Gray Triggerfish Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2014)

Joseph C. Ballenger and Tracey I. Smart

SEDAR41-DW52

Submitted: 17 August 2015

Please cite this document as:

Ballenger, J. C. and T. I. Smart. 2015. Gray Triggerfish Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2014). SEDAR41-DW52. SEDAR, North Charleston, SC. 43 pp.

Gray Triggerfish Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2014)

Joseph C. Ballenger and Tracey I. Smart

SEDAR41-DW52

Submitted: August 17, 2015

*Report documents development of Gray Triggerfish relative abundance index based on the SERFS chevron trap survey during the years 1990-2014. This model configuration was recommended for use in the SEDAR 41 Gray Triggerfish Assessment model

Gray Triggerfish Fishery-Independent Index of Abundance in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2014)

Joseph C. Ballenger and Tracey I. Smart

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

SEDAR41-DW52
MARMAP Technical Report # 2015-010

This work represents partial fulfillment of the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program contract (NA11NMF4540174) sponsored by the National Marine Fisheries Service (Southeast Fisheries Science Center) and the South Carolina Department of Natural Resources.

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, since 1990 chevron traps have 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. In 2008, with a first field season in 2009, the Southeast Area Monitoring and Assessment Program, South Atlantic Region (SEAMAP-SA) provided funding to a project called the "Reef Fish Complement" 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 as the Southeast Reef Fish Survey (SERFS).

Objective

This report presents a standardized relative abundance index of Gray Triggerfish derived from the SERFS chevron trap survey during the years 1990-2014. The standardized index accounts for annual sampling distribution shifts with respect to covariates that affect catch of Gray Triggerfish in chevron traps. This index model was recommended for use during the SEDAR 41 Gray Triggerfish benchmark stock assessment during the SEDAR 41 Data Workshop held in Charleston, SC on August 4-6, 2015.

Also provided are annual length and age compositions of Gray Triggerfish captured during the chevron trap SERFS. This information is critical at informing the selectivity pattern at size and age of Gray Triggerfish by chevron traps.

Data presented in this report are based on the combined SERFS database accessed on July 21, 2015.

Methods

Survey Design and Gear

(see Smart et al. 2015 for full description)

<u>Sampling area</u>

- Cape Hatteras, NC, to St. Lucie Inlet, Fl (Figure 1)
    - General increase in sampling intensity (# of annual chevron trap deployments) through time
    - Gradual shift regarding the spatial coverage of samples through time (Figure 2)
        - More geographic coverage in southern and northern latitudes in later years
        - Number of known live-bottom and/or hard-bottom chevron trap stations identified increases dramatically (Figure 3)
- Sampling depths range from 13 to 218 m

    - Generally less than 100 m

Sampling season

(see Figure 4)

- May through September
    - Limited earlier and later sampling in some years

Survey Design

- Simple random sample survey design
    - Annually, randomly select 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 CPUE analysis

Sampling Gear – Chevron Traps

(see Collins 1990 and MARMAP 2009 for descriptions that are more complete; Figure 5)

- 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

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
    - 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 were limited to:

- Projects conducting monitoring efforts
    - P05 – MARMAP
    - T59 – SEAMAP-SA Reef Fish Complement
    - 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 used (e.g. not all fish were measured for length frequency) these samples are excluded from CPUE development
- Traps that fished properly (i.e., appropriate catch IDs)
  - 0 – no catch
  - 1 – catch with finfish
  - 2 – catch without finfish
  - 9 – recon trap deployment
  - 90 – recon trap deployment with no catch
  - 91 – recon trap deployment with finfish
  - 92 – recon trap deployment without finfish catch
- 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
- 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
- For Gray Triggerfish specifically, only the depths at which Gray Triggerfish have ever been captured by any of the monitoring programs (included 10-94 m)
- Excluded any chevron trap samples missing covariate information (Table 1)
- Excluded all traps sampled prior to 1990

Standardized Index Model Formulation

<u>Model Basics</u>

- Response variable – Catch/Trap (Figure 6)
- Offset term – natural log of soak time ($\ln(soak\ time)$)
- Dependent variables
  - Year
  - Covariates
    - Depth, latitude (^{o}N), bottom temperature (^{o}C), and day of year
      - Annual summary of covariates available in Table 2
      - Distribution of covariates available in Figure 7
- Model structure – zero-inflated negative binomial GLM (ZINB)

- Other model structures considered: Poisson GLM, negative binomial GLM, and zero-inflated Poisson GLM (ZIP)
  - ZINB favored over other model structures in all analyses
- Annual year effect coefficients of variation (CVs) computed using bootstrapping
- Software used
  - R (Version 3.1.0; R Development Core Team 2014)
  - Function zeroinfl in package *pscl* (Jackman 2011; Zeileis et al. 2008)
  - Function gam in package *mgcv* (Wood 2011; Wood 2006; Wood 2004; Wood 2003; Wood 2000)
  - Function boot in package *boot* (Canty and Ripley 2014; Davison and Hinkley 1997)

<u>Zero-Inflated Model Background</u>
(see Cameron & Trivedi 1998, Hardin and Hilbe 2007, Hilbe 2007, Zeileis et al. 2008, and Chapter 11 in Zuur et al. 2009 for a more complete review of zero-inflation models)

Zero-inflated models are appropriate for use when observed count data appears to have excess zeros than would be expected based on a Poisson or negative binomial distribution. Zuur et al. (2009) suggest that zero-inflation occurs frequently in many ecological count data sets. Ignoring zero-inflation when it exists has two major consequences: 1) estimated parameters and standard errors may be biased and 2) the excessive number of zeros can cause over dispersion (Zuur et al. 2009). In the SEDAR process, zero-inflated models were used to standardize fishery-independent relative abundance indices in SEDARs 32 and 36. Use of this technique was also suggested during the Fishery-Independent Survey Independent Review for the South Atlantic (SEFSC 2012).

Zeros due to design and observer errors are called false zeros or false negatives while structural and "animal" zeros are known as positive zeros, true zeros, or true negatives (Zuur et al. 2009). Mixture models (zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB)), as used here, treat zeros via two different processes: the binomial (subsequently called the zero-inflation model in this report) process and the count process (Zuur et al. 2009). A binomial generalized linear model is used to model the probability of measuring a zero while the count process is modeled by a Poisson or negative binomial GLM. In such a setup, the zeros resulting from the count process model represent true zeros, while the binomial GLM models the probability of measuring a false zero versus all other types of data (counts and true zeros; Zuur et al. 2009). In short, the probability functions of a ZINB are:

$$f(y_i = 0) = \pi_i + (1 - \pi_i) * \left(\frac{k}{\mu_i + k}\right)^k$$

$$f(Y_i = y_i | y_i > 0) = (1 - \pi_i) * \frac{\Gamma(y_i + k)}{\Gamma(k) * \Gamma(y_i + 1)} * \left(\frac{k}{\mu_i + k}\right)^k * \left(1 - \frac{k}{\mu_i + k}\right)^k$$

for the binomial component and the non-zero component, respectively. In ZINB, the expected mean and variance are slightly different due to the definition of the probability functions. The mean and variance of a ZINB are:

$$\mathrm{E}(Y_i) = \mu_i * (1 - \pi_i)$$

$$\mathrm{var}(Y_i) = (1 - \pi_i) * \left(\mu_i + \frac{\mu_i^2}{k}\right) + \mu_i^2 * \left(\pi_i^2 + \pi_i\right).$$

If the probability of false zeros is 0, the mean and variance of the negative binomial GLM are equal.

Covariate Treatment

- Prior to inclusion in the model, preliminary analyses were used to investigate the possibility of collinearity between any of the considered variables
  - Pairs plot (Figure 8) of continuous covariates revealed high correlation between latitude and longitude (due to the shape of the survey region), and moderate correlation between bottom temperature and depth, bottom temperature and latitude, and bottom temperature and day of year
  - Variance inflation factor (VIF) estimates for all considered covariates were all <2 (Table 3)
  - Box plots and violin plots of the covariates among years showed no obvious strong collinearity (Figure 9)
- Included the covariates (depth, latitude, bottom temperature, and day of year) in the model as continuous variables modeled with polynomials
  - Used function poly in package *stats* (R Core Team 2014), with option raw=TRUE
  - Maximum allowed polynomial order for each covariate was based on preliminary generalized additive models (GAMs) (Table 4 and Figure 10)
    - Used function gam in package *mgcv* (Wood 2011; Wood 2006; Wood 2004; Wood 2003; Wood 2000)
    - Investigated use of several different spline options (see gam function help in R for available options and descriptions)
      - Chose maximum polynomial order based on the effective degrees of freedom estimate (rounded to the nearest whole number) for the covariate in question using the spline type that provided the lowest REML estimate
  - Modeled Gray Triggerfish abundance (catch) versus all covariates (Catch GAM columns in Table 4)
    - Used to inform maximum polynomial order for the count sub-model of the ZIP and ZINB models
    - Used to inform maximum polynomial order for the Poisson GLM and negative binomial GLM models
  - Modeled Gray Triggerfish presence/absence versus all covariates (Presence/Absence columns in Table 4)
    - Used to inform maximum polynomial order for the zero-inflation sub-model of the ZIP and ZINB models
- Model selection based on Bayesian information criterion (BIC; Schwarz 1978) to increase the penalty associated with adding parameters to the model
  - ZIP and ZINB Models (2 step process, optimizing one sub-model during each step; needed because of computational demand)
    - Remove all covariates from the zero-inflation sub-model (i.e., intercept only zero-inflation sub-model) and optimize count sub-model for all covariates

        - Fixing count sub-model to the optimum values found during step 1, optimize the covariate structure of the zero-inflation sub-model

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 to 2014
    - Measured lengths were either fork length or maximum (pinched) total length in a given year
        - All total lengths were converted fork length using conversions developed by Ballenger et al. (2012)
        - Length compositions were calculated for each year using 1-cm length bens centered on the integer
        - All lengths are presented in mm
- Aging methods – sagittal otoliths were removed from all Gray Triggerfish to serve as the aging structure
    - Ages presented here are calendar age based on increment counts, estimated increment formation on July 1st, and edge type (White et al. 2010)

Results

Sampling Summary

- A total of 11,704 chevron trap samples from 1990-2014 were retained and used in the development of the relative abundance index (Table 1 and Table 2)
- Proportion of traps positive for Gray Triggerfish averaged 0.286
    - Spatial distribution of positive traps compared to all traps can be inferred from Figure 1
- Caught on average 456 Gray Triggerfish annually

ZINB Index

<u>Model Selection</u>
(see Table 5 for model selection results)

- The effect of year is removed from the zero-inflation sub-model
- Model Structure
    - Count model structure covariate polynomial orders
        - Depth = 3rd order polynomial
        - Latitude = 7th order polynomial
        - Temperature = 2nd order polynomial
        - Day of Year = 6th order polynomial
    - Zero-inflation model structure covariate polynomial orders
        - Depth = 2nd order polynomial
        - Latitude = 2nd order polynomial
        - Temperature = 1st order polynomial
        - Day of year = 4th order polynomial

- Best fit model suggest little to no overdispersion remaining in the data

<u>Covariate Effects</u>
(see Figure 11)

- Relative effect of latitude is larger than the relative effect of the other three covariates
  - Only true at the extreme values of latitude in the survey
  - Across much of the range of the covariates, covariates suggest similar magnitude of effect on catch of Gray Triggerfish
- Predicted covariate effects
  - Depth – catch is above average at depths of ~25-60 m
  - Latitude – catch is higher than average at latitudes <29.5^{o}N and32^{o}N
    - Indication of smaller peaks at just less than 32^{o}N and >34^{o}N
  - Bottom temperature – catch of Gray Triggerfish generally increases through approximately 27^{o}C, before leveling off or slightly declining
  - Day of Year – predicted effect of day of year is fairly non-linear, with relative catch of gray triggerfish being higher early in the sampling season and near the very end of the sampling season

<u>Final Index</u>
(see Table 6 and Figure 12)

- CV estimates average 13.4%, ranging from 7.6-24.9% (2014 and 2003, respectively)

<u>Diagnostics</u>
- Annual CV and variance estimates converged to stable values by 10,000 bootstraps (Figure 13)
- Observed and predicted catch frequency plot (Figure 14)
- Pearson's residuals versus fitted values and observed data (Figure 15), year (Figure 16), included covariates (Figure 17), excluded covariates (Figure 18), and spatial position (Figure 19)

Length and Age Composition
Length compositions (

- Table 7 and Figure 20)
- Age compositions (

	Year																								
FL	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**
10	0.00	0.25	0.00	0.00	0.00	0.15	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	0.00	0.00	0.00	0.00
11	0.00	0.50	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
13	0.00	0.25	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	2.56	0.25	0.00	1.01	0.22	0.60	0.08	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1.28	2.51	0.98	1.68	0.00	0.45	0.33	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.00
16	1.28	6.03	1.47	0.34	0.45	1.64	0.58	0.21	0.58	1.05	0.00	0.78	0.29	0.00	1.53	0.00	0.57	0.00	0.90	0.00	0.00	0.34	0.00	0.00	0.00
17	1.28	8.04	0.00	2.35	0.45	1.64	0.92	0.21	0.77	0.00	0.37	0.39	2.01	1.49	0.76	0.26	0.00	0.24	0.30	0.00	0.00	0.00	0.09	0.00	0.12
18	0.00	10.05	1.96	2.68	1.79	1.94	1.17	0.42	0.39	0.53	0.37	0.78	1.72	0.00	1.15	0.52	2.30	0.71	2.10	0.00	0.00	0.34	0.87	0.55	0.18
19	6.41	6.53	3.43	1.34	2.24	1.79	1.67	1.88	0.00	0.53	1.12	1.16	2.30	1.49	1.91	0.26	1.72	0.47	0.90	0.00	0.00	0.34	0.35	0.39	0.30
20	7.69	5.28	4.41	2.35	1.57	1.05	1.25	1.25	0.58	4.74	1.12	4.65	1.44	1.49	2.29	0.52	1.15	0.71	2.40	0.94	0.00	1.18	0.61	0.55	0.36
21	3.85	5.28	2.45	2.01	2.68	2.54	1.75	1.25	0.77	1.58	1.49	2.33	5.75	0.00	1.53	0.26	1.15	0.71	1.50	0.00	0.17	0.67	0.52	0.79	0.30
22	6.41	5.28	3.43	6.04	2.01	3.44	1.42	1.57	0.58	3.68	0.00	3.10	5.46	2.99	1.53	0.52	4.60	2.84	3.59	1.25	1.19	1.01	1.48	1.73	1.51
23	5.13	3.52	2.45	6.04	2.68	4.78	0.92	1.98	0.96	4.21	1.49	1.94	4.02	0.00	1.91	0.79	2.30	0.71	0.90	0.63	0.34	1.01	1.83	1.02	0.54
24	1.28	4.77	4.90	8.72	3.36	2.99	2.92	1.67	1.93	2.11	0.37	3.49	4.31	2.99	3.05	2.09	4.02	1.65	0.60	1.25	1.71	1.68	1.74	1.42	1.33
25	5.13	3.02	3.92	6.04	2.68	2.99	2.50	2.30	3.08	2.11	2.60	2.71	4.31	1.49	5.34	1.57	2.30	3.07	1.20	2.19	1.71	1.34	2.96	2.36	0.84
26	0.00	3.02	2.94	6.04	3.13	2.24	5.26	1.25	3.08	4.74	1.49	3.88	3.16	1.49	4.58	2.36	5.75	4.49	2.99	7.84	2.05	3.36	8.01	4.49	3.56
27	1.28	3.77	5.39	6.04	3.13	1.05	4.84	2.30	2.70	4.21	2.23	2.71	2.59	1.49	4.58	2.36	2.30	3.78	1.50	1.88	2.73	2.86	4.09	2.44	1.99
28	2.56	3.27	2.94	7.05	4.70	2.09	8.35	3.24	4.24	2.63	2.60	3.49	2.59	1.49	7.25	1.31	2.30	2.84	2.10	4.39	4.44	3.19	4.62	2.60	2.53
29	1.28	3.52	5.88	5.03	5.15	2.99	8.18	3.86	4.82	6.84	3.35	3.10	2.59	4.48	8.40	2.62	3.45	4.49	1.80	3.13	5.63	3.87	3.57	3.94	3.62
30	5.13	3.52	2.45	4.70	5.15	2.24	9.27	6.26	4.43	5.26	5.58	2.33	4.60	7.46	7.25	3.14	6.90	7.80	3.89	15.99	4.78	4.20	7.84	7.09	8.20
31	3.85	2.51	8.33	6.38	6.04	1.49	10.02	7.41	7.32	4.74	4.83	3.10	3.74	8.96	5.73	3.93	4.02	4.49	2.69	7.84	6.14	5.21	3.57	7.09	5.37
32	0.00	1.26	4.41	1.68	3.36	1.49	8.10	8.46	8.09	5.26	6.32	5.81	3.45	2.99	6.49	6.02	2.30	5.67	2.69	6.58	5.12	5.38	3.57	6.54	5.25
33	0.00	1.76	0.98	3.36	6.04	3.89	9.18	9.39	7.13	5.79	7.06	4.65	5.17	10.45	7.25	6.28	1.72	4.73	3.89	6.90	8.02	6.72	2.79	6.85	6.82
34	8.97	1.76	4.41	2.35	5.15	5.83	4.42	7.93	8.29	2.63	7.81	9.30	4.02	5.97	6.11	7.33	9.77	10.17	11.08	11.29	8.53	6.55	7.58	13.86	11.88
35	2.56	2.01	3.92	1.68	3.13	5.53	4.59	8.66	7.51	1.05	6.32	7.75	3.16	1.49	4.96	7.33	6.90	7.80	3.29	5.33	8.02	8.07	3.83	6.69	5.79
36	5.13	0.75	2.45	2.35	6.26	6.43	1.92	7.41	8.29	4.21	14.13	6.20	5.46	8.96	2.29	7.07	2.87	5.20	6.89	3.76	6.14	7.23	4.44	6.14	5.43
37	3.85	0.75	2.94	2.35	3.58	5.53	2.17	6.99	8.09	6.32	8.55	6.59	4.02	7.46	3.44	7.59	2.87	3.31	7.78	3.45	4.95	6.55	4.70	2.99	4.83
38	3.85	1.01	2.45	1.68	3.13	5.23	1.84	3.76	3.66	7.37	5.20	2.71	2.87	4.48	1.91	6.28	5.75	7.33	11.38	6.27	4.95	5.55	8.10	6.06	9.17
39	2.56	1.01	2.94	1.01	3.58	5.68	2.00	1.77	4.43	4.21	4.46	3.49	6.03	5.97	1.91	7.33	4.02	3.55	5.39	1.57	4.95	4.37	4.18	2.28	3.26
40	6.41	1.26	2.45	1.01	6.71	5.98	0.33	2.51	2.12	4.74	3.35	3.10	2.30	2.99	2.67	6.02	4.02	2.60	3.59	1.57	4.44	5.21	3.92	1.81	3.14
41	3.85	1.51	3.92	1.68	2.46	4.19	1.09	1.88	2.12	2.11	2.60	1.94	3.45	2.99	0.76	4.97	2.30	2.36	2.99	0.63	3.07	3.70	3.75	1.89	2.71

42	2.56	0.50	1.96	0.34	1.79	2.69	0.92	1.25	1.93	1.05	2.23	1.94	3.45	1.49	0.76	5.24	4.02	2.84	4.49	2.51	2.22	2.69	4.79	2.99	4.58
43	1.28	1.26	0.98	1.34	2.46	2.09	0.67	0.73	0.77	2.63	1.49	2.33	1.72	5.97	0.76	3.40	1.72	2.13	1.50	0.31	2.56	2.18	1.22	0.94	1.93
44	0.00	1.01	3.43	0.67	0.67	1.94	0.17	0.73	0.39	2.63	0.37	1.55	1.72	0.00	0.38	0.79	1.15	1.18	1.20	0.94	1.37	1.68	0.87	1.02	1.75
45	1.28	0.75	0.00	0.34	2.01	2.69	0.42	0.42	0.39	0.00	0.74	1.94	1.44	0.00	0.76	1.31	0.57	0.24	0.90	0.94	1.19	0.84	1.48	0.55	0.78
46	0.00	1.26	1.47	0.00	0.67	1.20	0.17	0.31	0.00	0.00	0.00	0.00	0.29	1.49	0.38	0.00	1.72	1.18	2.40	0.63	1.02	1.01	1.39	0.87	0.90
47	0.00	0.25	0.98	0.00	0.22	0.60	0.17	0.42	0.00	0.53	0.00	0.39	0.00	0.00	0.38	0.26	0.57	0.47	0.00	0.00	1.19	0.50	0.09	0.94	0.36
48	0.00	0.25	0.98	0.67	0.67	0.60	0.08	0.00	0.39	0.53	0.00	0.39	0.29	0.00	0.00	0.00	0.57	0.24	0.60	0.00	0.34	0.50	0.17	0.24	0.30
49	0.00	0.00	0.49	0.67	0.00	0.00	0.00	0.10	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.17	0.17	0.26	0.16	0.12
50	0.00	0.25	0.00	1.01	0.00	0.15	0.00	0.10	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.34	0.35	0.31	0.06
51	0.00	0.00	0.00	0.00	0.45	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	0.26	0.24	0.00
52	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.17	0.00	0.00	0.00	0.00
53	0.00	0.25	0.49	0.00	0.00	0.00	0.08	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	0.17	0.00	0.09	0.16	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.08	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	0.12
55	0.00	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
56	1.28	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
57	0.00	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.22	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
59	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
60	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
61	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	0.17	0.00	0.00	0.00	0.00
Traps	41	134	88	118	154	156	179	194	124	62	92	99	112	34	96	108	75	123	72	90	216	169	341	367	464
Fish	78	398	204	298	447	669	1198	958	519	190	269	258	348	67	262	382	174	423	334	319	586	595	1148	1270	1658

- Table 8, Figure 21 and Figure 22)

References

Ballenger, J. C., T. I. Smart, and M. J. M. Reichert. 2012. Trends in relative abundance of reef fishes in water off the SE US based on fishery-independent surveys. MARMAP Technical Report # 2012-018.

Cameron A.C. and P.K. Trivedi. 1998. Regression analysis of count data. Cambridge University Press, Cambridge.

Canty, A. and B. Ripley. 2014. boot: Bootstrap R (S-Plus) Functions. R package version 1. 3-13.

Collins, M.R. 1990. A comparison of three fish trap designs. Fisheries Research 9(4): 325-332.

Davison, A.C. and D.V. Hinkley. 1997. Bootstrap methods and their applications. Cambridge University Press, Cambridge. ISBN 0-521-57391-2.

Hardin J.W. and J.M. Hilbe. 2007. Generalized linear models and extensions, 2nd Edition. Stata Press, Texas.

Hilbe J.M. 2007. Negative binomial regression. Cambridge University Press, Cambridge.

Jackman, S. 2011. pscl: Classes and Methods for R Developed in the Political Science Computational Laboratory, Stanford University. Department of Political Science, Stanford University. Stanford, California. R package version 1.04.1. URL http://pscl.stanford.edu/.

MARMAP. 2009. Overview of sampling gear and vessels used by MARMAP: Brief descriptions and sampling protocol. Marine Resources Research Institute, South Carolina Department of Natural Resources, Charleston, SC, 40p.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Schwarz, G. 1978. Estimating the dimension of a model. Annals of Statistics 6: 461-464.

SEFSC. 2012. Review of fishery-independent survey programs in southeastern U.S. Atlantic waters. NOAA SEFSC-Beaufort Laboratory, Beaufort, NC. 22 pp.

Smart, T.I. and M.J.M. Reichert. 2015. Southeast Reef Fish Survey (SERFS) Sampling Protocols. SEDAR41-RD55.

White, D.B., M.J. Reichert, L. DiJoy, and D. Wyanski. 2010. Marine Resources Monitoring, Assessment and Prediction Program: Report on Atlantic Gray Triggerfish, *Lutjanus campechanus*, for the SEDAR 24 Data Workshop (vrs. 1a). MARMAP Report 2010-02 and SEDAR 24 DW – 14.

Wood, S.N. 2000. Modeling and smoothing parameter estimation with multiple quadratic penalties. Journal of the Royal Statistical Society (B) 62(2): 413-428.

Wood, S.N. 2003. Thin-plate regression splines. Journal of the Royal Statistical Society (B) 65(1): 95-114.

Wood, S.N. 2004. Stable and efficient multiple smoothing parameter estimation for generalized additive models. Journal of the American Statistical Association 99: 673-686.

Wood, S.N. 2006. Generalized Additive Models: An Introduction with R. Chapman and Hall/CRC.

Wood, S.N. 2011. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. Journal of the Royal Statistical Society (B) 73(1): 3-36.

Zeileis, A., C. Kleiber, and S. Jackman. 2008. Regression models for count data in R. Journal of Statistical Software 27(8). URL http://www.jstatsoft.org/v27/i08/.

Zuur, A. F., E. N. Ieno, N. J. Walker, A. A. Saveliev, and G. M. Smith. 2009. Mixed Effects Models and Extensions in Ecology with R. Spring Science + Business Media, LLC, New York, NY.

Tables

Table 1: Annual and total exclusion of chevron trap monitoring station collections from analysis due to missing covariate data (mostly due to missing bottom temperature data). Pre-exclusion and Post-exclusion refers to the sample size prior to or after exclusion of samples due to missing covariate data.

Year	Pre-exclusion	Post-exclusion	% Change
1990	348	305	12.36
1991	298	267	10.40
1992	315	288	8.57
1993	395	395	0.00
1994	435	396	8.97
1995	384	333	13.28
1996	388	376	3.09
1997	432	394	8.80
1998	481	445	7.48
1999	237	216	8.86
2000	302	292	3.31
2001	264	245	7.20
2002	244	244	0.00
2003	225	225	0.00
2004	290	290	0.00
2005	303	303	0.00
2006	297	292	1.68
2007	336	336	0.00
2008	303	303	0.00
2009	404	398	1.49
2010	733	703	4.09

2011	872	688	21.10
2012	1207	1151	4.64
2013	1372	1354	1.31
2014	1465	1465	0.00
Total	**12330**	**11704**	**5.08**

Table 2: Number of chevron trap deployments on live/hard-bottom areas, proportion of traps positive for Gray Triggerfish, total number of Gray Triggerfish caught, and information regarding covariate distribution annually.

				Depth (m)				Latitude (°N)				Temperature (°C)				Day of Year			
					Range				Range				Range				Range		
Year	n	Prop. Pos	# of Fish	Avg	Min	Max	SE	Avg	Min	Max	SE	Avg	Min	Max	SE	Avg	Min	Max	SE
1990	305	0.111	69	34	17	93	0.71	32.52	30.42	33.82	0.0372	22	18.2	27.8	0.144	149	114	222	1.66
1991	267	0.453	366	33	17	93	0.70	32.65	30.75	34.61	0.0517	25	15.9	27.7	0.107	217	163	268	2.04
1992	288	0.288	191	34	17	62	0.59	32.77	30.42	34.32	0.0407	21.3	15.3	24.5	0.161	155	92	227	2.51
1993	395	0.289	284	35	16	94	0.67	32.4	30.43	34.32	0.0395	22.8	17.7	28.5	0.135	176	131	226	1.49
1994	396	0.386	446	39	16	93	0.71	32.35	30.74	33.82	0.0305	22.8	18.1	26.9	0.103	175	130	300	1.83
1995	333	0.450	657	35	16	60	0.72	32.18	29.78	33.75	0.0443	24.5	20.1	28.3	0.131	192	124	299	2.53
1996	376	0.383	729	38	14	94	0.76	32.23	27.92	34.33	0.0598	21.8	14.2	27.0	0.166	189	121	261	2.24
1997	394	0.409	701	39	15	93	0.79	32.01	27.87	34.59	0.079	22.7	16.8	28.0	0.117	193	126	273	1.49
1998	445	0.254	493	42	14	92	0.79	32.06	27.44	34.59	0.0728	20.7	9.5	28.6	0.229	182	126	231	1.83
1999	216	0.255	180	38	15	75	0.88	31.9	27.27	34.41	0.1188	22.8	17.9	28.8	0.140	202	154	272	1.81
2000	292	0.281	212	38	15	92	0.83	32.38	28.95	34.28	0.0654	23.9	18.0	28.5	0.136	195	138	292	2.36
2001	245	0.335	225	39	14	91	0.96	32.35	27.87	34.28	0.0711	23.4	16.0	29.2	0.172	205	144	298	2.22
2002	244	0.402	320	38	13	94	0.94	31.87	27.86	33.95	0.0853	24.2	15.2	28.3	0.210	207	169	268	1.90
2003	225	0.129	53	40	16	92	0.95	32.07	27.43	34.33	0.1083	18.9	13.4	25.1	0.142	203	155	266	2.12
2004	290	0.255	184	41	14	91	0.98	32.26	29.00	33.97	0.0615	20.9	16.7	25.8	0.161	176	127	303	2.18
2005	303	0.304	328	38	15	69	0.74	32.08	27.33	34.32	0.0842	23	18.0	28.5	0.170	191	124	273	2.84
2006	292	0.226	150	38	15	94	0.88	32.28	27.27	34.39	0.0872	22.5	15.0	26.7	0.179	203	158	272	1.95
2007	336	0.313	313	38	15	92	0.83	32.18	27.33	34.33	0.0781	23.2	15.3	28.9	0.161	201	142	268	2.05
2008	303	0.215	323	38	15	92	0.81	32.17	27.27	34.59	0.0841	21.9	15.2	27.2	0.145	195	127	275	2.60
2009	398	0.201	257	37	14	91	0.76	32.25	27.27	34.6	0.0819	22.5	15.4	27.2	0.134	202	127	282	2.38
2010	703	0.235	423	39	14	92	0.54	31.42	27.34	34.59	0.0625	22.1	12.3	29.4	0.158	220	125	301	2.03
2011	688	0.206	522	41	15	93	0.58	30.88	27.23	34.54	0.0699	21.6	14.8	28.8	0.148	208	140	299	1.72
2012	1151	0.281	1081	40	15	94	0.47	31.85	27.23	35.02	0.0638	22.1	12.9	27.8	0.101	195	116	285	1.31
2013	1354	0.267	1250	38	15	92	0.39	31.26	27.23	35.01	0.0539	22.1	12.4	28.1	0.083	197	115	278	1.26
2014	1465	0.311	1645	39	15	94	0.37	31.91	27.23	35.01	0.0537	23.4	16.1	29.3	0.070	193	114	295	1.15

Table 3: Variance inflation factor (VIF) estimates and degrees of freedom (df) for all considered covariates.

Variable	**VIF**	**df**
Year	1.425	24
Depth	1.334	1
Bottom Temperature	1.947	1
Latitude	1.169	1
Day of Year	1.479	1

Table 4: Preliminary generalized additive model (GAM) results used to inform maximum polynomial order for each sub-model of the ZINB glm used to standardized Gray Triggerfish relative abundance. EDF = effective degrees of freedom of smoothed spline.

	Presence/Absence GAM		**Catch GAM**	
Variable	**EDF**	**p-value**	**EDF**	**p-value**
Depth (m)	6.85	<0.0001	7.11	<0.0001
Latitude (^{o}N)	7.72	<0.0001	7.86	<0.0001
Bottom Temperature (^{o}C)	6.11	<0.0001	4.69	<0.0001
Day of Year	4.67	<0.0001	7.01	0.4694

Table 5: Results of BIC selection for the top 6 ranked ZINB models. Also include are the best-fit alternative model structures.

	Count Model				Zero-Inflation Model							
Rank	**Depth**	**Latitude**	**Temperature**	**Day of Year**	**Year**	**Depth**	**Latitude**	**Temperature**	**Day of Year**	**BIC**	**Δ**	**Theta**
1	3	7	2	6	0	2	2	1	4	25745	0.00	1.24
2	3	7	2	6	0	1	2	1	0	25746	1.02	1.25
3	3	7	2	6	0	1	2	2	0	25747	2.33	1.25
4	3	7	2	6	0	2	2	2	4	25748	3.38	1.23
5	3	7	2	6	0	2	2	1	5	25749	4.23	1.24
6	3	7	2	6	0	2	2	1	0	25749	4.40	1.25
NB Best	3	7	2	6	NA	NA	NA	NA	NA	25822	76.8	1.34
ZIP Best	6	7	3	7	0	3	7	3	0	31044	5299	2.02
Poisson Best	5	7	3	7	NA	NA	NA	NA	NA	39994	14249	5.27

Table 6: Gray Triggerfish relative abundance index based on the SERFS chevron trap survey, 1990-2014, as standardized using a ZINB GLM. Index = relative abundance of Gray Triggerfish, Bias = observed bias in bootstrap analysis. CV = coefficient of variation.

					Confidence Interval	
Year	**Index**	**Bias**	**SE**	**CV**	**Lower**	**Upper**
1990	0.2466	0.000	0.0487	0.1974	0.1457	0.3350
1991	1.0789	-0.001	0.1260	0.1168	0.8110	1.3068
1992	0.8461	-0.002	0.1319	0.1558	0.5695	1.0920
1993	0.7919	-0.001	0.0864	0.1091	0.6177	0.9535
1994	1.0300	-0.002	0.1075	0.1043	0.8097	1.2325
1995	1.3489	0.004	0.1336	0.0990	1.0744	1.5935
1996	1.6166	0.003	0.1670	0.1033	1.2774	1.9266
1997	1.4688	0.002	0.1586	0.1080	1.1385	1.7577
1998	1.7517	0.004	0.2213	0.1263	1.2900	2.1536
1999	0.7253	0.000	0.1233	0.1700	0.4645	0.9487
2000	0.6171	-0.002	0.1159	0.1879	0.3578	0.8097
2001	0.8689	0.000	0.1146	0.1319	0.6312	1.0744
2002	1.5322	0.004	0.2255	0.1472	1.0463	1.9309
2003	0.8040	0.020	0.2002	0.2490	0.3430	1.1303
2004	1.2765	0.001	0.1793	0.1404	0.9166	1.6068
2005	0.7475	-0.003	0.0961	0.1285	0.5514	0.9287
2006	0.5336	-0.004	0.0798	0.1495	0.3709	0.6812
2007	0.9368	-0.005	0.1383	0.1476	0.6506	1.1900
2008	0.8778	-0.007	0.1340	0.1526	0.6060	1.1309
2009	0.6811	-0.001	0.1001	0.1469	0.4714	0.8637
2010	0.6481	0.005	0.0829	0.1279	0.4703	0.7940
2011	0.8198	-0.010	0.0920	0.1123	0.6386	0.9993
2012	1.0165	0.002	0.0875	0.0861	0.8360	1.1839
2013	1.2454	-0.005	0.0962	0.0772	1.0482	1.4278
2014	1.4899	0.000	0.1126	0.0756	1.2633	1.7032

Table 7: Length composition of Gray Triggerfish collected by the SERFS chevron rap survey from 1990-2014. 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.

	Year																								
FL	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**
10	0.00	0.25	0.00	0.00	0.00	0.15	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	0.00	0.00	0.00	0.00
11	0.00	0.50	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
13	0.00	0.25	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	2.56	0.25	0.00	1.01	0.22	0.60	0.08	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1.28	2.51	0.98	1.68	0.00	0.45	0.33	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.00
16	1.28	6.03	1.47	0.34	0.45	1.64	0.58	0.21	0.58	1.05	0.00	0.78	0.29	0.00	1.53	0.00	0.57	0.00	0.90	0.00	0.00	0.34	0.00	0.00	0.00
17	1.28	8.04	0.00	2.35	0.45	1.64	0.92	0.21	0.77	0.00	0.37	0.39	2.01	1.49	0.76	0.26	0.00	0.24	0.30	0.00	0.00	0.00	0.09	0.00	0.12
18	0.00	10.05	1.96	2.68	1.79	1.94	1.17	0.42	0.39	0.53	0.37	0.78	1.72	0.00	1.15	0.52	2.30	0.71	2.10	0.00	0.00	0.34	0.87	0.55	0.18
19	6.41	6.53	3.43	1.34	2.24	1.79	1.67	1.88	0.00	0.53	1.12	1.16	2.30	1.49	1.91	0.26	1.72	0.47	0.90	0.00	0.00	0.34	0.35	0.39	0.30
20	7.69	5.28	4.41	2.35	1.57	1.05	1.25	1.25	0.58	4.74	1.12	4.65	1.44	1.49	2.29	0.52	1.15	0.71	2.40	0.94	0.00	1.18	0.61	0.55	0.36
21	3.85	5.28	2.45	2.01	2.68	2.54	1.75	1.25	0.77	1.58	1.49	2.33	5.75	0.00	1.53	0.26	1.15	0.71	1.50	0.00	0.17	0.67	0.52	0.79	0.30
22	6.41	5.28	3.43	6.04	2.01	3.44	1.42	1.57	0.58	3.68	0.00	3.10	5.46	2.99	1.53	0.52	4.60	2.84	3.59	1.25	1.19	1.01	1.48	1.73	1.51
23	5.13	3.52	2.45	6.04	2.68	4.78	0.92	1.98	0.96	4.21	1.49	1.94	4.02	0.00	1.91	0.79	2.30	0.71	0.90	0.63	0.34	1.01	1.83	1.02	0.54
24	1.28	4.77	4.90	8.72	3.36	2.99	2.92	1.67	1.93	2.11	0.37	3.49	4.31	2.99	3.05	2.09	4.02	1.65	0.60	1.25	1.71	1.68	1.74	1.42	1.33
25	5.13	3.02	3.92	6.04	2.68	2.99	2.50	2.30	3.08	2.11	2.60	2.71	4.31	1.49	5.34	1.57	2.30	3.07	1.20	2.19	1.71	1.34	2.96	2.36	0.84
26	0.00	3.02	2.94	6.04	3.13	2.24	5.26	1.25	3.08	4.74	1.49	3.88	3.16	1.49	4.58	2.36	5.75	4.49	2.99	7.84	2.05	3.36	8.01	4.49	3.56
27	1.28	3.77	5.39	6.04	3.13	1.05	4.84	2.30	2.70	4.21	2.23	2.71	2.59	1.49	4.58	2.36	2.30	3.78	1.50	1.88	2.73	2.86	4.09	2.44	1.99
28	2.56	3.27	2.94	7.05	4.70	2.09	8.35	3.24	4.24	2.63	2.60	3.49	2.59	1.49	7.25	1.31	2.30	2.84	2.10	4.39	4.44	3.19	4.62	2.60	2.53
29	1.28	3.52	5.88	5.03	5.15	2.99	8.18	3.86	4.82	6.84	3.35	3.10	2.59	4.48	8.40	2.62	3.45	4.49	1.80	3.13	5.63	3.87	3.57	3.94	3.62
30	5.13	3.52	2.45	4.70	5.15	2.24	9.27	6.26	4.43	5.26	5.58	2.33	4.60	7.46	7.25	3.14	6.90	7.80	3.89	15.99	4.78	4.20	7.84	7.09	8.20
31	3.85	2.51	8.33	6.38	6.04	1.49	10.02	7.41	7.32	4.74	4.83	3.10	3.74	8.96	5.73	3.93	4.02	4.49	2.69	7.84	6.14	5.21	3.57	7.09	5.37
32	0.00	1.26	4.41	1.68	3.36	1.49	8.10	8.46	8.09	5.26	6.32	5.81	3.45	2.99	6.49	6.02	2.30	5.67	2.69	6.58	5.12	5.38	3.57	6.54	5.25
33	0.00	1.76	0.98	3.36	6.04	3.89	9.18	9.39	7.13	5.79	7.06	4.65	5.17	10.45	7.25	6.28	1.72	4.73	3.89	6.90	8.02	6.72	2.79	6.85	6.82
34	8.97	1.76	4.41	2.35	5.15	5.83	4.42	7.93	8.29	2.63	7.81	9.30	4.02	5.97	6.11	7.33	9.77	10.17	11.08	11.29	8.53	6.55	7.58	13.86	11.88
35	2.56	2.01	3.92	1.68	3.13	5.53	4.59	8.66	7.51	1.05	6.32	7.75	3.16	1.49	4.96	7.33	6.90	7.80	3.29	5.33	8.02	8.07	3.83	6.69	5.79
36	5.13	0.75	2.45	2.35	6.26	6.43	1.92	7.41	8.29	4.21	14.13	6.20	5.46	8.96	2.29	7.07	2.87	5.20	6.89	3.76	6.14	7.23	4.44	6.14	5.43
37	3.85	0.75	2.94	2.35	3.58	5.53	2.17	6.99	8.09	6.32	8.55	6.59	4.02	7.46	3.44	7.59	2.87	3.31	7.78	3.45	4.95	6.55	4.70	2.99	4.83
38	3.85	1.01	2.45	1.68	3.13	5.23	1.84	3.76	3.66	7.37	5.20	2.71	2.87	4.48	1.91	6.28	5.75	7.33	11.38	6.27	4.95	5.55	8.10	6.06	9.17
39	2.56	1.01	2.94	1.01	3.58	5.68	2.00	1.77	4.43	4.21	4.46	3.49	6.03	5.97	1.91	7.33	4.02	3.55	5.39	1.57	4.95	4.37	4.18	2.28	3.26
40	6.41	1.26	2.45	1.01	6.71	5.98	0.33	2.51	2.12	4.74	3.35	3.10	2.30	2.99	2.67	6.02	4.02	2.60	3.59	1.57	4.44	5.21	3.92	1.81	3.14

41	3.85	1.51	3.92	1.68	2.46	4.19	1.09	1.88	2.12	2.11	2.60	1.94	3.45	2.99	0.76	4.97	2.30	2.36	2.99	0.63	3.07	3.70	3.75	1.89	2.71
42	2.56	0.50	1.96	0.34	1.79	2.69	0.92	1.25	1.93	1.05	2.23	1.94	3.45	1.49	0.76	5.24	4.02	2.84	4.49	2.51	2.22	2.69	4.79	2.99	4.58
43	1.28	1.26	0.98	1.34	2.46	2.09	0.67	0.73	0.77	2.63	1.49	2.33	1.72	5.97	0.76	3.40	1.72	2.13	1.50	0.31	2.56	2.18	1.22	0.94	1.93
44	0.00	1.01	3.43	0.67	0.67	1.94	0.17	0.73	0.39	2.63	0.37	1.55	1.72	0.00	0.38	0.79	1.15	1.18	1.20	0.94	1.37	1.68	0.87	1.02	1.75
45	1.28	0.75	0.00	0.34	2.01	2.69	0.42	0.42	0.39	0.00	0.74	1.94	1.44	0.00	0.76	1.31	0.57	0.24	0.90	0.94	1.19	0.84	1.48	0.55	0.78
46	0.00	1.26	1.47	0.00	0.67	1.20	0.17	0.31	0.00	0.00	0.00	0.00	0.29	1.49	0.38	0.00	1.72	1.18	2.40	0.63	1.02	1.01	1.39	0.87	0.90
47	0.00	0.25	0.98	0.00	0.22	0.60	0.17	0.42	0.00	0.53	0.00	0.39	0.00	0.00	0.38	0.26	0.57	0.47	0.00	0.00	1.19	0.50	0.09	0.94	0.36
48	0.00	0.25	0.98	0.67	0.67	0.60	0.08	0.00	0.39	0.53	0.00	0.39	0.29	0.00	0.00	0.00	0.57	0.24	0.60	0.00	0.34	0.50	0.17	0.24	0.30
49	0.00	0.00	0.49	0.67	0.00	0.00	0.00	0.10	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.17	0.17	0.26	0.16	0.12
50	0.00	0.25	0.00	1.01	0.00	0.15	0.00	0.10	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.34	0.35	0.31	0.06
51	0.00	0.00	0.00	0.00	0.45	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	0.26	0.24	0.00
52	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.17	0.00	0.00	0.00	0.00
53	0.00	0.25	0.49	0.00	0.00	0.00	0.08	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	0.17	0.00	0.09	0.16	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.08	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	0.12
55	0.00	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
56	1.28	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
57	0.00	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.22	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
59	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
60	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
61	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	0.17	0.00	0.00	0.00	0.00
Traps	41	134	88	118	154	156	179	194	124	62	92	99	112	34	96	108	75	123	72	90	216	169	341	367	464
Fish	78	398	204	298	447	669	1198	958	519	190	269	258	348	67	262	382	174	423	334	319	586	595	1148	1270	1658

Table 8: Age composition of Gray Triggerfish collected by the SERFS chevron rap survey from 1991-2014. Ages are calendar ages and composition is in percent of fish in each year corresponding to a given age.   Note, no Gray Triggerfish were retained for age determination in 1990.

	Year																							
Age	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**
0	0.77	2.42	1.95	0.21	0.00	0.16	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.47	0.28	0.00	0.00	4.41	0.42	1.52	0.30	0.44	0.99	2.25
1	53.21	22.22	13.68	15.35	10.16	6.64	5.85	2.65	12.38	9.09	23.33	19.23	8.11	19.16	1.67	6.99	4.26	10.66	18.07	16.75	10.95	4.66	10.78	11.48
2	27.51	29.95	32.25	25.59	23.51	19.77	17.43	11.17	19.80	17.05	21.48	30.22	17.57	28.50	8.64	12.90	20.17	16.54	38.24	35.03	17.46	17.07	29.37	24.49
3	6.43	19.32	29.32	29.85	29.46	28.88	30.27	30.49	25.25	30.68	23.70	16.76	29.73	29.91	22.01	30.11	27.56	24.63	26.89	26.90	27.81	22.39	29.26	26.84
4	6.94	17.87	11.07	17.48	20.17	25.02	25.37	30.49	19.31	22.35	20.37	14.01	16.22	13.08	35.38	17.74	24.72	17.65	10.50	11.68	19.23	25.06	13.53	16.70
5	2.06	4.83	9.12	7.25	10.89	12.31	13.67	17.42	14.85	12.50	7.78	10.44	22.97	4.67	17.27	20.97	13.35	12.87	3.36	6.09	13.61	18.63	9.90	9.22
6	1.54	2.42	1.95	1.92	1.74	3.61	3.76	3.60	5.45	4.55	0.37	4.12	2.70	1.40	7.80	5.91	5.11	4.78	2.10	0.00	5.33	3.99	2.53	5.02
7	1.03	0.97	0.65	2.13	2.32	2.46	2.30	3.22	2.48	1.89	2.22	4.12	2.70	2.80	5.29	3.23	2.84	4.41	0.00	0.51	2.37	2.88	1.98	2.56
8	0.00	0.00	0.00	0.21	1.02	0.98	1.36	0.38	0.00	1.52	0.74	0.82	0.00	0.00	0.84	0.00	1.99	2.94	0.00	0.51	1.78	2.88	1.21	1.02
9	0.51	0.00	0.00	0.00	0.73	0.16	0.00	0.19	0.50	0.38	0.00	0.00	0.00	0.00	0.56	1.08	0.00	0.37	0.42	0.51	1.18	0.89	0.22	0.31
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	1.08	0.00	0.37	0.00	0.51	0.00	0.22	0.00	0.00
11	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	0.28	0.00	0.00	0.37	0.00	0.00	0.00	0.44	0.22	0.00
12	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	0.44	0.00	0.10
Traps	**47**	**70**	**112**	**142**	**134**	**166**	**164**	**118**	**60**	**86**	**78**	**102**	**33**	**74**	**99**	**64**	**96**	**64**	**79**	**97**	**116**	**190**	**281**	**304**
Fish	**389**	**207**	**307**	**469**	**689**	**1219**	**958**	**528**	**202**	**264**	**270**	**364**	**74**	**214**	**359**	**186**	**352**	**272**	**238**	**197**	**338**	**451**	**909**	**976**

Figures

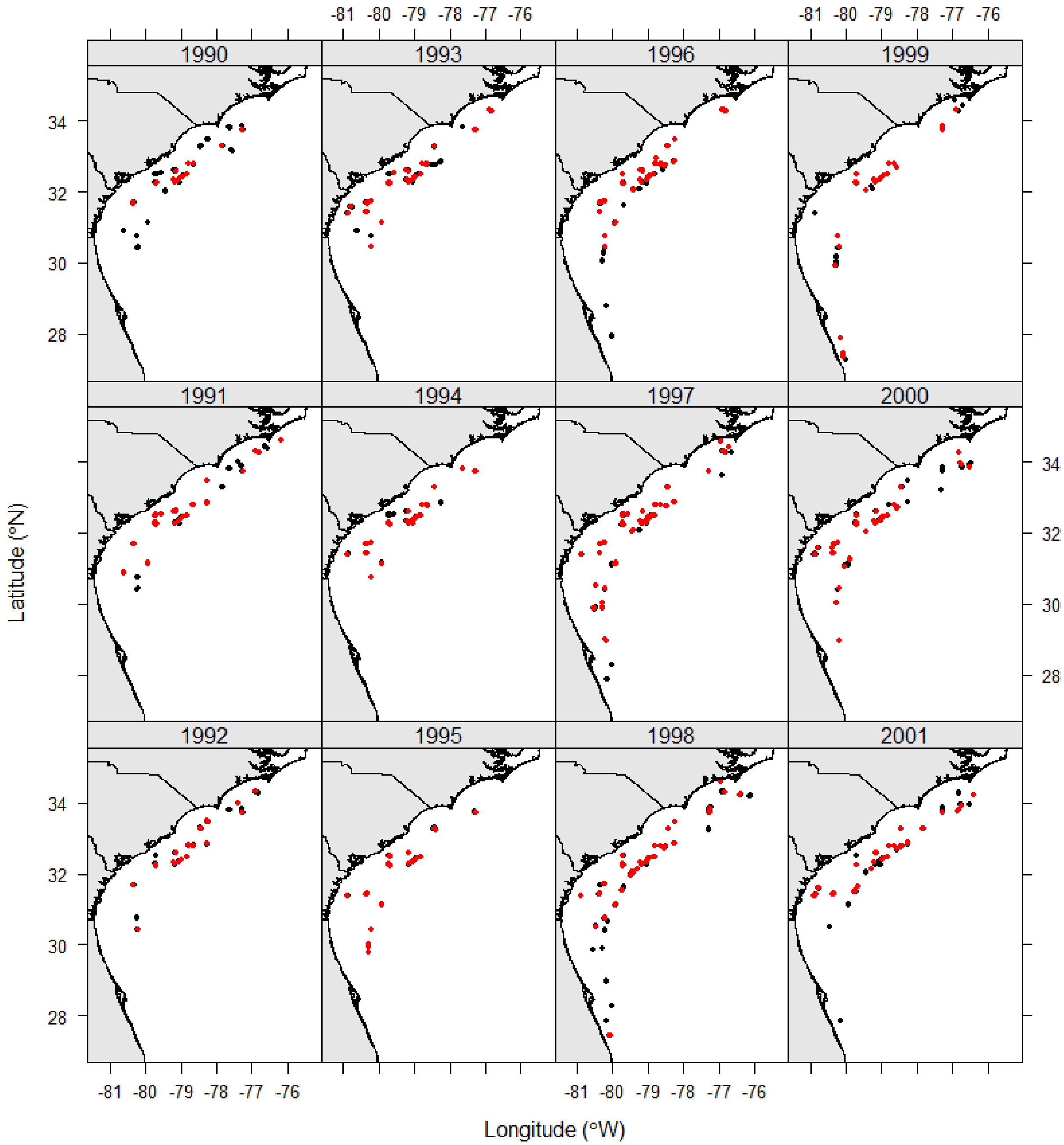

Figure 1: Annual sampling distribution of the SERFS chevron trap survey from 1990-2014. Black dots represent samples absent of Gray Triggerfish. Red dots represent samples where Gray Triggerfish were captured. Dots are semi-transparent so that a general sense of sampling magnitude in each area can be determine

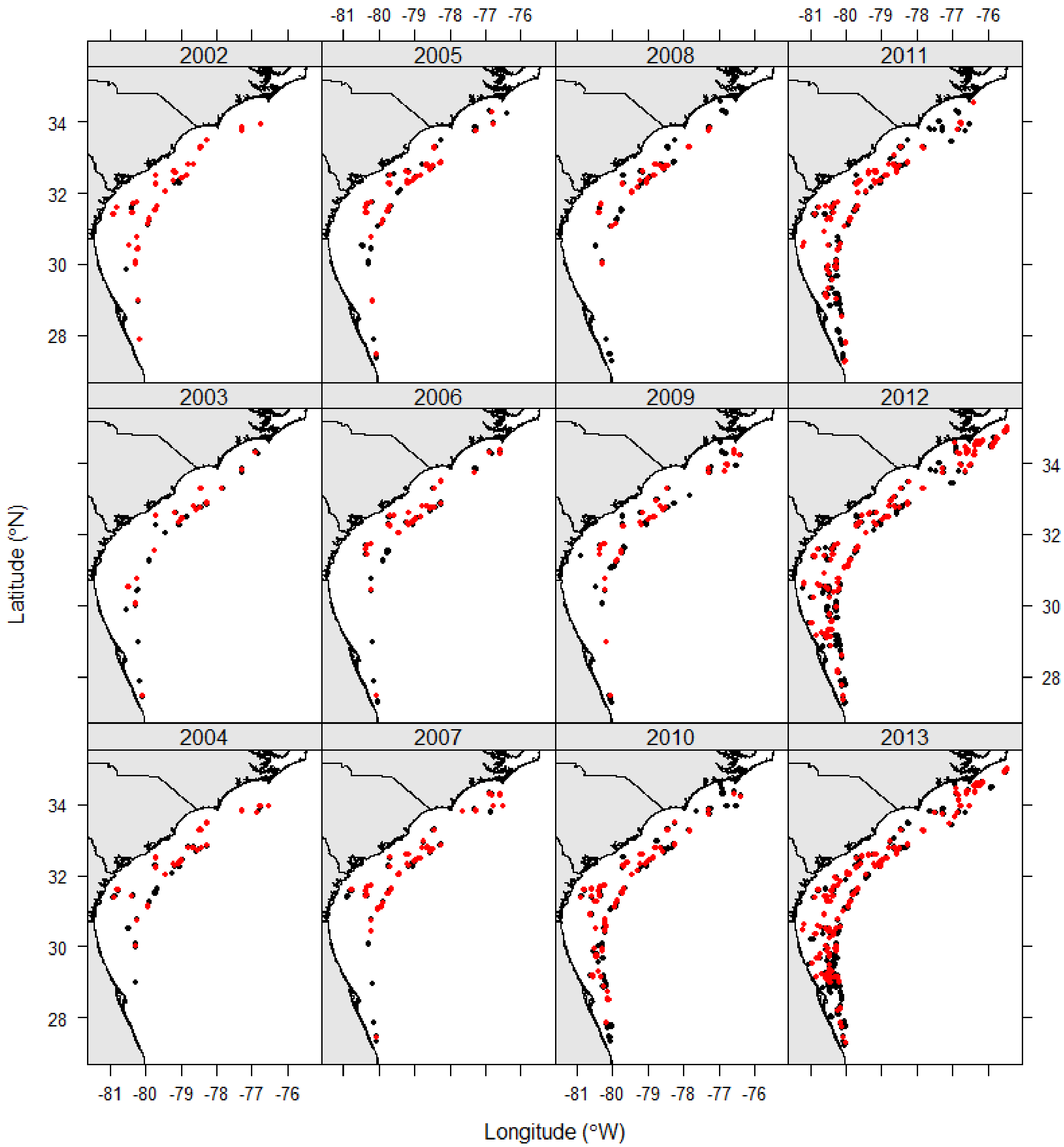

Figure 1: continued

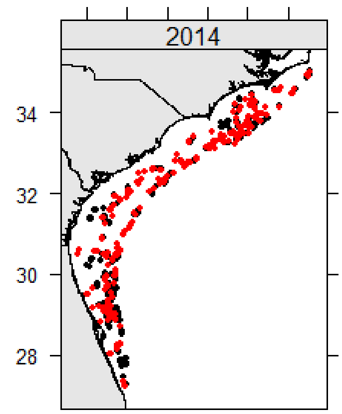

Figure 1: continued

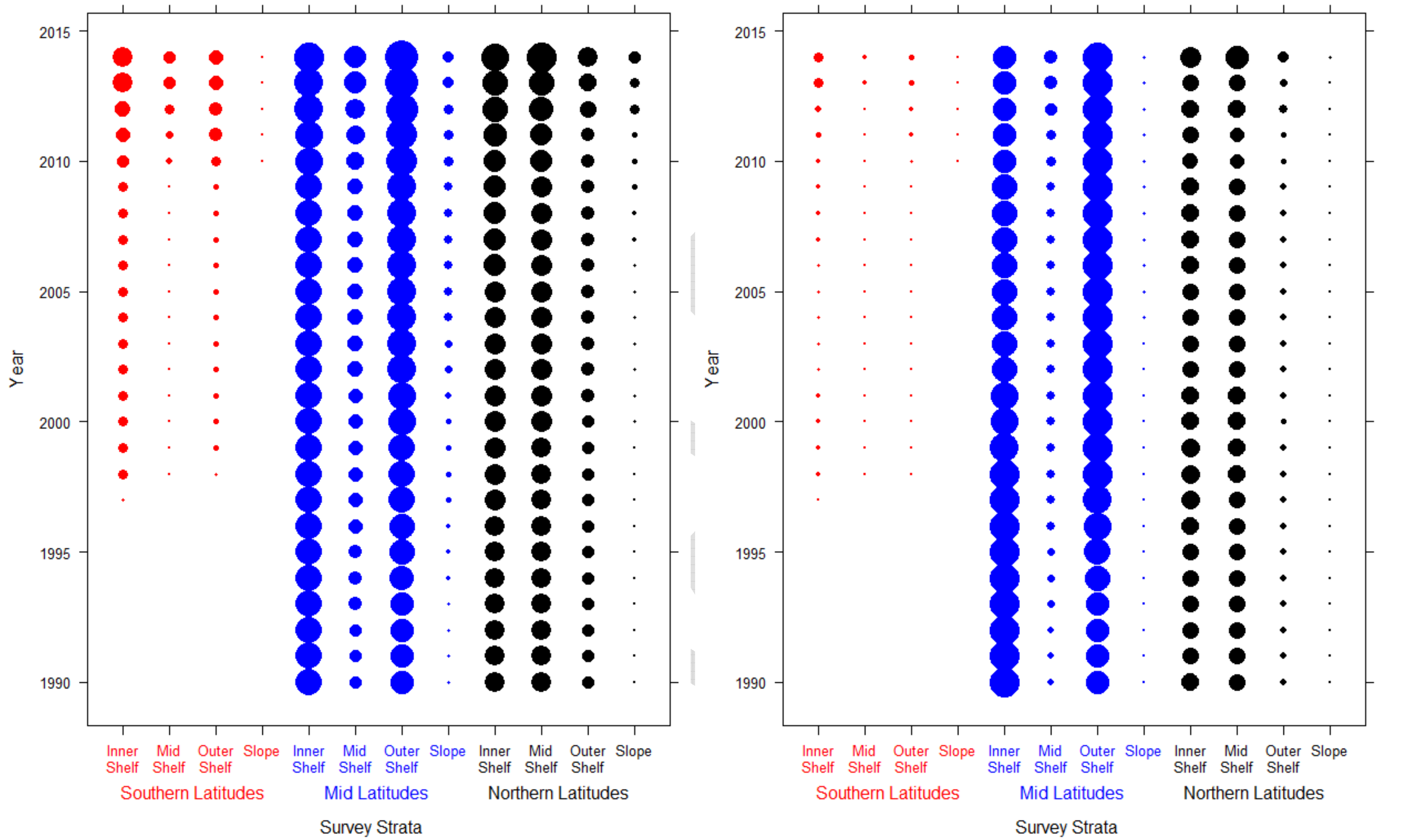

Figure 2: Distribution of SERFS chevron trap stations according to latitude and depth strata. Left panel – area of each circle is proportional to the total number of stations found in the stratum. Right panel – size of each circle in each year is proportional to the stratum possessing the maximum number of stations in that year. Strata are defined based on multivariate partitioning based on changes in chevron trap catch species composition. Depth strata: Inner Shelf, <30 m; Mid Shelf, 30-42 m; Outer Shelf, 43-63 m; Slope, ≥64 m. Latitude strata: Southern Latitudes, <29.71°N; Mid Latitudes, 29.71-32.60°N; Northern Latitudes, ≥32.61°N.

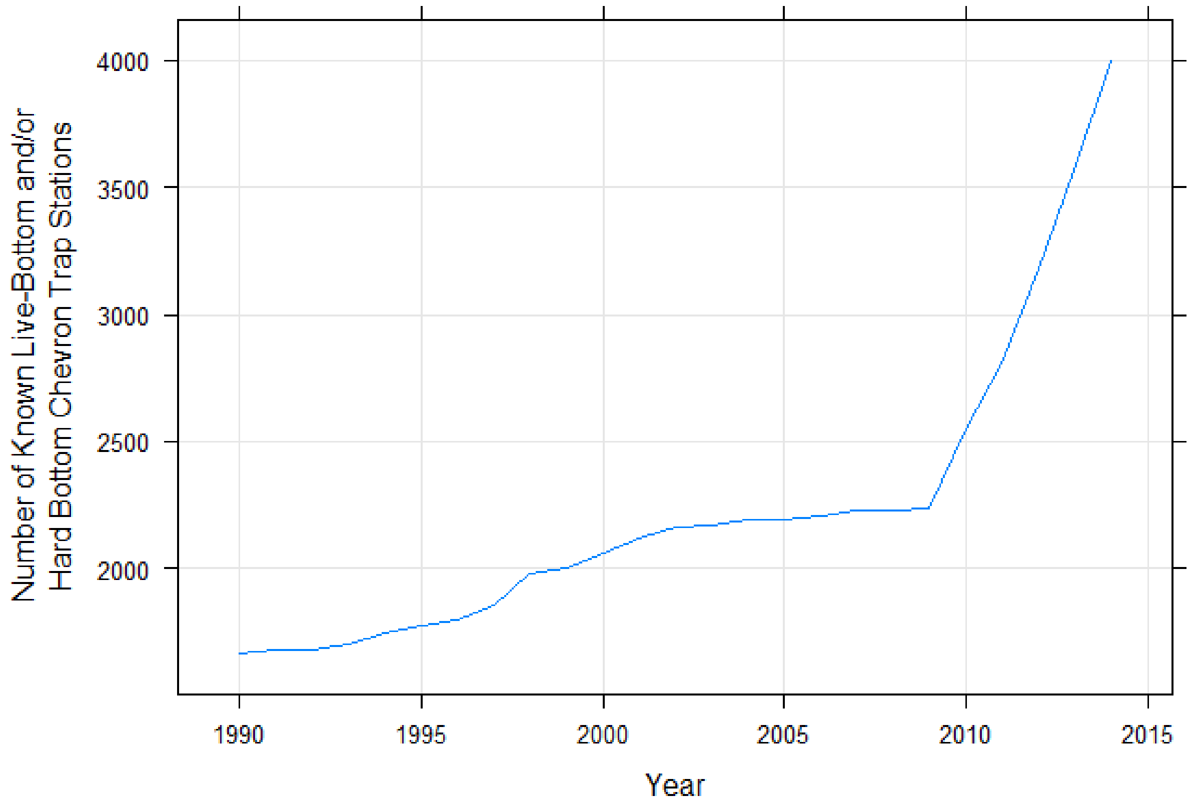

Figure 3: Time series of the number of stations composing the SERFS chevron trap station universe (locations with known live-bottom and/or hard-bottom habitat suitable for sampling via chevron traps). The drastic increase in known live-bottom and/or hard bottom stations since 2009 is driven primarily by the geographic expansion in the survey made possible due to the addition of funds via the SEAMAP-SA Reef Fish Complement and SEFIS programs. The chevron trap universe in 2014 represents the current universe of known live-bottom and/or hard-bottom habitat identified by the SERFS program.

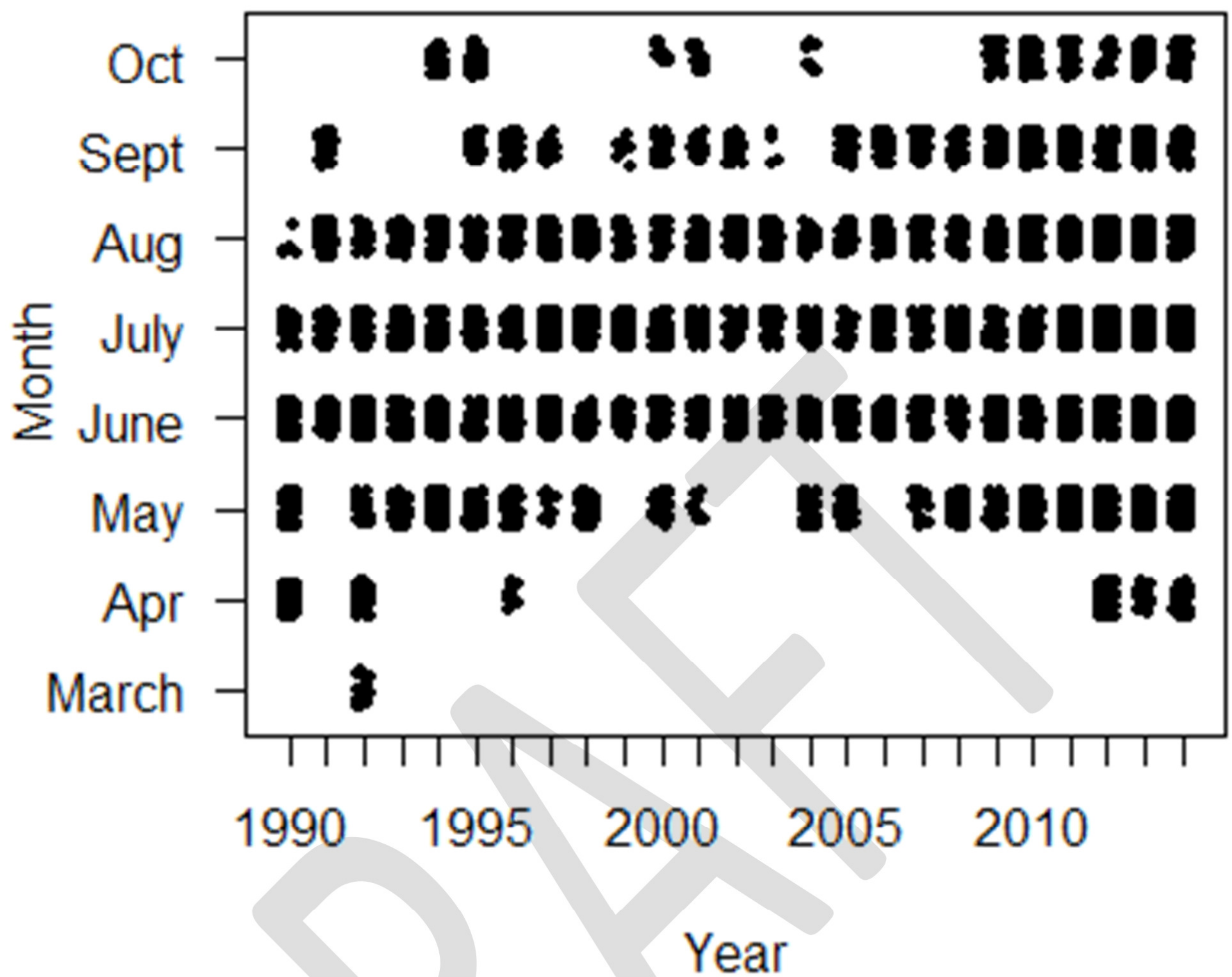

Figure 4: Distribution of chevron trap samples by month and year. Individual data points are jittered to create a cloud to give a sense of the total sample size by month and year combination.

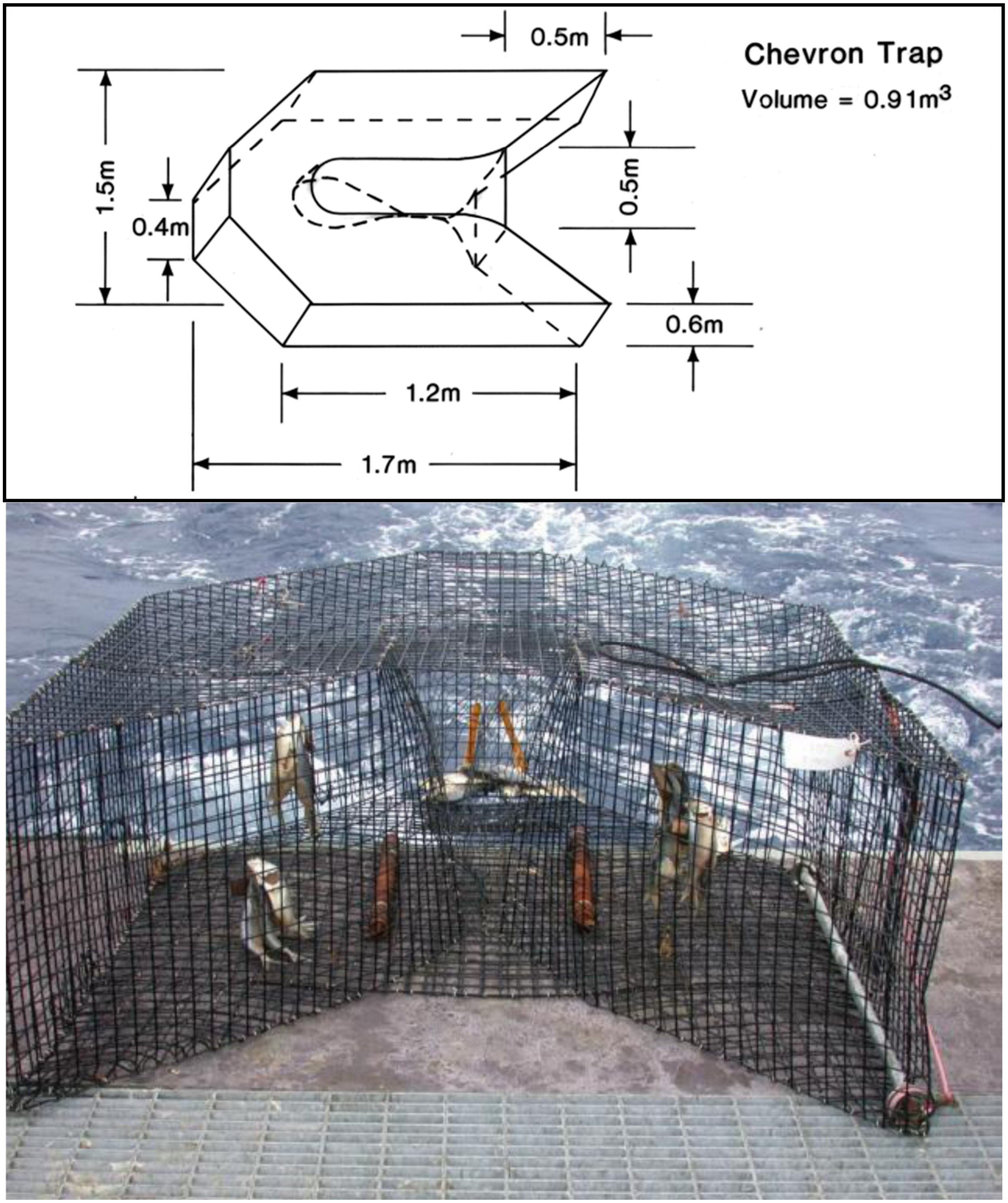

Figure 5: Chevron traps used by SERFS for monitoring reef fish. A. Diagram with dimensions. B. Chevron trap ready for deployment baited with clupeids. Iron sashes attached to the bottom weigh the trap down and help maintain the proper orientation of the trap on the bottom.

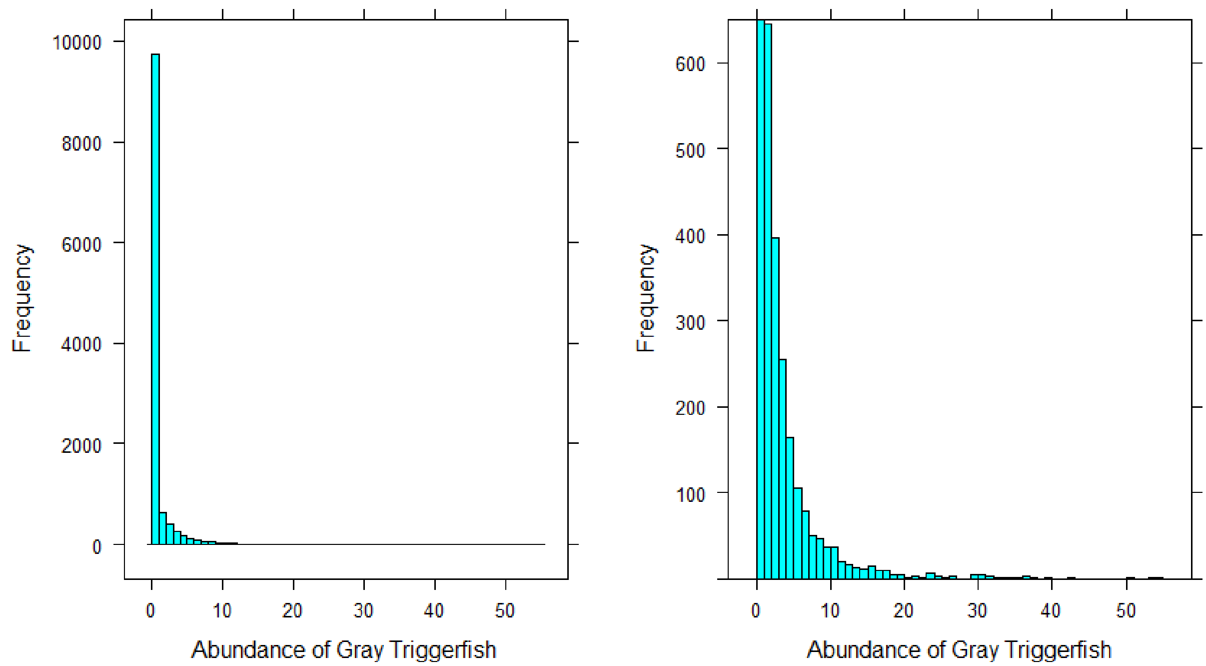

Figure 6: Frequency of occurrence of chevron traps with a given catch of Gray Triggerfish. Left panel – full distribution showing the excess zeros; Right panel – restricted distribution better depicting frequency of traps with a given catch of Gray Triggerfish

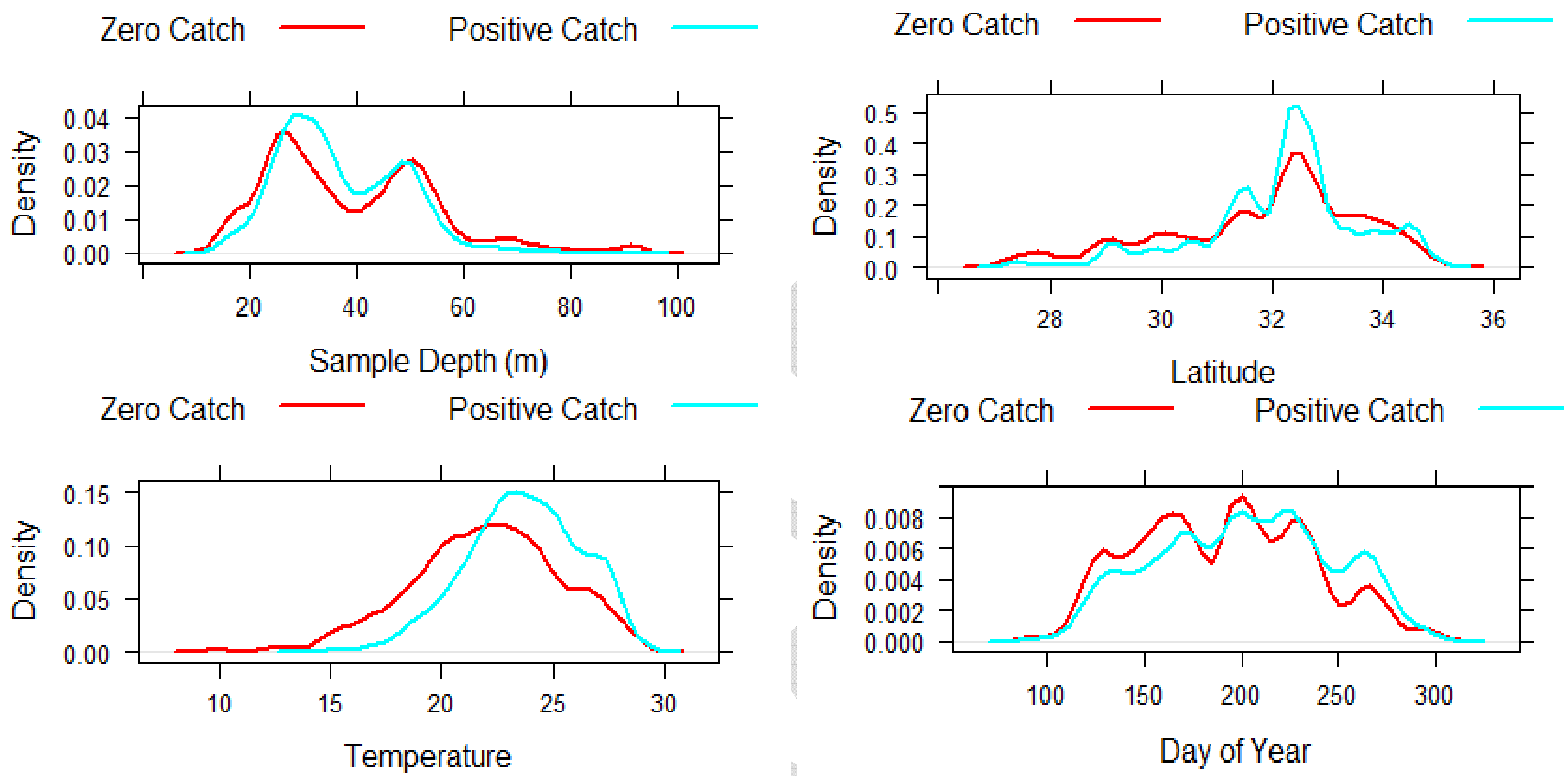

Figure 7: Density plots of traps negative and positive for Gray Triggerfish with respect to each covariate considered in the model.

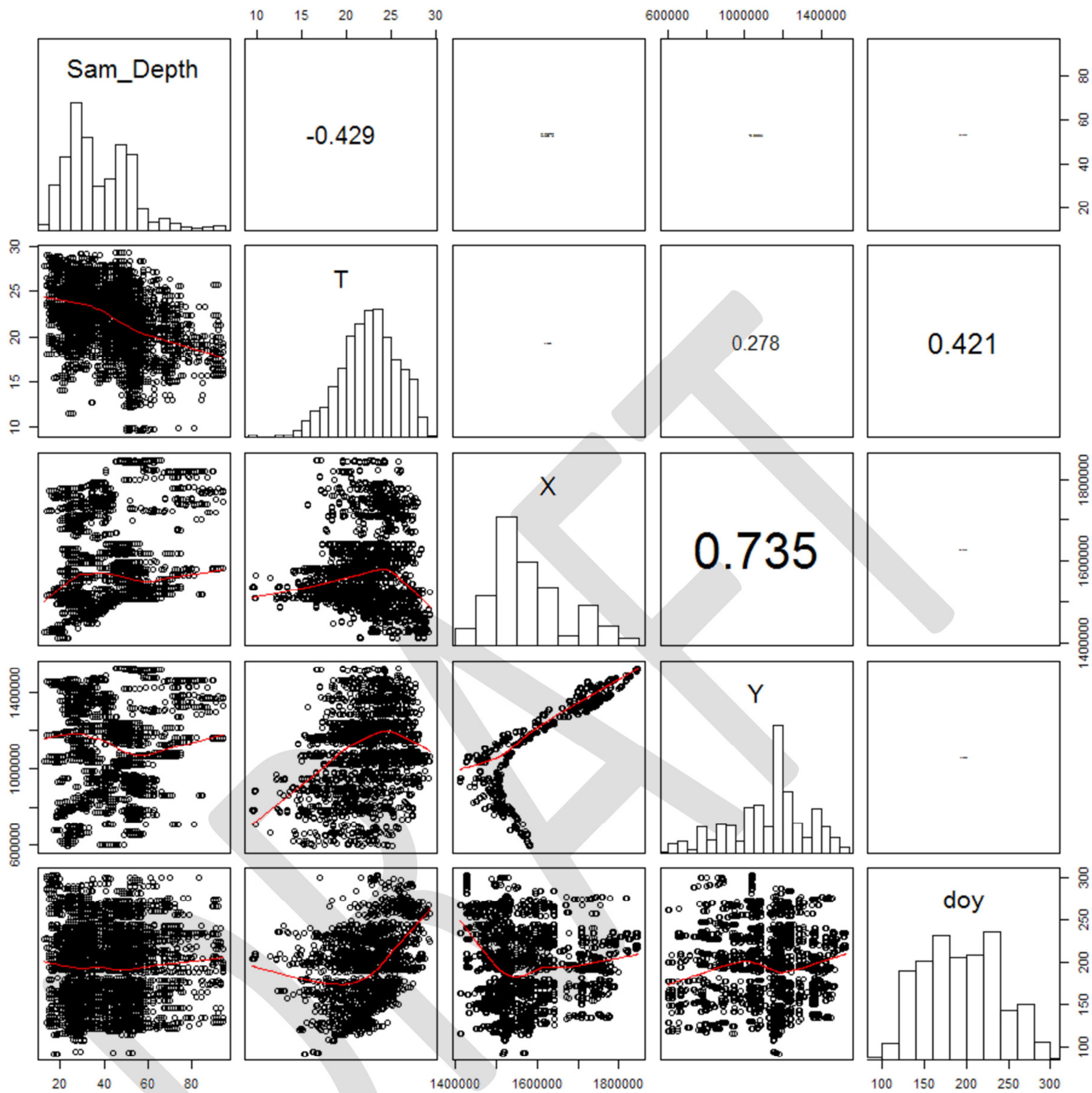

Figure 8: Pairs plot depicting the correlation among several variables available for consideration as covariates in the relative abundance index standardization model. Upper triangle presents the observed correlation among pairs of variables, with text size reflecting degree of correlation. Diagonal shows the distribution of pairs of variables. Lower triangle shows an xyplot of individual pairs of data, with the red line reflecting a loess smoother. Sam_Depth = depth, T = bottom temperature, X = longitude, Y = latitude, and doy = day of year.

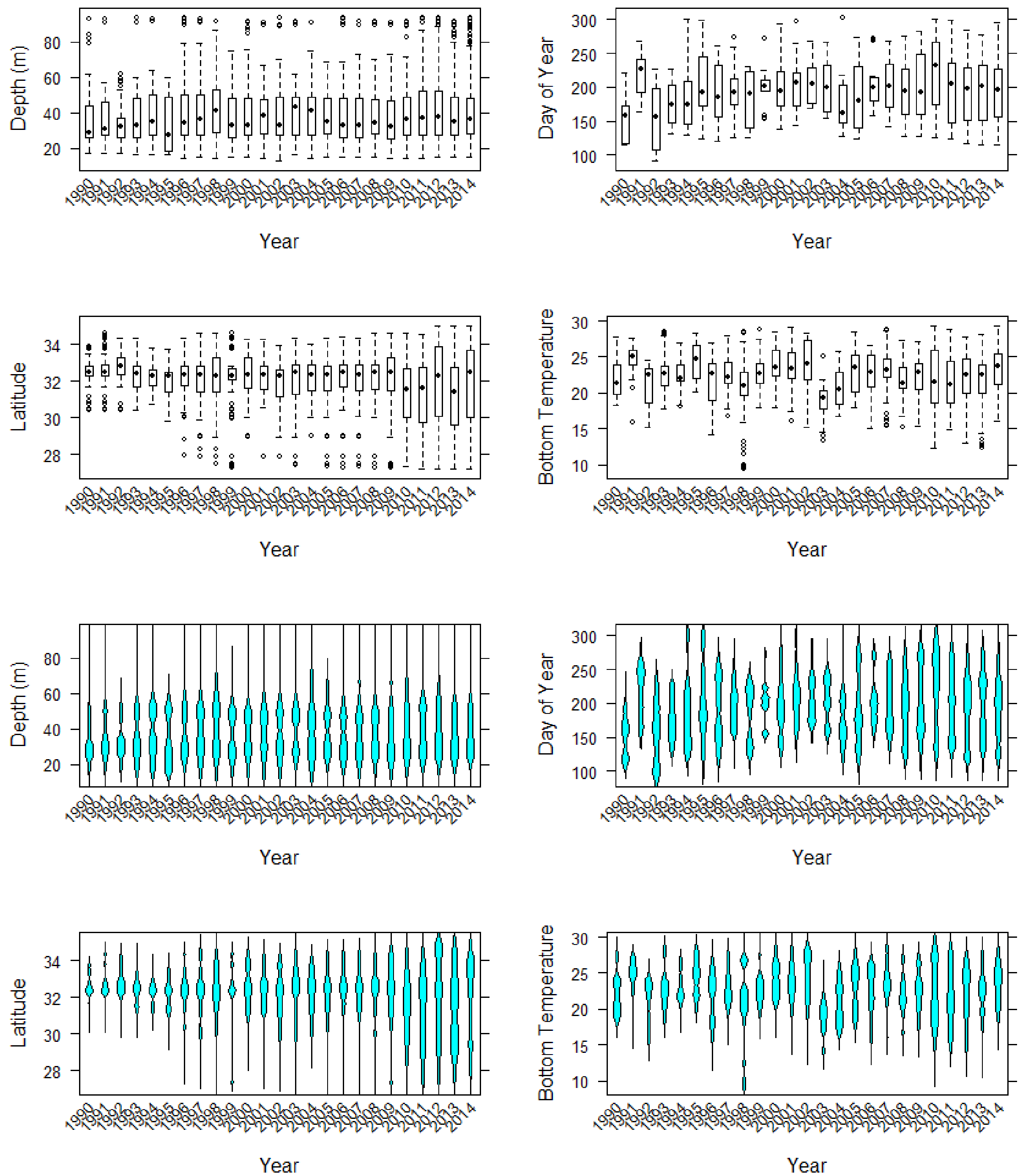

Figure 9: Box plots (top panel) and violin plots (bottom panel) of depth, latitude, bottom temperature, and day of year as a function of year.

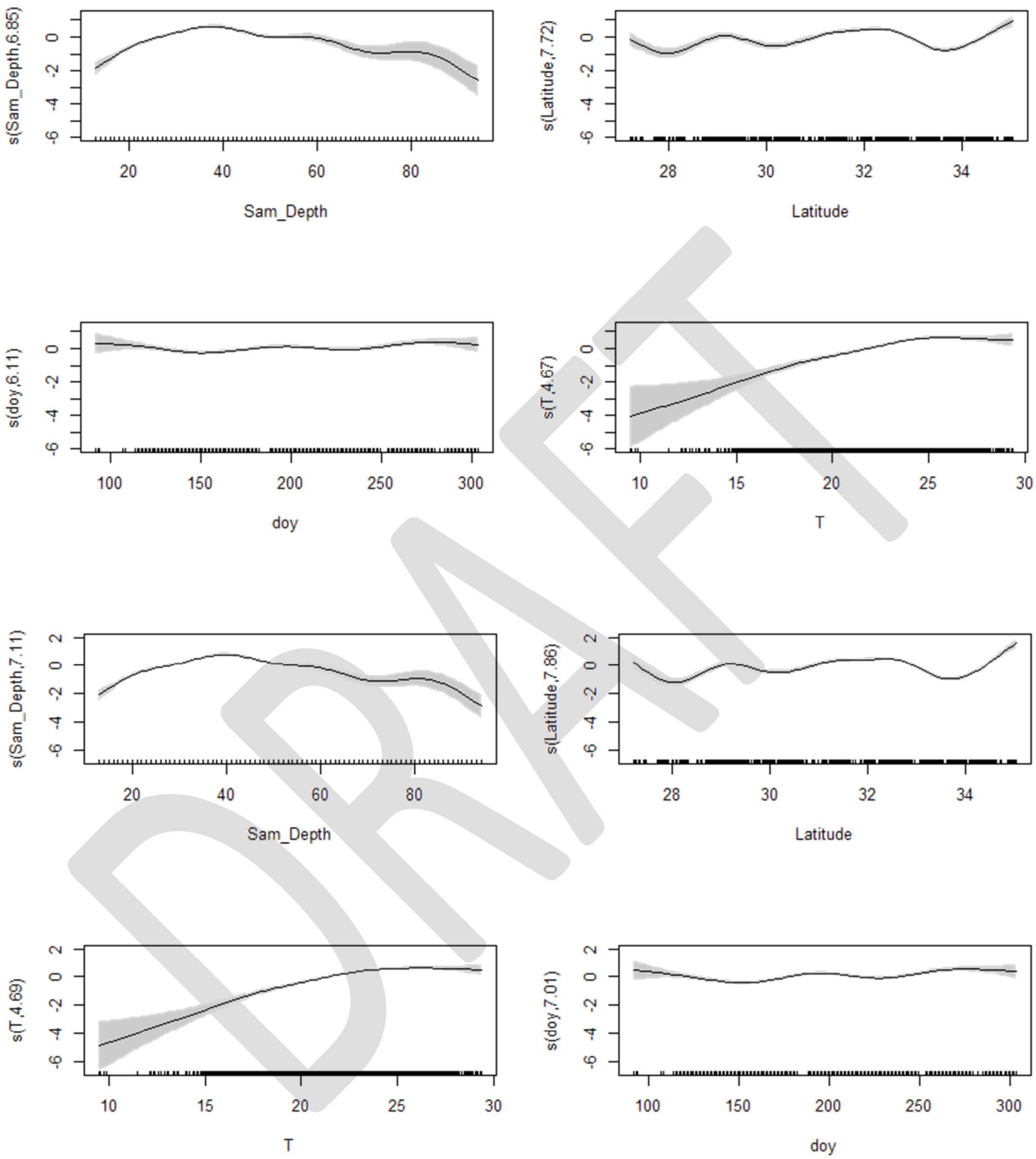

Figure 10: Preliminary GAM analysis predicted relative effects of covariates on the presence/absence (top 4 plots) and abundance (catch; bottom 4 plots) of Gray Triggerfish in chevron traps. Rug on the bottom of each of the plots gives a sense of the distribution of each of the covariates in the data set. Sam_Depth = depth, doy = day of year, and T = bottom temperature.

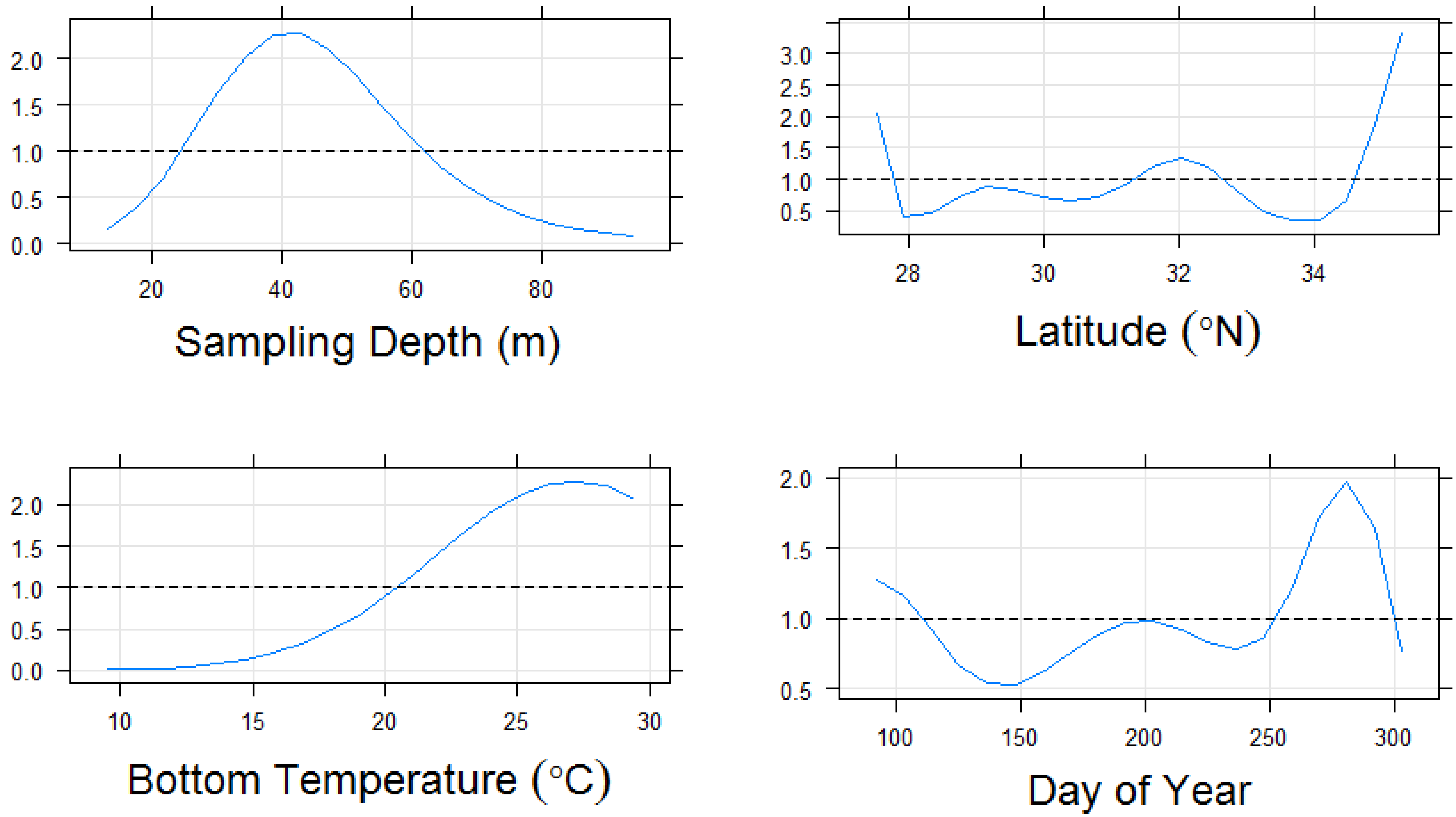

Figure 11: Predicted relative effect of each covariate on the catch of Gray Triggerfish in chevron traps. Note that the scale of the y-axis changes among panels, and hence y-axis scale can provide an indication of the magnitude of the effect of individual covariates. The covariate day of year was not retained in the best-fit standardization model

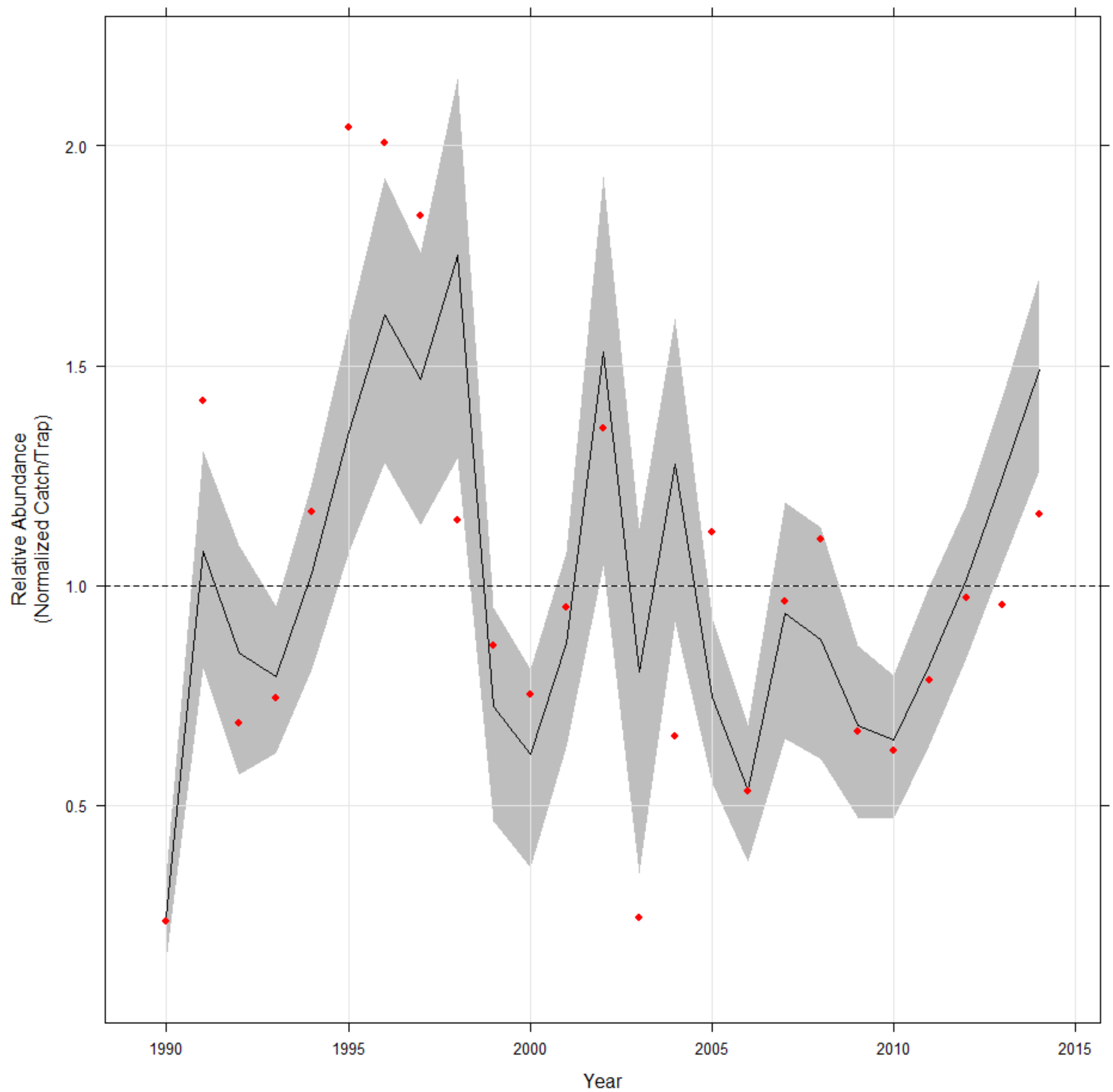

Figure 12: Gray Triggerfish index of relative abundance based on the SERFS chevron trap survey during the years 1990-2014. The ZINB standardized catch (sold black line) is normalized to the average relative abundance, as estimated by the model, during the period 1990-2014. Red dots represent normalized nominal annual relative abundance. Gray shaded region represents the 95% confidence interval of annual relative abundance based on 10,000 bootstraps.

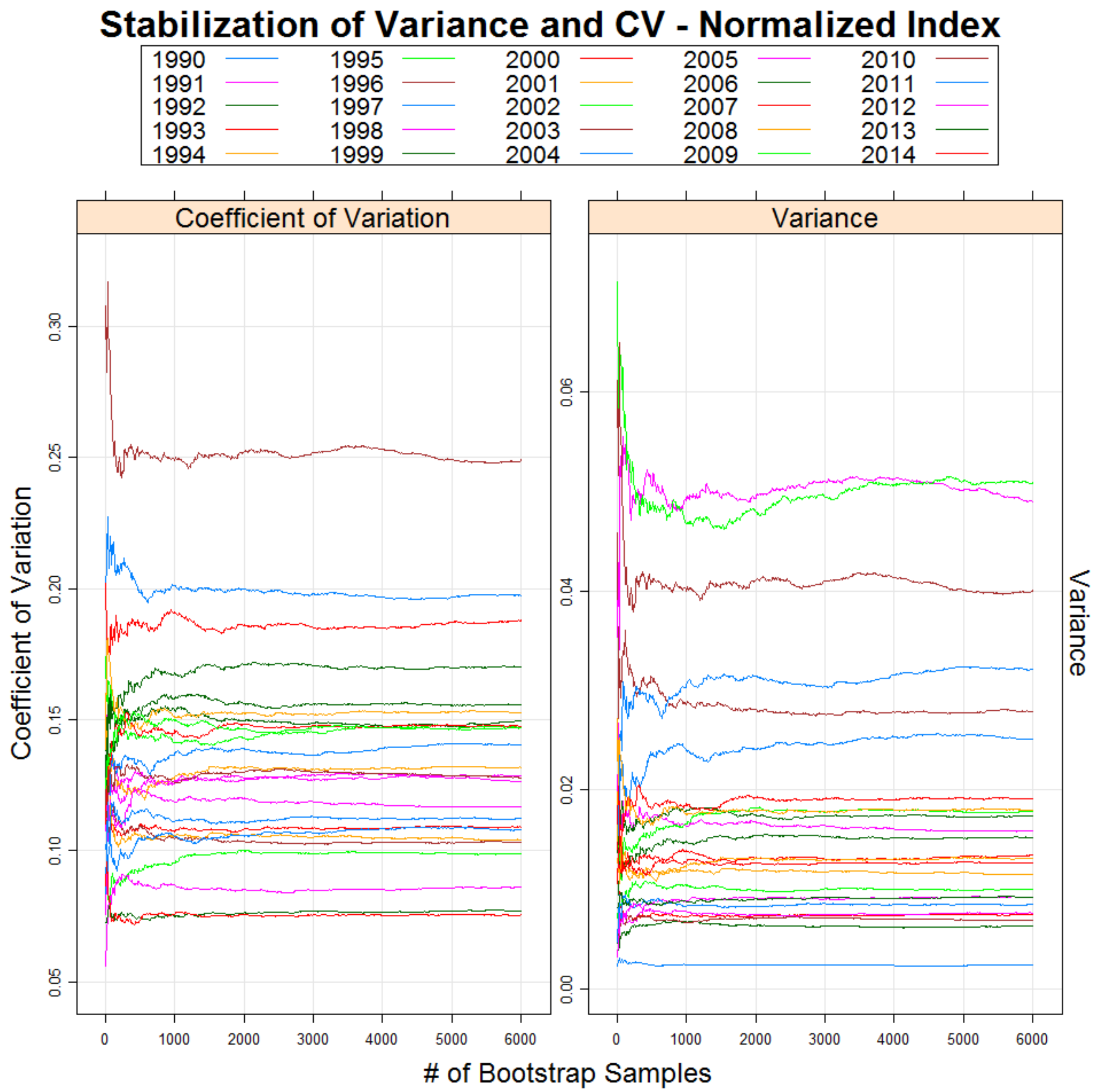

Figure 13: Bootstrap diagnostic plots used to determine if coefficient of variation (CV; left) and variance (left) estimates stabilized over the number of bootstrap iterations run. Each line represents an individual year in the survey.

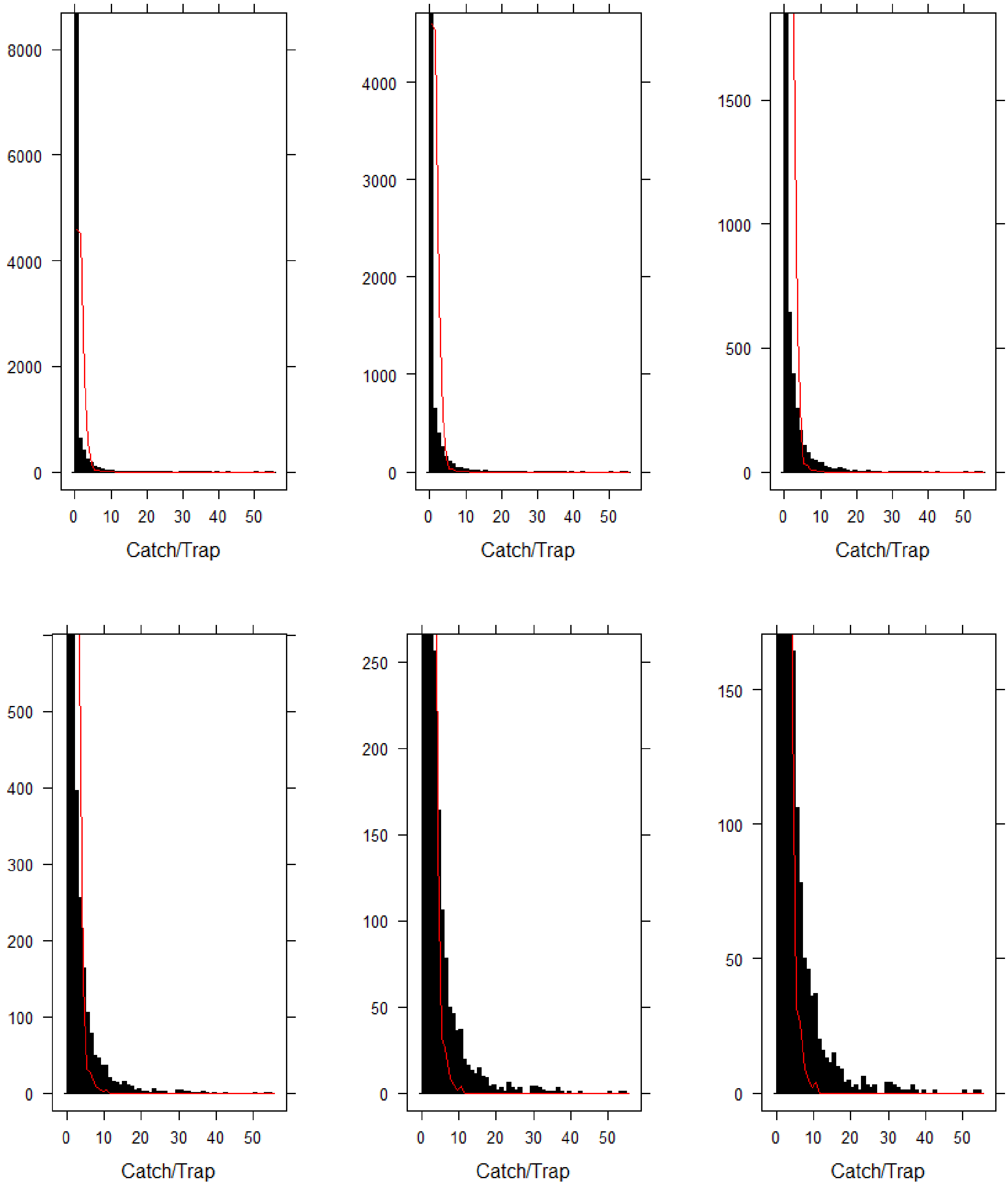

Figure 14: Frequency of traps observed (black bars) with a given catch of Gray Triggerfish or predicted by the ZINB (red line). Plots present the same data, with the y-axis truncated to better resolve low frequencies as one moves across rows and down columns starting with the top left plot.

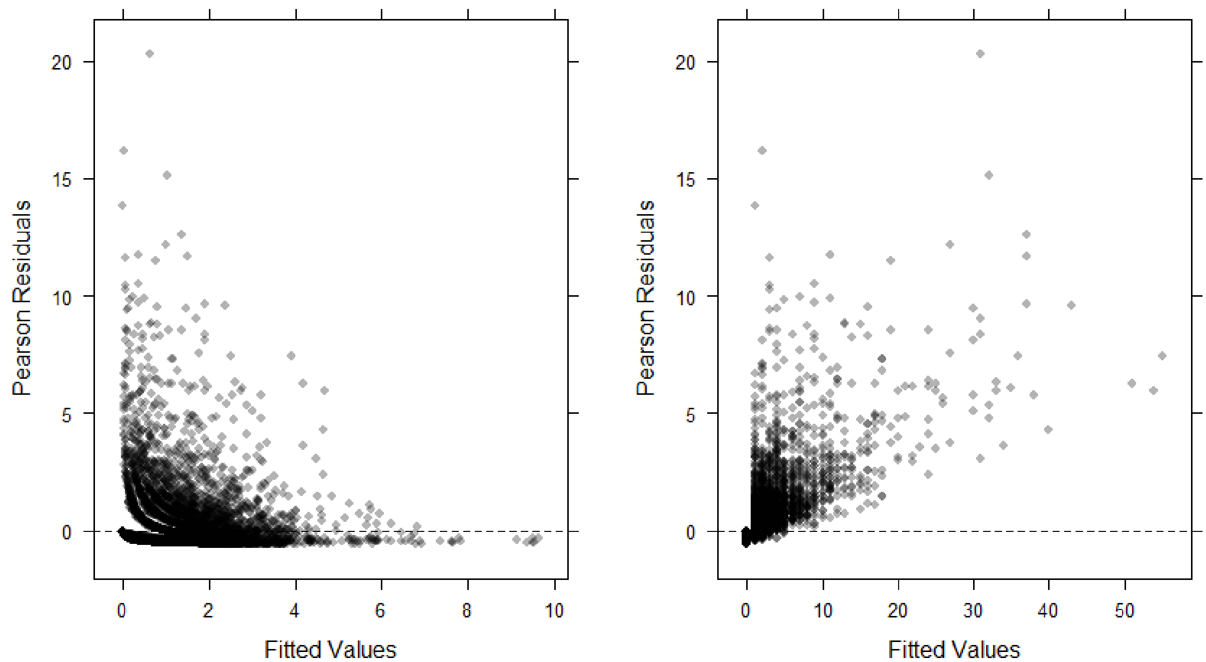

Figure 15: Model diagnostic plots showing fitted model values (left plot) and observed data (right plot) versus Pearson's residuals for the ZINB GLM model.

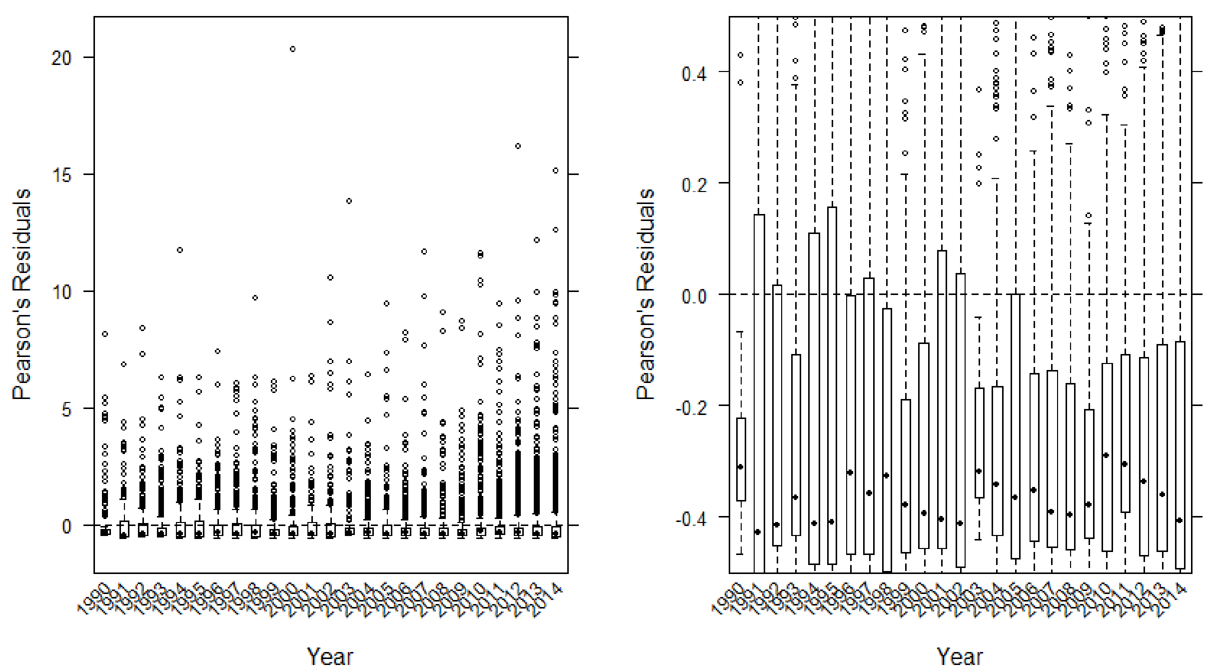

Figure 16: Model diagnostic plot showing Pearson's residuals versus year for the final ZINB model. Left – full residual scale; Right – restricted residual scale.

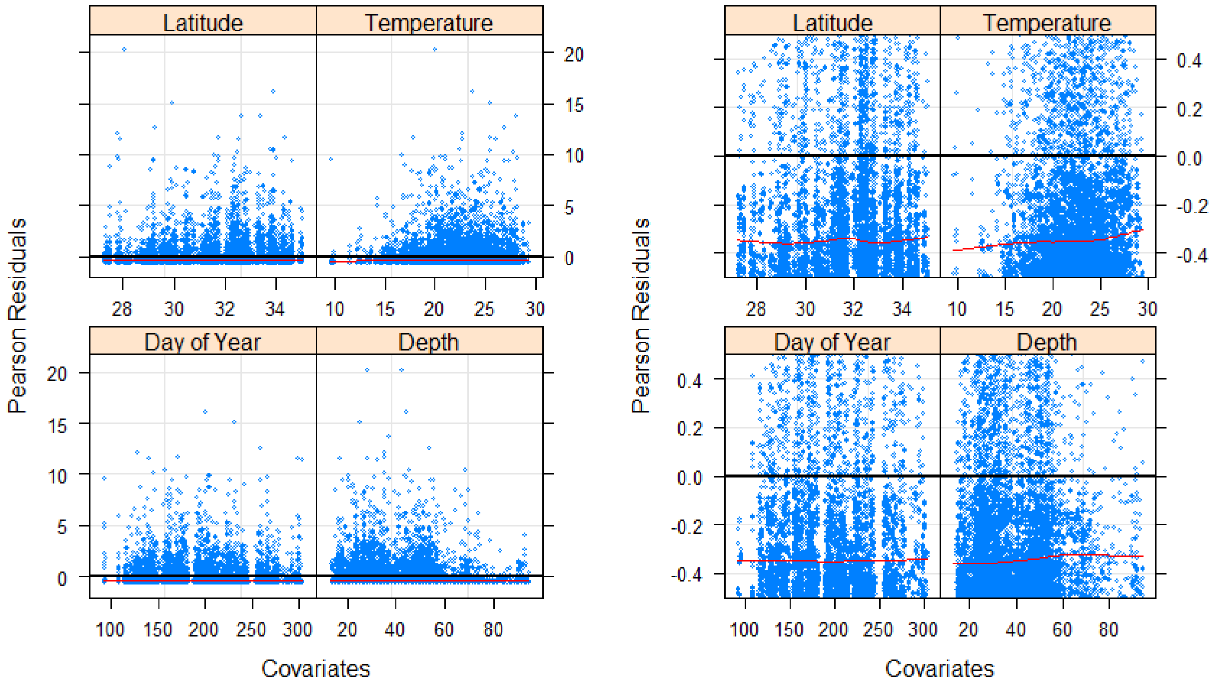

Figure 17: Pearson’s residuals versus covariates included in the final ZINB GLM.

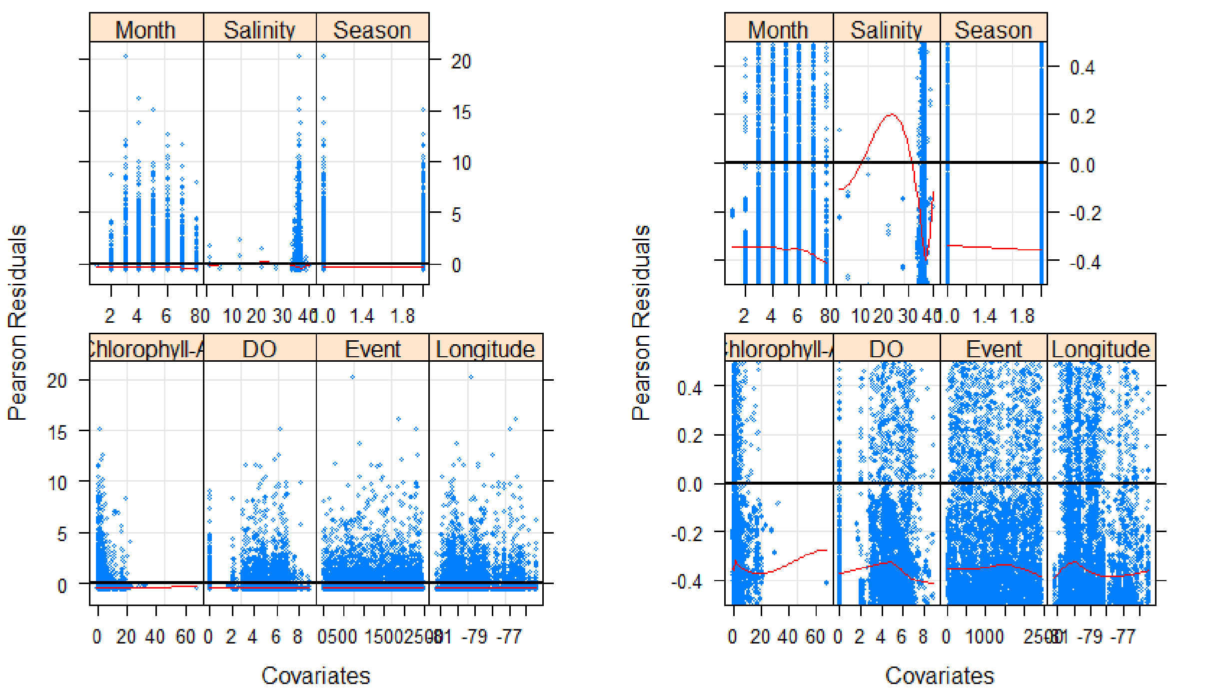

Figure 18: Pearson's residuals versus covariates excluded from the final ZINB GLM.

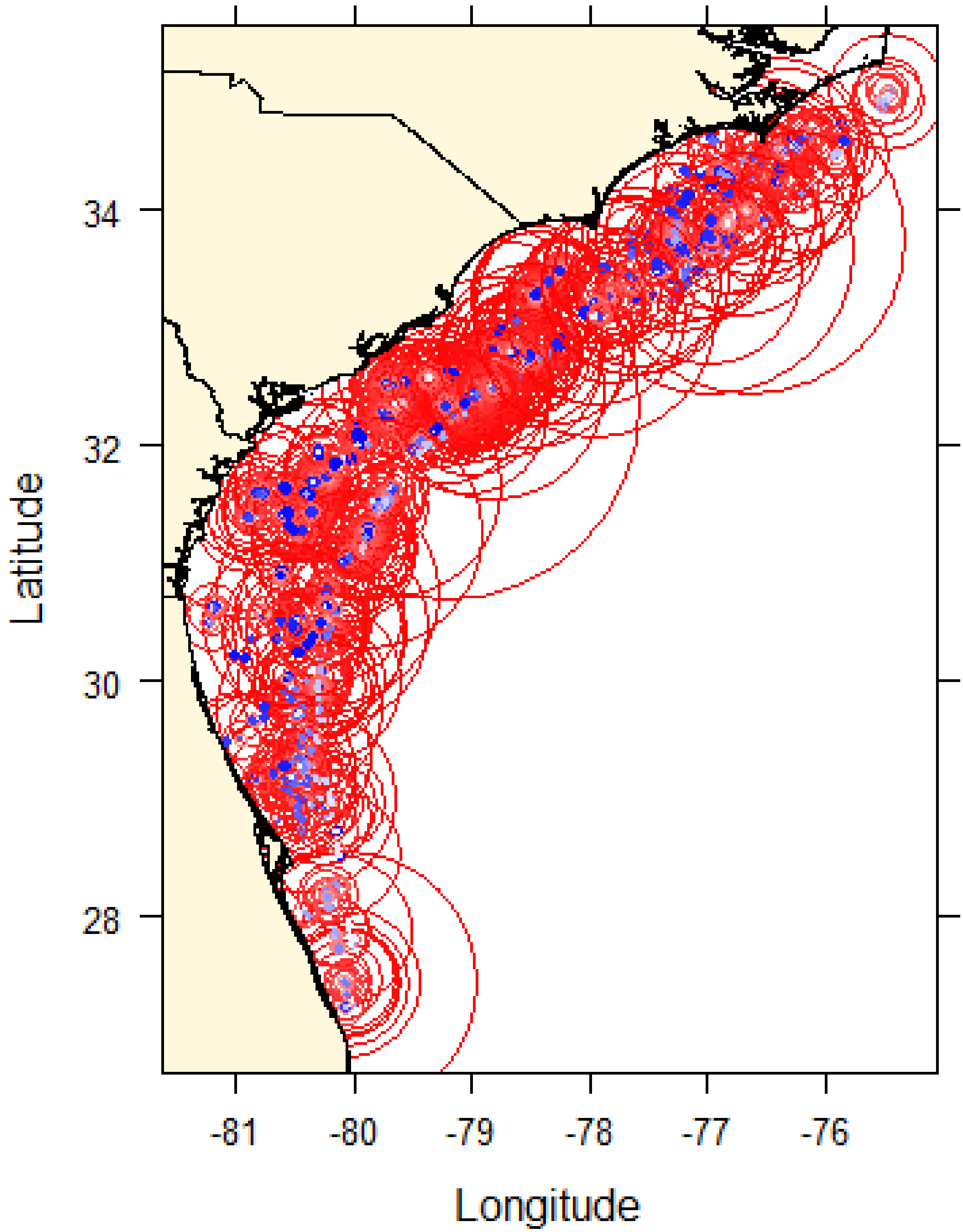

Figure 19: Spatial distribution of Pearson's residuals. Red circles indicate positive Pearson's residuals and blue circles represent negative Pearson residuals. Size of the circle is indicative of the magnitude of the residual with larger circles corresponding to larger absolute value Pearson's residual values.

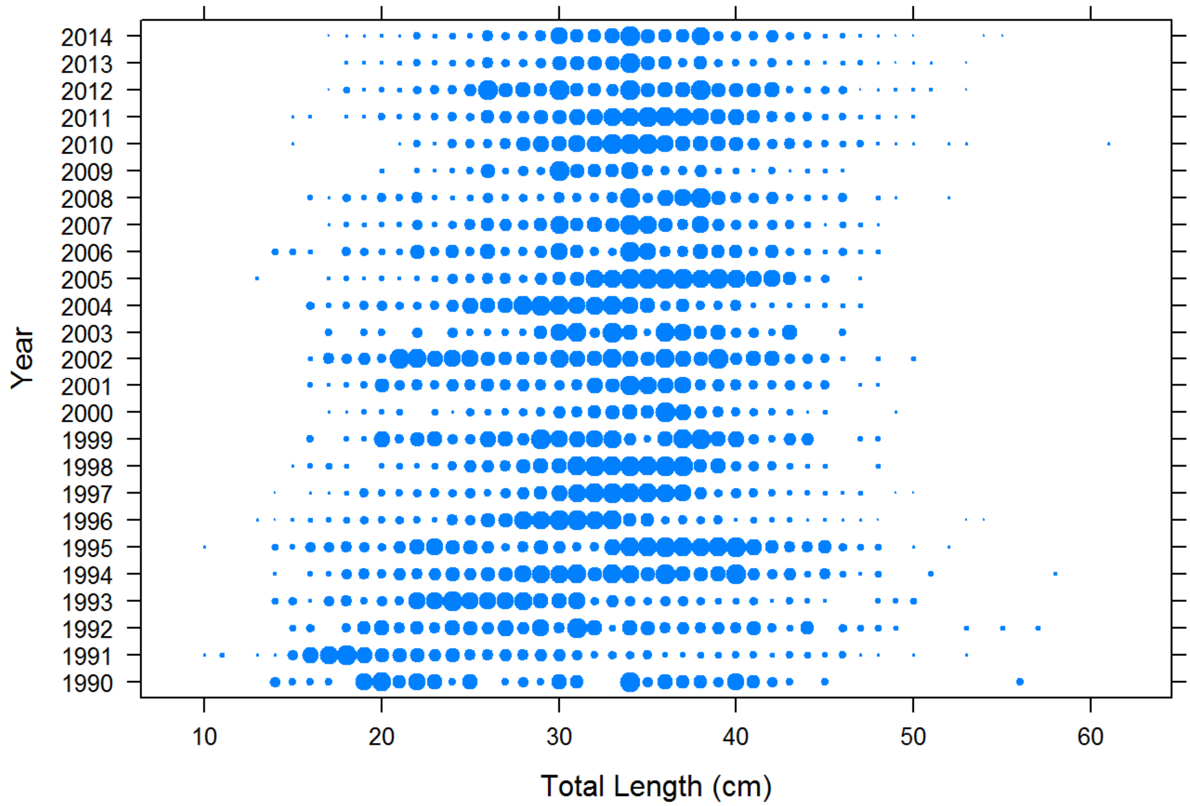

Figure 20: Observed length composition of Gray Triggerfish catch via the SERFS chevron trap survey.

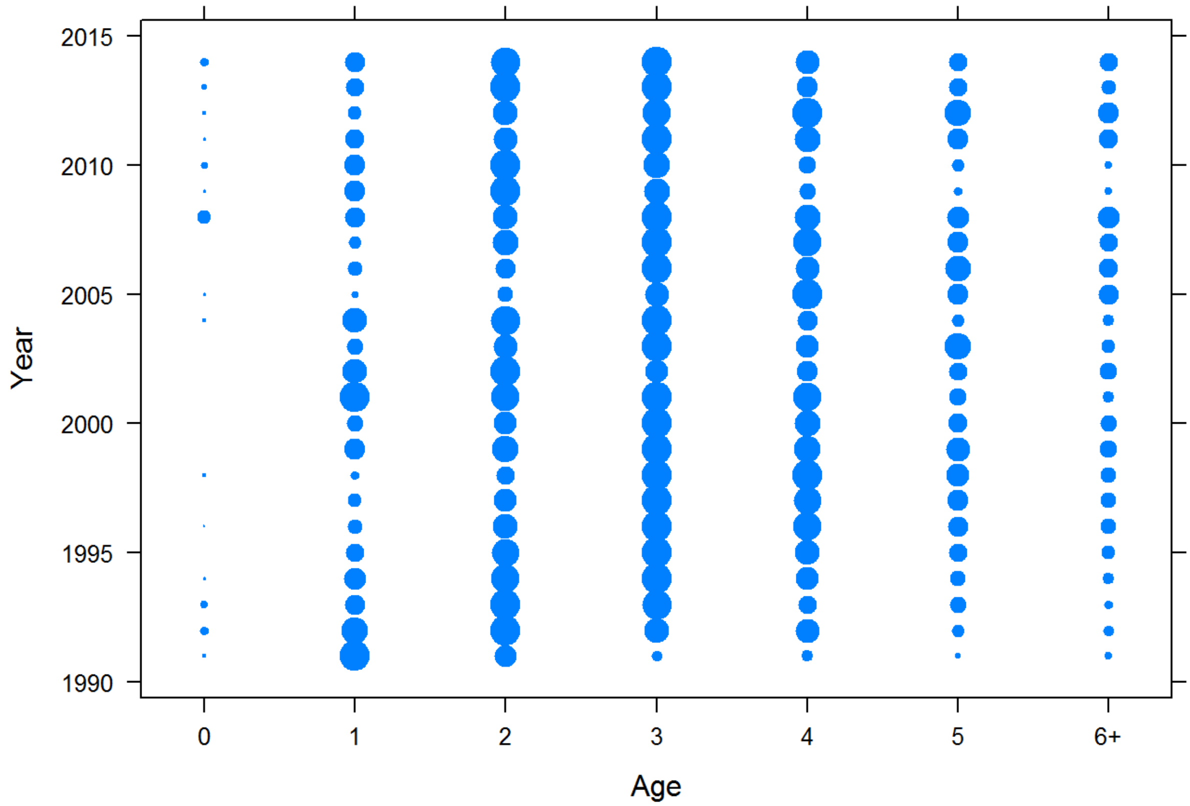

Figure 21: Age composition of Gray Triggerfish captured via the SERFS chevron trap survey during the period 1990-2014. Area of circle represents percentage of fish at a given age in a given year

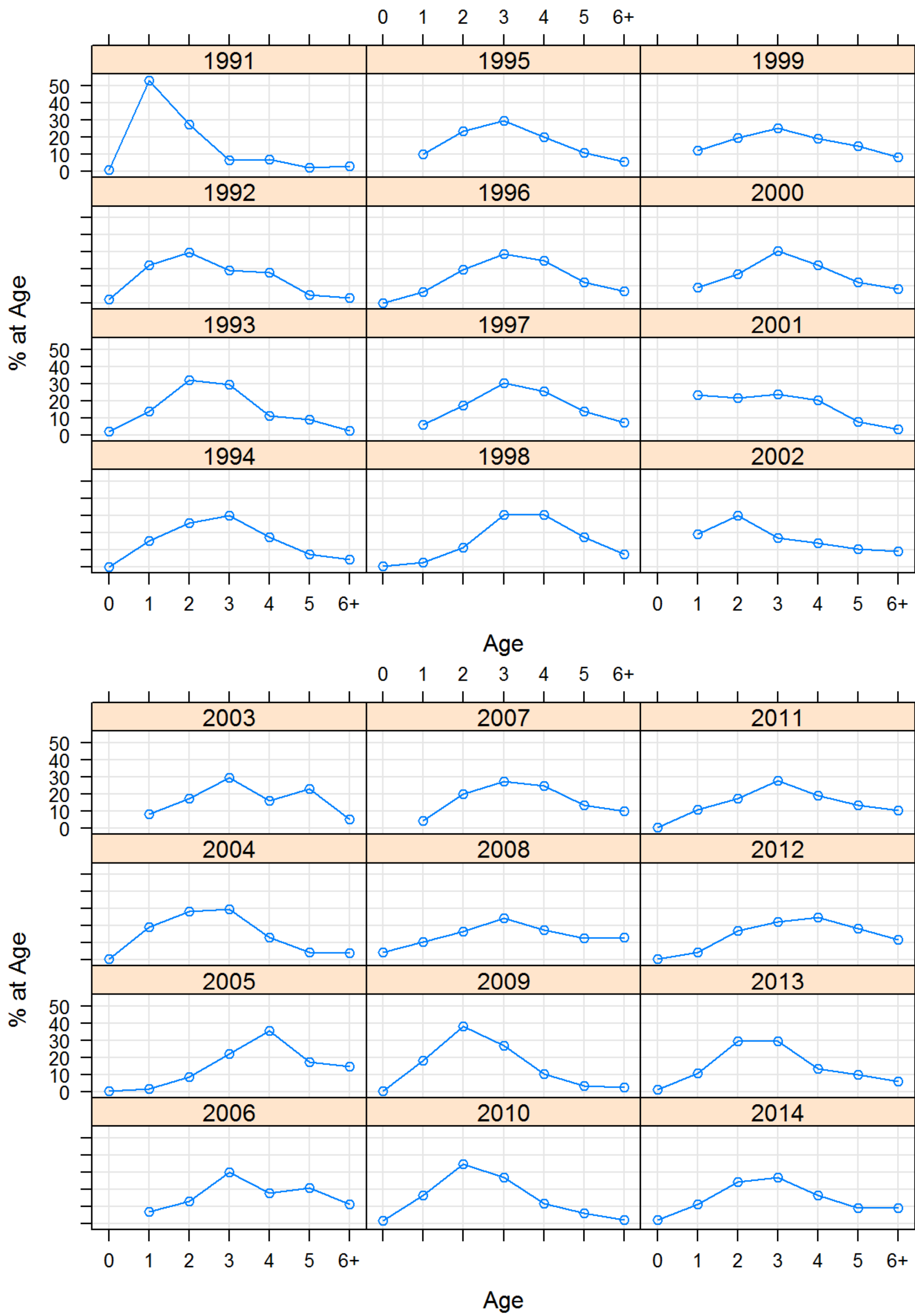

Figure 22: Age composition by year time-series plot. Top panel – 1991-2002; Bottom panel – 2003-2014.