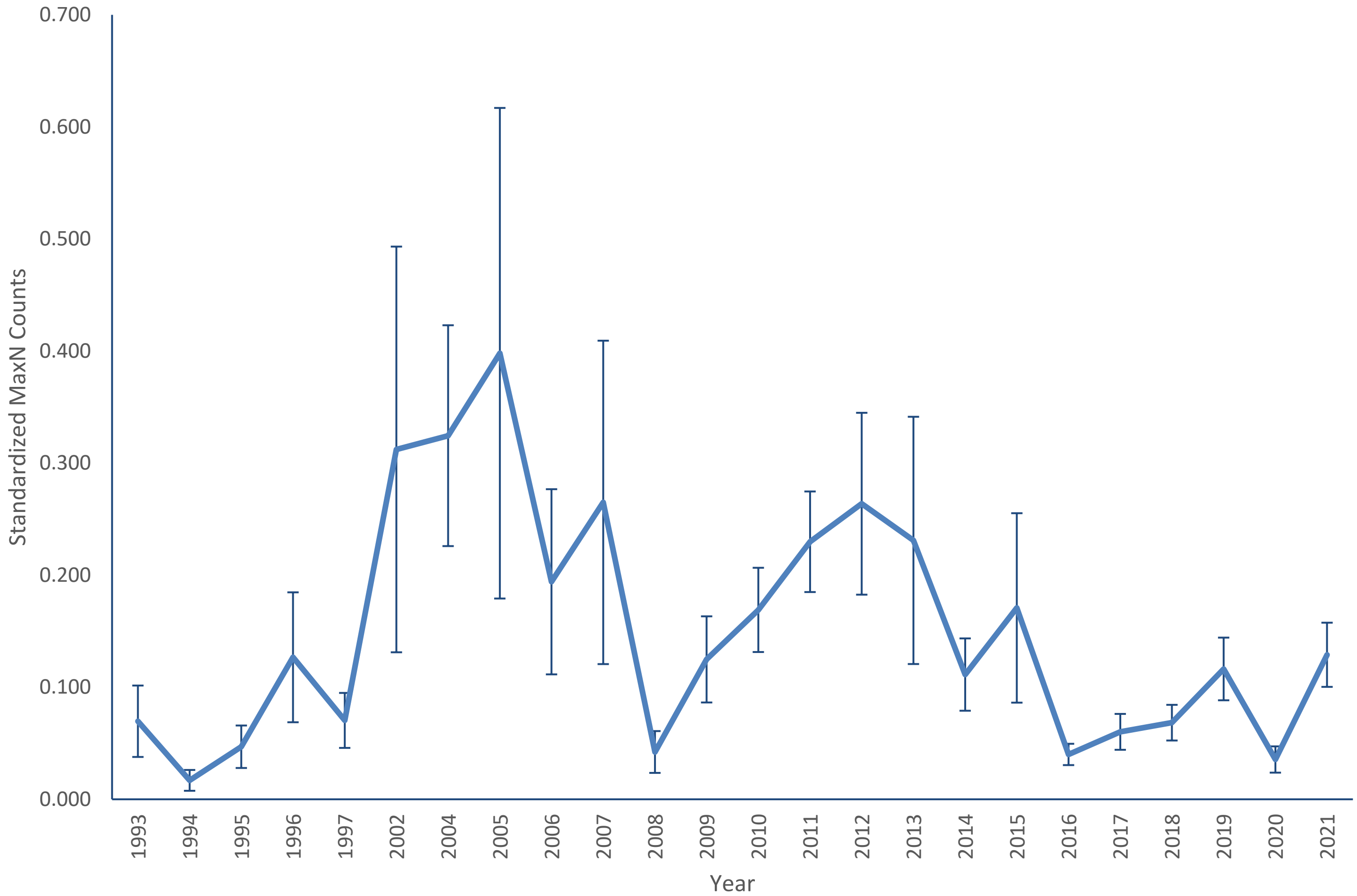
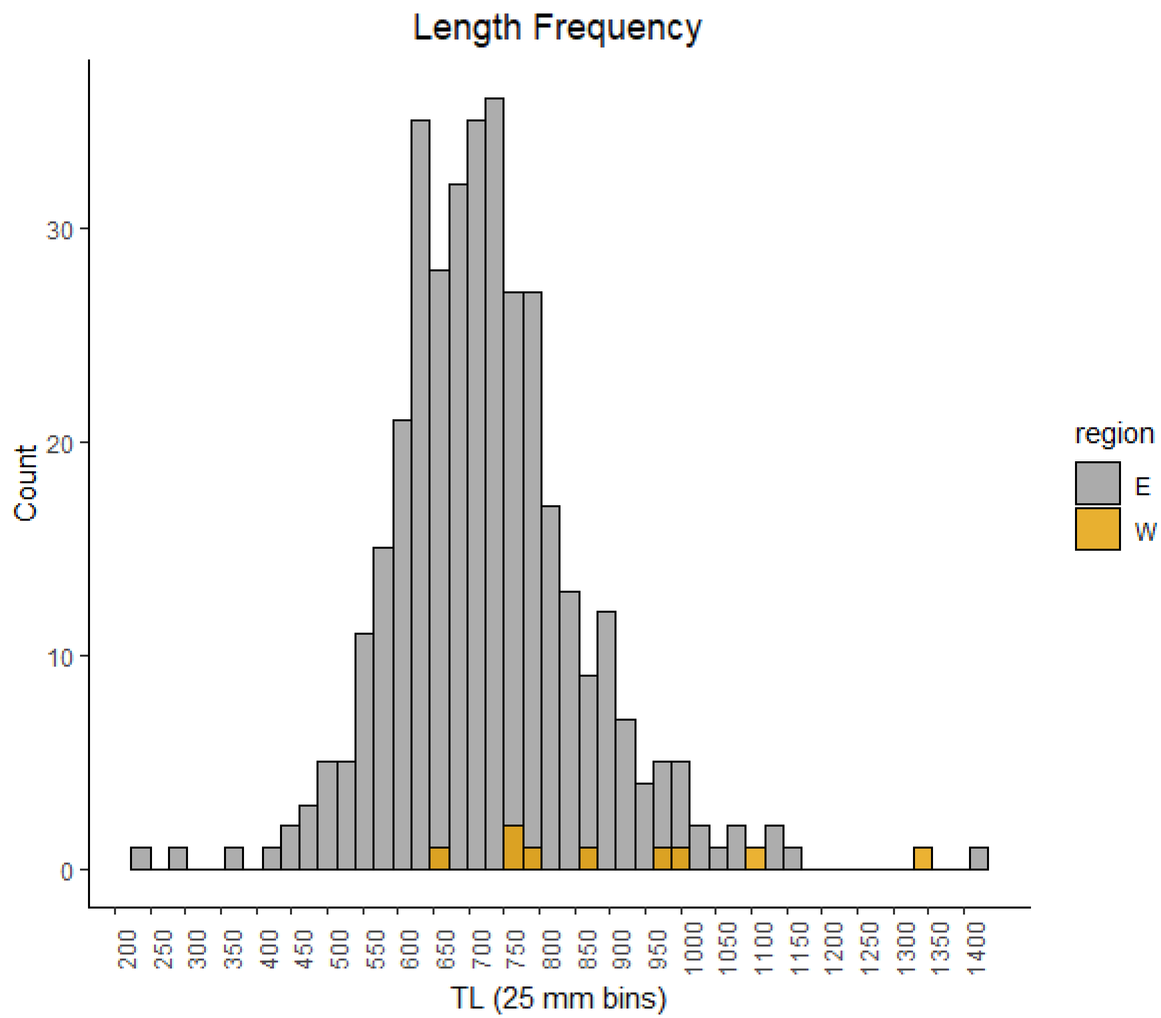


Table 3. Gag lengths (TL) from the SEAMAP reef fish video cruise from 1993 – 2021 for the east and west Gulf of Mexico. FWC conducted surveys in 2020 and length data were not available at the time of submission of the report.

	East			West		
year	***n***	***Mean***	***SD***	***n***	***Mean***	***SD***
1996	1	429.00	-	-	-	-
2002	11	721.35	79.27	-	-	-
2003	43	662.06	142.33	-	-	-
2004	47	709.85	81.89	-	-	-
2005	68	728.70	109.34	-	-	-
2006	42	643.81	103.38	-	-	-
2007	20	740.82	84.18	-	-	-
2008	3	743.68	129.42	2	698.73	74.22
2009	13	678.67	85.59	1	1352.94	-
2010	15	799.12	124.52	-	-	-
2011	21	801.51	153.08	1	794.92	-
2012	32	767.67	122.87	2	941.56	242.00
2013	33	758.32	188.87	-	-	-
2014	10	795.48	196.98	1	977.20	-
2015	5	903.46	157.49	1	868.79	-
2016	2	726.45	99.16	1	1001.11	-
2017	1	675.32	-	-	-	-
2018	6	970.48	265.10	3	839.47	84.37
2019	4	815.93	271.73	-	-	-
2020	-	-	-	-	-	-
2021	1	683.5	-	3	719.87	113.13
Pooled	378	710.33	136.39	15	839.23	181.08

Figure 2. Length frequency histogram (TL, 25 mm bins) of Gag observed during the SEAMAP reef fish video cruise from 1993 – 2021 for East (grey) and West (Orange) Gulf observations.



Fishery-independent surveys of juvenile gag grouper in the Gulf of Mexico (1994-2022)

Walter Ingram
NOAA Fisheries Service, Southeast Fisheries Science Center, PEM Division

In order to develop abundance indices of age-0 gag grouper in the Gulf of Mexico, three available data bases were combined and subsequently analyzed. In the following sections, each database is briefly outlined along with the survey methodology. Next is presented the statistical approach by which the indices are developed from the combined data. The analyses herein follow those detailed in Ingram (2021).

1. FSU estuarine gag survey

Gear: 5-m otter trawl towed for 5 minutes at ~2 km/h covering approximately a 150 m transect. Numbers of gag caught are standardized by tow time and estimates of area covered.

Areas covered: St. Andrew Bay, St. Joe Bay, Turkey Point, Big Bend (Keaton Beach, Cedar Key), Crystal River, Anclote Key, Sarasota Bay, Sanibel, primarily in seagrass habitat. The 35 sampling locations in this survey were lumped into 9 sampling regions (Table 1.1 and Figure 1.1) similar to those of Brown et al. (2000).

Index years: 1991-1999, 2003-2009, 2011

Index value based upon: Number of gag per 100-m tow

Noteworthy: Gag is the target species, primarily captured during summer months in the post-settlement juvenile stage. In early years 1991 and 1993, survey efforts were limited to the Turkey Point area, and no sampling was conducted in years 2000, 2001 and 2003. While this is currently one of the longer-term age-0 surveys, the hiatus in sampling during those years resulted in this survey not being recommended during the data workshop for use in the SEDAR 10 assessment (where data was included up to 2005).

Principal contacts: Chris Koenig (koenig@bio.fsu.edu), FSU Marine Lab

Pertinent references: Koenig and Coleman 1998 a & b, Brown et al. 2000.

2. NMFS PC Lab St. Andrew Bay survey

Gear: Weekly sampling, May-November, 16 (50 m) tows taken using 1 m beam trawl (“crab scrape”) at 5 fixed locations pre-determined to be settlement areas. Area covered is precisely measured.

Areas covered: St. Andrew Bay, Florida, principally 1-2 meters depth in conjunction with seagrass habitat

Index years: 1998-2014.

Index value based upon: Catch per meter^2

Noteworthy: Gag, grey snapper, and lane snapper are the target species; fish are primarily sampled soon after settlement into seagrass habitats. This survey has not been used previously as an assessment index for gag.

Principal contacts: Stacey Harter, (Stacey.Harter@noaa.gov) NMFS Panama City

Pertinent references: Harter 2008, 2009, NOAA-FWC 2009

3. State of Florida FWC estuarine (FIM) survey

Gear: 183-m haul seine, a component of the Fishery Independent Monitoring Program (FIM); and 183-m haul seine and 6.1 m otter trawl, components of a polyhaline seagrass survey.

Areas covered: Apalachicola Bay, Cedar Key, Tampa Bay, Charlotte Harbor, in estuarine near-shore habitats (~0.5 m depth).

Index years: 1996-2022

Index value based upon: Catch per haul

Noteworthy: While the FIM survey includes several gear types, the 183-m haul seine catches the most gag juveniles, typically later in the year (about ¾ of a year old) and closer to period of movement to deeper water. Similar sized fish are collected in the 183-m haul seine and 6.1 m otter trawl gears of the recently initiated polyhaline seagrass survey. There was a 2008 expansion to St. Andrew Bay, Big Bend and Apalachicola Bay resulting in increased coverage of seagrass habitats likely to hold juvenile gag. There was a programmatic change in 2019, where the haul seine was discontinued, and that effort was converted into additional trawl effort for the polyhaline seagrass survey. The reason for this was to gain more statistical power; and major size differences between gears for gag and other reef fishes were not observed.

Principal contacts: Ted Switzer (Ted.Switzer@MyFWC.com), FWC St. Petersburg

Pertinent references: Casey et al. 2005, Ingram et al. 2005, NOAA-FWC 2009

4. Combined index of abundance

4.1 Methodology

In order to develop standardized indices of annual abundance of juvenile gag from Florida estuaries and coastal waters in the Gulf of Mexico, data from the above described surveys were combined, following the methods of Ingram (2021). This was accomplished by first calculating the overall mean catch rate for each data set and scaling the data in each dataset to a mean of one. Due to the presence of two gear-types in the FWRI data, each gear type was considered a separate dataset, resulting in four datasets (FWRI trawl, FWRI seine, PCNMFS trawl and FSU trawl); and a database code was assigned to each dataset in order to model for differences between datasets. Next, sampling locations in each dataset were lumped into the 9 sampling regions as described in Section 1 (Table 1.1 and Figure 1.1). Therefore, while the FSU dataset (Section 1) had nine regions sampled, the NMFS PC Lab St. Andrew Bay survey (Section 2) sampled only that region (i.e. St. Andrew Bay, SAR) and the FWC estuarine (FIM) survey (Section 3) had four regions sampled (i.e. Charlotte Harbor, CHR; Cedar Key, CKR; Mid Big Bend, MBB; and Tampa Bay, TBR).

Two indices were developed using data from 1994 through 2022. This was due to sampling limited only to the Turkey Point Region in 1991 and 1993. While employing each of the two different time series, an index was developed that was weighted by the aerial coverage of seagrass in each sampling region (Figure 1.1), and an index was developed that was not weighted.

The weight for each region was based on the seagrass coverage area in each region, between 0 and 6 feet of water depth. This depth range was said to be that in which the majority of juvenile gag are captured (Chris Koenig, personal communication). The area between 0 and 6 feet water depth was estimated in each region using a NOAA bathy model of medium scale (http://www.ngdc.noaa.gov/mgg/coastal/model.html for more details). The seagrass aerial coverage for each region was estimated using a GIS data set based on a compilation of statewide seagrass data from various source agencies and scales. The GIS seagrass data were mapped from sources ranging in date from 1987 to 2007. Not all data in this compilation are mapped from photography; some are the results of field measurements. Some used the Florida Land Use Cover and Forms Classification System (FLUCCS) codes 9113 for discontinuous seagrass and 9116 for continuous seagrass; some defined only presence and absence of seagrass, and some defined varying degrees of seagrass percent cover. In order to merge all of these data sources into one compilation data set, FWRI reclassified the various source data attribute schemes into two categories: "continuous" and "discontinuous" seagrass. In areas where studies overlap, the most recent study where a given area has been interpreted is represented in this data set. The seagrass data was cross-referenced with the bathymetry data to estimate the seagrass coverage area in each region, between 0 and 6 feet of water depth (Figure 1.1). When region-specific abundance patterns were examined (Figure 4.1), data from the Marco Island Region had a short time series, limited sampling area, and the location of the region was in the southern end of the juvenile gag range. Therefore, these data were not included in the analyses.

A delta-lognormal model, as described by Lo et al. (1992) was employed for each index. The GLMMIX and MIXED procedures in SAS were employed to provide yearly index values for both the binomial and lognormal sub-models, respectively. A backward stepwise selection procedure was employed to develop both sub-models. Type 3 analyses were used to test each parameter for inclusion or exclusion into the sub-model. Both variable inclusion and exclusion significance level was set at an $\alpha = 0.05$. The parameters tested for inclusion in each sub-model were categorical variables of year, database code, region code, and season (spring: months 4-5; early summer: months 6-7; late summer: month 8-9; and fall: months 10-11). The fit of each model was evaluated using the fit statistics provided by the GLMMIX macro. For this analysis, both the unweighted and weighted indices for years 1994-2022 were developed, excluding the data from the Marco Island region.

4.2 Unweighted, 1994-2022

Table 4.2.1 summarizes the results of Type 3 analyses for those variables retained in the binomial sub-model. Table 4.2.2 summarizes the results of Type 3 analyses for those variables retained in the lognormal sub-model. Figure 4.2.1 shows the approximate normality of the residual for the lognormal sub-model. Table 4.2.3 and Figure 4.2.2 summarize the unweighted index values for gag in Gulf estuaries of Florida based on all data sets combined from 1994-2022, excluding the data from the Marco Island region.

4.3 Weighted, 1994-2022

Table 4.3.1 summarizes the results of Type 3 analyses for those variables retained in the binomial sub-model. Table 4.3.2 summarizes the results of Type 3 analyses for those variables retained in the lognormal sub-model. Figure 4.3.1 shows the approximate normality of the residual for the lognormal sub-model. Table 4.3.3 and Figure 4.3.2 summarize the weighted index values for gag in Gulf estuaries of Florida based on all data sets combined from 1994-2022, excluding the data from the Marco Island region.

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Table 1.1. Sampling location and corresponding region codes for data used in these analyses.

Location	Site_code	Region	Region_code
Cedar Key	CED	Cedar Key region	CKR
Crystal River	CRY	Cedar Key region	CKR
Homasassa	HOM	Cedar Key region	CKR
Suwanee Sound	SUS	Cedar Key region	CKR
Waccasassa	WAC	Cedar Key region	CKR
Captiva Pass	CAP	Charlotte Harbor region	CHR
Fisherman Key	FIK	Charlotte Harbor region	CHR
Jug Creek Shoal	JUG	Charlotte Harbor region	CHR
Punta Rassa	PUN	Charlotte Harbor region	CHR
Redfish Pass	RED	Charlotte Harbor region	CHR
Sanibel	SAN	Charlotte Harbor region	CHR
Smokehouse Bay	SHB	Charlotte Harbor region	CHR
Ussepa Island	USI	Charlotte Harbor region	CHR
Wulford Pass	WUP	Charlotte Harbor region	CHR
Cape Romano	CPR	Marco Island region	MIR
Horseshoe Beach	HSB	Mid Big Bend region	MBB
Keaton Beach	KEB	Mid Big Bend region	MBB
St Marks	SMK	Mid Big Bend region	MBB
Steinhatchee	STE	Mid Big Bend region	MBB
Longboat Pass	LBP	Sarasota Bay region	SBR
New Pass	NWP	Sarasota Bay region	SBR
Sarasota Bay	SAR	Sarasota Bay region	SBR
Crooked Is Sound	CIS	St. Andrew Bay region	SAR
St Andrew Bay	SAB	St. Andrew Bay region	SAR
St Joe Bay	SJB	St. Joe Bay region	SJR
Anclote	ANC	Tampa Bay region	TBR
Aripeka	ARI	Tampa Bay region	TBR
Bunces Pass	BPN	Tampa Bay region	TBR
Egmont Key	EGM	Tampa Bay region	TBR
Mullet Key	MUL	Tampa Bay region	TBR
NE Anna Maria	NAM	Tampa Bay region	TBR
Tampa Bay	TPB	Tampa Bay region	TBR
Dog Is Shoal	DIS	Turkey Pt region	TPR
Lanark	LAN	Turkey Pt region	TPR
Turkey Point	TUP	Turkey Pt region	TPR

Figure 1.1. Nine sampling regions used in this study. The green areas indicate seagrass coverage between 0 and 6 feet of water depth. Seagrass coverage in acres for each region is listed.

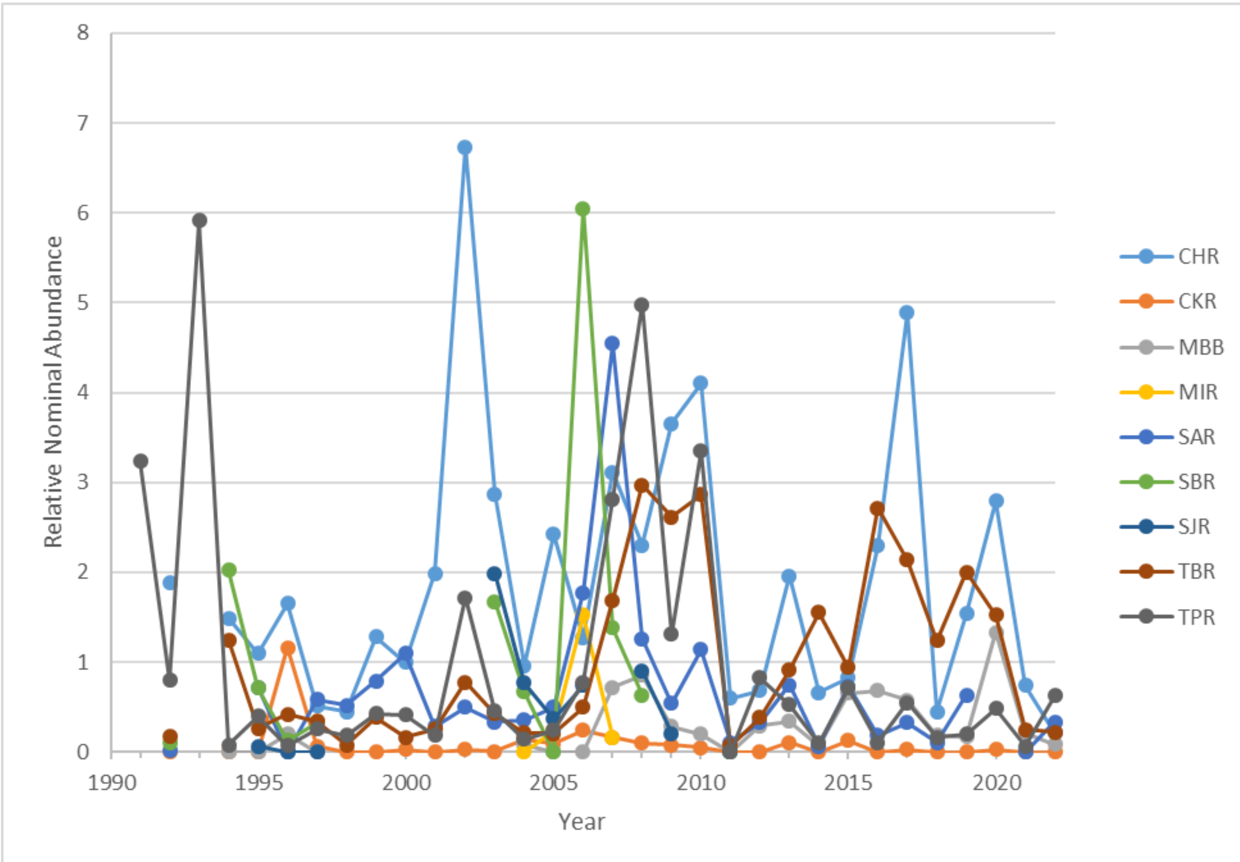

Figure 4.1. Nominal relative abundance per region. Region codes described in Table 1.1.

Table 4.2.1. Type 3 tests of fixed effects for binomial sub-model for the unweighted index from 1994-2022.

Type 3 Tests of Fixed Effects						
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
Year	28	27E3	798.58	28.52	<.0001	<.0001
season	3	27E3	425.64	141.88	<.0001	<.0001
region_code	7	27E3	704.33	100.62	<.0001	<.0001
database_code	3	27E3	704.37	234.79	<.0001	<.0001

Table 4.2.2. Type 3 tests of fixed effects for lognormal sub-model for the unweighted index from 1994-2022.

Type 3 Tests of Fixed Effects				
Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	28	3028	9.92	<.0001
season	3	3028	7.91	<.0001
region_code	7	3028	8.57	<.0001
database_code	3	3028	500.93	<.0001

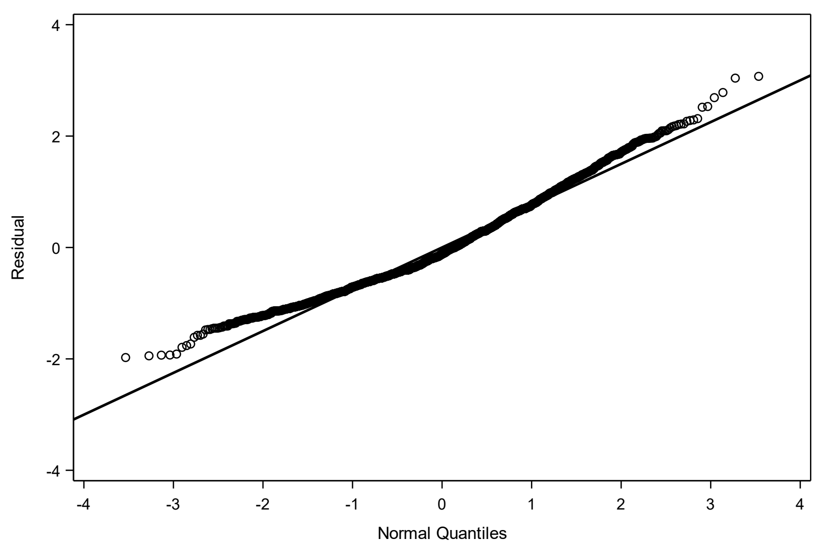

Figure 4.2.1. QQplot of residuals from the lognormal sub-model for the unweighted index based on all data sets combined from 1994-2022.

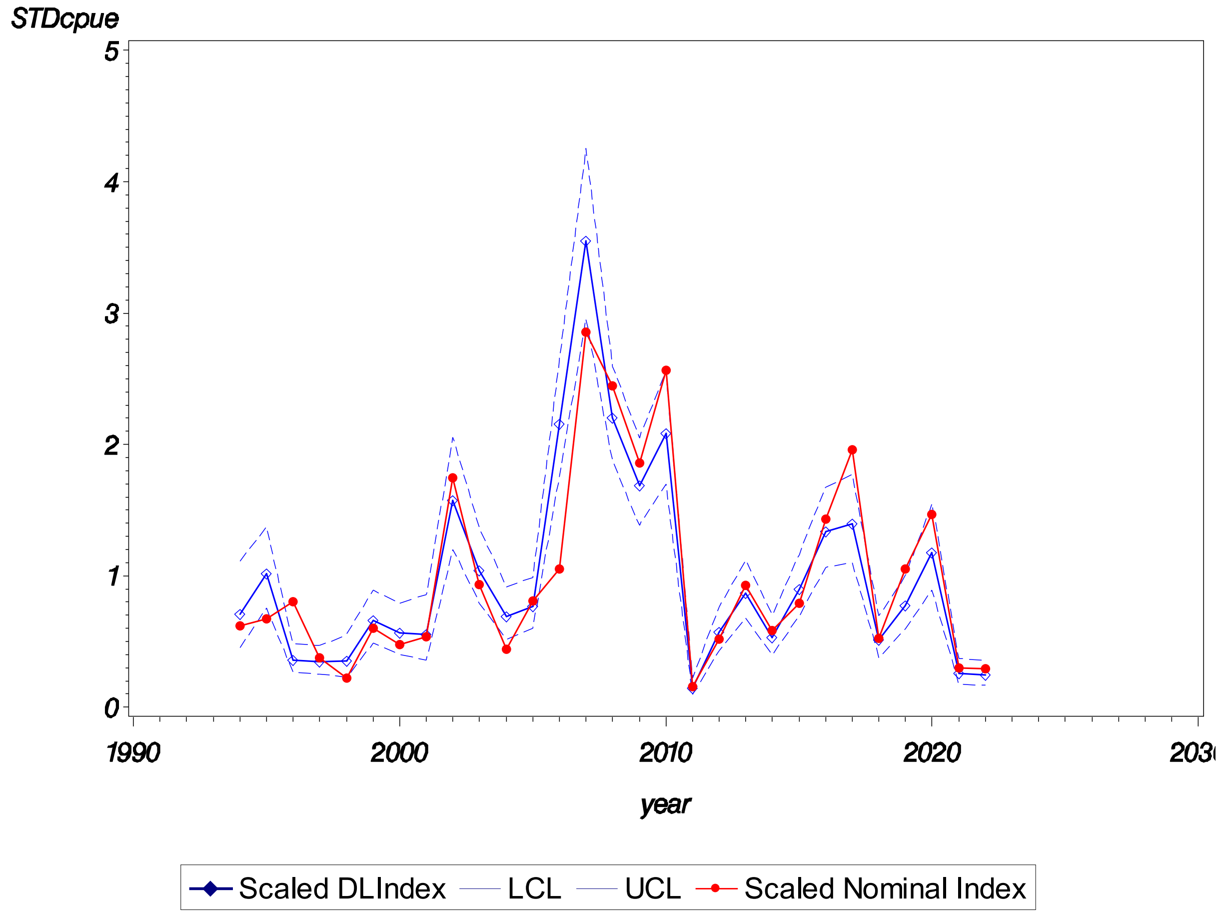

Figure 4.2.2. Unweighted abundance indices developed from all data sets combined from 1994-2022.

Table 4.2.3. Unweighted abundance indices developed from all data sets combined from 1994-2022.

Survey Year	*Nominal Frequency*	*N*	*DL Index*	*Scaled DL Index*	*CV*	*LCL*	*UCL*
1994	0.34921	126	0.40864	0.70693	0.22841	0.45030	1.10982
1995	0.50742	337	0.58761	1.01655	0.15056	0.75351	1.37141
1996	0.16134	626	0.20512	0.35485	0.15300	0.26177	0.48102
1997	0.13803	681	0.19848	0.34336	0.15551	0.25205	0.46776
1998	0.06140	570	0.20338	0.35183	0.22470	0.22572	0.54842
1999	0.11203	723	0.38000	0.65739	0.15245	0.48548	0.89018
2000	0.08179	648	0.32630	0.56448	0.17083	0.40210	0.79244
2001	0.04372	709	0.32051	0.55448	0.22093	0.35832	0.85801
2002	0.09832	895	0.90833	1.57138	0.13442	1.20239	2.05362
2003	0.11982	868	0.60021	1.03835	0.13670	0.79097	1.36310
2004	0.10867	865	0.39836	0.68915	0.14320	0.51829	0.91636
2005	0.12883	977	0.44416	0.76838	0.12522	0.59873	0.98610
2006	0.19565	966	1.24656	2.15651	0.10235	1.75824	2.64499
2007	0.23799	895	2.05025	3.54688	0.09138	2.95554	4.25654
2008	0.18265	1533	1.27250	2.20138	0.08245	1.86724	2.59531
2009	0.14466	1265	0.97415	1.68525	0.09820	1.38538	2.05002
2010	0.14162	1158	1.20623	2.08674	0.10318	1.69857	2.56360
2011	0.02829	1343	0.08464	0.14642	0.20444	0.09769	0.21946
2012	0.06932	1154	0.33124	0.57303	0.14440	0.42993	0.76376
2013	0.08446	1255	0.50305	0.87026	0.12630	0.67667	1.11924
2014	0.06516	1243	0.30536	0.52827	0.14345	0.39709	0.70277
2015	0.08932	1142	0.51859	0.89714	0.12910	0.69373	1.16019
2016	0.12642	1060	0.77125	1.33424	0.11404	1.06291	1.67483
2017	0.11509	1060	0.80813	1.39805	0.11893	1.10302	1.77199
2018	0.06660	1051	0.29602	0.51211	0.15375	0.37722	0.69523
2019	0.09237	1180	0.44727	0.77376	0.13002	0.59724	1.00245
2020	0.11973	735	0.68018	1.17669	0.13815	0.89379	1.54913
2021	0.03817	1179	0.14667	0.25374	0.19173	0.17352	0.37104
2022	0.03729	1180	0.14012	0.24241	0.19359	0.16517	0.35575

Table 4.3.1. Type 3 based on all data sets combined from 1994-2022.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
Year	28	27E3	558.83	19.96	<.0001	<.0001
season	3	27E3	290.92	96.97	<.0001	<.0001
region_code	7	27E3	1350.75	192.96	<.0001	<.0001
database_code	3	27E3	904.95	301.65	<.0001	<.0001

Table 4.3.2. Type 3 tests of fixed effects for lognormal sub-model for the weighted index from 1994-2022.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	28	3028	6.48	<.0001
season	3	3028	10.05	<.0001
region_code	7	3028	19.51	<.0001
database_code	3	3028	543.07	<.0001

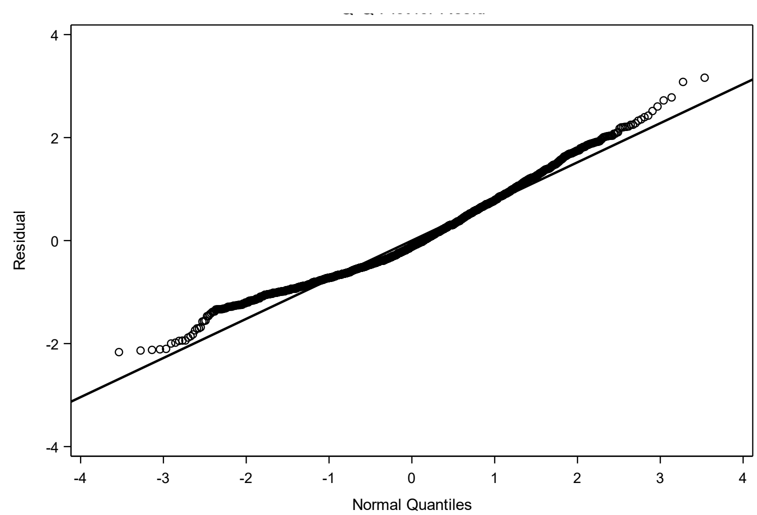

Figure 4.3.1. QQplot of residuals from the lognormal sub-model for the weighted index from 1994-2022.

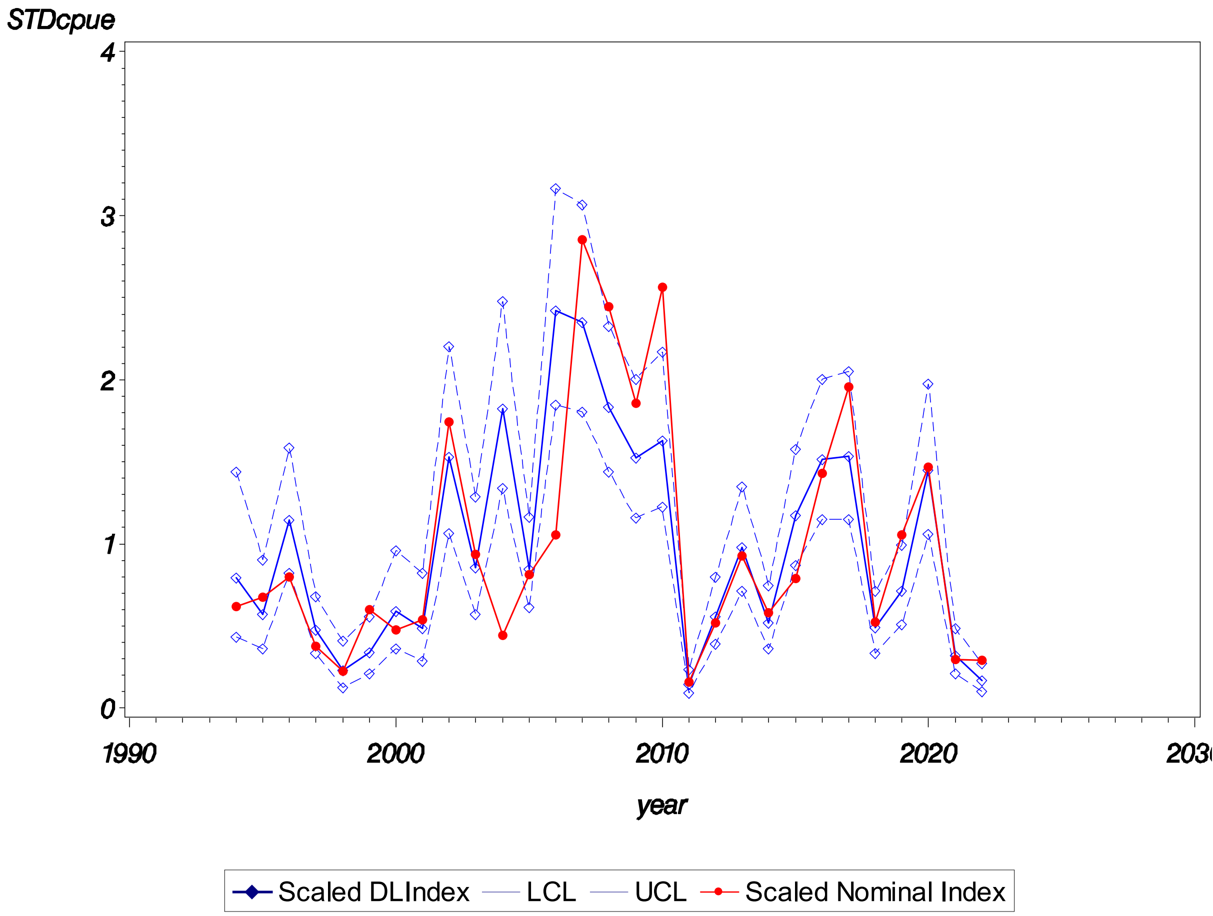

Figure 4.3.2. Weighted abundance indices developed from all data sets combined from 1994-2022.

Table 4.3.3. Weighted abundance indices developed from all data sets combined from 1994-2022.

Survey Year	*Nominal Frequency*	*N*	*DL Index*	*Scaled DL Index*	*CV*	*LCL*	*UCL*
1994	0.34921	126	0.31941	0.79170	0.30571	0.43544	1.43944
1995	0.50742	337	0.23016	0.57048	0.23384	0.35961	0.90501
1996	0.16134	626	0.46113	1.14300	0.16490	0.82371	1.58605
1997	0.13803	681	0.19187	0.47557	0.18183	0.33156	0.68214
1998	0.06140	570	0.09151	0.22682	0.30204	0.12561	0.40956
1999	0.11203	723	0.13719	0.34004	0.24823	0.20851	0.55453
2000	0.08179	648	0.23856	0.59131	0.24630	0.36394	0.96075
2001	0.04372	709	0.19574	0.48518	0.26897	0.28599	0.82311
2002	0.09832	895	0.61782	1.53136	0.18369	1.06377	2.20450
2003	0.11982	868	0.34576	0.85703	0.20565	0.57045	1.28757
2004	0.10867	865	0.73548	1.82301	0.15415	1.34178	2.47682
2005	0.12883	977	0.34076	0.84464	0.16170	0.61253	1.16472
2006	0.19565	966	0.97626	2.41982	0.13507	1.84924	3.16645
2007	0.23799	895	0.94885	2.35188	0.13326	1.80375	3.06658
2008	0.18265	1533	0.73870	1.83100	0.12061	1.43980	2.32847
2009	0.14466	1265	0.61537	1.52529	0.13687	1.16151	2.00301
2010	0.14162	1158	0.65792	1.63076	0.14371	1.22519	2.17058
2011	0.02829	1343	0.05869	0.14548	0.24247	0.09020	0.23464
2012	0.06932	1154	0.22496	0.55761	0.18006	0.39010	0.79704
2013	0.08446	1255	0.39551	0.98034	0.16140	0.71135	1.35103
2014	0.06516	1243	0.20954	0.51938	0.18372	0.36077	0.74772
2015	0.08932	1142	0.47285	1.17205	0.14916	0.87115	1.57687
2016	0.12642	1060	0.61170	1.51620	0.13960	1.14838	2.00183
2017	0.11509	1060	0.61967	1.53596	0.14561	1.14964	2.05209
2018	0.06660	1051	0.19739	0.48926	0.19010	0.33565	0.71317
2019	0.09237	1180	0.28704	0.71148	0.16808	0.50955	0.99343
2020	0.11973	735	0.58404	1.44763	0.15675	1.06007	1.97689
2021	0.03817	1179	0.12895	0.31963	0.21071	0.21067	0.48493
2022	0.03729	1180	0.06701	0.16609	0.25194	0.10113	0.27279