Gray Triggerfish Fishery-Independent Index of Abundance and Length/Age Compositions in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2021)

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Abstract

Fishery-independent measures of catch and effort with standard gear types and the deployment strategies are valuable for monitoring the status of stocks, interpreting fisheries landings data, performing stock assessments, and developing regulations for managing fish resources. This report presents a summary of the fishery-independent monitoring of Gray Triggerfish in the US South Atlantic region and includes data from three monitoring programs (MARMAP, SEAMAP-SA, and SEFIS, now known collectively as SERFS). Specifically, it presents annual nominal catch per unit effort (CPUE) of Gray Triggerfish, *Balistes capriscus*, in chevron traps from 1990 to 2021. Also included are annual CPUE estimates for chevron trap catches over this same time period that are standardized by a zero-inflated negative binomial model (ZINB) to account for the effects of potential covariates on these estimates. The ZINB model produced standardized CPUE estimates which show a decrease since 2019 with 2021 being about half the value of the time series mean following no sampling in 2020.

Background

The Marine Resources Monitoring, Assessment, and Prediction program (MARMAP) has conducted fishery-independent research on reef fish species of the continental shelf and shelf edge between Cape Hatteras, North Carolina, and St. Lucie Inlet, Florida, for over 40 years. Although the MARMAP program has used various gear types and methods of deployment since its inception, starting in 1990, the chevron trap has been the primary gear deployed to allow for analyses of long-term changes in relative abundance, length compositions, age compositions, and other information regarding reef fish species on live-bottom and/or hard-bottom habitats. In 2008, with a first field season in 2009, the Southeast Area Monitoring and Assessment Program - South Atlantic region (SEAMAP-SA) provided funding to assist with the expansion of the geographical sampling coverage of the MARMAP fishery-independent chevron trap survey. Again in 2010, with the formation of the Southeast Fishery-Independent Survey (SEFIS), additional funds were provided to, among other things, expand the geographical coverage and sampling intensity of the MARMAP fishery-independent chevron trap survey. Collectively, we now refer to these three surveys' combined reef fish monitoring efforts from 2010 to present as the Southeast Reef Fish Survey (SERFS), which uses methodology identical to the historical MARMAP chevron trap survey.

Objective

This report presents a standardized relative abundance index of Gray Triggerfish derived from the MARMAP/SERFS chevron trap survey during the years 1990-2021, apart from 2020 during which COVID-19 prevented standard sampling from occurring and therefore data are not available for that year. The standardized index accounts for annual sampling distribution shifts, changes in sampling effort, and environmental covariates that may affect catch of Gray Triggerfish in chevron traps. Also provided are annual length and age compositions of Gray Triggerfish captured by chevron trap. This information is critical for informing the selectivity pattern of Gray Triggerfish by chevron traps. Data presented in this report are based on the combined SERFS database accessed on February 17, 2022 (indices) and August 25, 2022 (length and age compositions). **Methods**

Survey Design and Gear

(see Smart et al. 2015 for full description)

Sampling area

- Cape Hatteras, NC, to St. Lucie Inlet, FL

Sampling season

- May through September
  - Limited earlier (mid-April) and later (mid-October) sampling in some years

Survey Design

- Simple random sample survey design
  - Annually, random stations are selected from a chevron trap universe of confirmed live-bottom and/or hard-bottom habitat stations
  - No two stations are randomly selected that are closer than 200 m from each other
    - Minimum distance is typically closer to 400 m
- Traps deployed on suspected live-bottom and/or hard-bottom each year (reconnaissance) are evaluated based on catch and/or video or photographic evidence of bottom type for inclusion in the universe in subsequent years
  - If added to the known habitat universe, data from the reconnaissance deployment is included in index development

Sampling Gear – Chevron Traps

(see Collins 1990 and MARMAP 2009 for more detailed descriptions)

- Arrowhead shaped, with a total interior volume of 0.91 m^3
- Constructed of 35 x 35 mm square mesh plastic-coated wire with a single entrance funnel (“horse neck”)
- Baited with whole and/or cut clupeids (*Brevoortia* or *Alosa* spp., family Clupeidae), with *Brevoortia* spp. most often used
  - Four whole clupeids on each of four stringers suspended within the trap
  - Approximately 8 clupeids placed loose in the trap
- Soak time of approximately 90 minutes

- Daylight hours

Oceanographic Data

- Hydrographic data collected via CTD during soaking of a "set" (typically 6 traps, but may be less) of chevron traps deployed at the same time and same reef patch
  - Bottom temperature (^{o}C) is defined as the temperature of the deepest recording within 5 m of the bottom

Data Filtering/Inclusion

Chevron trap data (Gear = 324) were limited to:

- Projects conducting monitoring efforts
  - P05 – MARMAP
  - T59 – SEAMAP-SA
  - T60 – SEFIS
- Reef fish monitoring samples
  - Data source ≠ "Tag-MARMAP" – represents special historic MARMAP cruises that were used to tag various species of fish
    - Because standard sampling procedures were not consistently used (e.g., not all fish were measured for length frequency or counted for abundance) these samples are excluded from index development
- Traps that fished properly (i.e., appropriate catch IDs)
  - 0 – no catch
  - 1 – catch with finfish
  - 2 – catch without finfish
  - 8 - Species catch subsampled for Length Frequency
- Traps on live-bottom and/or hard-bottom habitat (i.e., appropriate station types)
  - Random –randomly-selected live-bottom stations
  - Alternate – non-randomly sampled live-bottom station (haphazard or opportunistic sample) that still maintains the minimum distance
  - ReconConv – reconnaissance deployments that were subsequently converted into live-bottom chevron trap stations that still maintains the minimum distance
  - Null – traps for which there is no station code value
    - Use of station codes is new, with MARMAP historically using only the catch ID (see above) to indicate randomly selected stations
  - Monitoring - Station whose sampling selection (random, nonrandom) is not known, but is part of overall station universe
- Traps with soak times that were neither extremely short nor long which often indicates an issue with the deployment not captured elsewhere (included 45-150 minutes)
  - SERFS targets a soak time of 90 minutes for all chevron trap deployments
- Excluded any chevron trap samples missing covariate information
- Excluded all traps sampled prior to 1990

Standardized Index Model Formulation

Model Basics

- Response variable
  - Catch per trap
- Offset term
  - Soak time
- Dependent variables
  - Year
  - Covariates
    - 4 covariates explored
      - Depth – Continuous variable
      - Latitude (^{o}N) - Continuous variable
      - Bottom temperature (^{o}C) - Continuous variable
      - Day of year (DOY) - Continuous variable
    - Modelled with polynomials
      - Maximum allowed polynomial order set using preliminary generalized additive models (GAMs)
        - Limited polynomial to maximum of fourth order for biological relevance
    - Due to widely differing scales, the covariates were centered and scaled
      - Centered – subtract covariate mean
      - Scaled – divided centered values by their standard deviation prior to the GAMs
- Model structure – Zero-inflated negative binomial, zero-inflated Poisson, negative binomial, and Poisson error distributions were explored
  - Mixture model for both zero-inflated error structures
    - Two parts to the model, with Bayesian Information Criteria (BIC) used to select the best model from each of the 2 zero-inflated error distributions
      - Presence/absence (binomial sub-model)
      - Catch (count sub-model)
    - Sub-models optimized using a two-step approach due to computational demands
      - Count sub-model was optimized with all covariates removed from the zero-inflation sub-model
      - Binomial sub-model was optimized using fixed count sub-model covariates obtained in previous step
      - Allows for different covariates to be included in the two sub-models
  - Bayesian Information Criteria (BIC) also used to select the best model from the negative binomial and Poisson error distribution models
  - Final model was selected amongst the best models from each of the 4 error distributions using BIC
- Annual year effect coefficients of variation (CVs) and standard errors (SE) computed using bootstrapping
  - 5,000 bootstraps

- Software used
  - R (Version 3.6.1; R Development Core Team 2019)

Length and Age Composition

- Length methods – all fish measured following retrieval of each trap set to the nearest centimeter prior to 2010 and to the nearest millimeter from 2010 and after
  - Measured lengths were either fork length or maximum (pinched) total length in a given year
    - All total lengths were converted to fork length using conversions developed by Glasgow et al. (2019)
    - Length compositions were calculated for each year using 1-cm length bens centered on the integer
    - All lengths are presented in cm
- Aging methods – the first dorsal spine was removed from each Gray Triggerfish to serve as the aging structure in 1991-2019
  - Ages presented here are calendar age based on increment counts with an estimated increment formation on September 1
    - Exceptions to this increment bumping criteria for age 0 and age 1 individuals were established during SEDAR 41 (SEDAR 2016), and are as follows:
      - If the fish was caught January-June, then calendar age was assumed to be 1
      - If the fish was caught July-September and the FL > 160mm, then calendar age = 1
      - If the fish was caught July-September and the FL < 160mm, the calendar age = 0
  - Prior to 2008, selection of fish retained for aging were sub-sampled based on length bins. To correct age compositions prior to 2008, we corrected the number of fish in each age bin based on the abundance and length frequency in each trap according to the method developed for SEDAR 25 Black Sea Bass (Ballenger et al., 2011)
  - From 2008 and on, only fish caught in chevron traps that had age samples taken were included in the age compositions. Selection of fish retained for aging was either randomly sub-sampled or 100% of fish collected were processed for ageing.
  - Although fish were collected and spines collected for ageing, no ages were available for 2021 due to time and funding constraints.

Results

<u>Sampling area</u>

- General increase in sampling intensity (# of annual chevron trap deployments) through time (Table 1 and Figure 1)
- Gradual shift regarding the spatial density of samples through time (Table 1 and Figure 1)
  - More dense geographic coverage in southern and northern latitudes in later years
- Chevron trap sampling depths range from 13 to 115 m (Table 1 and Figure 2)
  - Generally less than 100 m

Sampling season

- May through September (Table 1 and Figure 2)

Data Filtering/Inclusion

- Included traps (n = 19,681; Table 1)

Standardized Index Model Formulation

Model Basics

- Dependent variables
  - Covariates (Inclusion and polynomial order in sub-models available Table 2)
    - The effect on positive catches, both raw and modelled was determined (Figures 2 and 3)
    - Depth, latitude, and day of year were included in the final model (Figure 4)
- Model structure
  - Final model selected was ZINB (Table 2)
    - Selected over non-zero inflated models due to high proportion of zero counts (Figure 5)
- Coefficients of variation (CVs) and variances stabilized within the 5,000 bootstraps (Figure 6)
- Annual standardized and normalized (relative to the long-term mean) index values for Gray Triggerfish, including CVs showed trends from 1990 to 2021, excluding 2020 (Table 3 and Figure 7)

Length and Age Composition

- Length compositions from chevron traps in 1990-2021 (Table 4)
- Calendar ages caught by chevron traps in 1991-2019 (Tables 5 and 6).
- Sampling did not occur in 2020 due to COVID-19.

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Table 1. Sampling summary table for the MARMAP/SERFS fishery-independent chevron trap survey. Provided are the average and range of all the covariates by year.

		Depth (m)		Latitude (°N)		Temperature (°C)		Day of Year	
Year	Included Collections	Avg	Range	Avg	Range	Avg	Range	Avg	Range
1990	310	34	17-93	32.5	30.4-33.8	22	18.2-27.8	150	114-222
1991	259	34.3	17-95	32.6	30.8-34.6	24.9	15.9-27.5	216	163-268
1992	286	34	17-62	32.8	30.4-34.3	21.3	15.3-24.5	155	92-227
1993	380	34.9	16-94	32.4	30.4-34.3	22.8	17.7-28.5	176	131-226
1994	340	39.4	16-93	32.3	30.7-33.8	22.7	18.2-26.9	174	130-300
1995	336	33.4	16-60	32.1	29.9-33.7	24.6	20.1-28.3	199	124-299
1996	323	36.9	14-100	32.5	30.0-34.3	22.1	15.6-27.0	185	121-261
1997	345	39.2	15-97	32.2	27.9-34.6	22.8	15.0-28.0	194	126-273
1998	373	38.8	14-92	32	27.4-34.6	21.5	9.5-28.6	176	126-231
1999	213	35.8	15-59	31.9	27.3-34.6	23	17.9-28.8	201	153-272
2000	272	35.2	15-91	32.2	29.0-34.3	24	18.5-28.5	202	138-294
2001	231	38.3	14-91	32.3	27.9-34.3	23.6	16.0-29.2	204	144-298
2002	225	38.4	13-94	31.8	27.9-34.0	24	15.2-28.3	205	169-268
2003	206	40.7	16-92	32	27.4-34.3	18.8	13.4-25.1	203	155-266
2004	259	40.8	14-91	32.2	30.0-34.0	20.8	16.7-25.8	176	127-303
2005	278	38.9	16-69	32	27.3-34.3	23	18.0-28.5	192	124-273
2006	281	38.7	15-94	32.2	27.3-34.4	22.4	15.0-26.7	203	158-272
2007	317	38.5	15-92	32.1	27.3-34.3	23.2	15.3-28.9	202	142-268
2008	277	39	15-92	32.1	27.3-34.6	21.8	15.2-27.2	195	127-275
2009	404	36.3	14-91	32.2	27.3-34.6	22.6	15.4-27.2	203	127-282
2010	732	38.6	14-92	31.3	27.3-34.6	22.2	12.3-29.4	222	125-301
2011	731	40.7	14-93	30.9	27.2-34.5	21.6	14.8-28.8	210	140-300
2012	1174	40.8	15-106	31.9	27.2-35.0	22.1	12.9-27.8	195	116-285
2013	1358	38.3	15-110	31.3	27.2-35.0	22	12.4-28.1	197	115-278
2014	1473	39.3	15-110	31.9	27.2-35.0	23.3	16.1-29.3	192	114-295
2015	1464	39.3	16-110	31.9	27.3-35.0	22.6	13.6-28.5	187	112-296
2016	1485	40.9	17-115	32.1	27.2-35.0	23.8	15.5-29.3	217	126-301
2017	1541	40.5	15-114	32	27.2-35.0	22.6	14.8-28.2	187	117-273
2018	1736	40.3	16-114	32	27.2-35.0	22.5	13.6-28.3	177	116-278
2019	1665	40.2	16-113	32	27.2-35.0	23.3	15.0-29.5	185	121-269
2020	-	-	-	-	-	-	-	-	-
2021	1832	38.3	16-110	31.8	27.2-35.0	23.3	17.9-28.1	191	119-274

Table 2. Model error structure comparison, including covariates that were included and their polynomial level for both the count and binomial sub-models. Polynomial values of "0" indicate that the covariate was not included in the final model. Negative binomial and Poisson models only had the count sub-model. The best model (highlighted) was chosen based on Bayesian Information Criteria (BIC).

	Count Sub-model					Binomial Sub-model				
Model Error Structure	**Year**	**Lat**	**Depth**	**Temp**	**DOY**	**Lat**	**Depth**	**Temp**	**DOY**	**BIC**
Zero-Inflated Negative Binomial	1	4	4	2	3	1	3	1	0	44610
Negative Binomial	1	4	4	2	3	—	—	—	—	44769
Zero-Inflated Poisson	1	4	3	3	4	4	3	3	0	56327
Poisson	1	4	3	4	4	—	—	—	—	73958

Table 3. The annual summary of data informative to index development and the results of the standardization. The data includes number of collections included in index development, the number of positive collections for Gray Triggerfish, the proportion of those positive collections in relation to the included collections, the total number of Gray Triggerfish caught, and these totals for the survey. The results show the normalized nominal and standardized chevron trap catch of Gray Triggerfish from the MARMAP/SERFS fishery-independent chevron trap survey which meet criteria to be included in the standardization process. The zero-inflated negative binomial (ZINB) standardized catch also includes a coefficient of variation (CV) calculated from a bootstrapping procedure.

					Nominal Abundance	ZINB Standardized Abundance	
Year	Included Collections	Positive	Proportion Positive	Total Fish	Normalized	Normalized	CV
1990	310	35	0.11	70	0.23	0.24	0.21
1991	259	123	0.47	369	1.47	1.28	0.13
1992	286	84	0.29	192	0.69	0.82	0.14
1993	380	111	0.29	276	0.75	0.76	0.11
1994	340	134	0.39	396	1.2	1.12	0.11
1995	336	148	0.44	647	1.98	1.4	0.1
1996	323	128	0.4	572	1.82	1.52	0.11
1997	345	157	0.46	693	2.07	2.27	0.12
1998	373	110	0.29	494	1.36	1.91	0.13
1999	213	59	0.28	187	0.9	0.9	0.16
2000	272	81	0.3	245	0.93	0.71	0.19
2001	231	80	0.35	214	0.95	0.9	0.12
2002	225	86	0.38	285	1.31	1.38	0.15
2003	206	26	0.13	49	0.25	0.62	0.25
2004	259	63	0.24	164	0.65	1.08	0.15
2005	278	90	0.32	326	1.21	0.8	0.13
2006	281	64	0.23	147	0.54	0.65	0.17
2007	317	98	0.31	302	0.98	0.79	0.13
2008	277	64	0.23	322	1.2	0.9	0.16
2009	404	80	0.2	257	0.66	0.61	0.15
2010	732	175	0.24	469	0.66	0.59	0.12
2011	731	149	0.2	537	0.76	0.76	0.11
2012	1174	326	0.28	1082	0.95	0.99	0.08
2013	1358	361	0.27	1250	0.95	1.19	0.08
2014	1473	457	0.31	1647	1.15	1.27	0.08
2015	1464	409	0.28	1100	0.77	0.9	0.08
2016	1485	510	0.34	2101	1.46	1.28	0.09
2017	1541	451	0.29	1558	1.04	1.17	0.07
2018	1736	396	0.23	1263	0.75	0.87	0.09
2019	1665	365	0.22	1408	0.87	0.83	0.11
2020	-	-	-	-	-	-	-
2021	1832	288	0.16	862	0.48	0.48	0.13

Table 4. Length composition of Gray Triggerfish collected by the MARMAP/SERFS chevron trap survey from 1990 to 2021. Lengths are fork length in cm (measured or rounded to the nearest 1-cm bin) and composition is in percent of fish in each 1-cm bin for each year. Sampling did not occur in 2020 due to COVID-19. Total fish caught and deployments are summarized by year.

Year	10	11	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	61	Deployments	Fish
1990	0.00	0.00	0.00	2.56	1.28	1.28	1.28	0.00	6.41	7.69	3.85	6.41	5.13	1.28	5.13	0.00	1.28	2.56	1.28	5.13	3.85	0.00	0.00	8.97	2.56	5.13	3.85	3.85	2.56	6.41	3.85	2.56	1.28	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.00	0.00	41	78
1991	0.25	0.50	0.25	0.25	2.51	6.02	8.02	10.03	6.52	5.26	5.26	5.26	3.51	4.76	3.01	3.01	3.76	3.26	3.51	3.51	2.51	1.25	1.75	1.75	2.01	0.75	0.75	1.00	1.00	1.25	1.50	0.50	1.50	1.00	0.75	1.25	0.25	0.25	0.00	0.25	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	134	399
1992	0.00	0.00	0.00	0.00	0.98	1.46	0.00	1.95	3.41	4.39	2.44	3.41	2.44	4.88	3.90	2.93	5.37	2.93	5.85	2.93	8.29	4.39	0.98	4.39	3.90	2.44	2.93	2.44	2.93	2.44	3.90	1.95	0.98	3.41	0.00	1.46	0.98	0.98	0.49	0.00	0.00	0.00	0.49	0.00	0.49	0.00	0.49	0.00	0.00	89	205
1993	0.00	0.00	0.00	1.00	1.67	0.33	2.34	2.68	1.34	2.34	2.01	6.02	6.02	8.70	6.02	6.02	6.02	7.02	5.35	4.68	6.35	1.67	3.34	2.34	1.67	2.34	2.34	1.67	1.00	1.00	1.67	0.33	1.34	0.67	0.33	0.00	0.00	0.67	0.67	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	119	299
1994	0.00	0.00	0.00	0.22	0.00	0.45	0.45	1.79	2.24	1.57	2.68	2.01	2.68	3.36	2.68	3.13	3.13	4.70	5.15	5.15	6.04	3.36	6.04	5.15	3.13	6.26	3.58	3.13	3.58	6.71	2.46	1.79	2.46	0.67	2.01	0.67	0.22	0.67	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	154	447
1995	0.15	0.00	0.00	0.60	0.45	1.64	1.64	1.94	1.79	1.05	2.54	3.44	4.78	2.99	2.99	2.24	1.05	2.09	2.99	2.24	1.49	1.49	3.89	5.83	5.53	6.43	5.53	5.23	5.68	5.98	4.19	2.69	2.09	1.94	2.69	1.20	0.60	0.60	0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	156	669
1996	0.00	0.00	0.17	0.08	0.33	0.58	0.92	1.17	1.67	1.25	1.75	1.34	1.00	2.92	2.50	5.18	4.92	8.35	8.18	9.27	10.02	8.10	9.18	4.42	4.59	1.92	2.17	1.84	2.00	0.33	1.09	0.92	0.67	0.17	0.42	0.17	0.17	0.08	0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.00	179	1198
1997	0.00	0.00	0.00	0.10	0.00	0.21	0.21	0.42	1.88	1.25	1.25	1.57	1.98	1.67	2.30	1.25	2.30	3.24	3.86	6.26	7.41	8.46	9.39	8.04	8.66	7.41	6.99	3.76	1.67	2.51	1.88	1.25	0.73	0.73	0.42	0.31	0.42	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	194	958
1998	0.00	0.00	0.00	0.00	0.19	0.58	0.77	0.39	0.00	0.58	0.77	0.58	0.96	1.93	3.08	3.08	2.70	4.24	4.82	4.43	7.32	8.09	7.13	8.29	7.51	8.29	8.09	3.66	4.43	2.12	2.12	1.93	0.77	0.39	0.39	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	124	519
1999	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.53	0.53	4.74	1.58	3.68	4.21	2.11	2.11	4.74	4.21	2.63	6.84	5.26	4.74	5.26	5.79	2.63	1.05	4.21	6.32	7.37	4.21	4.74	2.11	1.05	2.63	2.63	0.00	0.00	0.53	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	62	190
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.37	1.12	1.12	1.49	0.00	1.49	0.37	2.60	1.49	2.23	2.60	3.35	5.58	4.83	6.32	7.06	7.81	6.32	14.13	8.55	5.20	4.46	3.35	2.60	2.23	1.49	0.37	0.74	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	92	269
2001	0.00	0.00	0.00	0.00	0.00	0.78	0.39	0.78	1.16	4.65	2.33	3.10	1.94	3.49	2.71	3.88	2.71	3.49	3.10	2.33	3.10	5.81	4.65	9.30	7.75	6.20	6.59	2.71	3.49	3.10	1.94	1.94	2.33	1.55	1.94	0.00	0.39	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99	258
2002	0.00	0.00	0.00	0.00	0.00	0.29	2.01	1.72	2.30	1.44	5.75	5.46	4.02	4.31	4.31	3.16	2.59	2.59	2.59	4.60	3.74	3.45	5.17	4.02	3.16	5.46	4.02	2.87	6.03	2.30	3.45	3.45	1.72	1.72	1.44	0.29	0.00	0.29	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	112	348
2003	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	1.49	1.49	0.00	2.99	0.00	2.99	1.49	1.49	1.49	1.49	4.48	7.46	8.96	2.99	10.45	5.97	1.49	8.96	7.46	4.48	5.97	2.99	2.99	1.49	5.97	0.00	0.00	1.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34	67
2004	0.00	0.00	0.00	0.00	0.00	1.48	0.99	1.48	1.48	2.46	1.48	1.48	1.97	2.46	4.43	4.43	4.43	7.39	5.91	6.90	4.93	5.42	8.87	6.40	5.42	2.96	4.43	2.46	1.97	3.45	0.99	0.99	0.99	0.49	0.49	0.49	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81	203
2005	0.00	0.00	0.29	0.00	0.00	0.00	0.29	0.29	0.29	0.57	0.29	0.57	0.86	2.00	1.43	2.29	2.57	0.86	2.57	3.43	3.43	5.71	5.14	7.43	7.71	7.71	6.86	6.86	7.43	6.29	5.43	5.71	3.14	0.86	1.43	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	102	350
2006	0.00	0.00	0.00	0.62	1.24	0.00	0.00	1.86	1.86	1.24	1.24	3.11	3.11	4.35	2.48	1.86	5.59	2.48	3.73	6.83	3.73	2.48	1.24	9.94	6.21	3.11	3.11	6.21	4.35	4.35	2.48	4.35	1.86	1.24	0.62	1.86	0.62	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	68	161
2007	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.63	0.95	0.95	0.95	1.58	2.84	1.89	2.84	2.84	5.99	2.21	3.79	6.31	4.42	6.62	4.73	9.46	6.94	4.10	3.79	6.62	4.42	3.47	2.52	2.52	2.21	1.26	0.32	1.58	0.63	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	108	317
2008	0.00	0.00	0.00	0.00	0.00	0.90	0.30	0.90	2.10	2.40	1.50	1.20	3.29	0.60	1.20	1.50	2.99	2.10	1.80	3.89	2.69	2.69	3.89	11.08	3.29	6.89	7.78	11.38	5.39	3.59	2.99	4.49	1.50	1.20	0.90	2.40	0.00	0.60	0.30	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	72	334
2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.63	1.25	1.25	2.19	2.82	6.90	4.39	3.13	15.99	7.84	6.58	6.90	11.29	5.33	3.76	3.45	6.27	1.57	1.57	0.63	2.51	0.31	0.94	0.94	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90	319
2010	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.17	1.19	0.34	1.71	1.71	2.05	2.73	4.44	5.63	4.78	6.14	5.12	8.02	8.53	8.02	6.14	4.95	4.95	4.95	4.44	3.07	2.22	2.56	1.37	1.19	1.02	1.19	0.34	0.17	0.17	0.00	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.17	216	586
2011	0.00	0.00	0.00	0.00	0.17	0.34	0.00	0.34	0.34	1.18	0.67	1.01	1.01	1.68	1.35	3.37	2.86	3.20	3.87	4.21	5.22	5.39	6.73	6.57	7.91	7.24	6.40	5.56	4.38	5.39	3.70	2.69	2.19	1.68	0.84	1.01	0.51	0.51	0.17	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	171	594
2012	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.44	0.79	0.61	0.52	0.61	2.71	1.75	2.97	3.84	8.30	3.76	3.58	7.86	3.58	3.58	3.06	7.86	3.93	4.45	4.72	8.12	4.19	3.93	3.76	4.80	1.22	0.87	1.48	1.40	0.09	0.17	0.26	0.35	0.26	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	342	1145
2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.71	0.55	0.79	0.55	2.20	1.42	2.36	2.28	4.64	2.60	3.93	7.16	7.08	6.53	6.85	13.85	6.69	6.14	2.99	6.06	2.28	1.81	1.89	2.99	0.94	1.02	0.55	0.87	0.94	0.24	0.16	0.31	0.24	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	368	1271
2014	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.18	0.30	0.36	0.30	0.60	1.45	1.33	0.84	1.21	4.34	2.53	3.62	8.20	5.37	5.25	6.82	11.88	5.79	5.43	4.83	9.17	3.26	3.14	2.71	4.58	1.93	1.75	0.78	0.90	0.36	0.30	0.12	0.06	0.00	0.00	0.00	0.12	0.06	0.00	0.00	0.00	0.00	464	1658
2015	0.00	0.00	0.00	0.00	0.08	0.00	0.08	0.17	0.75	0.33	0.59	0.84	2.34	1.51	1.51	1.84	3.51	1.34	2.43	5.94	4.02	3.43	4.69	10.96	5.52	4.69	6.36	10.54	4.77	4.18	3.93	5.44	2.26	1.51	0.92	1.51	0.67	0.33	0.33	0.42	0.08	0.00	0.08	0.00	0.00	0.08	0.00	0.00	0.00	428	1195
2016	0.00	0.00	0.00	0.00	0.09	0.05	0.05	0.09	0.60	0.79	1.29	1.90	5.18	3.33	3.93	4.48	8.14	4.21	4.39	7.54	4.81	4.02	4.11	7.30	3.84	3.79	4.11	6.43	2.36	2.08	1.62	3.56	1.16	0.92	0.83	1.11	0.79	0.32	0.09	0.42	0.09	0.09	0.05	0.05	0.00	0.00	0.00	0.00	0.00	529	2163
2017	0.00	0.00	0.00	0.00	0.00	0.13	0.26	0.19	0.51	0.45	0.32	0.26	1.54	0.96	1.47	1.79	5.96	4.23	5.38	13.21	7.95	7.56	6.03	13.46	4.87	3.97	2.37	5.06	1.60	1.54	1.22	2.12	0.96	1.09	0.58	1.28	0.51	0.19	0.26	0.51	0.06	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.00	452	1560
2018	0.00	0.08	0.00	0.00	0.16	0.16	0.08	0.08	0.87	0.39	0.63	1.18	2.37	2.05	2.29	2.60	5.44	4.18	4.57	11.59	5.91	5.91	6.15	10.57	4.02	4.81	3.63	7.10	2.52	2.05	1.74	3.15	0.55	0.47	0.87	1.10	0.24	0.16	0.08	0.16	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	400	1268
2019	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.27	0.73	0.60	0.87	0.80	3.54	3.07	2.20	3.47	8.54	4.80	5.67	10.27	5.47	5.80	4.54	9.21	4.60	3.47	3.94	6.00	2.54	2.27	1.73	2.13	1.27	0.47	0.67	0.67	0.00	0.13	0.07	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	391	1499
2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2021	0.00	0.00	0.00	0.11	0.11	0.11	0.22	0.22	0.79	0.22	1.01	1.35	1.91	1.35	1.91	2.25	6.18	3.26	4.61	8.99	5.62	5.73	5.73	11.01	4.16	6.18	2.81	5.62	2.70	2.81	1.57	4.04	1.69	1.46	1.35	1.01	0.67	0.67	0.11	0.22	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	302	890

Table 5. Annual age composition by calendar age of Gray Triggerfish caught in the MARMAP/SERFS fishery-independent chevron trap survey. Values per age bin by year are either estimated numbers of fish based on length frequency in 1990-2007 or actual number of fish processed in 2008-2021 and . Sampling did not occur in 2020 due to COVID-19. Deployments and total fish estimated or actually processed and are summarized by year. Note that ages are not currently available for 2021 due to funding and time constraints.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	Deployments	Fish
1990	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1991	3	64	108	74	34	9	4	4	0	2	0	0	0	56	302
1992	0	7	53	47	37	12	7	2	0	0	0	0	0	85	165
1993	1	23	165	398	320	36	30	1	2	0	0	0	0	119	976
1994	0	8	58	116	116	56	26	10	3	0	0	0	0	151	393
1995	0	7	74	158	193	79	32	12	9	1	3	0	0	145	568
1996	1	24	172	310	322	206	61	31	9	6	0	0	0	175	1142
1997	0	3	75	180	224	141	67	22	11	3	0	0	0	185	726
1998	0	6	26	112	148	101	39	18	6	1	0	0	0	122	457
1999	0	6	25	53	43	36	13	4	0	1	0	0	0	62	181
2000	0	6	23	59	67	43	10	7	4	1	0	0	0	90	220
2001	0	13	60	59	56	24	6	4	2	0	0	0	0	91	224
2002	0	13	67	98	57	37	20	15	4	1	1	0	0	107	313
2003	0	0	7	17	25	14	6	2	1	0	0	0	0	34	72
2004	0	17	36	62	45	17	7	8	1	0	0	0	0	79	193
2005	1	4	22	73	116	68	28	18	3	2	1	1	0	100	337
2006	0	2	21	42	49	42	7	8	0	2	2	0	0	68	175
2007	0	3	48	93	103	47	21	11	3	1	0	0	0	100	330
2008	12	29	45	67	48	35	13	12	8	1	1	1	0	64	272
2009	0	44	91	64	25	8	5	0	0	1	0	0	0	79	238
2010	3	33	69	53	23	12	0	1	1	1	1	0	0	97	197
2011	1	37	59	94	65	46	18	8	6	4	0	0	0	116	338
2012	2	21	77	101	113	84	18	13	13	4	1	2	2	190	451
2013	5	102	267	266	123	90	23	18	11	2	0	2	0	281	909
2014	16	118	239	262	163	90	49	25	10	3	0	0	1	304	976
2015	0	17	47	64	66	64	21	7	7	1	2	0	0	191	296
2016	0	13	82	76	49	33	27	8	5	2	0	0	0	177	295
2017	0	10	38	65	80	50	27	15	7	5	1	1	0	195	299
2018	0	8	27	64	79	70	30	13	2	4	1	0	0	153	298
2019	0	11	47	63	52	54	30	19	8	4	4	2	0	158	294
2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6. Annual age composition by calendar age of Gray Triggerfish caught in the MARMAP/SERFS fishery-independent chevron trap survey. This value is in percentage of by calendar age per year. Sampling did not occur in 2020 due to COVID-19 and ages are not currently available for 2021 due to funding and time constraints.Deployments and total fish estimated or actually processed are summarized by year.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	Deployments	Fish
1990	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1991	0.99	21.19	35.76	24.50	11.26	2.98	1.32	1.32	0.00	0.66	0.00	0.00	0.00	56	302
1992	0.00	4.24	32.12	28.48	22.42	7.27	4.24	1.21	0.00	0.00	0.00	0.00	0.00	85	165
1993	0.10	2.36	16.91	40.78	32.79	3.69	3.07	0.10	0.20	0.00	0.00	0.00	0.00	119	976
1994	0.00	2.04	14.76	29.52	29.52	14.25	6.62	2.54	0.76	0.00	0.00	0.00	0.00	151	393
1995	0.00	1.23	13.03	27.82	33.98	13.91	5.63	2.11	1.58	0.18	0.53	0.00	0.00	145	568
1996	0.09	2.10	15.06	27.15	28.20	18.04	5.34	2.71	0.79	0.53	0.00	0.00	0.00	175	1142
1997	0.00	0.41	10.33	24.79	30.85	19.42	9.23	3.03	1.52	0.41	0.00	0.00	0.00	185	726
1998	0.00	1.31	5.69	24.51	32.39	22.10	8.53	3.94	1.31	0.22	0.00	0.00	0.00	122	457
1999	0.00	3.31	13.81	29.28	23.76	19.89	7.18	2.21	0.00	0.55	0.00	0.00	0.00	62	181
2000	0.00	2.73	10.45	26.82	30.45	19.55	4.55	3.18	1.82	0.45	0.00	0.00	0.00	90	220
2001	0.00	5.91	27.27	26.82	25.45	10.91	2.73	1.82	0.91	0.00	0.00	0.00	0.00	91	224
2002	0.00	4.15	21.41	31.31	18.21	11.82	6.39	4.79	1.28	0.32	0.32	0.00	0.00	107	313
2003	0.00	0.00	9.72	23.61	34.72	19.44	8.33	2.78	1.39	0.00	0.00	0.00	0.00	34	72
2004	0.00	8.81	18.65	32.12	23.32	8.81	3.63	4.15	0.52	0.00	0.00	0.00	0.00	79	193
2005	0.30	1.19	6.53	21.66	34.42	20.18	8.31	5.34	0.89	0.59	0.30	0.30	0.00	100	337
2006	0.00	1.14	12.00	24.00	28.00	24.00	4.00	4.57	0.00	1.14	1.14	0.00	0.00	68	175
2007	0.00	0.91	14.55	28.18	31.21	14.24	6.36	3.33	0.91	0.30	0.00	0.00	0.00	100	330
2008	4.41	10.66	16.54	24.63	17.65	12.87	4.78	4.41	2.94	0.37	0.37	0.37	0.00	64	272
2009	0.00	18.49	38.24	26.89	10.50	3.36	2.10	0.00	0.00	0.42	0.00	0.00	0.00	79	238
2010	1.52	16.75	35.03	26.90	11.68	6.09	0.00	0.51	0.51	0.51	0.51	0.00	0.00	97	197
2011	0.30	10.95	17.46	27.81	19.23	13.61	5.33	2.37	1.78	1.18	0.00	0.00	0.00	116	338
2012	0.44	4.66	17.07	22.39	25.06	18.63	3.99	2.88	2.88	0.89	0.22	0.44	0.44	190	451
2013	0.55	11.22	29.37	29.26	13.53	9.90	2.53	1.98	1.21	0.22	0.00	0.22	0.00	281	909
2014	1.64	12.09	24.49	26.84	16.70	9.22	5.02	2.56	1.02	0.31	0.00	0.00	0.10	304	976
2015	0.00	5.74	15.88	21.62	22.30	21.62	7.09	2.36	2.36	0.34	0.68	0.00	0.00	191	296
2016	0.00	4.41	27.80	25.76	16.61	11.19	9.15	2.71	1.69	0.68	0.00	0.00	0.00	177	295
2017	0.00	3.34	12.71	21.74	26.76	16.72	9.03	5.02	2.34	1.67	0.33	0.33	0.00	195	299
2018	0.00	2.68	9.06	21.48	26.51	23.49	10.07	4.36	0.67	1.34	0.34	0.00	0.00	153	298
2019	0.00	3.74	15.99	21.43	17.69	18.37	10.20	6.46	2.72	1.36	1.36	0.68	0.00	158	294
2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

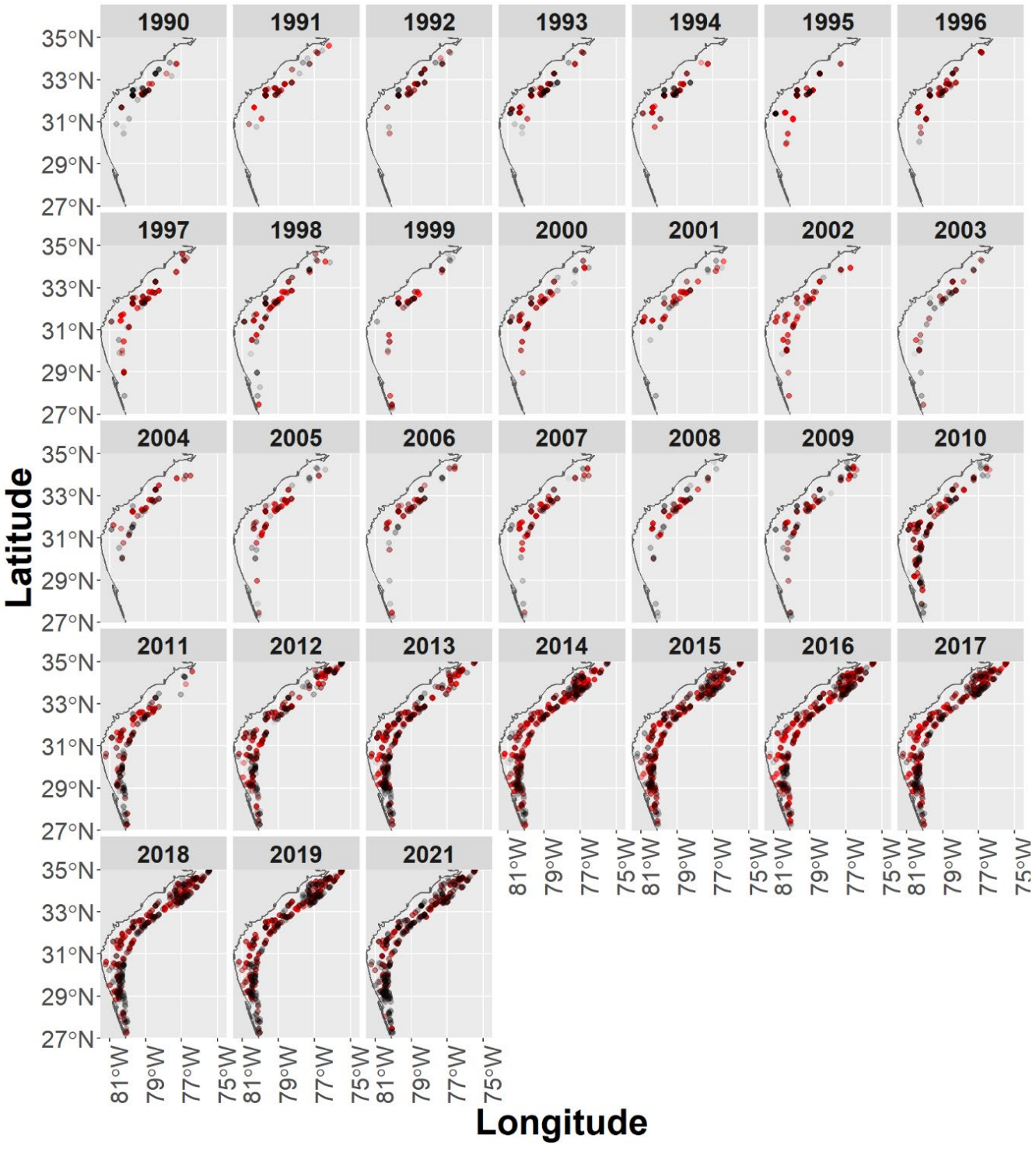

Figure 1. Sampling distribution of all collections by year of the MARMAP/SERFS fishery-independent chevron trap survey. Red circles indicate positive collections for Gray Triggerfish, while black circles represent no catch of Gray Triggerfish.

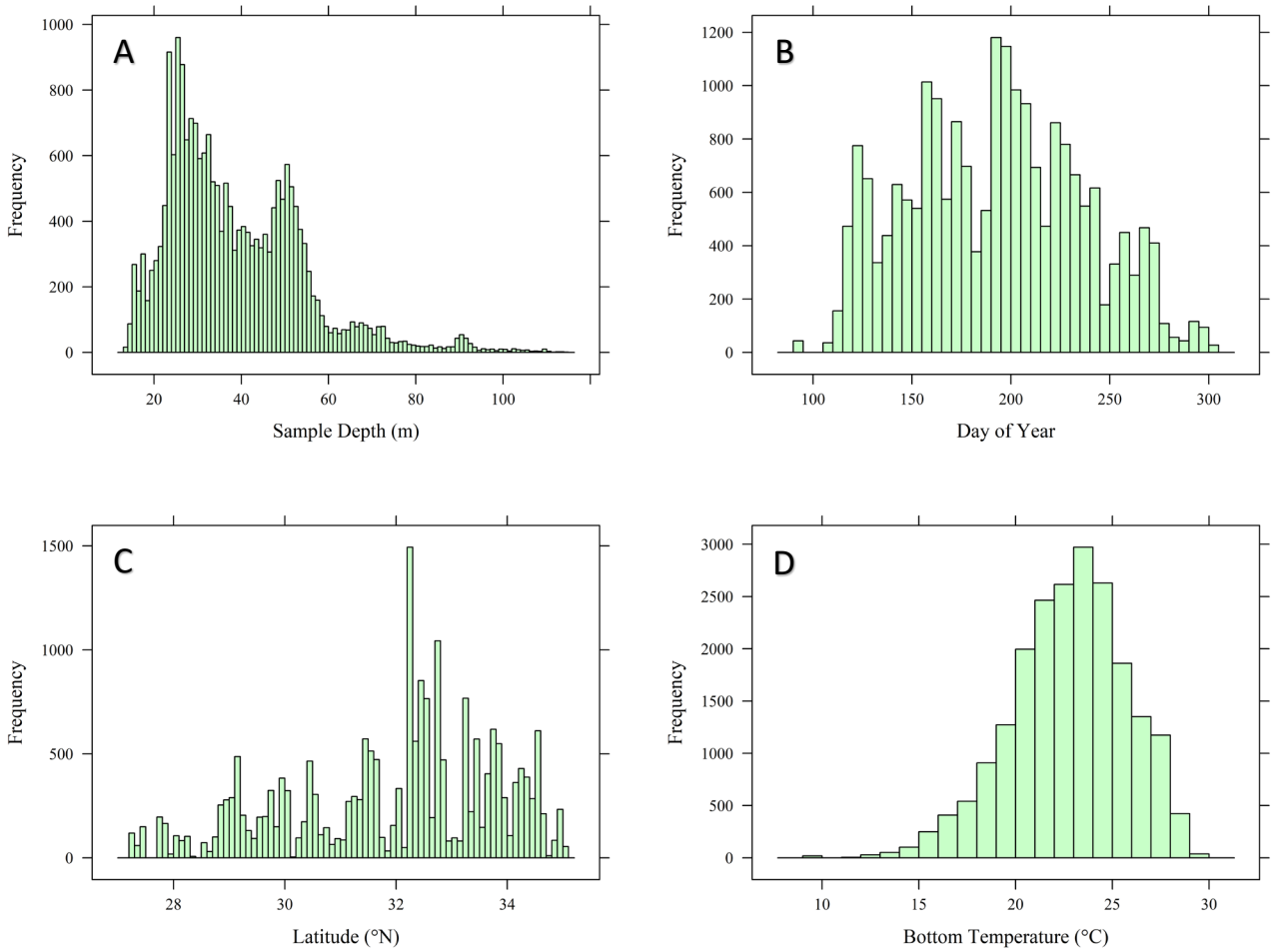

Figure 2. Sample distribution of covariate data from MARMAP/SERFS fishery-independent chevron trap survey collections for depth (A), day of year (B), latitude (C), and bottom temperature (D).

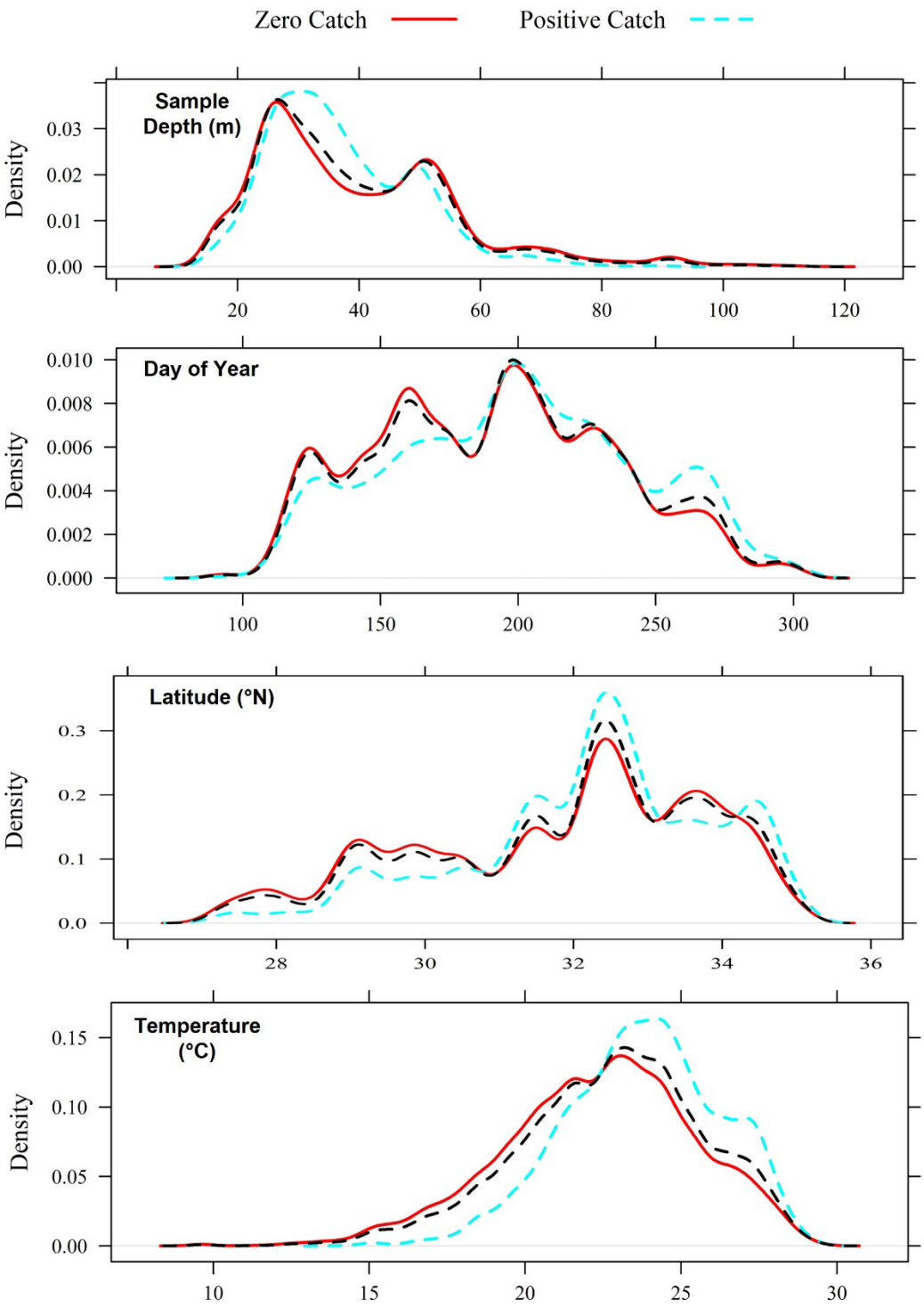

Figure 3. Sample distribution of catch of Gray Triggerfish and effects by covariate on positive and zero catches.

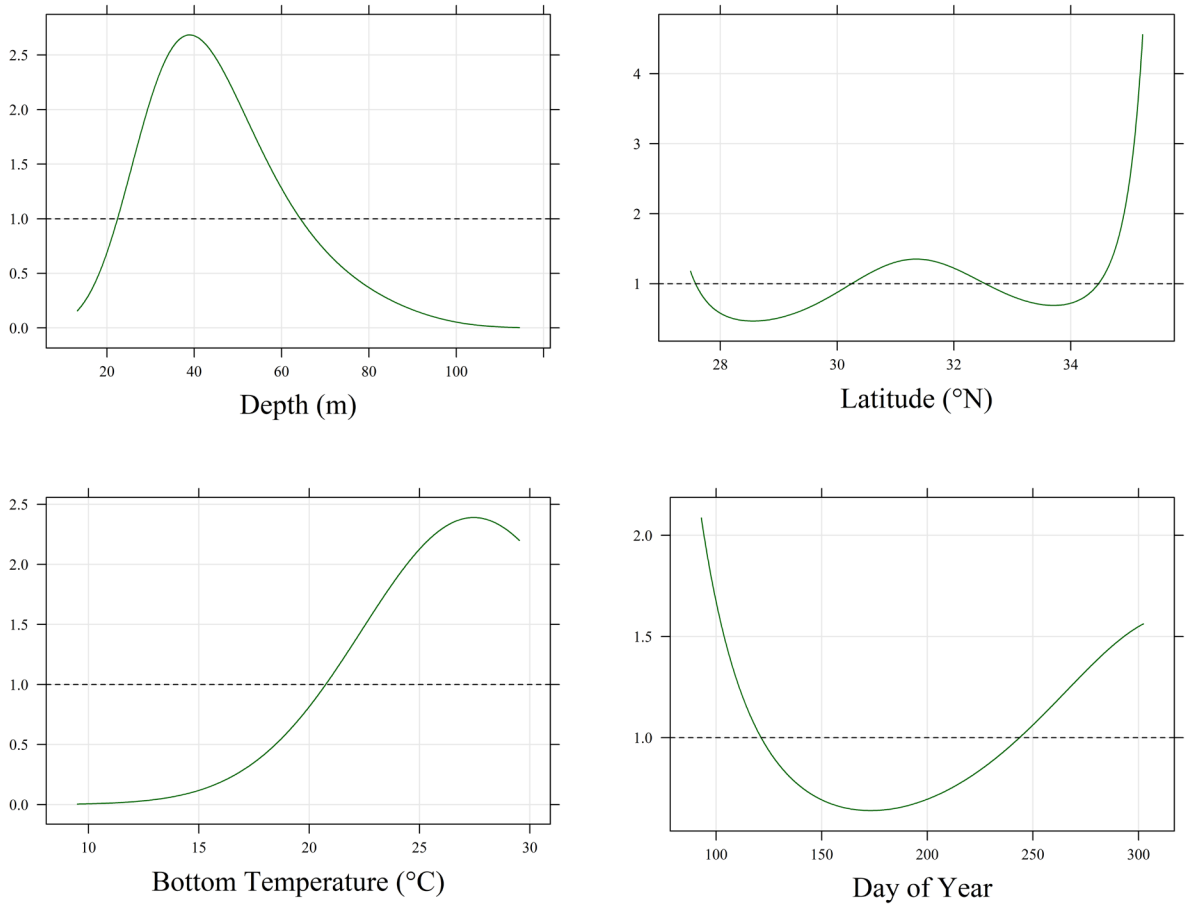

Figure 4. Modelled final covariate effects on catch of Gray Triggerfish from the ZINB standardization.

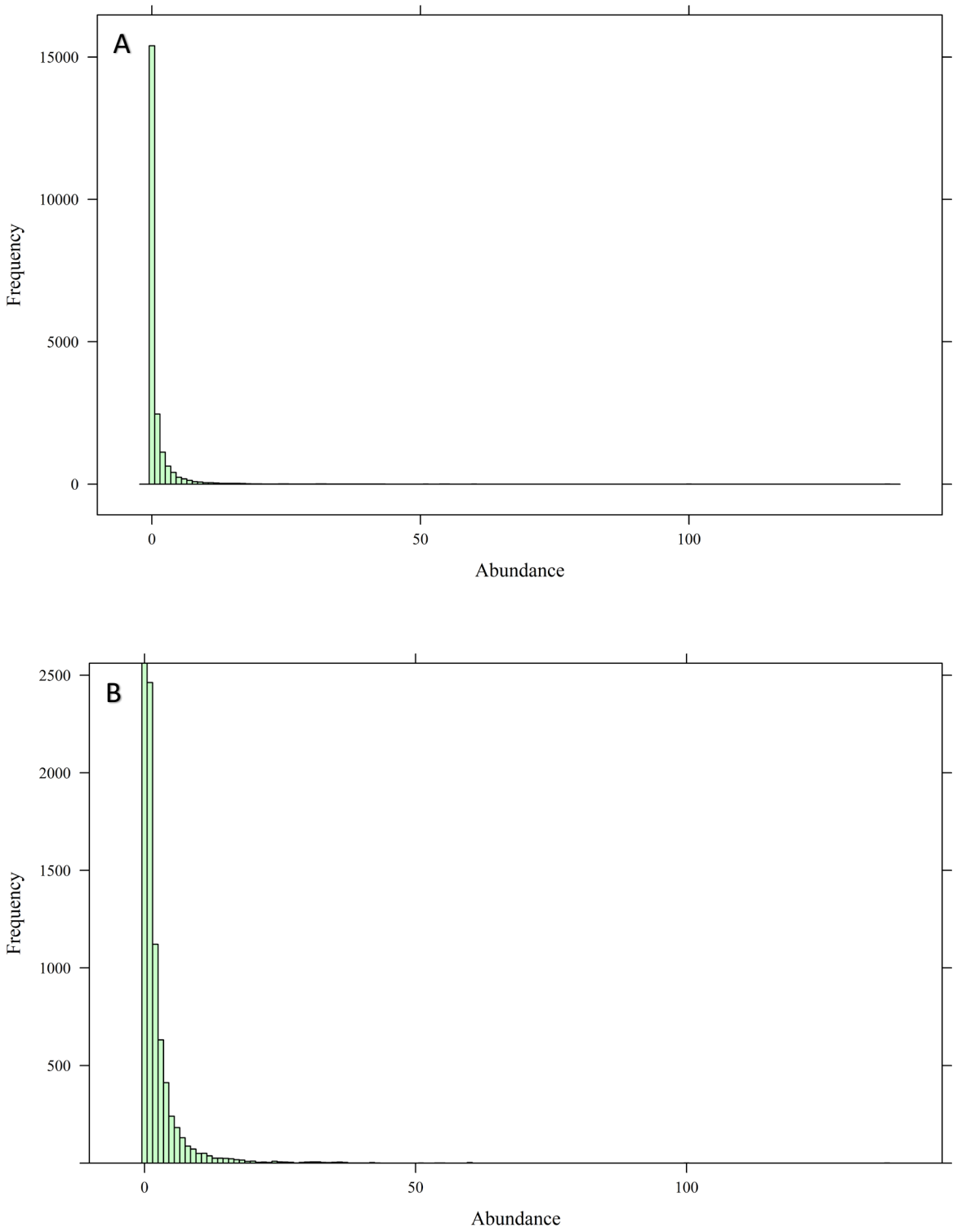

Figure 5. Count distribution of Gray Triggerfish catch from MARMAP/SERFS fishery-independent chevron trap survey showing full range of the distribution (A) and a truncated y-axis (B) to better show positive catches.

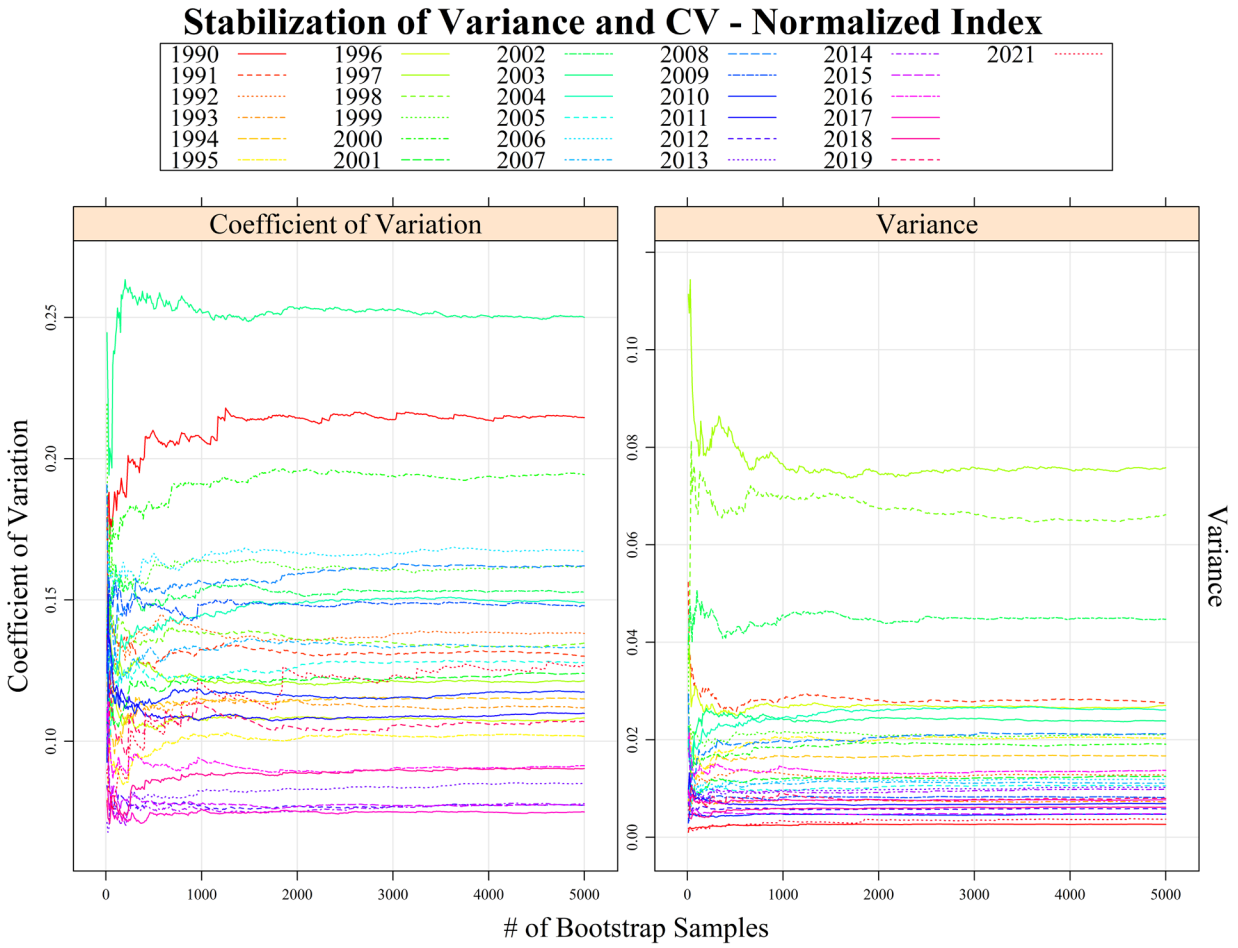

Figure 6. Stability of coefficient of variation and variance by bootstrap run during fishery-independent chevron video trap survey index development.

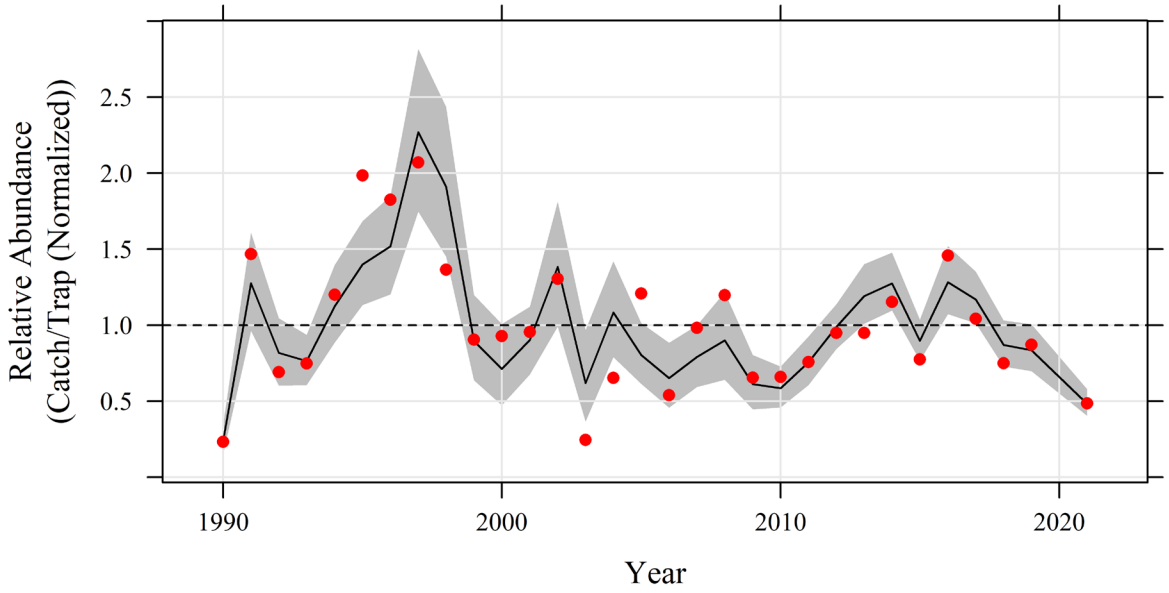

Figure 7. Normalized and standardized index (solid line) with 2.5% and 97.5% confidence intervals (gray) and the nominal index (red dots) for Gray Triggerfish in the MARMAP/SERFS fishery-independent chevron trap survey.