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SEDAR41-DW54

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*Report documents development of Red Snapper relative abundance index based on the SERFS chevron trap survey during the years 2010-2014

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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 Red Snapper derived from the SERFS chevron trap survey during the years 2010-2014. The standardized index accounts for annual sampling distribution shifts with respect to covariates that affect catch of Red Snapper in chevron traps.

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

Data presented in this report are based on the combined SERFS database accessed on July 20, 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
  - Minimal shift in geographic distribution of traps available for sampling (Figure 2) although 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 Red Snapper specifically, only the depths at which Red Snapper have ever been captured by any of the monitoring programs (included 15-75 m)
- Excluded any chevron trap samples missing covariate information (Table 1)
- Excluded all traps sampled prior to 2010

Standardized Index Model Formulation

Model Basics

- 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)

Zero-Inflated Model Background

(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 passed 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 Red Snapper 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 Red Snapper 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 fork lengths were converted to maximum (pinched) total length using conversions developed by Ballenger et al. (2012) from over 1,700 fish
    - 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 Red snapper 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 5,243 chevron trap samples from 2010-2014 were retained and used in the development of the relative abundance index (Table 1 and Table 2)
- Proportion of traps positive for Red Snapper averaged 0.106
  - Spatial distribution of positive traps compared to all traps can be inferred from Figure 1
- Caught on average 329 Red Snapper annually

ZINB Index

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

- Covariate day of year was removed from the final best fit ZINB model
- The effect of year and bottom temperature 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
  - Zero-inflation model structure covariate polynomial orders
    - Depth = 3rd order polynomial
    - Latitude = 4th order polynomial
- Best fit model suggest little to no overdispersion remaining in the data

Covariate Effects

(see Figure 11)

- Covariate day of year is removed from the final model
- Relative effects of latitude and bottom temperature is larger than the effect of sampling depth
- Predicted covariate effects
  - Depth – catch is above average at depths of ~25-55 m
  - Latitude – catch is higher than average at latitudes 28-30^{o}N
    - Indication of smaller peaks at just less than 32^{o}N and >34^{o}N
  - Bottom temperature – catch of Red Snapper increases exponentially as bottom temperature increases, over the range of bottom temperatures observed in the survey

Final Index

(see Table 6 and Figure 12)

- General increasing pattern of relative abundance during the period 2010-2014
- CV estimates average 13.5%, ranging from 10.6-17.6% (2014 and 2010, respectively)

Diagnostics

- 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 (Table 8 and Figure 21)

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Tables

Table 1: Annual and total exclusion of chevron trap monitoring station collections from analysis 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 water temperature data.

Year	Pre-exclusion	Post-exclusion	% Change
2010	724	695	4.01
2011	852	674	20.89
2012	1170	1114	4.79
2013	1349	1331	1.33
2014	1429	1429	0
Total	**5524**	**5243**	**5.09**

Table 2: Number of chevron trap deployments on live/hard-bottom areas, proportion of traps positive for Red Snapper, total number of Red Snapper 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
2010	695	0.088	148	38	15	72	0.51	31.4	27.3	34.6	0.063	22	12	29.4	0.16	219	125	301	2.0
2011	674	0.096	116	40	15	75	0.53	30.9	27.2	34.5	0.071	22	15	28.8	0.15	209	140	299	1.7
2012	1114	0.125	398	39	15	75	0.42	31.8	27.2	35	0.065	22	13	27.8	0.10	194	116	285	1.3
2013	1331	0.105	367	37	15	75	0.36	31.2	27.2	35	0.054	22	12	28.1	0.08	197	115	278	1.3
2014	1429	0.105	614	38	15	75	0.33	31.9	27.2	35	0.055	24	16	29.3	0.07	192	114	295	1.2

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

Variable	VIF	df
Year	1.180	4
Depth	1.303	1
Bottom Temperature	1.827	1
Latitude	1.136	1
Day of Year	1.443	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 Red Snapper relative abundance. EDF = effective degrees of freedom of smoothed spline.

	Presence/Absence GAM		Catch GAM	
Variable	**EDF**	**p-value**	**EDF**	**p-value**
Depth (m)	3.15	<0.0001	5.88	<0.0001
Latitude (^{o}N)	7.13	<0.0001	8.26	<0.0001
Bottom Temperature (^{o}C)	0.00	0.8108	2.68	<0.0001
Day of Year	2.63	<0.0001	0.00	0.3970

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	–	–	3	4	–	–	4934	0.00	1.08
2	3	7	2	–	–	3	5	–	–	4938	4.02	1.04
3	3	7	2	–	–	3	4	–	1	4939	4.56	1.05
4	3	7	2	–	–	4	4	–	–	4943	8.53	1.08
5	3	7	2	–	–	3	5	–	1	4944	9.39	1.03
6	3	7	2	–	–	3	8	–	–	4946	11.07	1.14
NB Best	3	7	2	–	NA	NA	NA	NA	NA	5018	84.04	1.64
ZIP Best	2	7	2	–	–	3	7	–	–	5987	1052.78	1.68
Poisson Best	3	7	2	–	NA	NA	NA	NA	NA	8563	3628.24	4.41

Table 6: Red Snapper relative abundance index based on the SERFS chevron trap survey, 2010-2014, as standardized using a ZINB GLM. Index = relative abundance of Red Snapper, Bias = observed bias in bootstrap analysis. CV = coefficient of variation.

					Confidence Interval	
Year	**Index**	**Bias**	**SE**	**CV**	**Lower**	**Upper**
2010	0.6556	0.003	0.1154	0.1761	0.4131	0.8656
2011	0.6881	0.007	0.1114	0.1619	0.4455	0.8796
2012	1.1428	0.004	0.1287	0.1126	0.8762	1.3770
2013	0.9073	-0.004	0.1063	0.1172	0.6931	1.1096
2014	1.6062	-0.011	0.1699	0.1058	1.2707	1.9390

Table 7: Length composition of Red Snapper collected by the SERFS chevron rap survey from 2010-2014. Lengths are maximum (pinched) total 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.

TL (cm)	2010	2011	2012	2013	2014
19	0.00	0.00	0.00	0.00	0.16
20	0.00	0.00	0.00	0.00	0.16
21	0.00	0.00	0.00	0.00	0.00
22	0.00	0.83	0.47	0.27	0.00
23	0.00	0.00	0.47	0.00	0.32
24	0.58	0.83	0.70	0.80	1.60
25	0.00	0.83	1.40	1.60	0.80
26	0.00	0.00	3.72	0.80	1.12
27	0.00	0.00	2.79	0.80	0.96
28	0.00	0.00	2.56	1.33	1.12
29	0.00	0.83	2.33	1.60	0.96
30	0.00	0.83	1.40	1.86	0.96
31	0.58	0.00	0.70	1.60	1.12
32	0.00	0.83	1.40	2.13	1.92
33	0.00	0.00	2.56	3.46	2.08
34	1.16	0.00	0.93	3.99	2.24
35	0.00	0.00	1.86	5.32	2.72
36	0.58	0.83	3.26	4.26	3.19
37	1.16	0.00	3.49	3.46	5.27
38	0.00	0.00	3.49	2.39	4.31
39	0.00	0.00	4.65	1.33	5.27
40	0.58	0.00	4.42	1.86	7.03
41	2.89	0.83	3.26	3.99	7.83
42	1.73	0.00	1.86	1.86	7.03
43	6.36	0.00	2.09	1.60	6.55
44	5.20	1.65	3.02	0.80	4.31
45	4.62	4.13	1.63	2.13	3.19
46	5.78	0.00	0.93	1.60	1.44
47	2.31	4.13	1.16	1.60	2.72

48	3.47	2.48	0.70	2.13	1.92
49	4.62	4.13	0.23	2.13	0.80
50	6.36	3.31	0.47	1.60	0.64
51	6.36	1.65	0.23	2.13	0.32
52	6.36	4.13	0.00	0.80	0.96
53	0.00	0.00	0.00	0.53	0.00
54	5.20	6.61	0.23	0.53	0.16
55	1.73	4.13	0.70	1.33	0.16
56	2.89	3.31	0.70	0.27	0.32
57	4.05	6.61	0.47	0.27	0.32
58	2.31	5.79	0.00	0.53	0.48
59	2.89	2.48	0.93	0.53	0.32
60	2.31	5.79	0.47	0.27	0.80
61	1.16	4.13	1.63	1.06	0.16
62	3.47	2.48	2.33	0.80	0.48
63	0.00	1.65	1.40	0.53	0.16
64	1.73	2.48	2.09	1.86	0.00
65	1.73	2.48	1.63	0.27	0.16
66	1.16	1.65	1.40	0.27	0.32
67	0.58	2.48	1.40	0.00	0.48
68	0.00	0.83	0.70	0.27	0.32
69	0.00	0.00	3.26	1.60	0.48
70	1.16	3.31	3.49	0.53	0.16
71	0.58	0.83	1.86	2.39	0.16
72	2.31	0.83	1.16	1.06	0.64
73	1.16	0.83	2.79	2.66	0.96
74	0.00	1.65	0.47	1.33	0.16
75	0.58	0.83	1.40	1.86	0.96
76	0.58	0.83	1.86	3.19	1.44
77	0.58	0.00	0.93	2.66	0.96
78	0.00	2.48	1.86	1.33	1.12
79	0.00	0.83	0.70	2.13	2.72
80	0.00	0.00	0.93	1.60	0.64
81	0.00	0.83	0.93	0.53	1.28
82	0.00	0.83	0.70	1.86	0.64
83	0.00	0.00	0.47	1.33	0.16
84	0.00	0.00	0.00	0.27	0.48
85	0.00	0.00	0.23	0.00	0.64
86	0.00	0.83	0.70	0.80	0.16
87	0.00	0.00	0.23	0.80	0.48
88	0.00	0.00	0.70	0.80	0.00
89	0.00	0.00	0.23	0.53	0.00
90	0.00	0.00	0.47	0.00	0.00
91	1.16	0.00	0.00	0.27	0.16
92	0.00	0.00	0.23	0.00	0.00
99	0.00	0.00	0.23	0.00	0.00
Traps	74	70	155	143	151
Fish	173	121	430	376	626

Table 8: Age composition of Red Snapper collected by the SERFS chevron rap survey from 2010-2014. Ages are calendar ages and composition is in percent of fish in each year corresponding to a given age.

	Year				
Age	**2010**	**2011**	**2012**	**2013**	**2014**
0	0.00	0.00	0.00	1.63	0.16
1	0.60	2.50	5.05	21.47	16.26
2	13.17	5.83	37.74	31.25	42.44
3	48.50	33.33	15.38	11.14	22.44
4	23.35	38.33	8.89	4.35	3.41
5	11.38	14.17	18.75	10.05	1.63
6	1.20	4.17	7.69	9.24	3.25
7	0.00	0.00	2.88	5.71	4.07
8	0.60	0.00	0.24	1.63	3.90
9	0.00	0.83	0.72	0.00	1.30
10	0.00	0.00	0.00	0.27	0.00
11	1.20	0.00	0.00	0.82	0.16
12	0.00	0.00	0.00	0.54	0.49
13	0.00	0.00	0.72	0.27	0.00
14	0.00	0.00	0.24	0.27	0.33
15	0.00	0.00	0.48	0.27	0.00
16	0.00	0.00	0.00	0.54	0.00
17	0.00	0.00	0.24	0.00	0.00
18	0.00	0.00	0.24	0.00	0.00
19	0.00	0.00	0.24	0.00	0.16
21	0.00	0.83	0.24	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.27	0.00
25	0.00	0.00	0.24	0.00	0.00
26	0.00	0.00	0.00	0.27	0.00
Traps	73	70	148	139	150
Fish	167	120	416	368	615

Figures

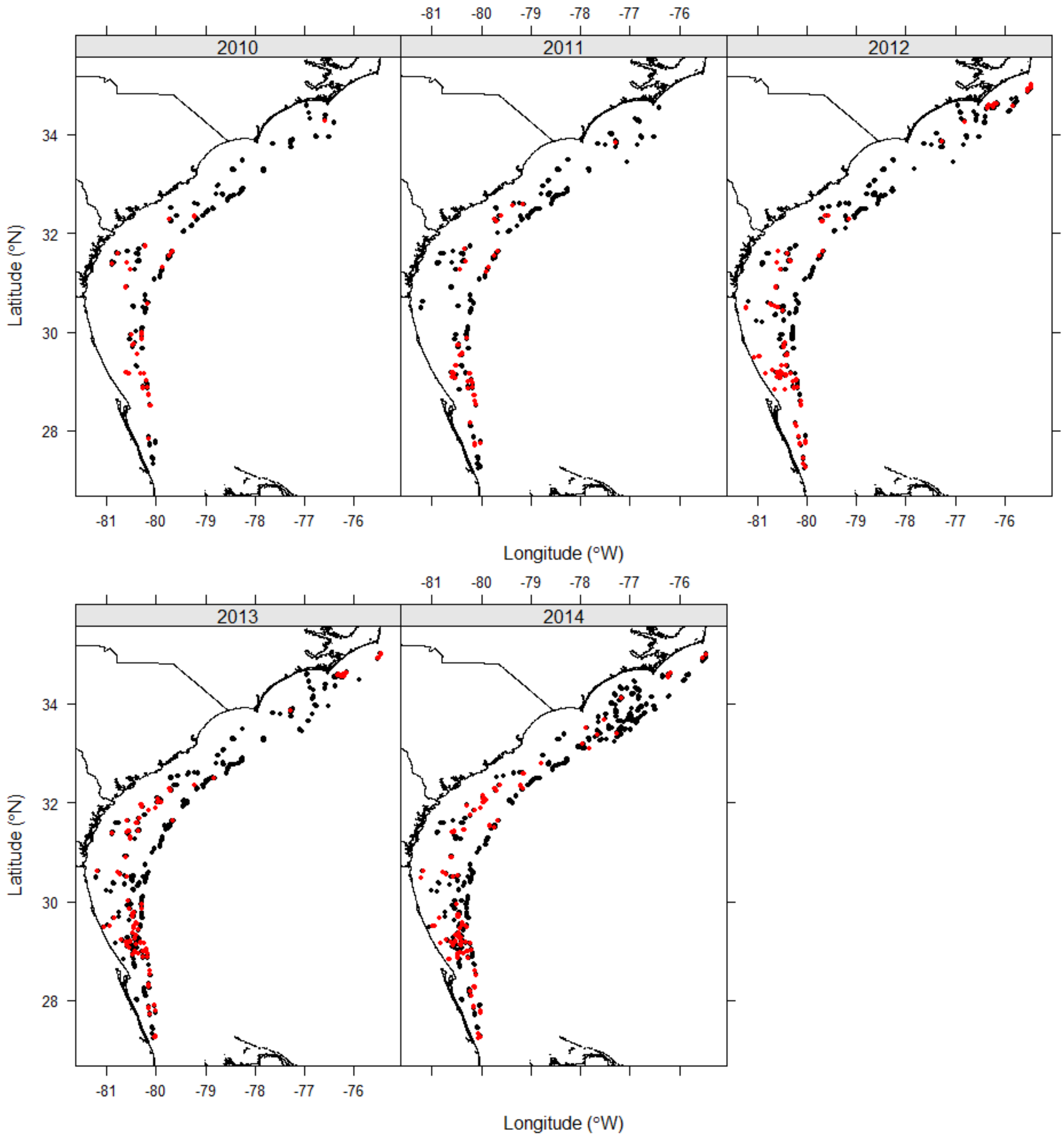


Figure 1: Annual sampling distribution of the SERFS chevron trap survey from 2010-2014. Black dots represent samples absent of Red Snapper. Red dots represent samples where Red Snapper were captured.

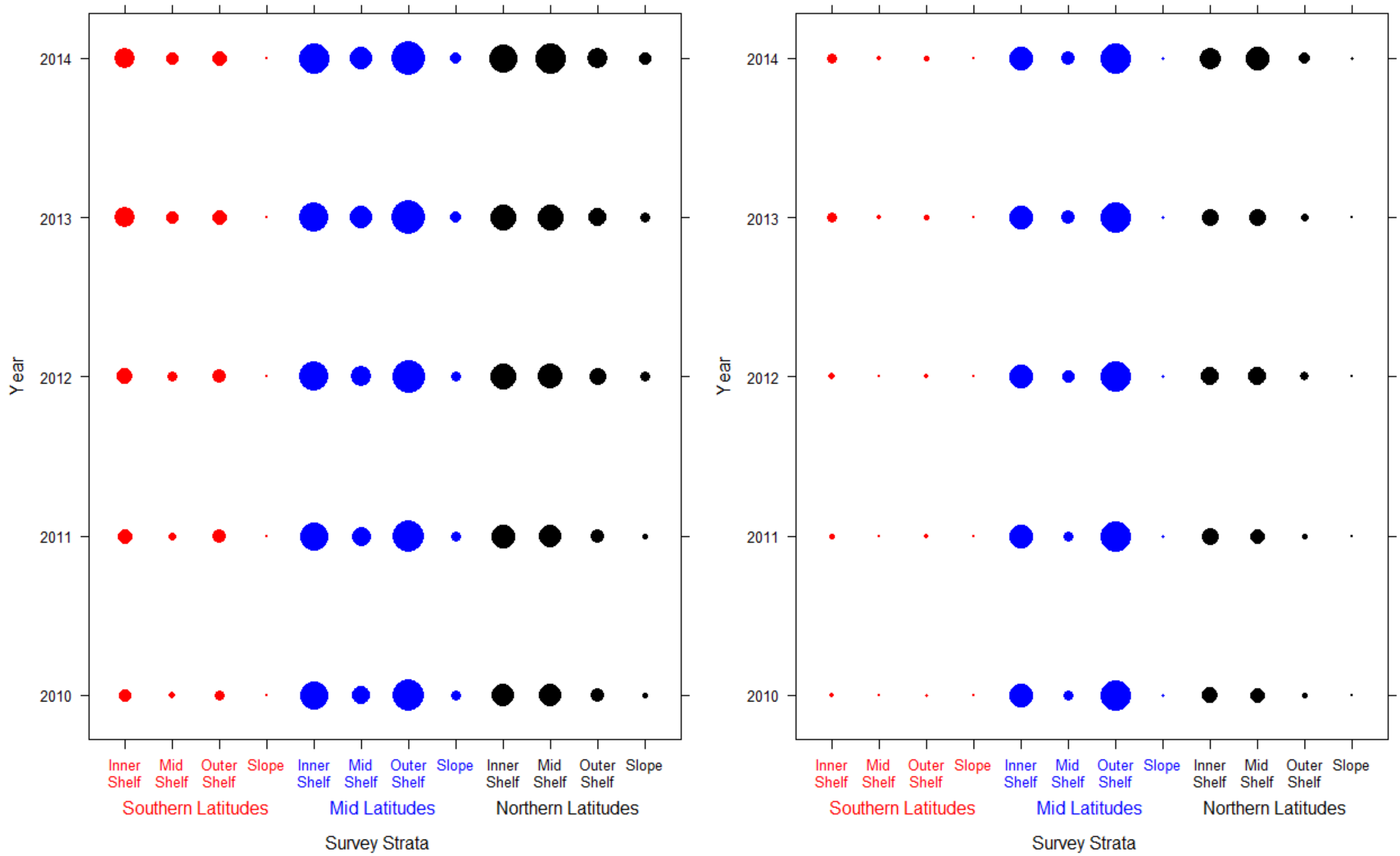


Figure 2: Distribution of SERFS chevron trap stations according to latitude and depth strata. Left panel – area of each circle is proportional to the total number of stations found in the stratum. Right panel – size of each circle in each year is proportional to the stratum possessing the maximum number 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.

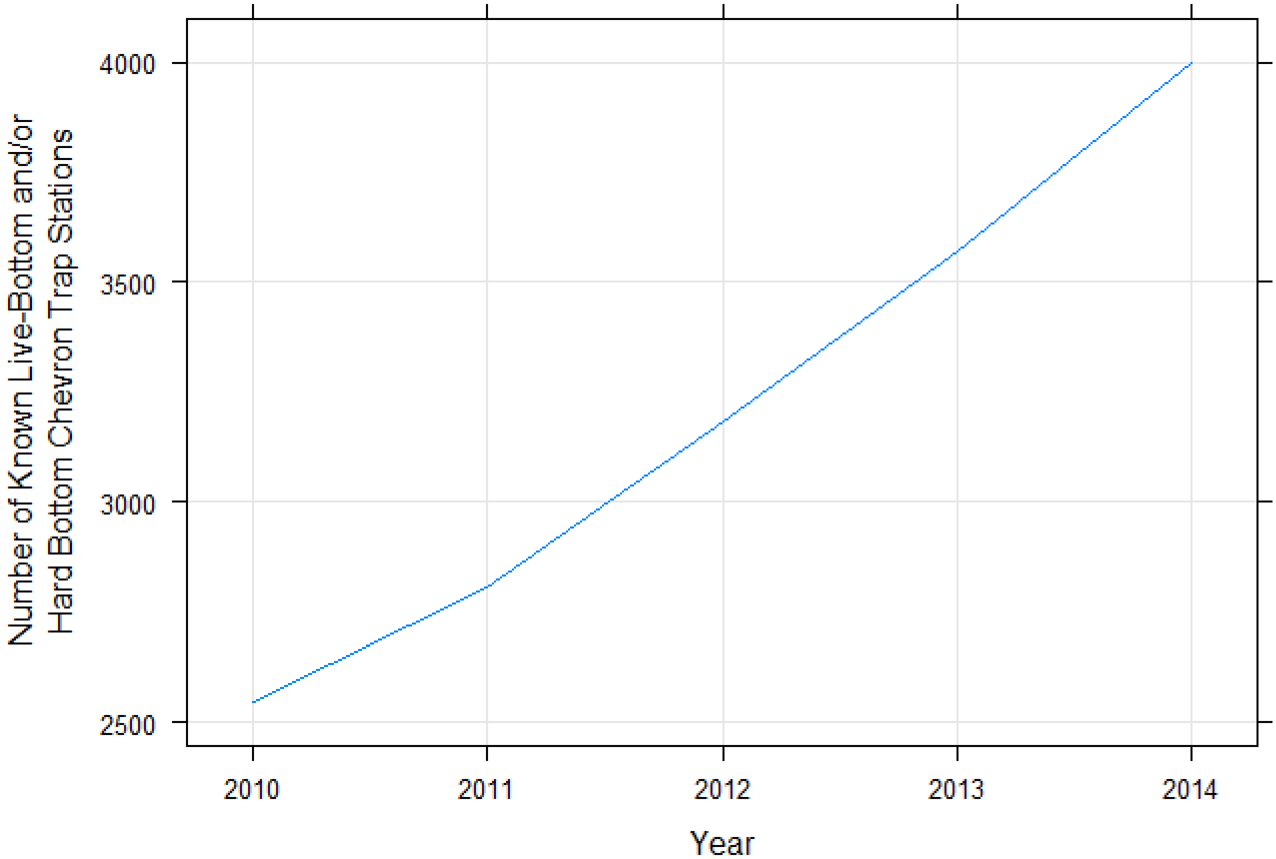


Figure 3: Time series of the number of stations composing the SERFS chevron trap station universe (locations with known live-bottom and/or hard-bottom habitat suitable for sampling via chevron traps). The drastic increase in known live-bottom and/or hard bottom stations since 2009 is driven primarily 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.

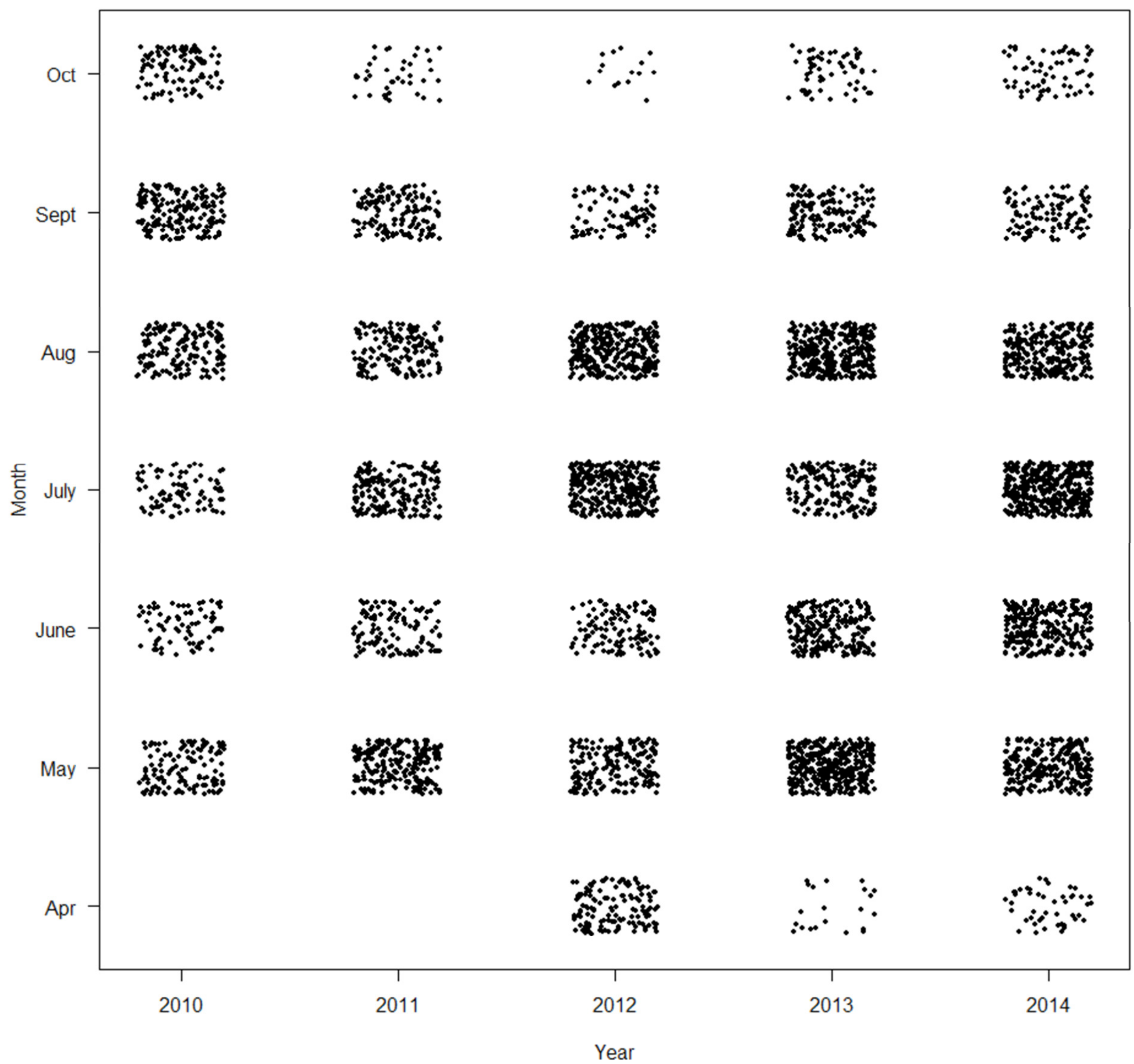


Figure 4: Distribution of chevron trap samples by month and year. Individual data points are jittered to create a cloud to give a sense of the total sample size by month and year combination.

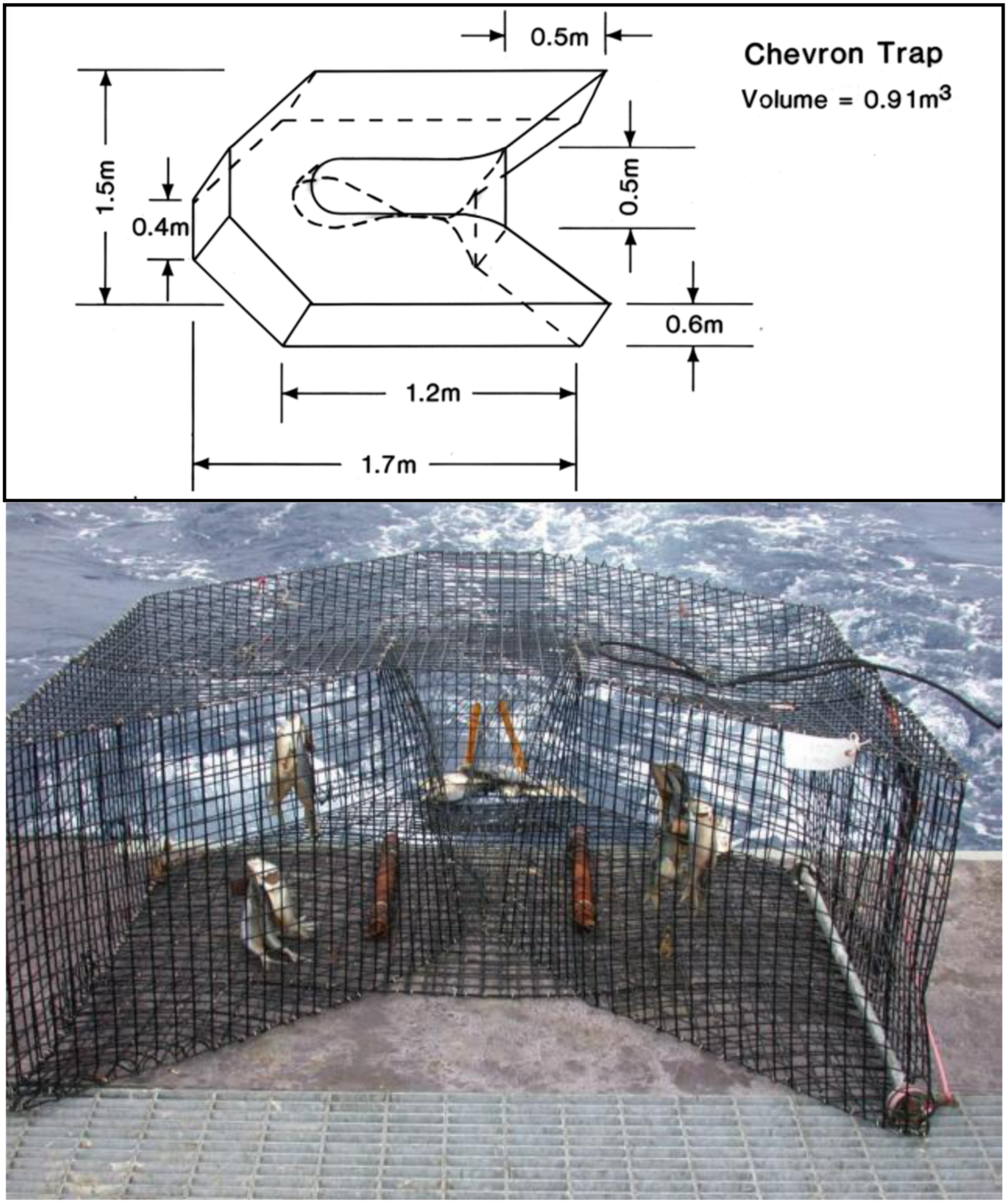


Figure 5: Chevron traps used by SERFS for monitoring reef fish. A. Diagram with dimensions. B. Chevron trap ready for deployment baited with clupeids. Iron sashes attached to the bottom weigh the trap down and help maintain the proper orientation of the trap on the bottom.

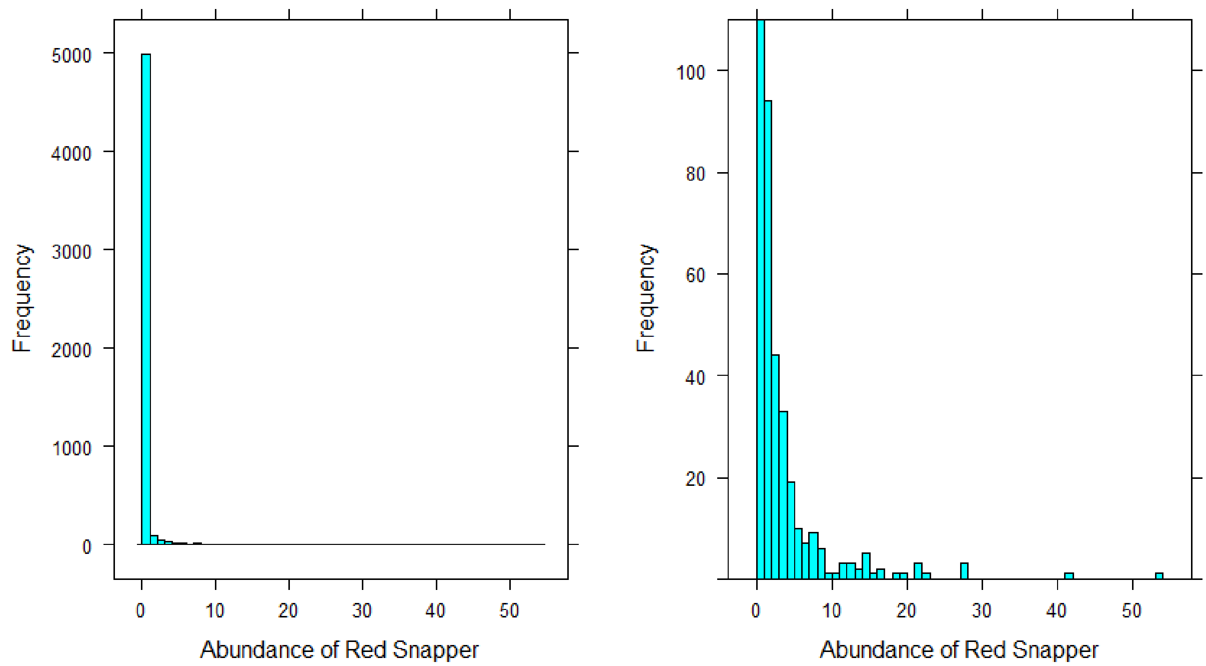


Figure 6: Frequency of occurrence of chevron traps with a given catch of Red Snapper. Left panel – full distribution showing the excess zeros; Right panel – restricted distribution better depicting frequency of traps with a given catch of Red Snapper

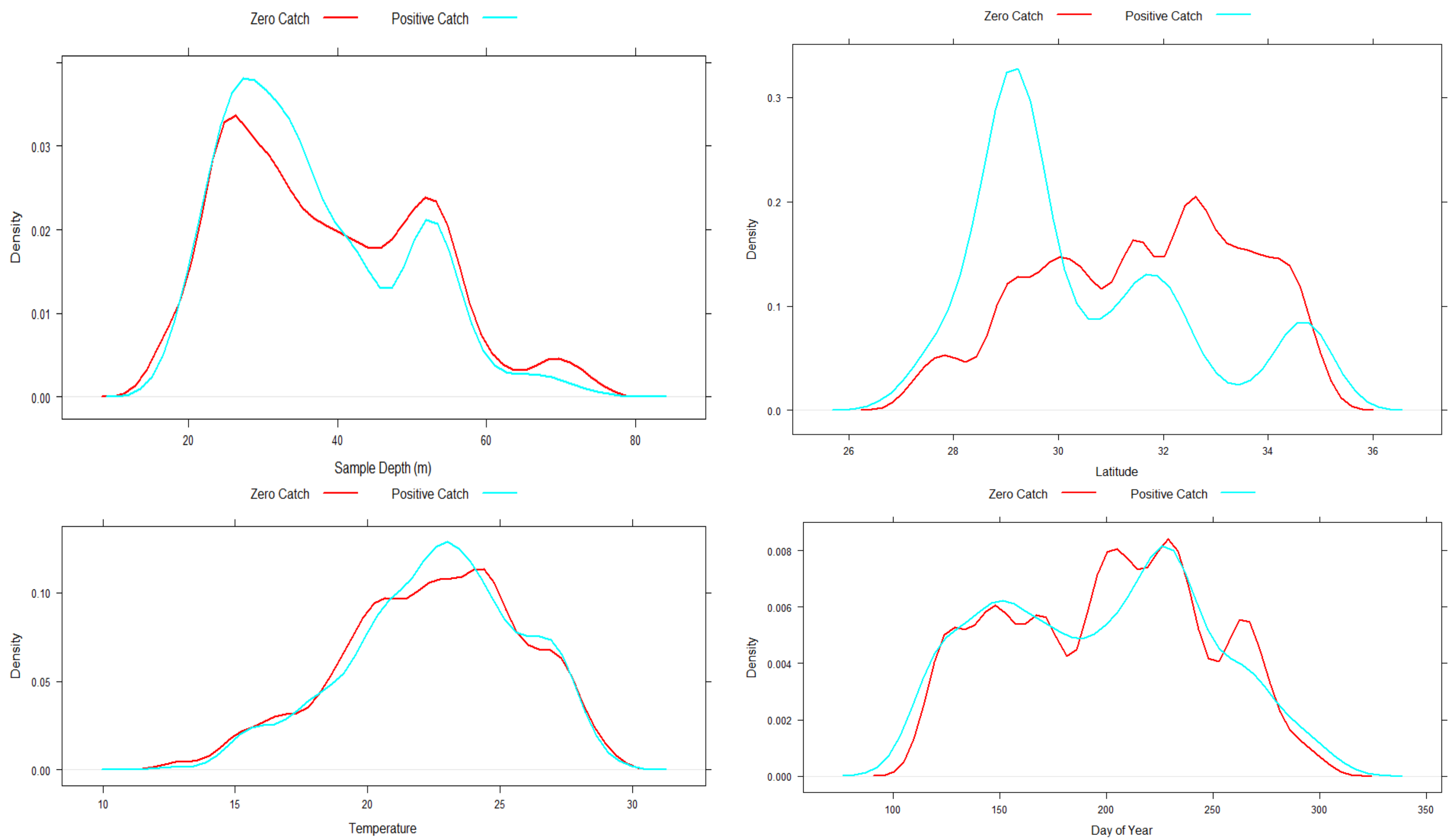


Figure 7: Density plots of traps negative and positive for Red Snapper with respect to each covariate considered in the model.

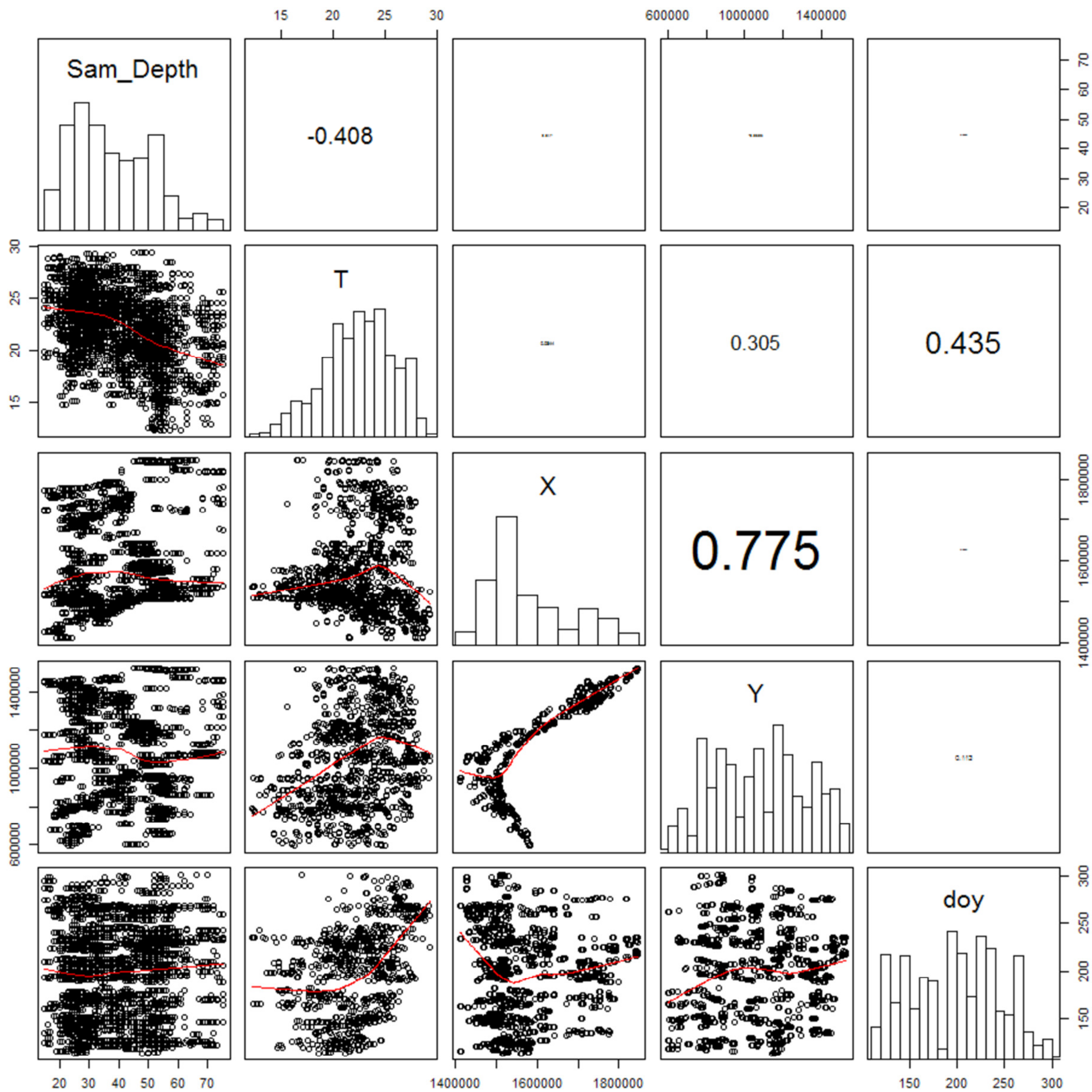


Figure 8: Pairs plot depicting the correlation among several variables available for consideration as covariates in the relative abundance index standardization model. Upper triangle presents the observed correlation among pairs of variables, with text size reflecting degree of correlation. Diagonal 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.

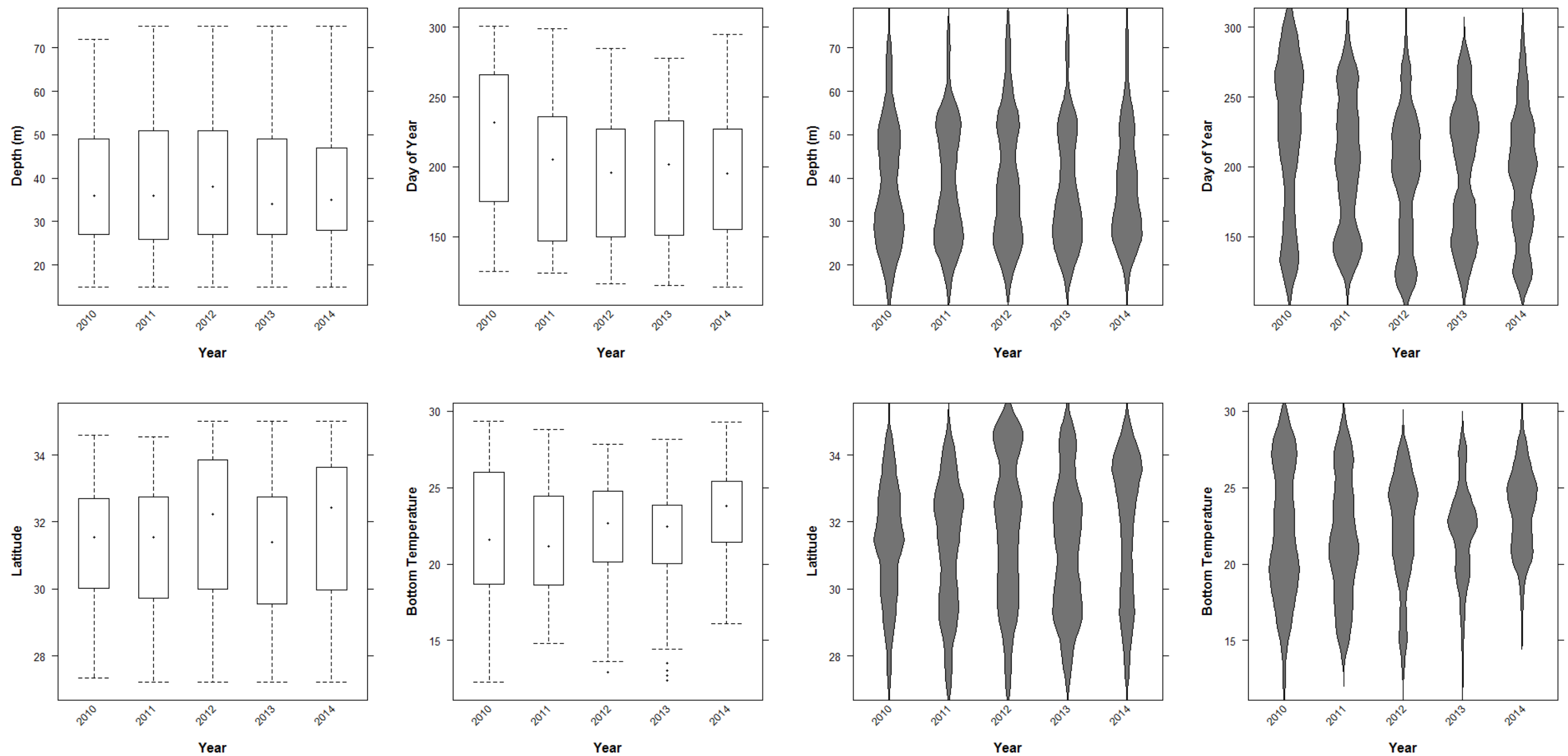


Figure 9: Box plots (left panel) and violin plots (right panel) of depth, latitude, bottom temperature, and day of year as a function of year.

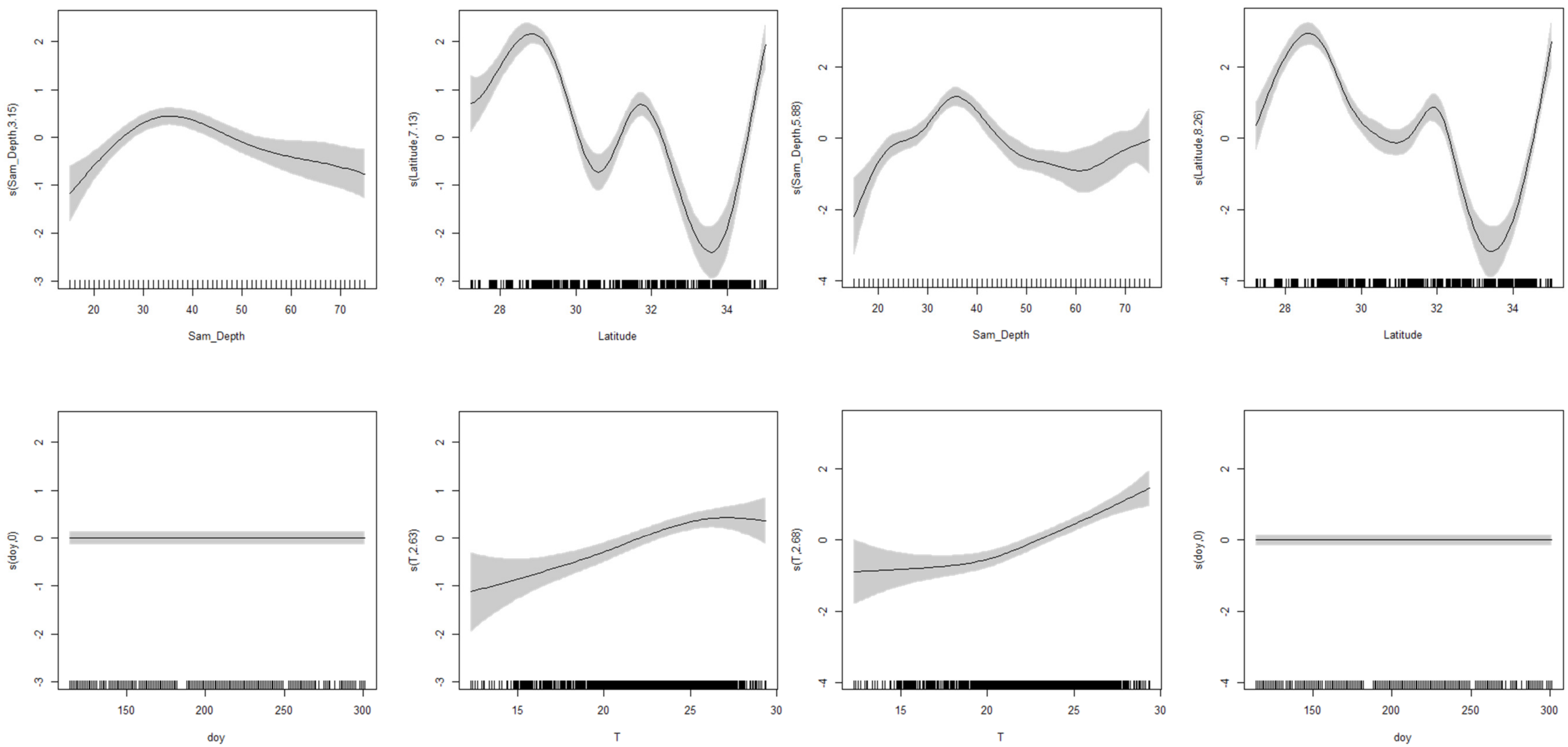


Figure 10: Preliminary GAM analysis predicted relative effects of covariates on the presence/absence (left 4 plots) and abundance (catch; right 4 plots) of Red Snapper in chevron traps. Rug on the bottom of each of the plot gives a sense of the distribution of each of the covariates in the data set.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

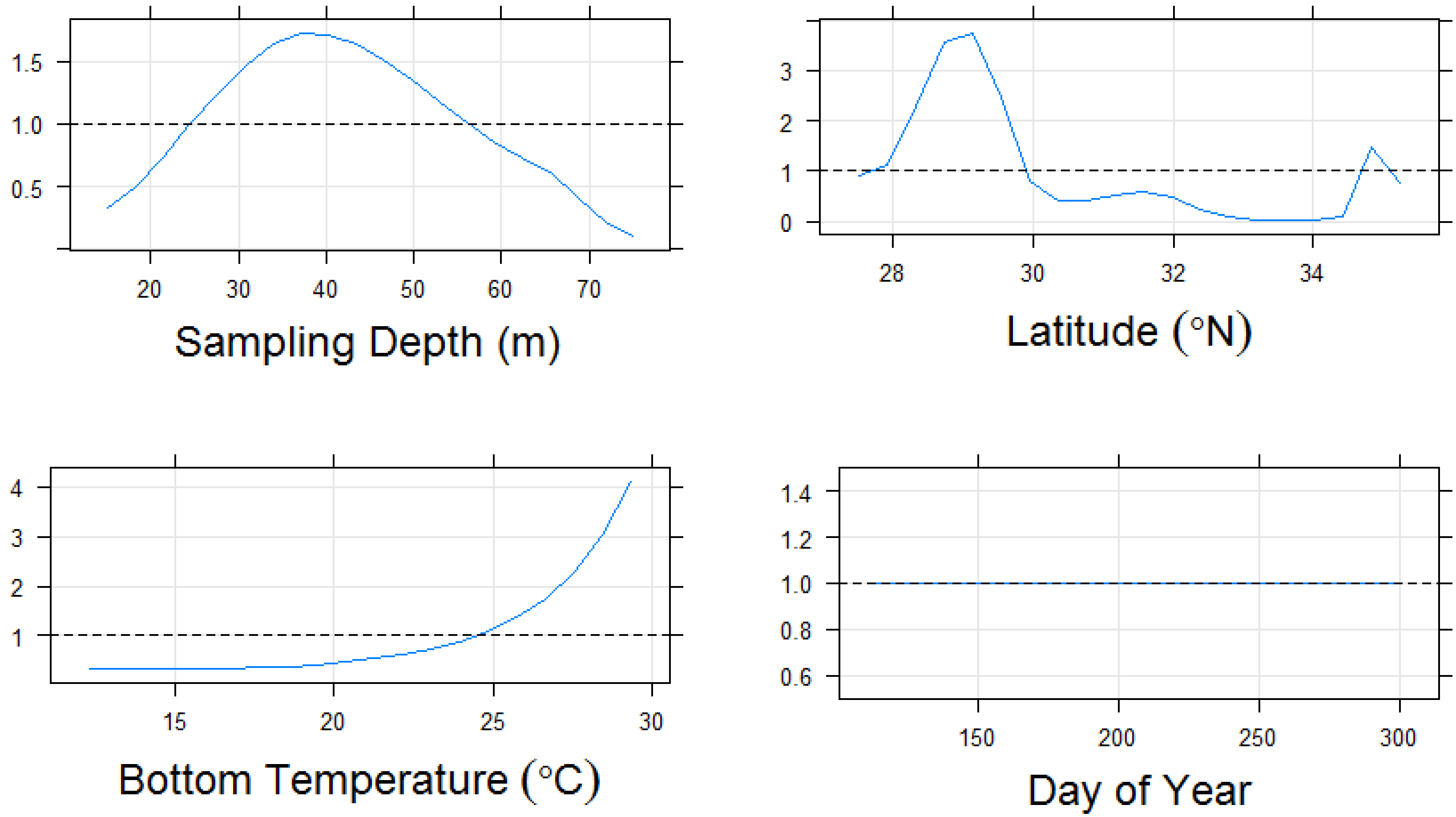


Figure 11: Predicted relative effect of each covariate on the catch of Red Snapper in chevron traps. Note that the scale of the y-axis changes among panels, and hence y-axis scale can provide an indication of the magnitude of the effect of individual covariates. The covariate day of year was not retained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

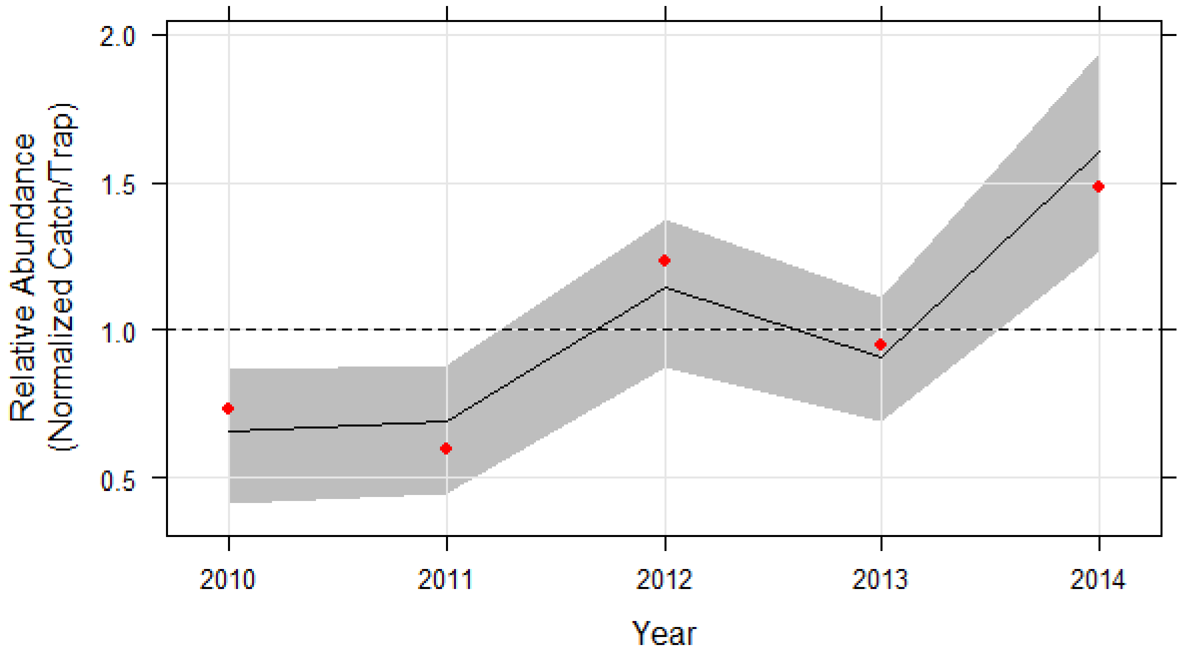


Figure 12: Red Snapper index of relative abundance based on the SERFS chevron trap survey during the years 2010-2014. The ZINB standardized catch (sold black line) is normalized to the average relative abundance, as estimated by the model, during the period 2010-2014. Red dots represent normalized nominal annual relative abundance. Gray shaded region represents the 95% confidence interval of annual relative abundance based on 10,000 bootstraps.

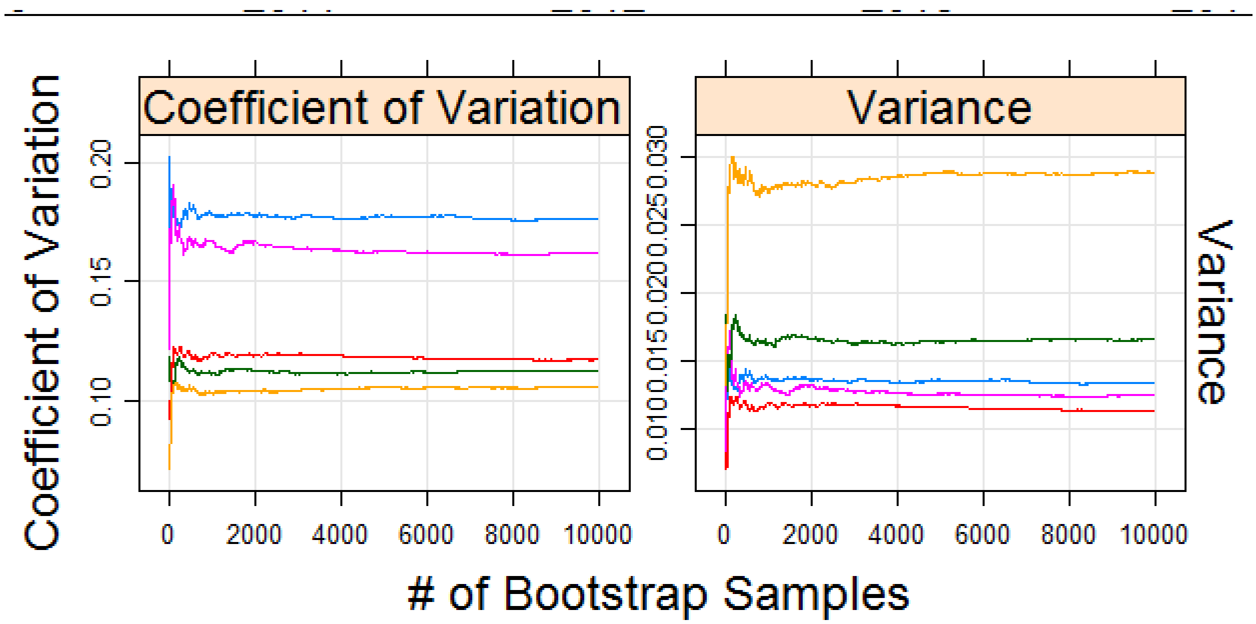


Figure 13: Bootstrap diagnostic plots used to determine if coefficient of variation (CV; left) and variance (left) estimates stabilized over the number of bootstrap iterations run. Each line represents an individual year in the survey.

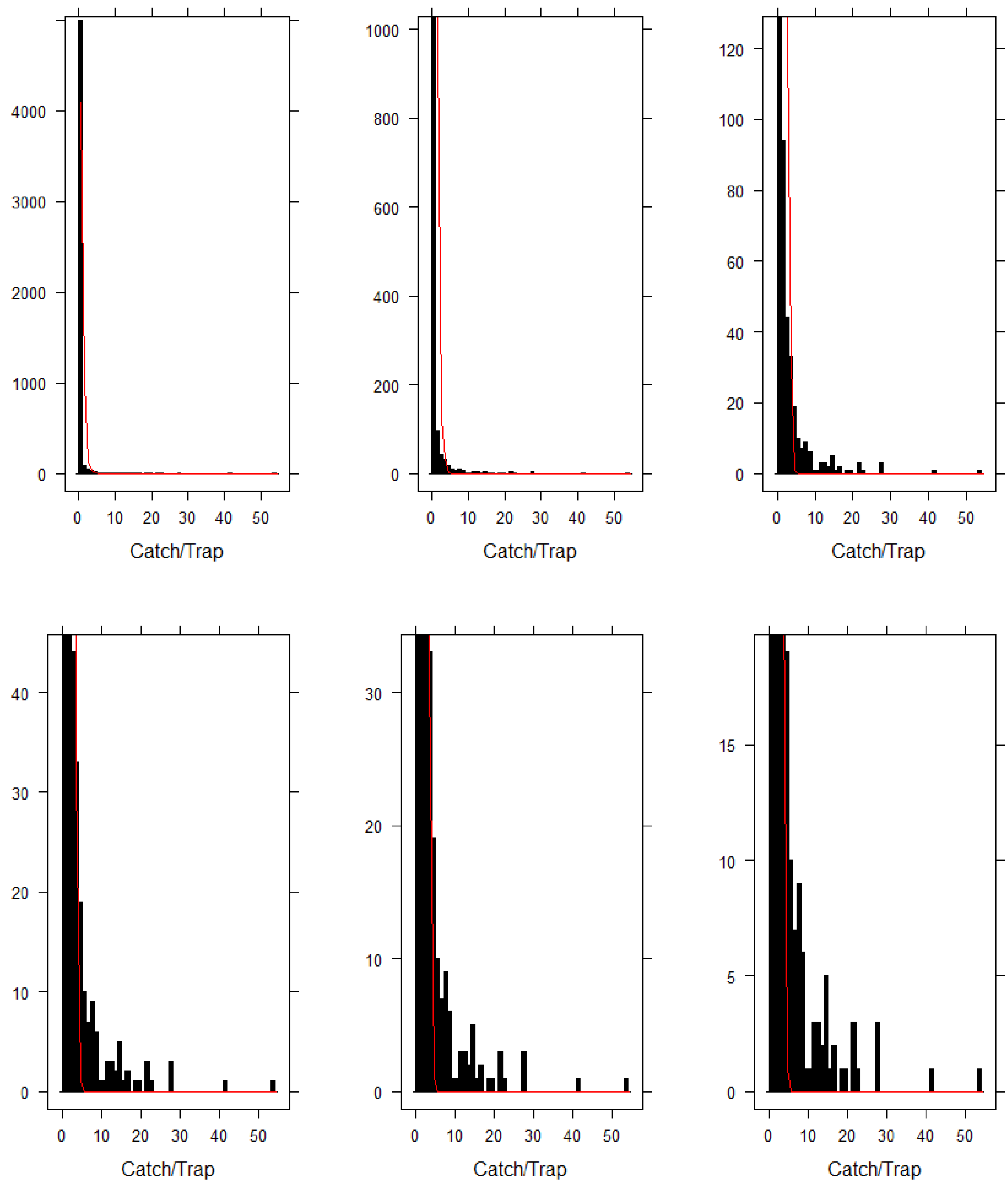


Figure 14: Frequency of traps observed (black bars) with a given catch of Red Snapper or predicted by the ZINB (red line). Plots present the same data, with the y-axis truncated to better resolve low frequencies as one moves across rows and down columns starting with the top left plot.

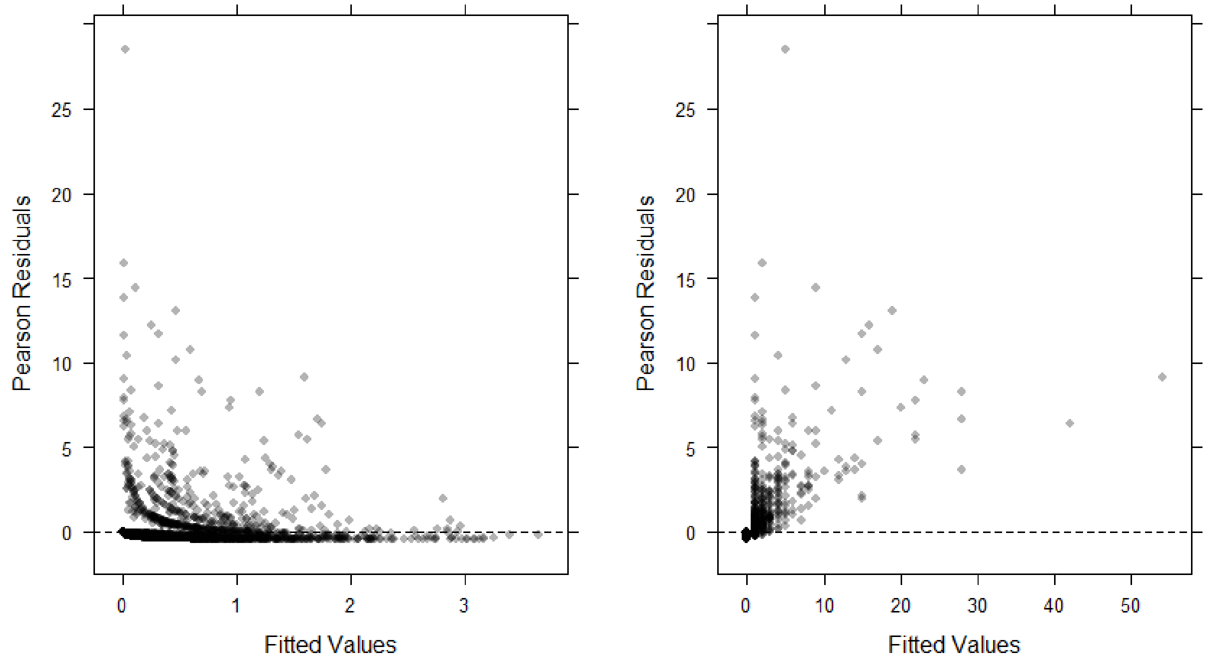


Figure 15: Model diagnostic plots showing fitted model values (left plot) and observed data (right plot) versus Pearson's residuals for the ZINB GLM model.

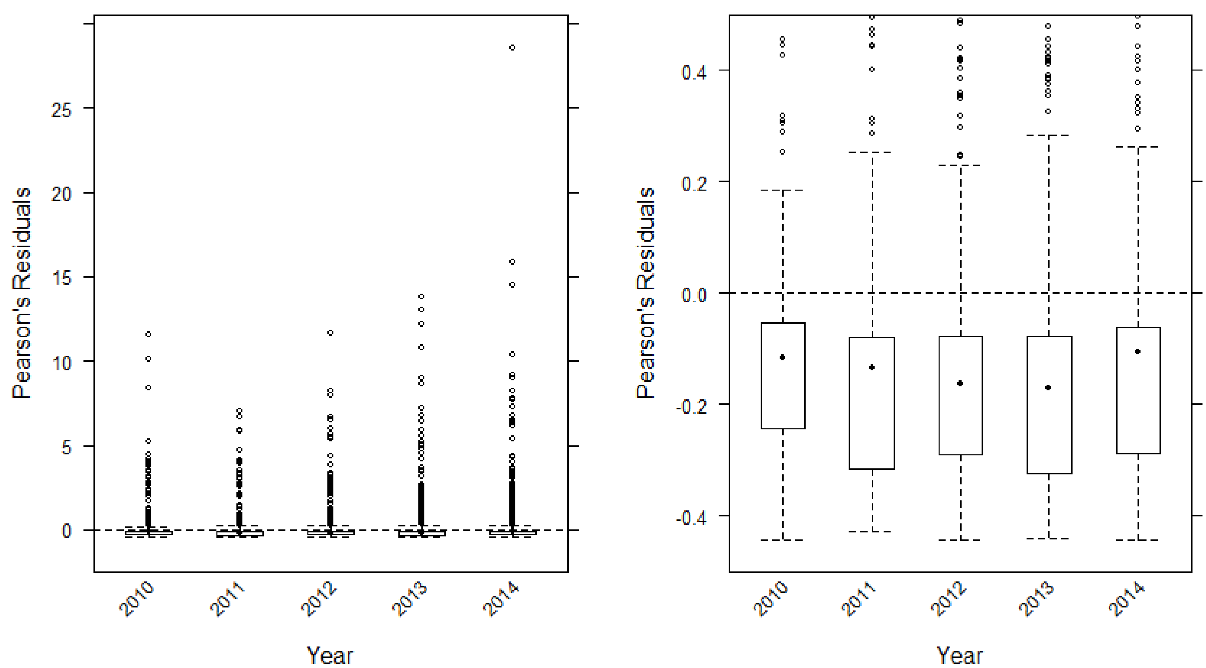


Figure 16: Model diagnostic plot showing Pearson's residuals versus year for the final ZINB model. Left – full residual scale; Right – restricted residual scale.

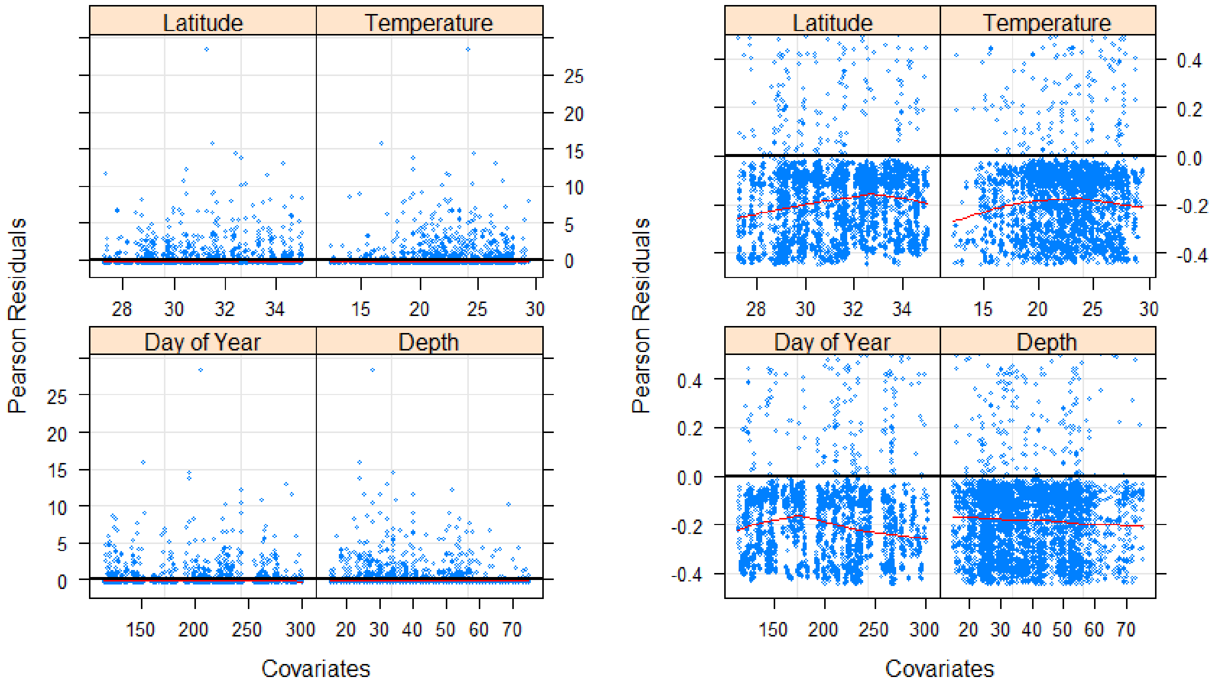


Figure 17: Pearson’s residuals versus covariates included in the final ZINB GLM.

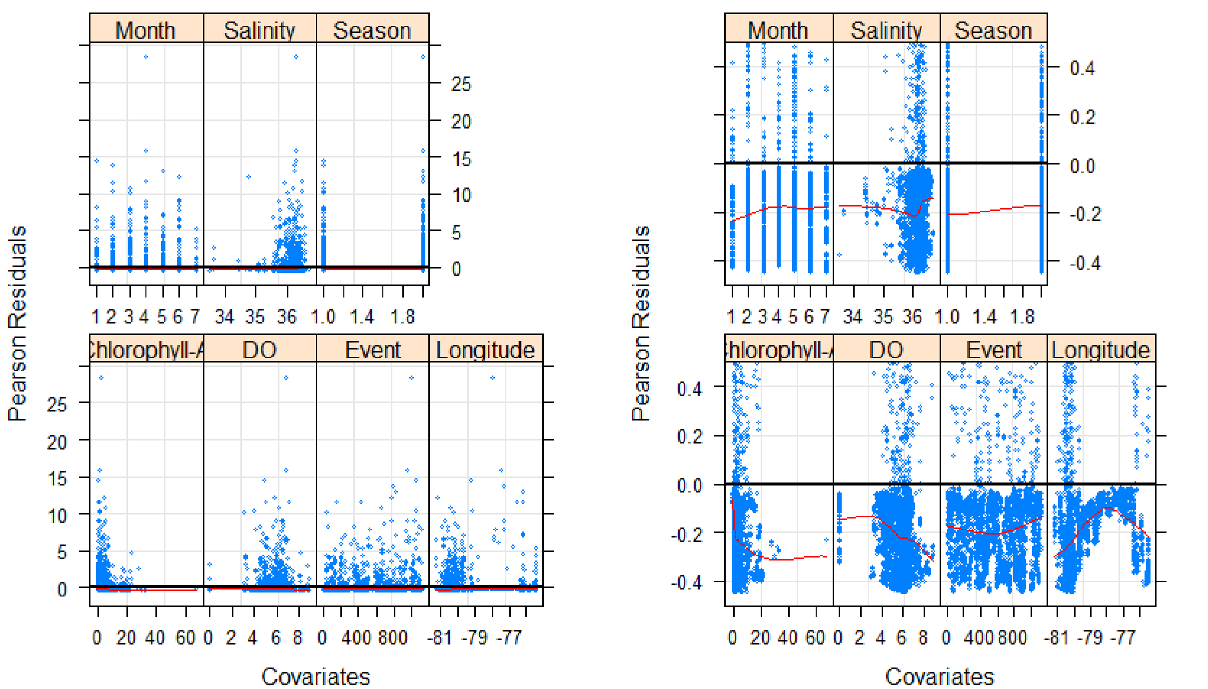


Figure 18: Pearson's residuals versus covariates excluded from the final ZINB GLM.

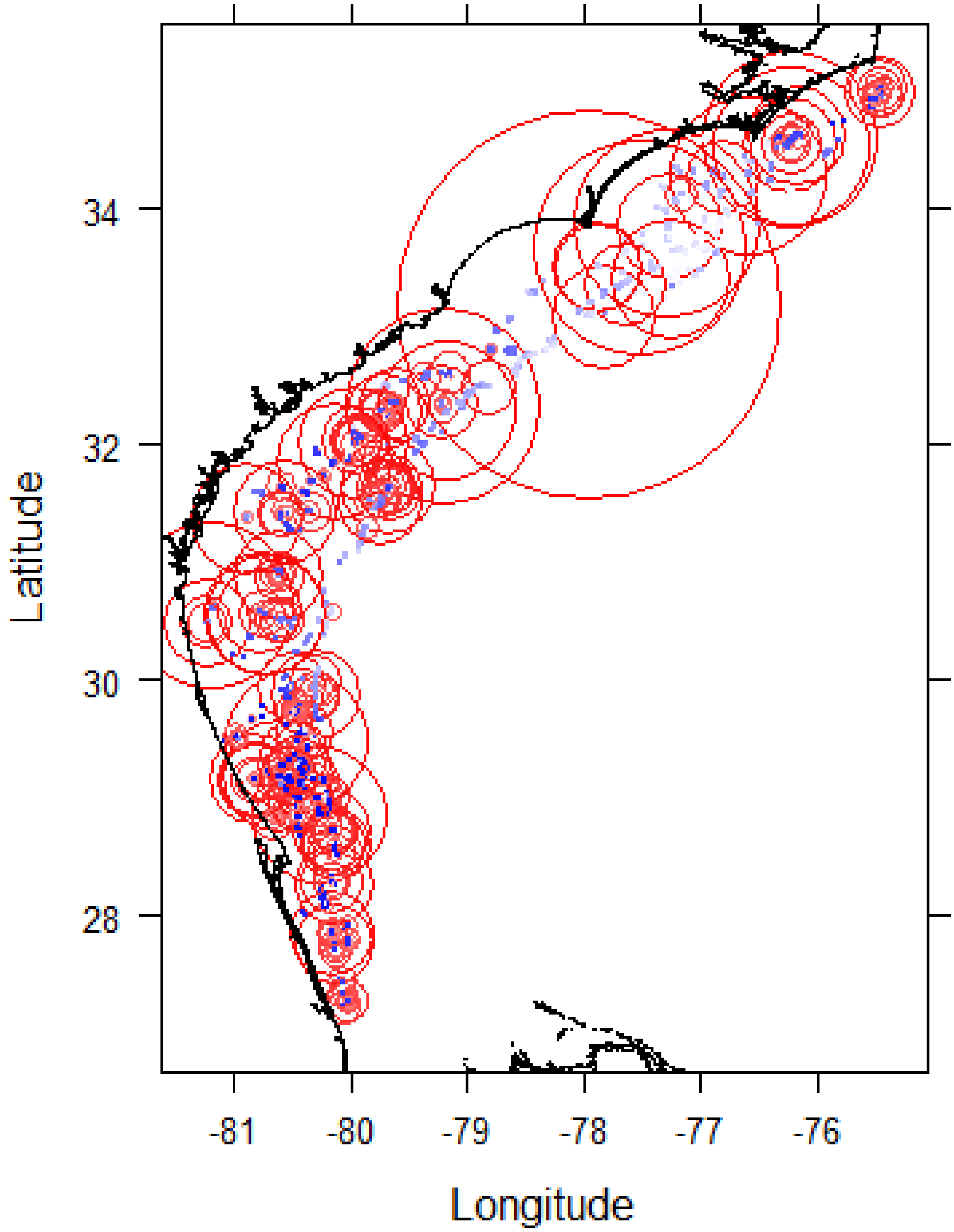


Figure 19: Spatial distribution of Pearson's residuals. Red circles indicate positive Pearson's residuals and blue circles represent negative Pearson residuals. Size of the circle is indicative of the magnitude of the residual with larger circles corresponding to larger absolute value Pearson's residual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

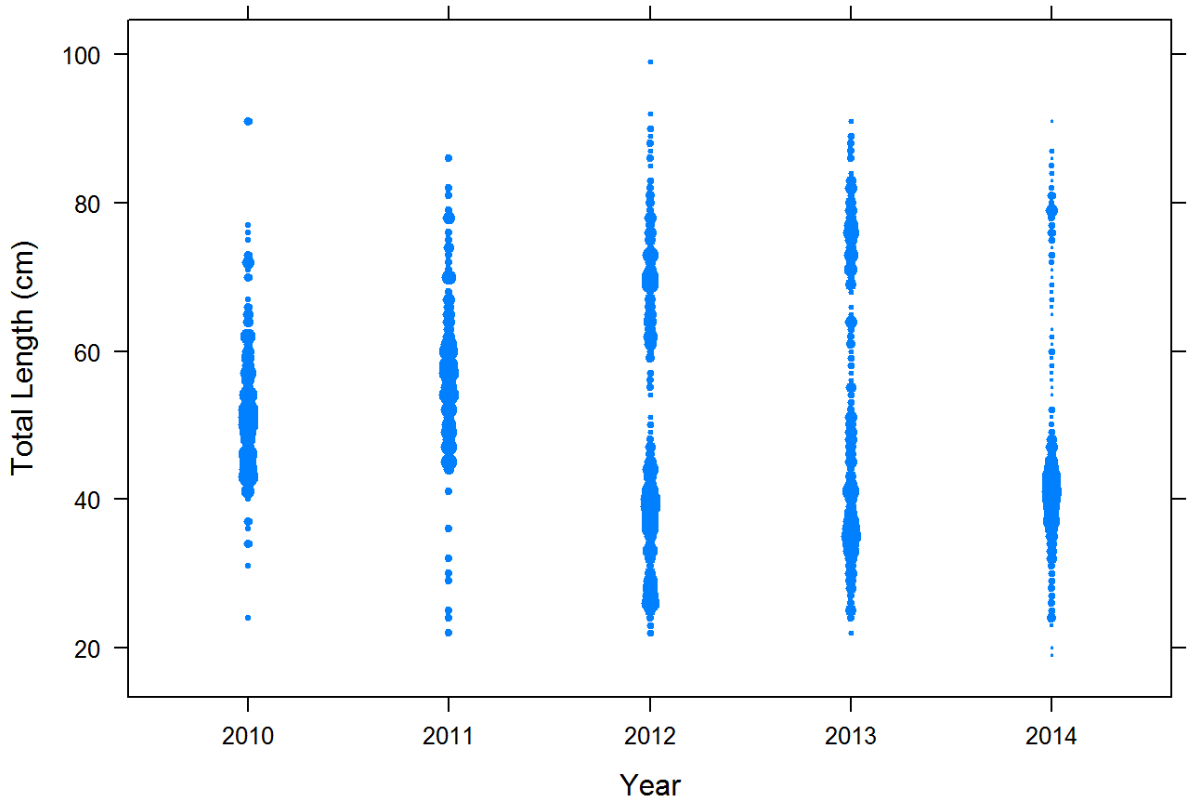
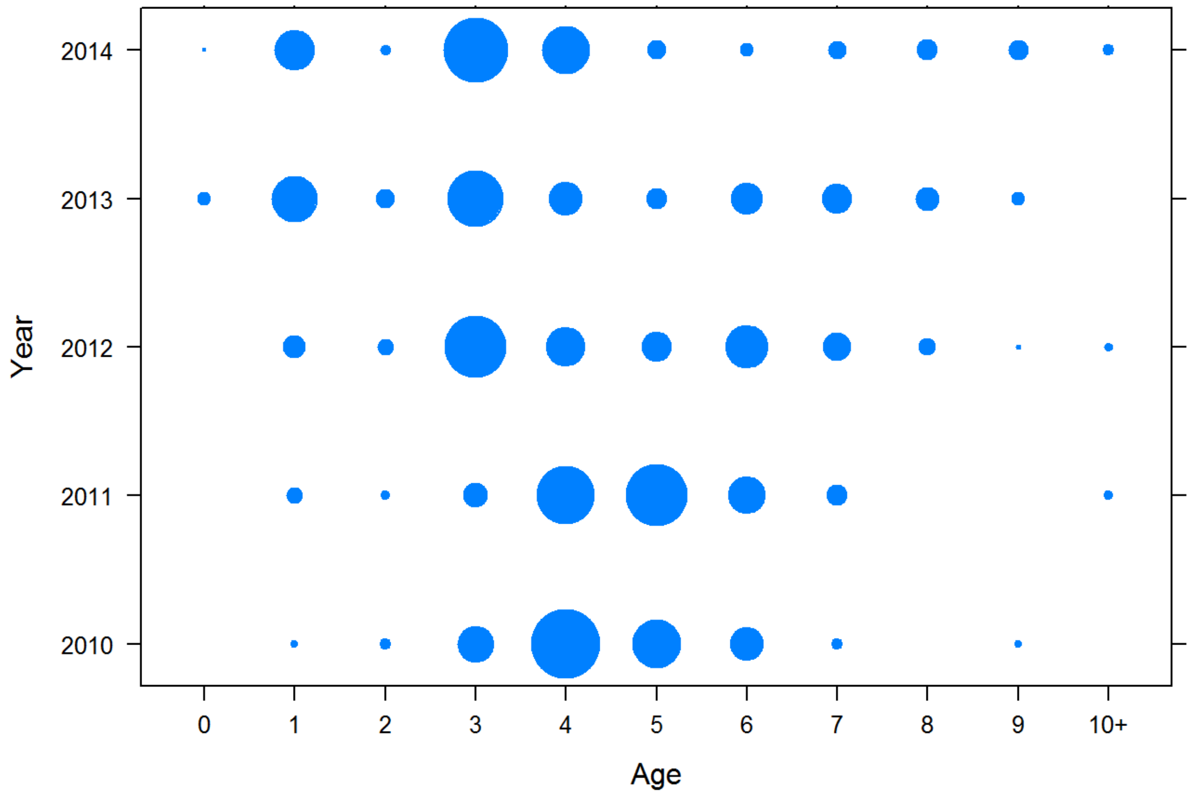


Figure 20: Observed length composition of Red Snapper catch via the SERFS chevron trap survey.



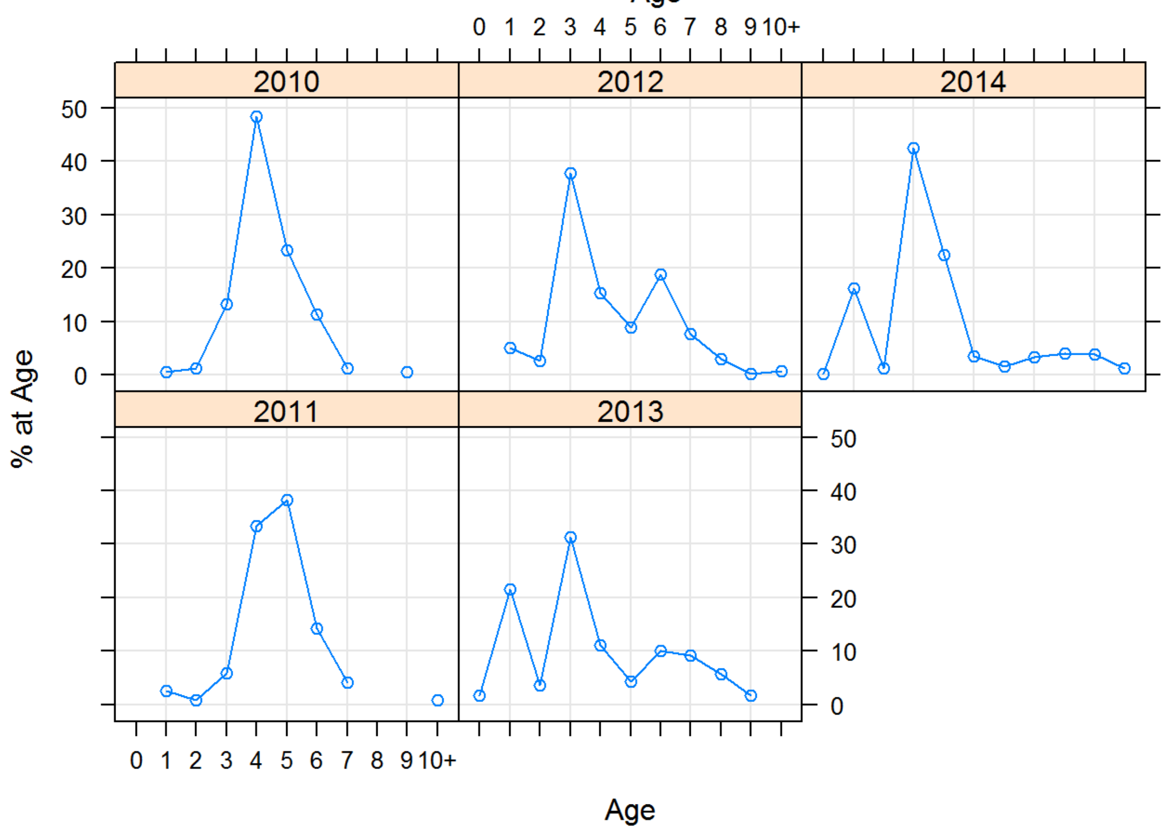


Figure 21: Age composition of Red Snapper captured via the SERFS chevron trap survey during the period 2010-2014. Top panel – area of circle represents percentage of fish at a given age in a given year. Bottom panel –% of fish in an age group by year.