Red Porgy Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2017)

Walter J. Bubley and Tracey I. Smart

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Walter J. Bubley and Tracey I. Smart

Marine Resources Research Institute
South Carolina Department of Natural Resources
P.O. Box 12259
Charleston, SC 29412

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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 Red Porgy in the US South Atlantic region and includes data from three monitoring programs (MARMAP, SEAMAP-SA, and SEFIS, known collectively as SERFS). Specifically, it presents annual nominal catch per unit effort (CPUE) of Red Porgy, *Pagrus pagrus*, in chevron traps from 1990 to 2017. 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 were highly variable but show a generally decreasing trend since 2012.

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, age compositions, length frequencies, and other information regarding reef fish species on live-bottom and/or hard-bottom habitats. Red Porgy, *Pagrus pagrus*, are one of the more common species encountered in the chevron trap sampling. 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).

Objective

This report presents a standardized relative abundance index of Red Porgy derived from the MARMAP/SERFS chevron trap survey during the years 1990-2017. The standardized index accounts for annual sampling distribution shifts with respect to covariates that affect catch of Red Porgy in chevron traps. Also provided are annual age compositions of Vermilion Snapper captured by chevron trap. This information is critical at informing the selectivity pattern at age of Vermilion Snapper by chevron traps. Data presented in this report are based on the combined SERFS database accessed on December 15, 2017.

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 and later sampling in some years

Survey Design

- Simple random sample survey design
  - Annually, randomly selected stations 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 in a given 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 a combination of whole 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 (^oC) 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) 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
  - NonRandom – non-randomly sampled live-bottom station (a.k.a haphazard or opportunistic sample)
  - ReconConv – reconnaissance deployments that were subsequently converted into live-bottom chevron trap stations
  - Null – traps for which there is no station code value
    - Use of station codes is fairly 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 (°N) - Continuous variable
        - Bottom temperature (°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 3.1.0; R Development Core Team 2014)

Age Composition

- Aging methods – sagittal otoliths were removed from Red Porgy to serve as the aging structure
    - Ages presented here are calendar age based on increment counts with an estimated increment formation on August 1 (See SEDAR60-WP09 for calendar age assignment) and increment count
    - Only fish caught in chevron traps that had age samples taken were included in the age compositions
    - Prior to 2008, selection of fish retained for aging were sub-sampled based on length bins. From 2008 and on, selection of fish retained for aging was either complete (100% retained) or randomly sub-sampled. 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)

Results

Sampling area

- General increase in sampling intensity (# of annual chevron trap deployments) through time (Table 1 and Fig. 1)
- Gradual shift regarding the spatial density of samples through time (Table 1 and Fig. 1)
    - More dense geographic coverage in southern and northern latitudes in later years
- Sampling depths range from 13 to 218 m (Table 1 and Fig. 2)
    - Generally less than 100 m

Sampling season

- May through September (Table 1 and Fig. 2)

Data Filtering/Inclusion

- Included traps (n = 15,771; Table 1)

Standardized Index Model Formulation

Model Basics

- Dependent variables
    - Covariates (Inclusion and polynomial order in sub-models available Table 2)
        - The affect 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 (Fig. 4)
- Model structure
    - Final model selected was ZINB (Table 2)
        - Selected over non-zero inflated models due to high proportion of zero counts (Fig. 5)
- Coefficients of variation (CVs) and variances stabilized within the 5,000 bootstraps (Fig. 6)
- Annual standardized and normalized (relative to the long-term mean) index values for Red Porgy, including CVs showed trends from 1990-2017 (Table 3 and Figure 7)

Age Composition

- Increment count caught by chevron traps in 1990-2017 (Tables 4 and 5)
- Calendar ages caught by chevron traps in 1990-2017 (Tables 6 and 7)

References

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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		Latitude		Temperature		Day of Year	
Year	Avg	Range	Avg	Range	Avg	Range	Avg	Range
1990	35.1	16-93	32.5	30.4-33.8	22.0	18.2-27.8	150	114-222
1991	34.7	17-95	32.6	30.8-34.6	24.9	15.9-27.5	217	163-268
1992	34.4	17-59	32.8	30.4-34.3	21.3	15.3-24.5	155	92-227
1993	33.3	14-90	32.4	30.4-34.3	22.8	17.7-28.5	176	131-226
1994	37.9	14-93	32.4	30.7-33.8	22.8	18.2-26.9	174	130-300
1995	33.8	14-63	32.1	29.8-33.7	24.6	20.1-28.3	198	124-299
1996	37.7	15-94	32.4	27.9-34.3	22.0	14.2-27.0	188	121-261
1997	39.3	14-93	32.0	27.9-34.6	22.8	16.7-28.0	194	126-273
1998	39.1	13-91	32.1	27.4-34.6	21.5	9.5-28.6	178	126-231
1999	35.9	14-79	32.0	27.3-34.6	22.9	17.9-28.8	199	153-272
2000	38.3	16-120	32.3	29.0-34.3	23.9	18.0-28.5	201	138-294
2001	39.6	15-93	32.3	27.9-34.3	23.5	16.0-29.2	204	144-298
2002	39.8	15-90	31.9	27.9-34.0	24.1	15.2-28.3	207	169-268
2003	41.8	17-92	32.1	27.4-34.3	18.9	13.4-25.1	203	155-266
2004	42.7	16-96	32.3	29.0-34.0	20.9	16.7-25.8	175	127-303
2005	41.6	16-71	32.1	27.3-34.3	23.0	18.0-28.5	191	124-273
2006	40.6	17-93	32.3	27.3-34.4	22.4	15.0-26.7	203	158-272
2007	40.9	17-97	32.2	27.3-34.3	23.2	15.3-28.9	201	142-268
2008	41.8	17-93	32.2	27.3-34.6	21.9	15.2-27.2	195	127-275
2009	39.4	17-94	32.2	27.3-34.6	22.6	15.4-27.2	203	127-282
2010	39.7	13-93	31.6	27.3-34.6	21.6	12.4-29.4	213	125-301
2011	44.2	16-117	30.9	27.2-34.5	21.7	14.8-28.8	211	140-300
2012	41.1	12-106	31.9	27.2-35.0	22.0	12.9-27.8	196	116-285
2013	36.8	14-102	31.3	27.2-35.0	22.1	12.4-28.1	198	115-278
2014	39.6	16-103	32.0	27.3-35.0	23.5	16.7-29.3	193	114-295
2015	39.8	16-115	31.9	27.3-35.0	22.7	13.6-28.5	187	112-296
2016	39.9	16-94	32.2	27.2-35.0	23.9	15.5-29.3	218	126-302
2017	39.8	14-108	31.8	27.2-35.0	22.7	14.8-28.2	184	117-273

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	0	1	4	2	0	1	42628
Negative Binomial	1	4	3	0	1	—	—	—	—	43956
Zero-Inflated Poisson	1	4	4	1	2	3	4	4	1	56687
Poisson	1	4	4	4	4	—	—	—	—	84825

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 Red Porgy, the proportion of those positive collections in relation to the included collections, the total number of Red Porgy caught, and these totals for the survey. The results show the normalized nominal and standardized chevron trap catch of Red Porgy 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 CPUE	ZINB Standardized CPUE	
Year	Included Collections	Positive Collections	Proportion Positive	Total Fish	Normalized	Normalized	CV
1990	313	159	0.51	715	1.08	0.87	0.09
1991	272	135	0.50	796	1.38	1.39	0.10
1992	288	178	0.62	1,086	1.78	1.35	0.09
1993	392	160	0.41	702	0.84	0.81	0.09
1994	387	166	0.43	1,101	1.34	0.96	0.09
1995	361	148	0.41	872	1.14	1.27	0.10
1996	361	160	0.44	843	1.10	0.87	0.09
1997	400	122	0.30	532	0.63	0.65	0.11
1998	426	154	0.36	683	0.76	0.72	0.10
1999	230	98	0.43	423	0.87	0.86	0.11
2000	298	111	0.37	462	0.73	0.80	0.14
2001	246	100	0.41	663	1.27	1.13	0.13
2002	238	99	0.42	496	0.98	1.00	0.14
2003	224	94	0.42	437	0.92	0.79	0.12
2004	282	140	0.50	1,028	1.72	1.42	0.10
2005	303	161	0.53	1,092	1.70	1.45	0.10
2006	297	119	0.40	745	1.18	1.00	0.12
2007	337	153	0.45	1,124	1.57	1.42	0.09
2008	303	100	0.33	520	0.81	0.71	0.12
2009	404	112	0.28	513	0.60	0.61	0.12
2010	621	195	0.31	996	0.76	1.04	0.09
2011	706	203	0.29	1,143	0.76	1.09	0.10
2012	1,143	316	0.28	2,131	0.88	1.27	0.07
2013	1,322	315	0.24	1,785	0.64	1.04	0.08
2014	1,388	436	0.31	2,650	0.90	1.12	0.07
2015	1,421	380	0.27	1,881	0.62	0.84	0.07
2016	1,439	380	0.26	1,729	0.57	0.83	0.08
2017	1,369	300	0.22	1,370	0.47	0.68	0.09
Totals	15,771	5,194	0.33	28,518			

Table 4. Annual age composition by increment count of Red Porgy caught in the MARMAP/SERFS fishery-independent chevron trap survey. This value is in numbers of fish processed in 2008-2018 and estimated numbers of fish based on length frequency in 1990-2007. Total fish caught and deployments are summarized by year.

Increments	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0	45	83	38	31	8	0	0	48	0	0	0	0	0	11	29	2	0	8	2	2	7	14	2	1	0	0	0	3
1	338	346	394	255	223	468	432	152	402	258	43	152	227	181	151	199	261	441	40	55	142	132	51	56	110	47	216	33
2	357	249	423	218	487	216	550	116	177	148	169	101	182	212	377	266	241	452	105	56	126	269	340	142	123	215	209	260
3	203	89	132	165	140	135	156	226	155	28	256	160	42	96	397	447	156	206	123	82	134	203	511	370	341	219	287	310
4	24	67	73	54	149	60	86	82	113	38	76	218	73	33	184	261	138	104	43	97	164	126	203	301	576	440	209	277
5	16	18	39	25	96	24	71	46	48	33	68	137	81	39	71	62	83	104	48	52	122	128	170	99	307	577	370	172
6	4	8	13	18	29	16	41	29	22	8	45	55	43	21	63	20	29	50	24	35	39	69	162	94	88	230	313	228
7	8	3	4	1	7	9	31	27	16	10	25	73	26	6	47	54	7	20	13	16	27	36	91	83	90	63	161	158
8	3	3	1	1	3	5	7	9	3	5	9	15	15	5	22	25	5	8	2	9	19	24	57	63	62	52	42	75
9	0	0	4	1	0	0	1	6	1	3	8	13	9	2	9	11	9	5	1	5	3	24	35	31	56	47	21	23
10	1	1	0	1	0	0	0	1	3	3	8	6	4	0	8	16	2	1	5	3	1	7	38	21	29	30	22	10
11	0	0	0	0	0	0	0	0	2	0	3	7	2	1	2	2	2	4	1	5	0	1	15	22	15	18	10	16
12	0	0	0	0	0	0	0	1	1	1	3	5	2	1	4	4	2	3	2	2	4	3	0	10	19	12	15	10
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	2	0	1	2	1	3	1	3	6	11	8	4
14	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	0	2	6	0	0	2	1	2	8	6	1
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	2	0	4	0	2	7	3
16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2	6	1	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	1	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Fish	**999**	**867**	**1,121**	**770**	**1,142**	**933**	**1,375**	**743**	**943**	**535**	**714**	**942**	**708**	**608**	**1,369**	**1,372**	**937**	**1,406**	**412**	**428**	**791**	**1,042**	**1,678**	**1,305**	**1,836**	**1,975**	**1,896**	**1,586**
Deployments	**138**	**122**	**96**	**106**	**86**	**131**	**207**	**124**	**155**	**101**	**127**	**114**	**118**	**102**	**153**	**158**	**119**	**148**	**96**	**114**	**191**	**217**	**295**	**275**	**307**	**395**	**400**	**334**

Table 5. Annual age composition by increment count of Red Porgy caught in the MARMAP/SERFS fishery-independent chevron trap survey. This value is in percentage of fish processed in 2008-2018 and estimated numbers of fish based on length frequency in 1990-2007by that increment count per year. Total fish caught and deployments are summarized by year.

Increments	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0	4.50	9.57	3.39	4.03	0.70	0.00	0.00	6.46	0.00	0.00	0.00	0.00	0.00	1.81	2.12	0.15	0.00	0.57	0.49	0.47	0.88	1.34	0.12	0.08	0.00	0.00	0.00	0.19
1	33.83	39.91	35.15	33.12	19.53	50.16	31.42	20.46	42.63	48.22	6.02	16.14	32.06	29.77	11.03	14.50	27.85	31.37	9.71	12.85	17.95	12.67	3.04	4.29	5.99	2.38	11.39	2.08
2	35.74	28.72	37.73	28.31	42.64	23.15	40.00	15.61	18.77	27.66	23.67	10.72	25.71	34.87	27.54	19.39	25.72	32.15	25.49	13.08	15.93	25.82	20.26	10.88	6.70	10.89	11.02	16.39
3	20.32	10.27	11.78	21.43	12.26	14.47	11.35	30.42	16.44	5.23	35.85	16.99	5.93	15.79	29.00	32.58	16.65	14.65	29.85	19.16	16.94	19.48	30.45	28.35	18.57	11.09	15.14	19.55
4	2.40	7.73	6.51	7.01	13.05	6.43	6.25	11.04	11.98	7.10	10.64	23.14	10.31	5.43	13.44	19.02	14.73	7.40	10.44	22.66	20.73	12.09	12.10	23.07	31.37	22.28	11.02	17.47
5	1.60	2.08	3.48	3.25	8.41	2.57	5.16	6.19	5.09	6.17	9.52	14.54	11.44	6.41	5.19	4.52	8.86	7.40	11.65	12.15	15.42	12.28	10.13	7.59	16.72	29.22	19.51	10.84
6	0.40	0.92	1.16	2.34	2.54	1.71	2.98	3.90	2.33	1.50	6.30	5.84	6.07	3.45	4.60	1.46	3.09	3.56	5.83	8.18	4.93	6.62	9.65	7.20	4.79	11.65	16.51	14.38
7	0.80	0.35	0.36	0.13	0.61	0.96	2.25	3.63	1.70	1.87	3.50	7.75	3.67	0.99	3.43	3.94	0.75	1.42	3.16	3.74	3.41	3.45	5.42	6.36	4.90	3.19	8.49	9.96
8	0.30	0.35	0.09	0.13	0.26	0.54	0.51	1.21	0.32	0.93	1.26	1.59	2.12	0.82	1.61	1.82	0.53	0.57	0.49	2.10	2.40	2.30	3.40	4.83	3.38	2.63	2.22	4.73
9	0.00	0.00	0.36	0.13	0.00	0.00	0.07	0.81	0.11	0.56	1.12	1.38	1.27	0.33	0.66	0.80	0.96	0.36	0.24	1.17	0.38	2.30	2.09	2.38	3.05	2.38	1.11	1.45
10	0.10	0.12	0.00	0.13	0.00	0.00	0.00	0.13	0.32	0.56	1.12	0.64	0.56	0.00	0.58	1.17	0.21	0.07	1.21	0.70	0.13	0.67	2.26	1.61	1.58	1.52	1.16	0.63
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.42	0.74	0.28	0.16	0.15	0.15	0.21	0.28	0.24	1.17	0.00	0.10	0.89	1.69	0.82	0.91	0.53	1.01
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.11	0.19	0.42	0.53	0.28	0.16	0.29	0.29	0.21	0.21	0.49	0.47	0.51	0.29	0.00	0.77	1.03	0.61	0.79	0.63
13	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	0.00	0.29	0.00	0.21	0.00	0.24	0.47	0.13	0.29	0.06	0.23	0.33	0.56	0.42	0.25
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.07	0.07	0.00	0.00	0.49	1.40	0.00	0.00	0.12	0.08	0.11	0.41	0.32	0.06
15	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	0.00	0.00	0.07	0.00	0.00	0.00	0.23	0.13	0.19	0.00	0.31	0.00	0.10	0.37	0.19
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.33	0.05	0.00	0.00
17	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.16	0.05	0.00	0.00
18	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.05	0.05	0.00	0.00
19	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	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	0.00	0.13
20	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00
21	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	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	0.00	0.06
22	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
24	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Fish	**999**	**867**	**1,121**	**770**	**1,142**	**933**	**1,375**	**743**	**943**	**535**	**714**	**942**	**708**	**608**	**1,369**	**1,372**	**937**	**1,406**	**412**	**428**	**791**	**1,042**	**1,678**	**1,305**	**1,836**	**1,975**	**1,896**	**1,586**
Deployments	**138**	**122**	**96**	**106**	**86**	**131**	**207**	**124**	**155**	**101**	**127**	**114**	**118**	**102**	**153**	**158**	**119**	**148**	**96**	**114**	**191**	**217**	**295**	**275**	**307**	**395**	**400**	**334**

Table 6. Annual age composition by calendar age of Red Porgy caught in the MARMAP/SERFS fishery-independent chevron trap survey. This value is in numbers of fish processed in 2008-2018 and estimated numbers of fish based on length frequency in 1990-2007. Total fish caught and deployments are summarized by year.

Calendar Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0	0	76	0	0	0	0	0	26	0	0	0	0	0	7	2	0	0	3	1	2	6	10	1	0	0	0	0	3
1	226	280	297	220	173	404	303	110	234	195	38	97	188	150	104	145	221	299	23	42	116	104	34	42	101	39	192	24
2	371	288	443	250	415	239	569	139	299	195	139	144	200	232	381	270	254	526	97	56	141	263	263	120	100	202	209	229
3	281	120	203	157	207	156	247	208	174	39	233	148	55	106	408	420	169	256	133	91	121	227	523	312	259	180	292	304
4	77	69	94	81	170	74	91	127	121	37	119	214	77	36	228	315	143	121	54	88	159	116	245	348	546	371	173	289
5	17	22	49	34	111	24	75	45	56	33	61	141	72	39	77	89	85	96	44	62	122	125	118	126	369	547	329	154
6	11	6	19	20	50	20	42	29	25	10	51	61	51	23	63	16	34	61	29	29	62	81	201	71	132	334	336	212
7	7	5	7	7	14	10	34	28	19	10	33	77	23	5	53	41	9	21	15	22	27	46	96	80	88	93	210	192
8	4	3	3	1	7	4	12	15	6	7	15	23	21	6	25	30	5	4	4	10	25	24	67	78	64	44	50	94
9	1	1	2	1	0	1	2	7	1	5	7	16	9	1	8	22	9	9	1	7	4	25	54	44	73	48	29	33
10	0	0	2	0	0	0	1	3	3	2	8	9	6	1	10	15	4	1	5	3	1	10	28	24	36	46	25	11
11	1	1	0	1	0	0	0	0	2	1	5	6	2	1	2	5	2	4	1	3	0	2	37	23	20	24	14	13
12	0	0	0	0	0	0	0	0	1	1	2	7	1	1	4	4	1	2	1	4	3	0	8	19	21	18	9	12
13	0	0	0	0	0	0	0	1	0	0	2	0	1	0	4	1	2	1	2	2	2	5	1	8	11	7	13	7
14	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	6	0	1	0	2	3	11	5	2
15	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	1	0	2	0	1	7	8	2
16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	5	3	1	2	2
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	5	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1	1	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Fish	**996**	**871**	**1,119**	**772**	**1,147**	**932**	**1,376**	**738**	**941**	**535**	**714**	**943**	**708**	**608**	**1,370**	**1,376**	**939**	**1,404**	**412**	**428**	**791**	**1,042**	**1,678**	**1,305**	**1,836**	**1,975**	**1,896**	**1,586**
Deployments	**138**	**122**	**96**	**106**	**86**	**131**	**207**	**124**	**155**	**101**	**127**	**114**	**118**	**102**	**153**	**158**	**119**	**148**	**96**	**114**	**191**	**217**	**295**	**275**	**307**	**395**	**400**	**334**

Table 7. Annual age composition by calendar age of Red Porgy caught in the MARMAP/SERFS fishery-independent chevron trap survey. This value is in percentage of fish processed in 2008-2018 and estimated numbers of fish based on length frequency in 1990-2007by that increment count per year. Total fish caught and deployments are summarized by year.

Calendar Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0	0.00	8.73	0.00	0.00	0.00	0.00	0.00	3.52	0.00	0.00	0.00	0.00	0.00	1.15	0.15	0.00	0.00	0.21	0.24	0.47	0.76	0.96	0.06	0.00	0.00	0.00	0.00	0.19
1	22.69	32.15	26.54	28.50	15.08	43.35	22.02	14.91	24.87	36.45	5.32	10.29	26.55	24.67	7.59	10.54	23.54	21.30	5.58	9.81	14.66	9.98	2.03	3.22	5.50	1.97	10.13	1.51
2	37.25	33.07	39.59	32.38	36.18	25.64	41.35	18.83	31.77	36.45	19.47	15.27	28.25	38.16	27.81	19.62	27.05	37.46	23.54	13.08	17.83	25.24	15.67	9.20	5.45	10.23	11.02	14.44
3	28.21	13.78	18.14	20.34	18.05	16.74	17.95	28.18	18.49	7.29	32.63	15.69	7.77	17.43	29.78	30.52	18.00	18.23	32.28	21.26	15.30	21.79	31.17	23.91	14.11	9.11	15.40	19.17
4	7.73	7.92	8.40	10.49	14.82	7.94	6.61	17.21	12.86	6.92	16.67	22.69	10.88	5.92	16.64	22.89	15.23	8.62	13.11	20.56	20.10	11.13	14.60	26.67	29.74	18.78	9.12	18.22
5	1.71	2.53	4.38	4.40	9.68	2.58	5.45	6.10	5.95	6.17	8.54	14.95	10.17	6.41	5.62	6.47	9.05	6.84	10.68	14.49	15.42	12.00	7.03	9.66	20.10	27.70	17.35	9.71
6	1.10	0.69	1.70	2.59	4.36	2.15	3.05	3.93	2.66	1.87	7.14	6.47	7.20	3.78	4.60	1.16	3.62	4.34	7.04	6.78	7.84	7.77	11.98	5.44	7.19	16.91	17.72	13.37
7	0.70	0.57	0.63	0.91	1.22	1.07	2.47	3.79	2.02	1.87	4.62	8.17	3.25	0.82	3.87	2.98	0.96	1.50	3.64	5.14	3.41	4.41	5.72	6.13	4.79	4.71	11.08	12.11
8	0.40	0.34	0.27	0.13	0.61	0.43	0.87	2.03	0.64	1.31	2.10	2.44	2.97	0.99	1.82	2.18	0.53	0.28	0.97	2.34	3.16	2.30	3.99	5.98	3.49	2.23	2.64	5.93
9	0.10	0.11	0.18	0.13	0.00	0.11	0.15	0.95	0.11	0.93	0.98	1.70	1.27	0.16	0.58	1.60	0.96	0.64	0.24	1.64	0.51	2.40	3.22	3.37	3.98	2.43	1.53	2.08
10	0.00	0.00	0.18	0.00	0.00	0.00	0.07	0.41	0.32	0.37	1.12	0.95	0.85	0.16	0.73	1.09	0.43	0.07	1.21	0.70	0.13	0.96	1.67	1.84	1.96	2.33	1.32	0.69
11	0.10	0.11	0.00	0.13	0.00	0.00	0.00	0.00	0.21	0.19	0.70	0.64	0.28	0.16	0.15	0.36	0.21	0.28	0.24	0.70	0.00	0.19	2.21	1.76	1.09	1.22	0.74	0.82
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.19	0.28	0.74	0.14	0.16	0.29	0.29	0.11	0.14	0.24	0.93	0.38	0.00	0.48	1.46	1.14	0.91	0.47	0.76
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.28	0.00	0.14	0.00	0.29	0.07	0.21	0.07	0.49	0.47	0.25	0.48	0.06	0.61	0.60	0.35	0.69	0.44
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.07	0.07	0.11	0.00	0.24	1.40	0.00	0.10	0.00	0.15	0.16	0.56	0.26	0.13
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.07	0.00	0.00	0.24	0.23	0.13	0.00	0.12	0.00	0.05	0.35	0.42	0.13
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.38	0.16	0.05	0.11	0.13
17	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	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.27	0.00	0.00	0.00
18	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.15	0.05	0.05	0.00	0.00
19	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.06
20	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	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	0.00	0.06
21	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00
22	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	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	0.00	0.06
23	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
24	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Fish	**996**	**871**	**1,119**	**772**	**1,147**	**932**	**1,376**	**738**	**941**	**535**	**714**	**943**	**708**	**608**	**1,370**	**1,376**	**939**	**1,404**	**412**	**428**	**791**	**1,042**	**1,678**	**1,305**	**1,836**	**1,975**	**1,896**	**1,586**
Deployments	**138**	**122**	**96**	**106**	**86**	**131**	**207**	**124**	**155**	**101**	**127**	**114**	**118**	**102**	**153**	**158**	**119**	**148**	**96**	**114**	**191**	**217**	**295**	**275**	**307**	**395**	**400**	**334**

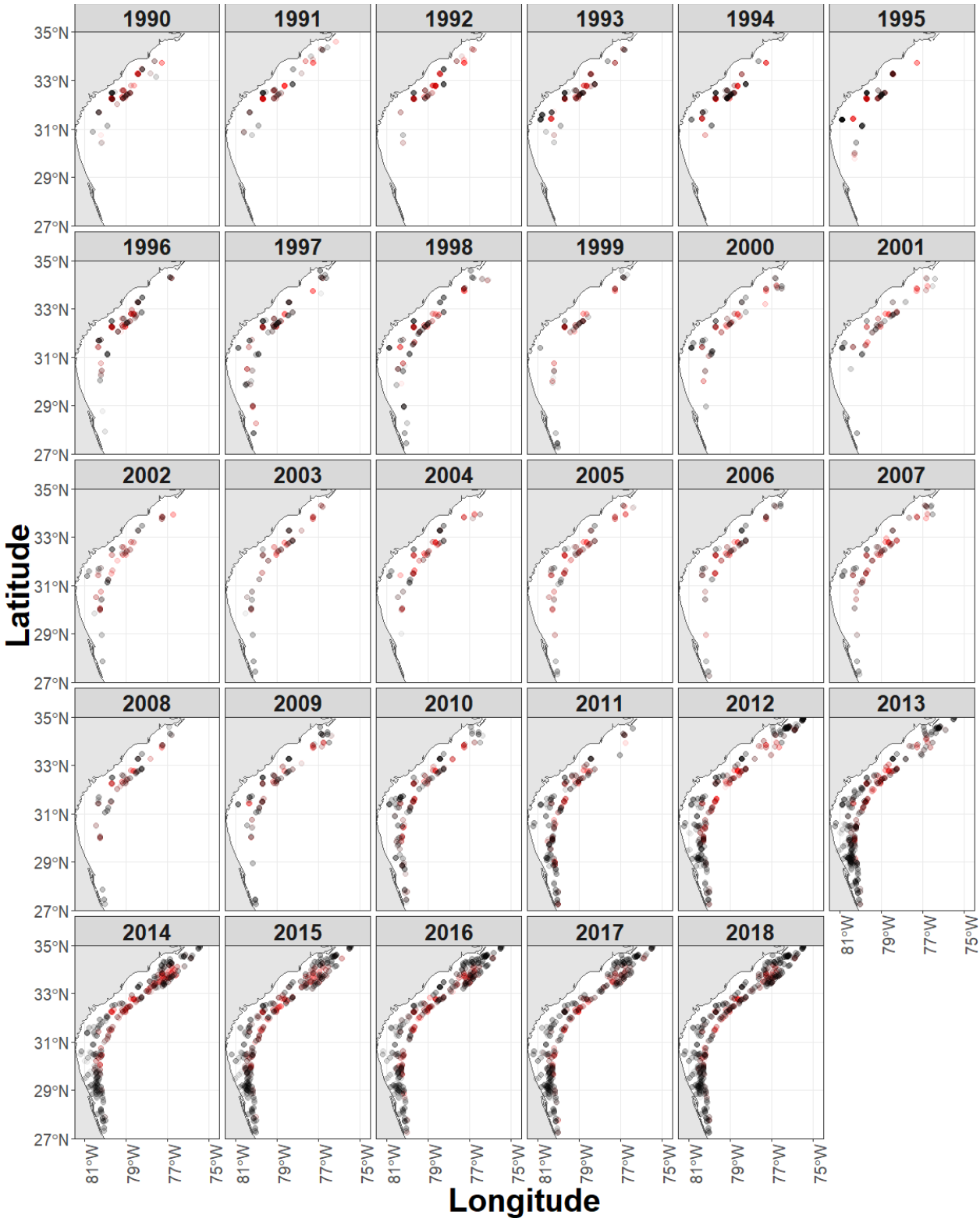

Figure 1. Sampling distribution of all collections by year of the MARMAP/SERFS fishery-independent chevron trap survey. Red circles indicate positive collections for Red Porgy, while black circles represent no catch of Red Porgy.

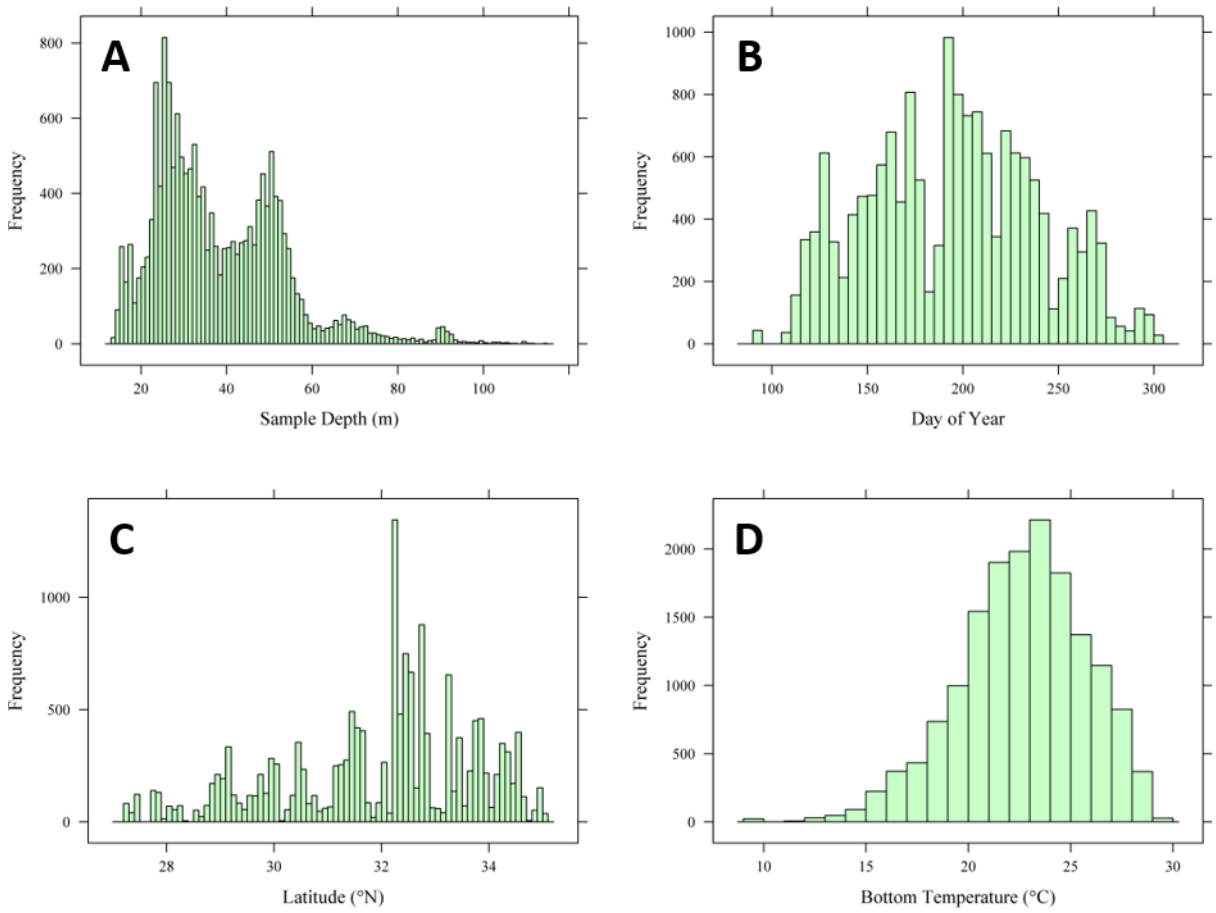

Figure 2. Sample distribution of covariate data from MARMAP/SERFS fishery-independent chevron trap survey collections for depth (A), day of year (B), latitude (C), and bottom temperature (D).

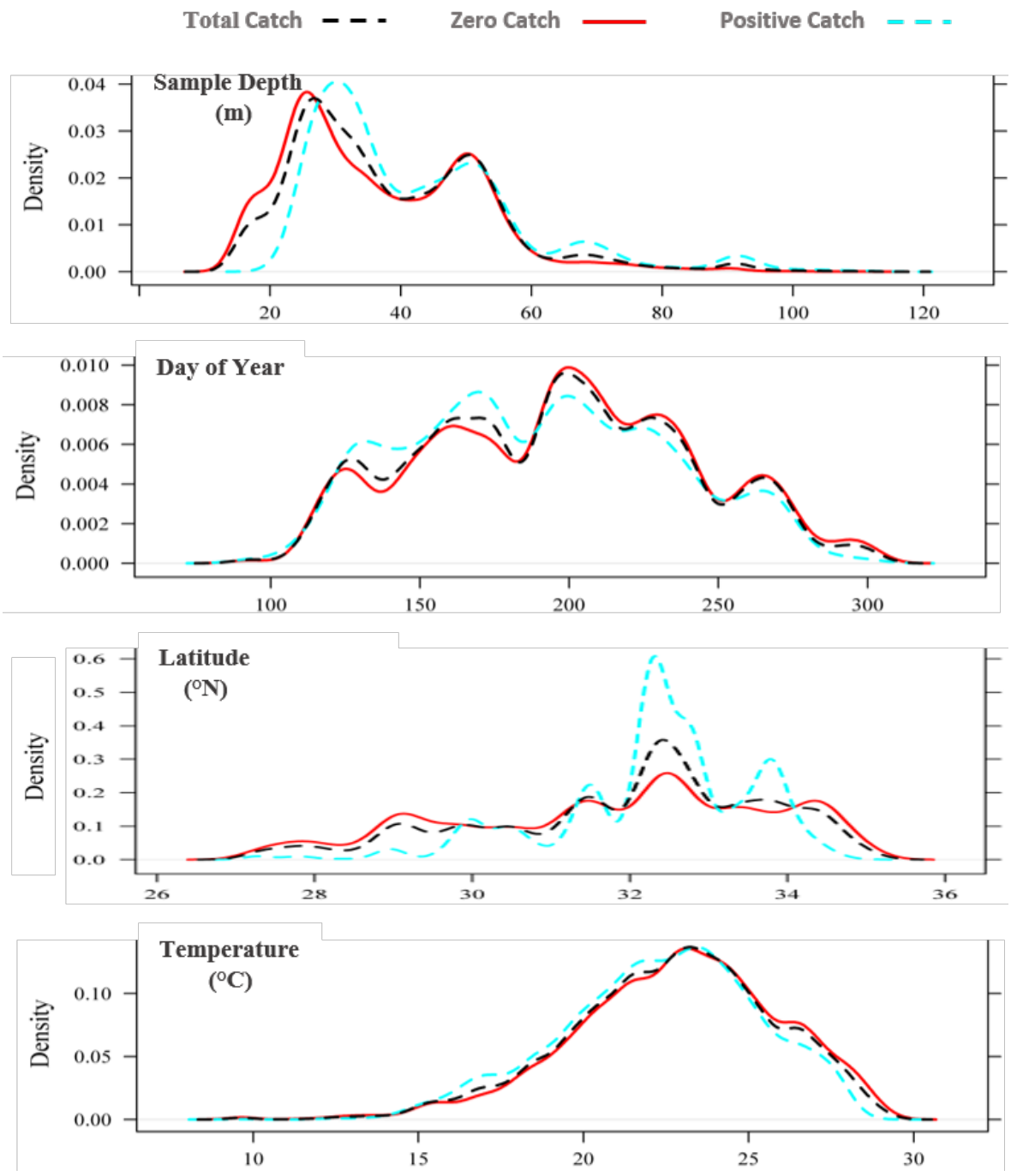

Figure 3. Sample distribution of catch of Red Porgy and effects by covariate on positive and zero catches.

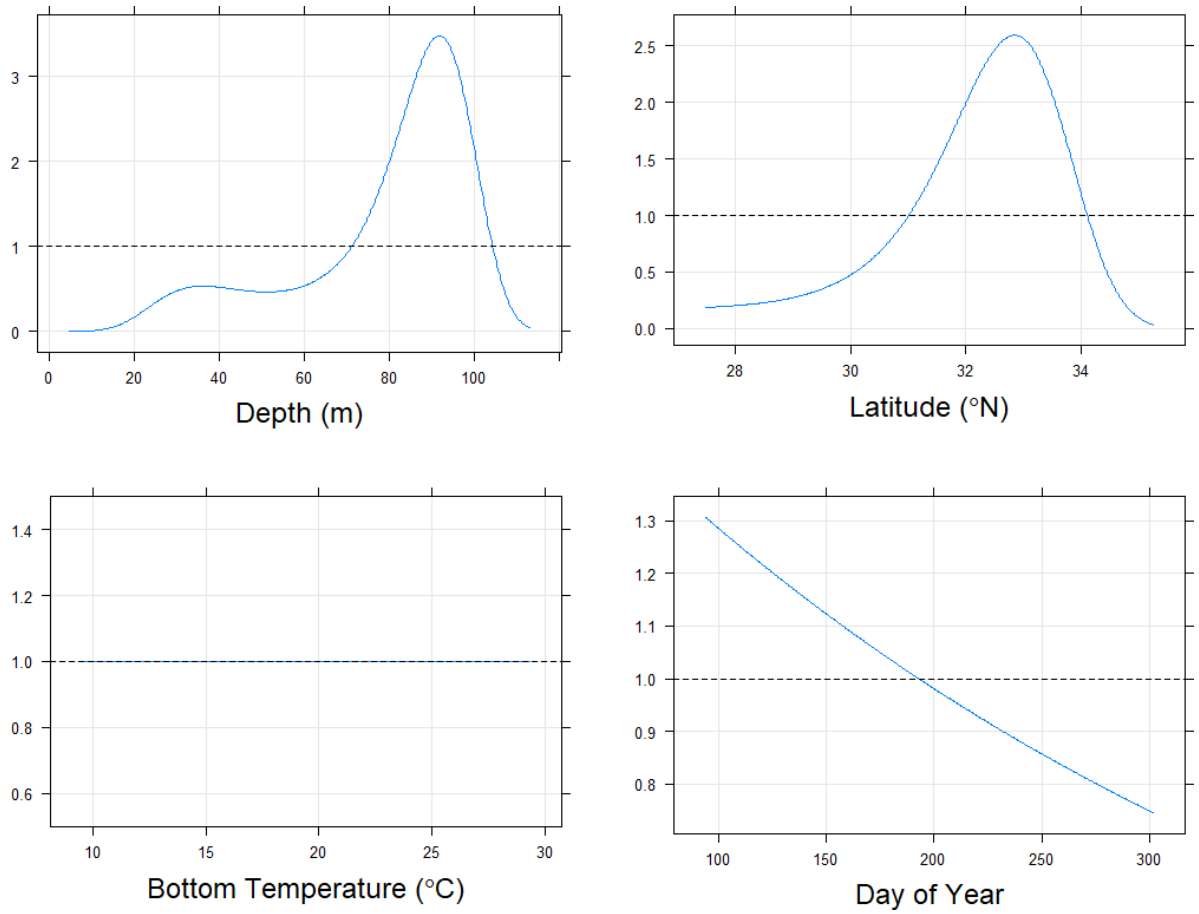

Figure 4. Modelled final covariate effects on catch of Red Porgy from the ZINB standardization. Bottom temperature was not included in the final model.

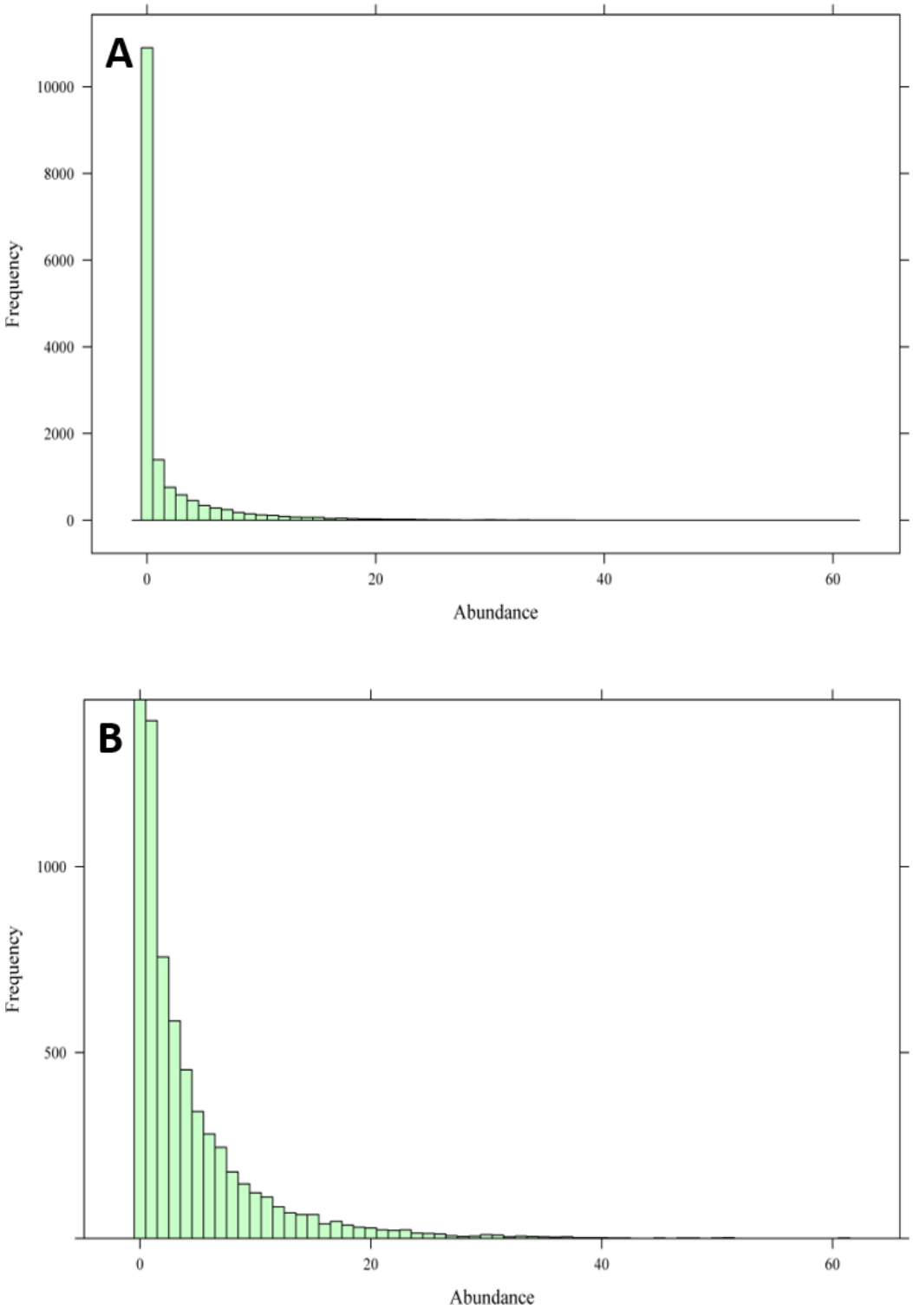

Figure 5. Count distribution of Red Porgy catch from MARMAP/SERFS fishery-independent chevron trap survey showing full range of the distribution (A) and a truncated y-axis (B) to better show positive catches.

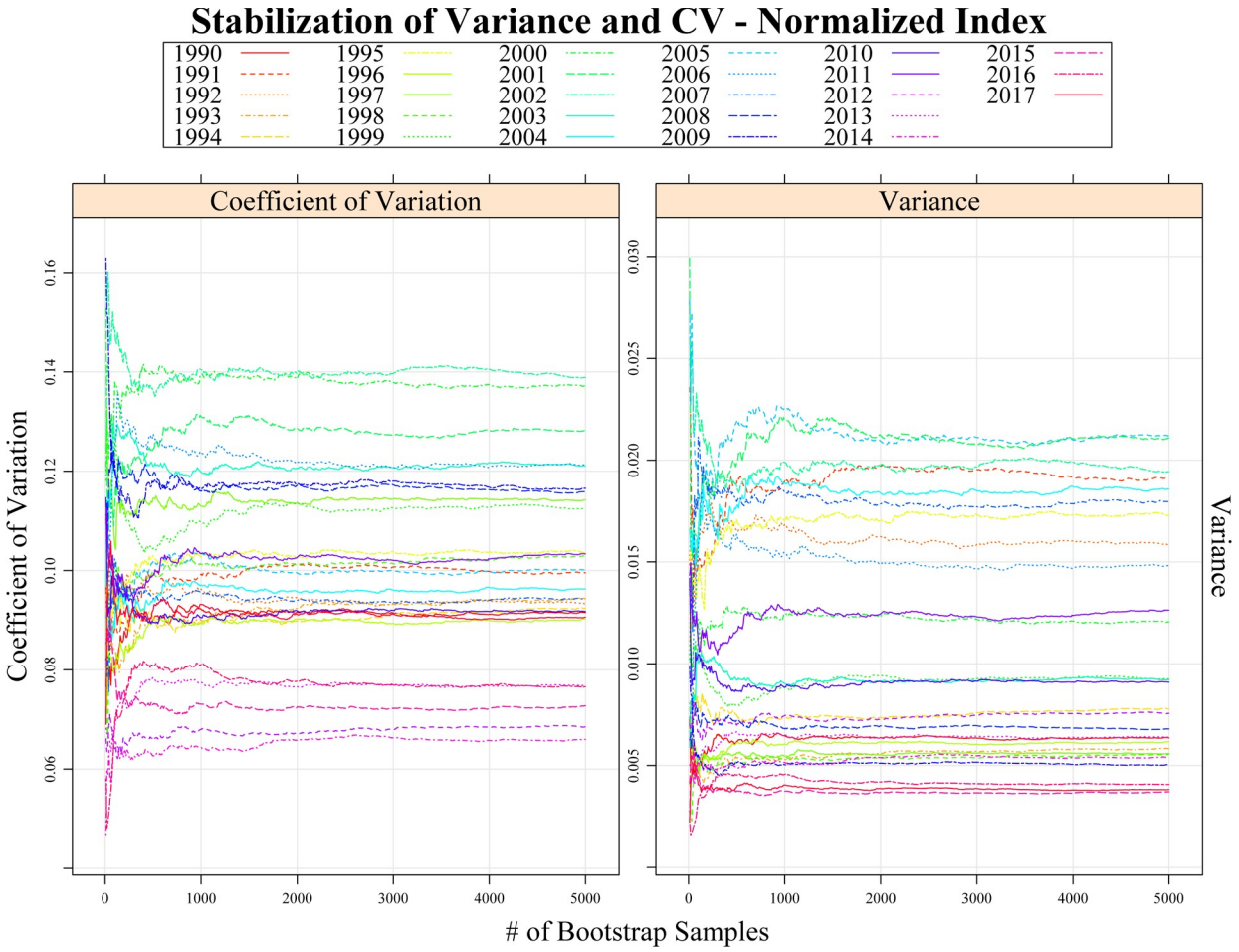

Figure 6. Count distribution of Red Porgy catch from MARMAP/SERFS fishery-independent chevron trap survey showing full range of the distribution (A) and a truncated y-axis (B) to better show positive catches.

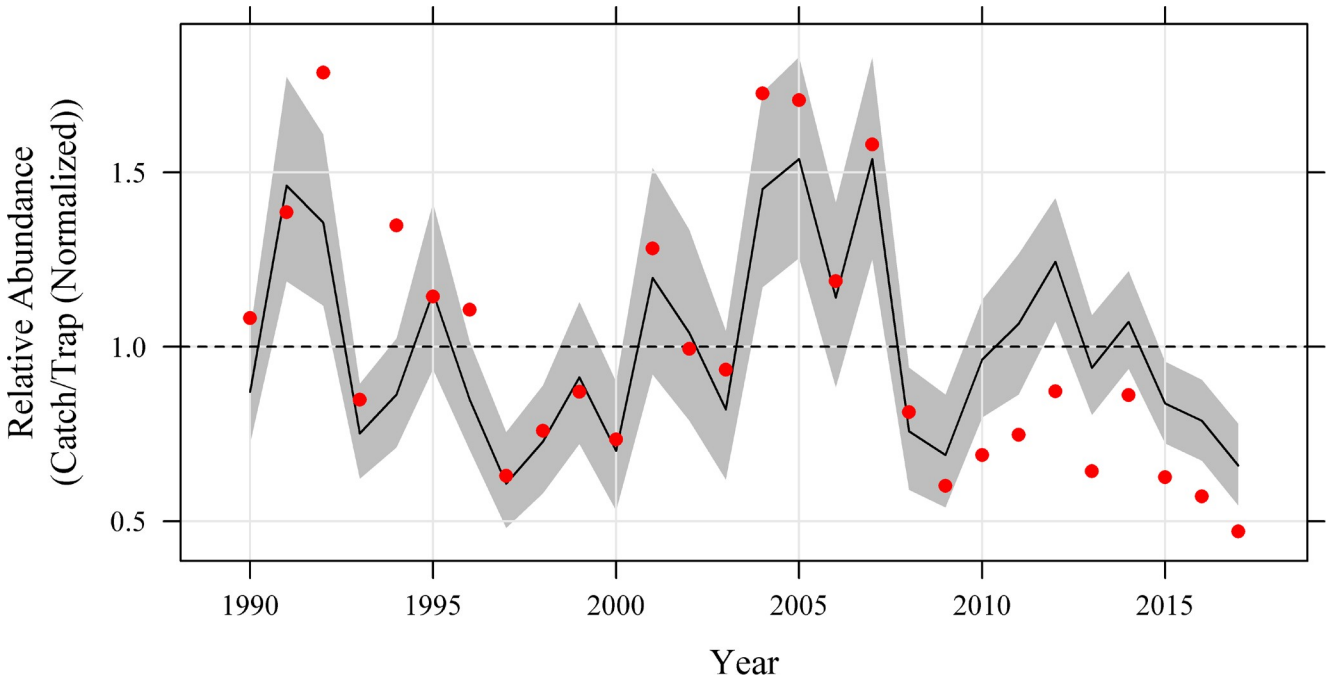

Figure 7. Normalized and standardized index (solid line) with 2.5% and 97.5% confidence intervals (gray) and the nominal index (red dots) for Red Porgy in the MARMAP/SERFS fishery-independent chevron trap survey.