Spanish Mackerel Indices of Abundance in U.S. South Atlantic Waters Based on the SEAMAP-SA Fishery-independent Coastal Trawl Survey

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Introduction

The Southeast Area Monitoring and Assessment Program, South Atlantic (SEAMAP-SA) is a federally-funded program for collection, management, and dissemination of fishery-independent data and information in the Atlantic waters of the southeastern United States. The SEAMAP-SA Coastal Trawl Survey (CTS) run by the South Carolina Department of Natural Resources collects fishery-independent data concerning species abundance, size, and age in trawlable coastal habitats off the U.S. Southeast coast (i.e. South Atlantic). The focus of this report is on the development of annual abundance indices for juvenile Spanish Mackerel (*Scomberomorus maculatus*) based on the SEAMAP-SA CTS from 1989 to 2019. During SEDAR 28, the panel recommended producing separate indices for Age 0 and Age 1 juveniles and used the delta-Generalized Linear Model (dGLM) approach with the abundance in the full data set being divided into the two age classes based on the length frequency of the catch with the length cutoffs based on age estimates known at the time. Since SEDAR 28, the SEAMAP-SA CTS has collected a subset of Spanish Mackerel to estimate ages and age-length relationships to better inform these indices as previous age estimates did not include many juveniles. The current index formulations used these ages to update the length cut-offs applied to catches. The SEDAR 78 panel also suggested authors investigate the zero-inflated negative binomial (ZINB) index development methods used in many recent SEDARs. Here, we present four standardized indices of abundance for juvenile Spanish Mackerel, a dGLM and a ZINB for Age 0 and a dGLM and a ZINB for Age 1.

Methods

Sample Collection by SEAMAP-SA Coastal Trawl Survey

For full sampling details, see Zimney (2021)

- Simultaneously fished 22.9 m mongoose-type Falcon trawl nets; mesh size of net body #15 twine, 1.875 cm stretch mesh from R/V *Lady Lisa* at target speed of 2.5 knots
- Trawls conducted during daylight hours for ~20 minutes
- Depths between ~4 and 10 m (only inner stratum used)
- Randomly selected stations within 24 latitude-based strata between Cape Hatteras, NC and Cape Canaveral, FL
- Three seasons each year: Spring (April-May), Summer (July-August), and Fall (September-November)
- Each net's catch processed independently with all finfish, elasmobranchs, decapod and stomatopod crustaceans, and cephalopods sorted to species (limited exceptions to genus only), counted, and weighed
- Length frequency is recorded to the nearest cm for priority species, including Spanish Mackerel (fork length, FL)
- Abundance, weight, and length-frequency data is recorded utilizing electronic measuring boards
- A subset of all Spanish Mackerel were dissected for otoliths and gonads based on 1-cm FL length bins with 2 fish per bin per stratum per season kept since 2010

- During each trawl, a CTD measures bottom temperature and bottom salinity

Data Filtering

- Response variable: fish per tow where number is sum of fish for both nets combined
- Dependent variables: Year, Season/Day of Year (DOY), Stratum/Latitude (°), Bottom Temperature (°C), Bottom Salinity (ppt), Area Swept (ha)
- Time Series and Season: 1989-2019 for Age 0 and 1990-2019 for Age 1
    - Spring 1989 trawls were conducted at nighttime before daytime became the standard operating procedure
    - Age 0 Spring percent positive is <0.5%, and so Spring was not used for Age 0, allowing the use of 1989 data
    - All Seasons were included in the Age 1 index, not allowing the use of 1989
- Age-specific length cutoffs (FL) updated from SEDAR 28 based on known length distributions of aged fish including juveniles (Fig. 1):
    - Age 0 = Spring <18 cm, Summer <26 cm, and Fall <33 cm
    - Age 1 = Spring ≥18 cm, Summer 26-40 cm, and Fall 33-43 cm
- Removed tows with small Area Swept, <1 ha, indicating issues with the tow

Delta-GLM Standardization (based on SEDAR 28 methods)

- Area Swept used as an offset term
- Season used as a categorical variable
- Strata grouped into 6 Latitude Bins
    - lat29=21,23,25,27; lat30=29,31,33; lat31=35,37,39; lat32=41,43,45,47; lat33=49,51,53,55,57; lat34=59,61,63,65,67
- Bottom Temperature and Salinity used as continuous variables
- Compared lognormal and gamma error distributions
    - Lognormal selected for both Age 0 and Age 1
- Final model selection based on backwards selection and AIC
- Bootstrapping used to compute coefficients of variation and standard errors
- R version 3.6.3
- For more details, see Lo et al. (1992).

Zero-Inflated Standardization

- Area Swept used as an offset term
- DOY, Latitude, Bottom Temperature, and Bottom Salinity used as continuous variables
- Compared negative binomial and Poisson error distributions
    - Negative binomial selected for both Age 0 and Age 1
- Final model selection based on BIC
- 5,000 bootstraps used to compute coefficients of variation and standard errors
- Both Age 0 and Age 1 models had a convergence rate of 100%
- R version 4.1.0

- For more details, see Ballenger et al. (2014).

Results

Spanish Mackerel juveniles generally were widely distributed across the region sampled by the SEAMAP-SA CTS (Figs 2 & 3). Both dGLM and ZINB standardization reduced the error around annual abundance values relative to nominal estimates for both age classes. Both models showed no issues with fit or convergence and were generally consistent in their trends. The ZINB model tended to fit more closely to nominal values than the dGLM (Figs 6 & 7). There was no consistent trend in standard errors being improved by using a ZINB model over the dGLM, nor were errors worse using the ZINB (Tables 1 & 2). This is likely the impact of both the relatively high percent positives for each age class and the stratified random sampling design of the survey.

Literature Cited

Ballenger, J.C., W.J. Bubley, T.I. Smart, and M.J.M. Reichert. 2014. Gray Triggerfish fishery-independent index of abundance in the US South Atlantic waters based on a chevron trap survey. SEDAR41-DW05. SEDAR, North Charleston, SC. 65 pp.

Lo, N., L. Jacobson, and J. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Sciences. 49: 2515-2526.

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Table 1. Sampling, percent positive, dGLM, and ZINB index values from the SEAMAP-SA Coastal Trawl Survey for Age 0 Spanish Mackerel. "Norm" values are those normalized to the grand mean of the full times series.

Age 0 Sampling			Age 0 Nominal Abundance				Age 0 Delta-GLM Index				Age 0 ZINB Index			
Year	n	% Pos	Mean	SE	Norm Mean	Norm SE	Index	SE	Norm Index	Norm SE	Index	SE	Norm Index	Norm SE
1989	52	96.2	6.04	1.77	1.33	0.39	4.98	0.79	1.21	0.19	5.24	1.22	1.16	0.27
1990	153	63.4	7.96	1.60	1.75	0.35	6.03	0.89	1.46	0.22	7.38	1.38	1.64	0.30
1991	155	60.7	10.78	2.02	2.37	0.44	7.26	1.20	1.76	0.29	9.95	1.60	2.21	0.34
1992	155	46.5	6.41	2.19	1.41	0.48	4.14	0.73	1.00	0.18	7.44	2.67	1.65	0.56
1993	156	46.2	3.56	0.55	0.78	0.12	3.81	0.63	0.92	0.15	3.56	0.55	0.79	0.12
1994	156	51.3	3.64	0.70	0.80	0.15	3.43	0.51	0.83	0.12	3.61	0.63	0.80	0.14
1995	156	56.4	6.69	1.04	1.47	0.23	5.31	0.85	1.28	0.21	6.12	0.99	1.36	0.22
1996	151	56.3	3.81	0.78	0.84	0.17	3.83	0.52	0.93	0.13	3.55	0.64	0.79	0.14
1997	155	32.3	1.77	0.58	0.39	0.13	1.46	0.28	0.35	0.07	1.63	0.56	0.36	0.12
1998	155	45.8	3.05	0.52	0.67	0.11	3.89	0.64	0.94	0.16	3.58	0.67	0.80	0.15
1999	156	44.9	3.99	0.89	0.88	0.20	3.62	0.61	0.88	0.15	3.88	0.83	0.86	0.18
2000	156	54.5	6.47	1.41	1.42	0.31	5.19	0.75	1.25	0.18	5.50	1.11	1.22	0.24
2001	195	54.9	9.38	2.83	2.06	0.62	4.71	0.65	1.14	0.16	8.50	2.49	1.89	0.52
2002	201	48.3	5.59	1.02	1.23	0.23	4.82	0.69	1.16	0.17	5.18	0.94	1.15	0.21
2003	202	33.7	2.87	0.62	0.63	0.14	2.76	0.47	0.67	0.11	3.24	0.71	0.72	0.16
2004	202	40.6	3.27	0.49	0.72	0.11	4.21	0.61	1.02	0.15	3.79	0.56	0.84	0.13
2005	201	36.3	4.68	0.86	1.03	0.19	4.66	0.78	1.13	0.19	4.51	0.75	1.00	0.17
2006	202	38.6	5.62	0.87	1.24	0.19	7.09	1.09	1.71	0.26	5.69	0.94	1.27	0.21
2007	204	47.1	5.85	0.86	1.29	0.19	6.78	0.95	1.64	0.23	5.95	0.88	1.32	0.19
2008	204	51.5	7.24	1.10	1.59	0.24	8.26	1.05	2.00	0.25	7.35	1.01	1.63	0.22
2009	224	49.6	4.47	0.76	0.98	0.17	5.19	0.66	1.25	0.16	5.30	1.06	1.18	0.23
2010	224	40.6	3.26	0.54	0.72	0.12	3.71	0.53	0.90	0.13	3.56	0.57	0.79	0.13
2011	224	30.8	1.39	0.28	0.31	0.06	1.97	0.31	0.48	0.08	1.81	0.39	0.40	0.09
2012	224	27.7	1.20	0.21	0.26	0.05	1.69	0.26	0.41	0.06	1.33	0.23	0.30	0.05
2013	204	35.8	3.70	0.82	0.81	0.18	2.79	0.50	0.67	0.12	3.70	0.78	0.82	0.17

2014	204	45.6	3.01	0.57	0.66	0.12	2.49	0.37	0.60	0.09	2.88	0.60	0.64	0.13
2015	220	31.8	1.97	0.40	0.43	0.09	2.11	0.34	0.51	0.08	2.09	0.40	0.46	0.09
2016	219	48.9	4.64	0.94	1.02	0.21	4.35	0.57	1.05	0.14	4.46	0.92	0.99	0.20
2017	192	40.6	4.20	1.33	0.92	0.29	3.28	0.52	0.79	0.13	4.33	1.21	0.96	0.26
2018	169	45.6	2.55	0.53	0.56	0.12	2.28	0.35	0.55	0.08	2.33	0.48	0.52	0.11
2019	170	33.5	1.82	0.42	0.40	0.09	2.15	0.38	0.52	0.09	2.02	0.45	0.45	0.10

Table 2. Sampling, percent positive, dGLM, and ZINB index values from the SEAMAP-SA Coastal Trawl Survey for Age 1 Spanish Mackerel.

Age 1 Sampling			Age 1 Nominal Abundance				Age 1 Delta-GLM Index				Age 1 ZINB Index			
Year	n	% Pos	Mean	SE	Norm Mean	Norm SE	Index	SE	Norm Index	Norm SE	Index	SE	Norm Index	Norm SE
1990	230	26.5	1.70	0.42	1.16	0.29	0.47	0.09	0.68	0.13	1.02	0.23	1.12	0.21
1991	233	40.3	1.69	0.31	1.15	0.21	0.97	0.17	1.39	0.24	1.52	0.39	1.68	0.40
1992	233	43.4	3.09	0.45	2.11	0.31	2.24	0.28	3.21	0.41	2.37	0.63	2.62	0.51
1993	234	16.2	1.09	0.36	0.75	0.24	0.40	0.09	0.57	0.13	0.69	0.23	0.77	0.22
1994	234	28.6	2.08	0.33	1.42	0.22	0.96	0.18	1.38	0.26	1.18	0.26	1.31	0.21
1995	234	23.5	1.05	0.23	0.72	0.16	0.51	0.10	0.73	0.14	0.66	0.14	0.73	0.13
1996	229	21.8	1.77	0.44	1.21	0.30	0.89	0.15	1.28	0.22	0.98	0.23	1.09	0.19
1997	233	20.6	1.31	0.46	0.89	0.32	0.47	0.10	0.68	0.14	0.71	0.21	0.79	0.20
1998	233	16.7	1.64	0.90	1.12	0.62	0.43	0.10	0.62	0.14	0.55	0.20	0.61	0.19
1999	234	26.5	2.75	0.76	1.88	0.52	1.00	0.19	1.43	0.27	1.66	0.50	1.83	0.49
2000	234	33.8	3.03	0.65	2.06	0.44	1.18	0.19	1.69	0.27	1.53	0.39	1.69	0.29
2001	297	28.6	1.66	0.42	1.13	0.29	0.76	0.12	1.10	0.17	1.17	0.36	1.30	0.32
2002	302	23.8	1.09	0.22	0.75	0.15	0.39	0.07	0.55	0.10	0.57	0.12	0.63	0.10
2003	304	23.7	1.17	0.26	0.80	0.18	0.83	0.13	1.20	0.19	0.51	0.11	0.56	0.11
2004	304	18.8	1.43	0.36	0.98	0.25	0.63	0.11	0.90	0.16	0.71	0.18	0.79	0.15
2005	301	13.3	0.92	0.22	0.63	0.15	0.62	0.15	0.89	0.21	0.84	0.29	0.93	0.25
2006	304	19.7	2.46	0.65	1.68	0.44	0.74	0.15	1.06	0.21	1.48	0.43	1.64	0.43
2007	305	23.3	1.39	0.23	0.95	0.16	0.84	0.13	1.21	0.19	1.07	0.26	1.19	0.22
2008	304	23.0	1.32	0.22	0.90	0.15	0.86	0.15	1.24	0.22	1.04	0.24	1.15	0.20
2009	336	35.4	1.67	0.25	1.14	0.17	1.19	0.15	1.71	0.21	1.42	0.31	1.57	0.28
2010	336	20.5	0.61	0.10	0.41	0.07	0.39	0.06	0.55	0.08	0.35	0.07	0.39	0.06
2011	336	27.7	0.89	0.15	0.61	0.10	0.51	0.07	0.73	0.11	0.54	0.11	0.60	0.09
2012	336	22.9	0.60	0.09	0.41	0.06	0.31	0.05	0.45	0.07	0.41	0.08	0.45	0.07
2013	294	13.3	0.19	0.03	0.13	0.02	0.22	0.05	0.32	0.07	0.16	0.04	0.18	0.04
2014	306	22.6	0.84	0.24	0.57	0.16	0.47	0.08	0.68	0.11	0.55	0.15	0.61	0.13

2015	329	13.7	0.31	0.06	0.21	0.04	0.22	0.04	0.32	0.06	0.20	0.05	0.23	0.05
2016	331	23.0	0.98	0.15	0.67	0.10	0.47	0.07	0.67	0.10	0.50	0.12	0.55	0.11
2017	293	23.2	0.83	0.14	0.56	0.10	0.44	0.08	0.63	0.12	0.58	0.11	0.64	0.11
2018	228	21.1	0.55	0.11	0.37	0.07	0.41	0.08	0.58	0.11	0.53	0.15	0.59	0.14
2019	258	31.0	3.86	0.69	2.63	0.47	1.10	0.20	1.57	0.29	1.61	0.40	1.78	0.32

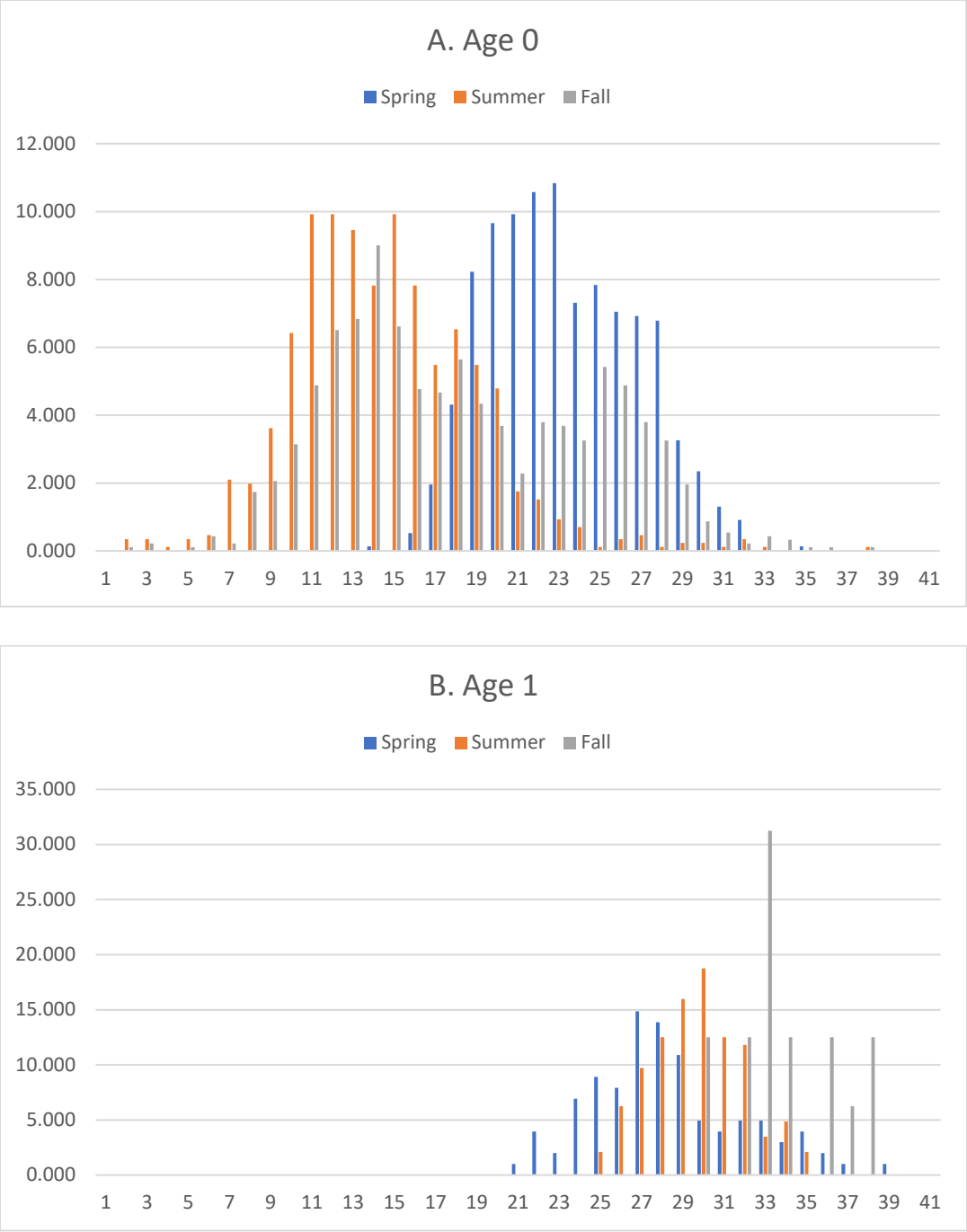


Figure 1. Length distributions of Spanish Mackerel caught in the SEAMAP-SA Coastal Trawl Survey (CTS) by Season and aged as either A) Age 0 and B) Age 1.

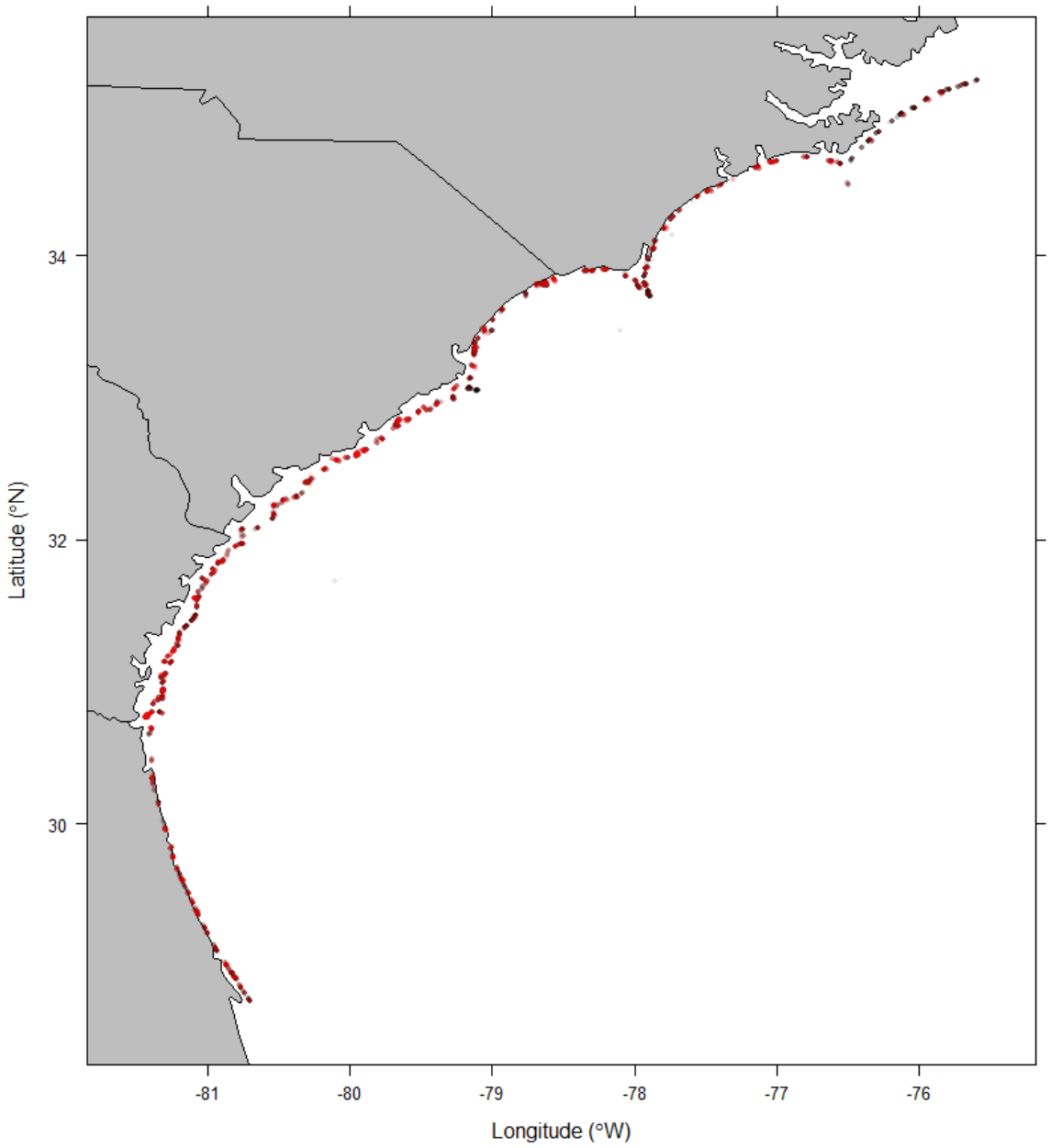


Figure 2. Sampling distribution of all tows 1989-2019 of the SEAMAP-SA Coastal Trawl Survey. Red circles indicate positive collections for Age 0 Spanish Mackerel and black circles indicate no catch of Age 0 Spanish Mackerel.

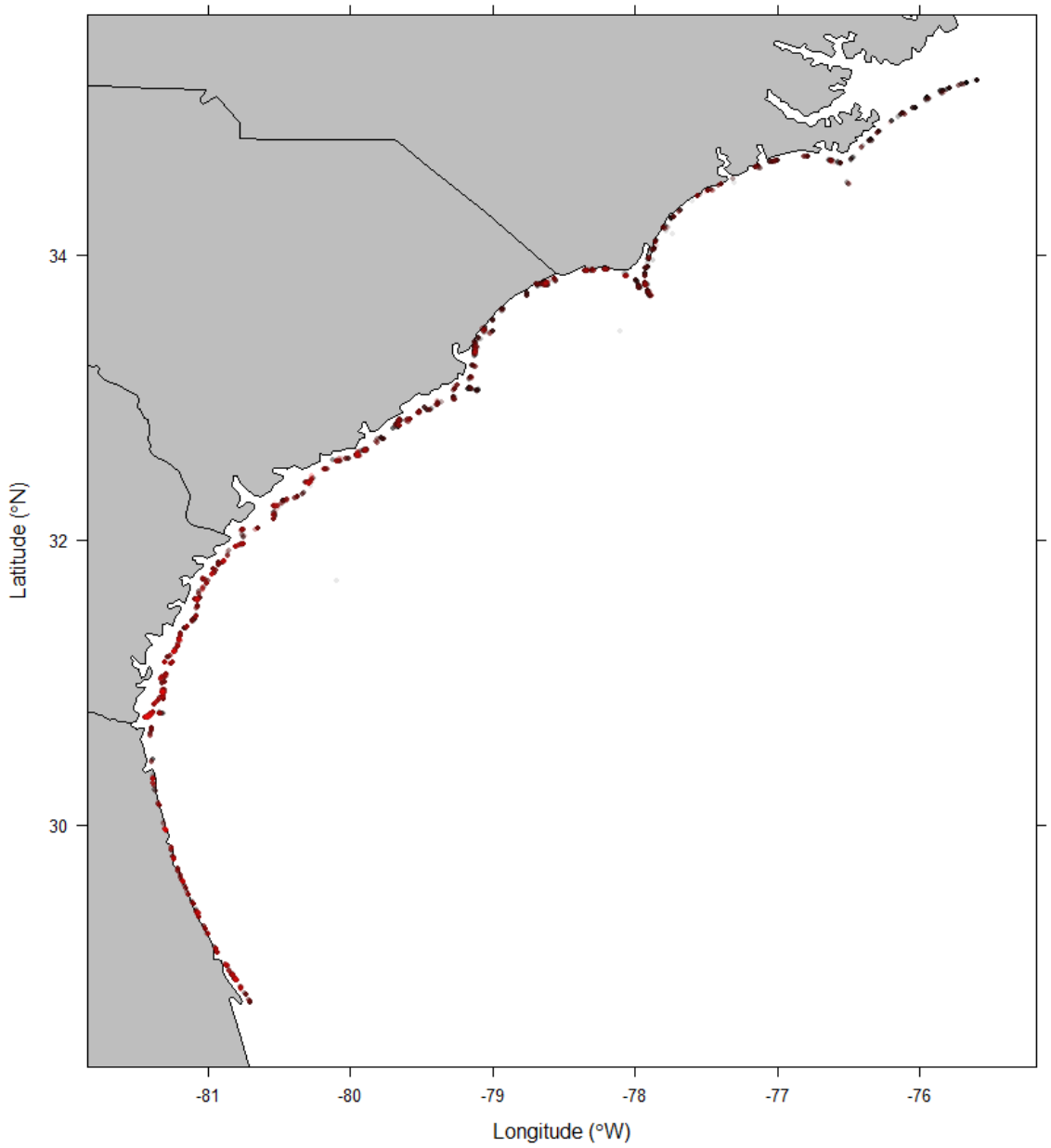


Figure 3. Sampling distribution of all tows 1990-2019 of the SEAMAP-SA Coastal Trawl Survey. Red circles indicate positive collections for Age 1 Spanish Mackerel and black circles indicate no catch of Age 1 Spanish Mackerel.

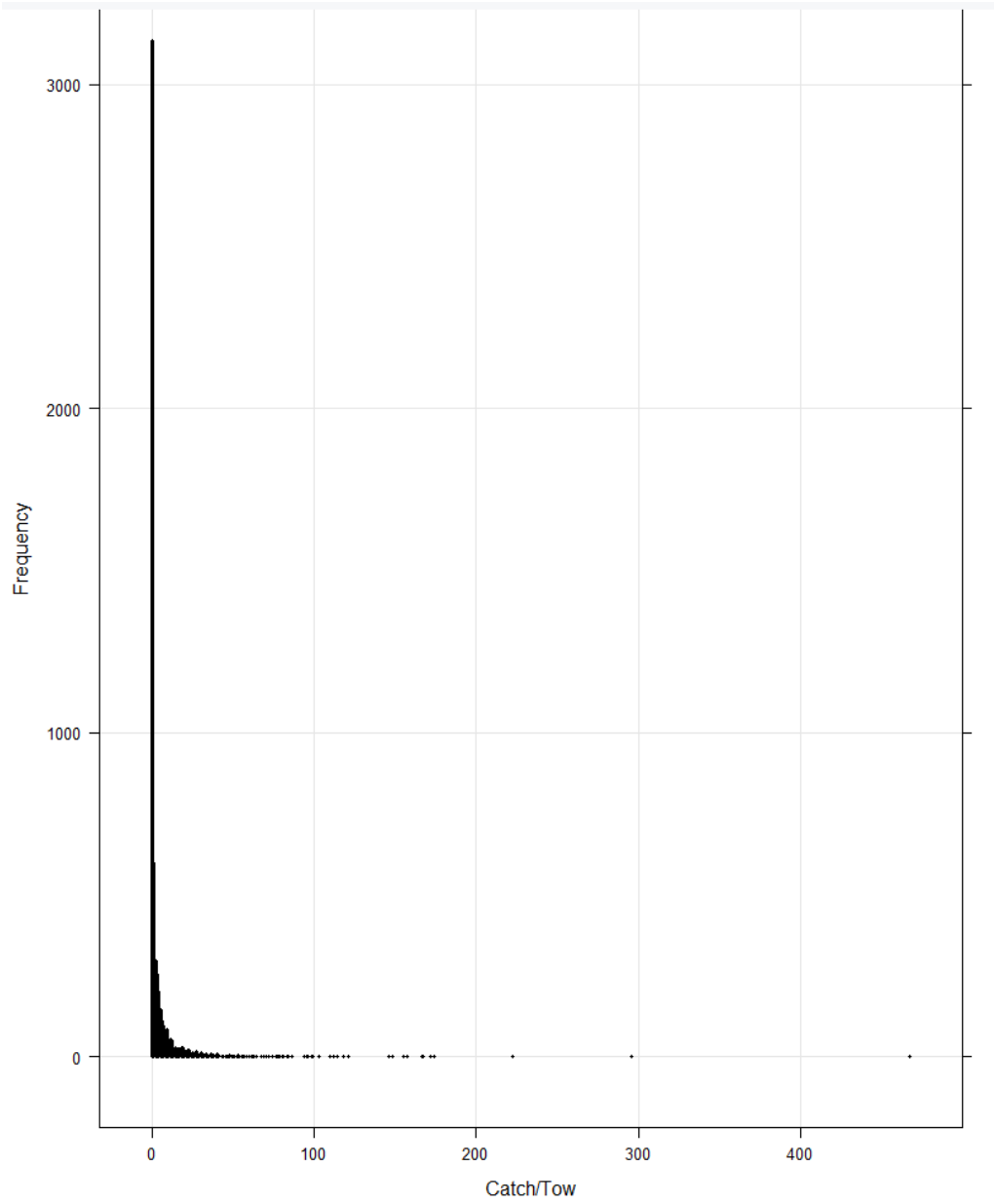


Figure 4. Count distribution of Age 0 Spanish Mackerel catch from SEAMAP-SA Coastal Trawl Survey showing full range of the distribution.

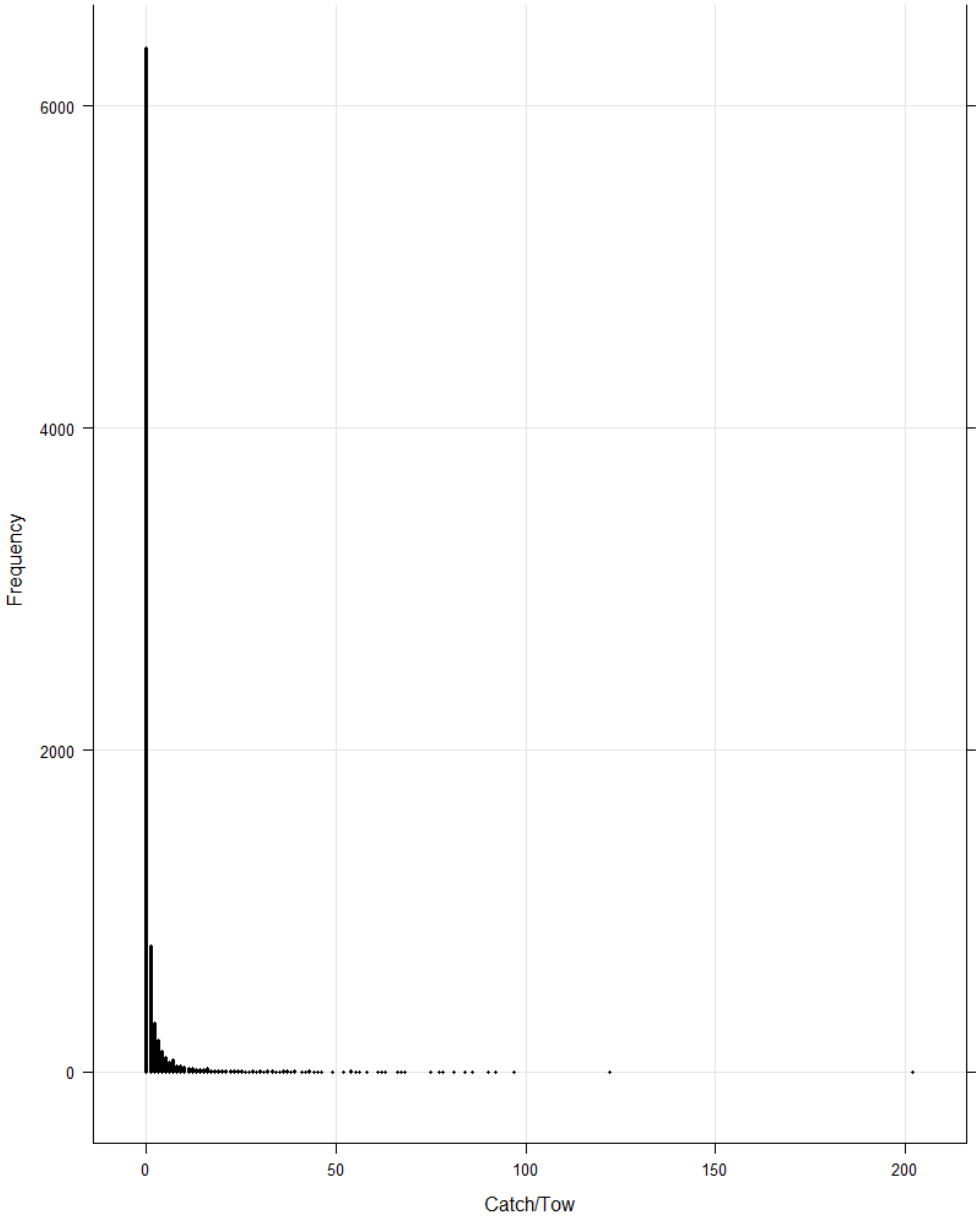


Figure 5. Count distribution of Age 1 Spanish Mackerel catch from SEAMAP-SA Coastal Trawl Survey showing full range of the distribution.

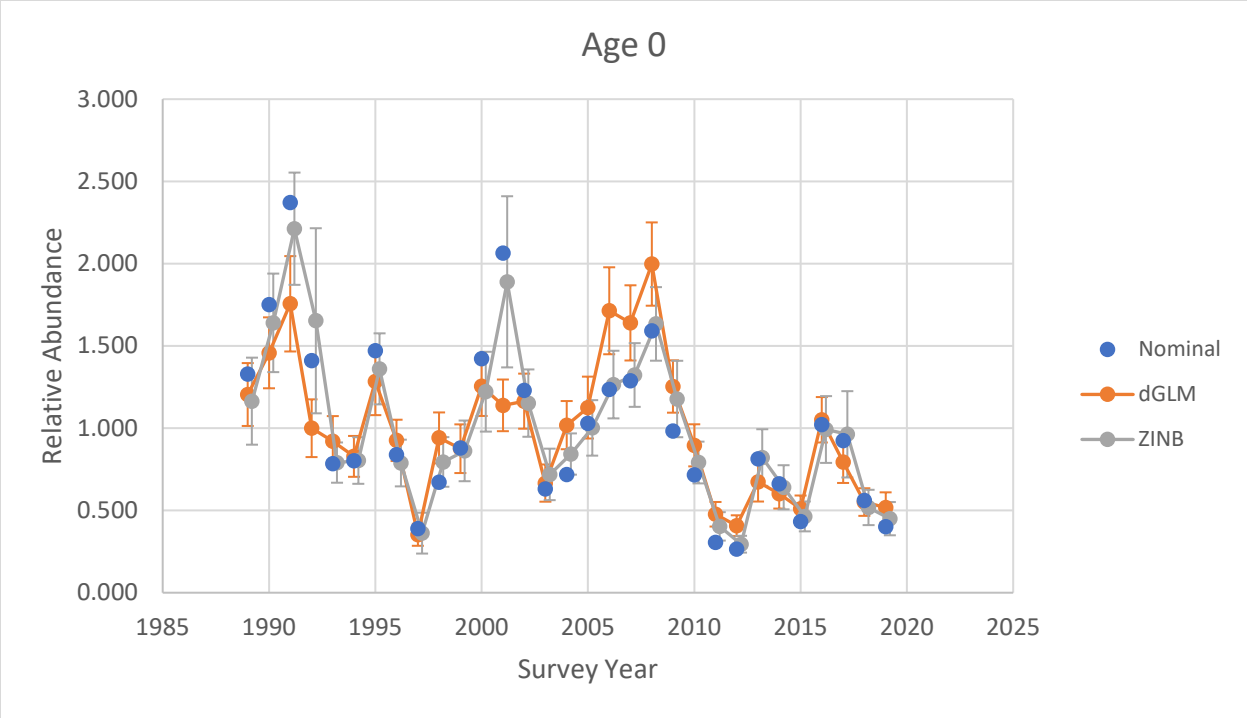


Figure 6. Normalized nominal, dGLM, and ZINB index values from the SEAMAP-SA Coastal Trawl Survey for Age 0 Spanish Mackerel. Error bars are normalized standard errors.

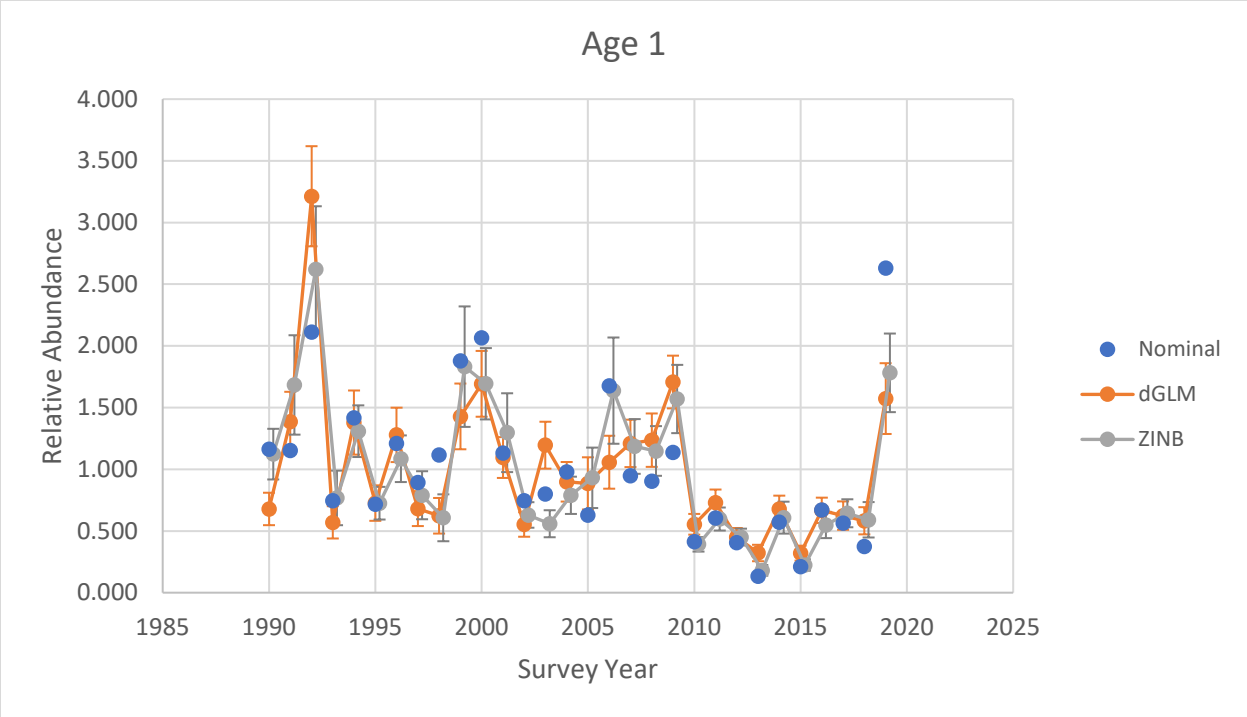


Figure 7. Normalized nominal, dGLM, and ZINB index values from the SEAMAP-SA? Coastal Trawl Survey for Age 1 Spanish Mackerel. Error bars are normalized standard errors.

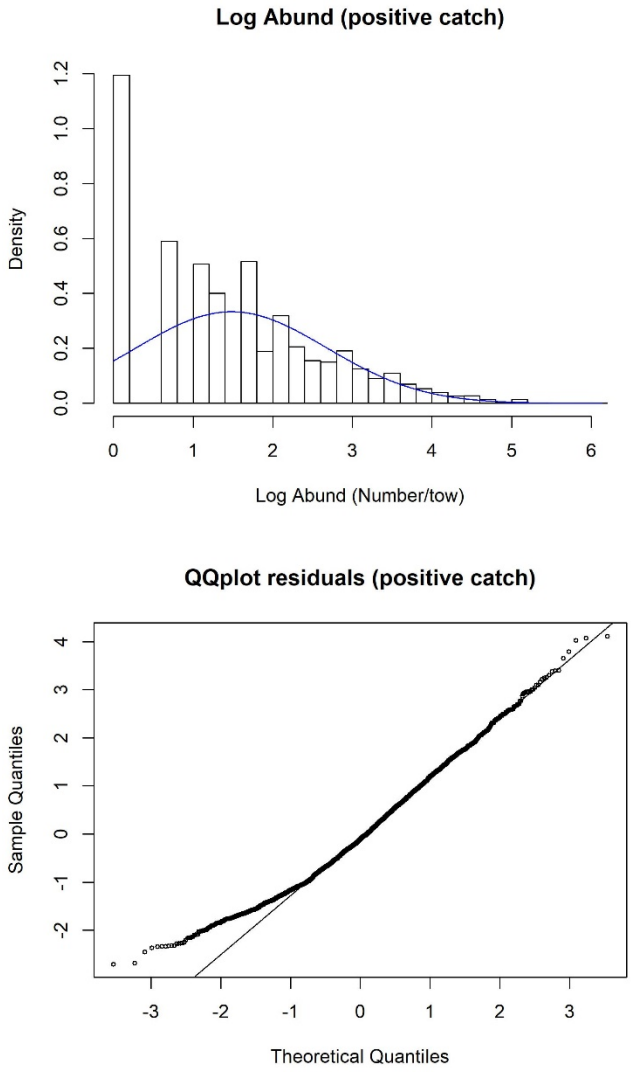


Figure 8. Quantiles from the lognormal model of the dGLM standardization of Age 0 Spanish Mackerel index.

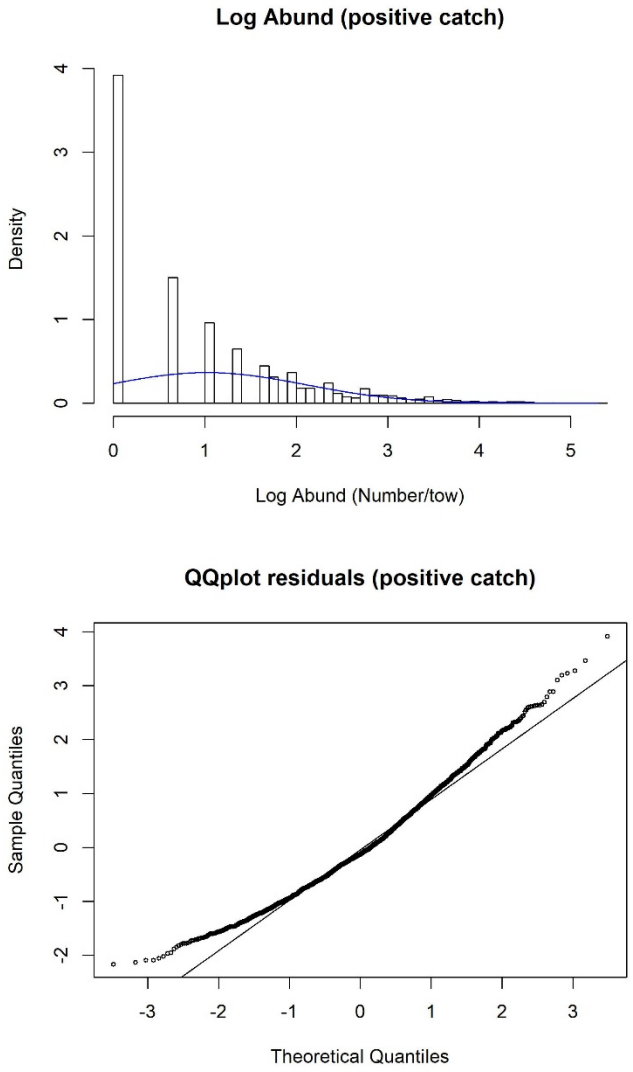
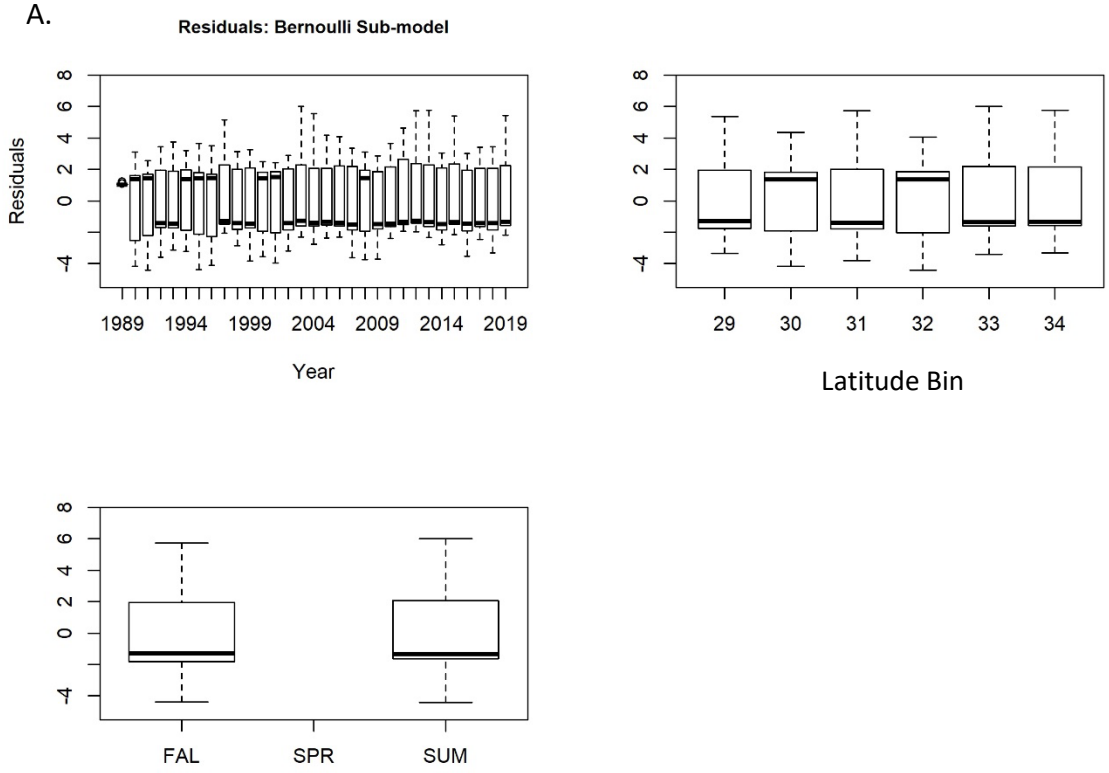


Figure 9. Quantiles from the lognormal model of the dGLM standardization of Age 1 Spanish Mackerel index.

A.


Residuals: Bernoulli Sub-model
Residuals
-4 0 2 4 6 8
1989 1994 1999 2004 2009 2014 2019
Year
-4 0 2 4 6 8
29 30 31 32 33 34
Latitude Bin
-4 0 2 4 6 8
FAL SPR SUM

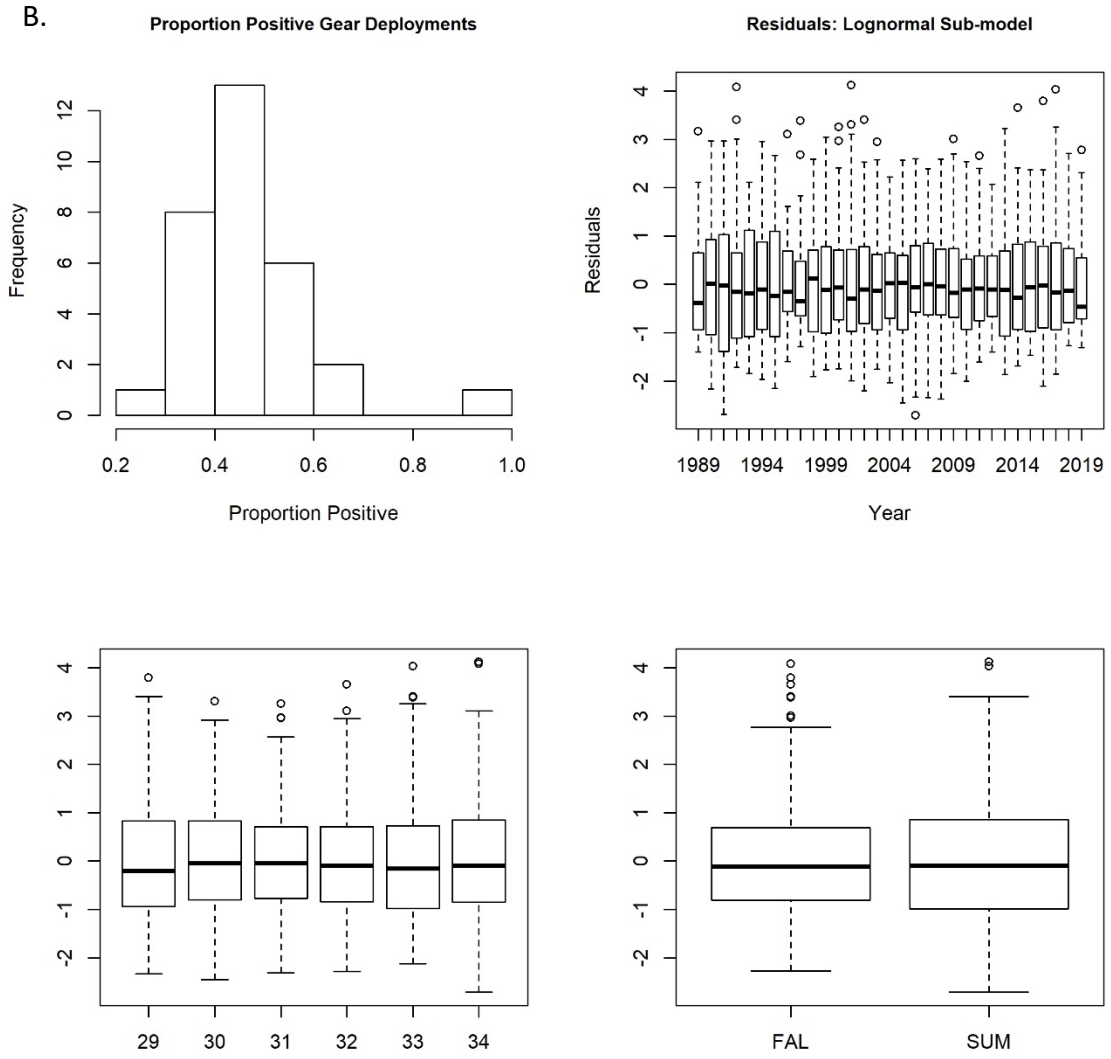
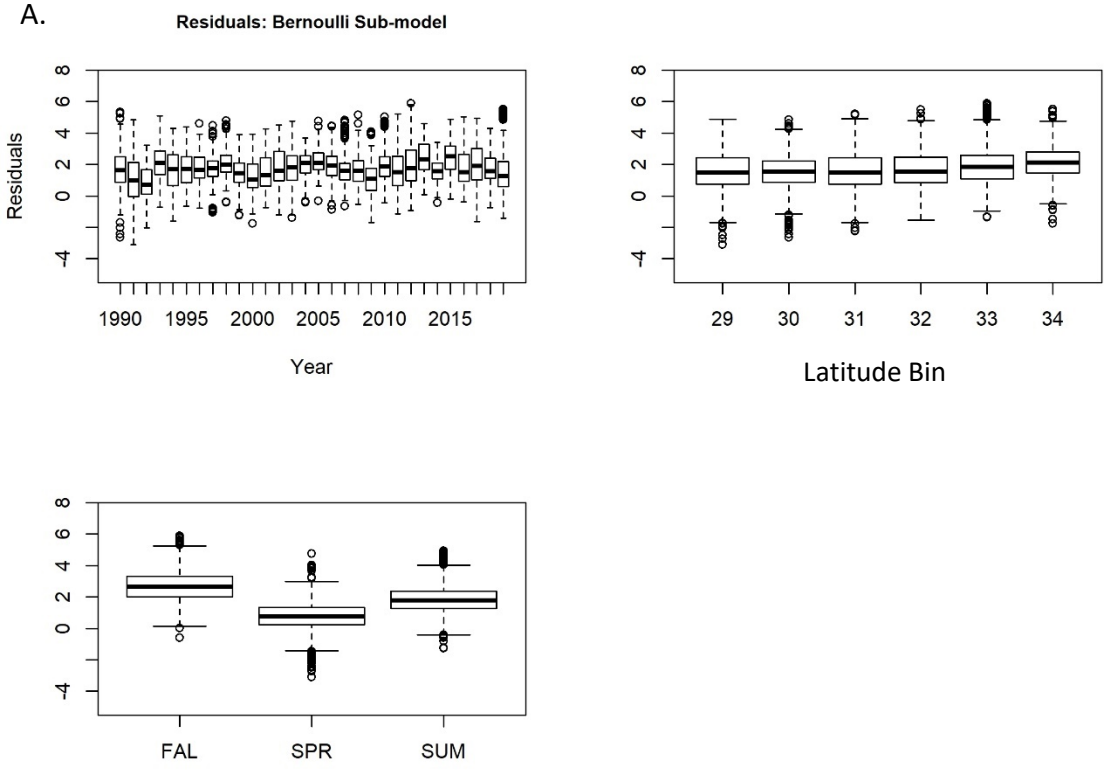


Figure 10. Residuals for A) the Bernoulli sub-model and B) the lognormal sub-model of the dGLM standardized index for Age 0 Spanish Mackerel.

A.


Residuals: Bernoulli Sub-model
Residuals
-4 0 2 4 6 8
1990 1995 2000 2005 2010 2015
Year
29 30 31 32 33 34
Latitude Bin
-4 0 2 4 6 8
FAL SPR SUM

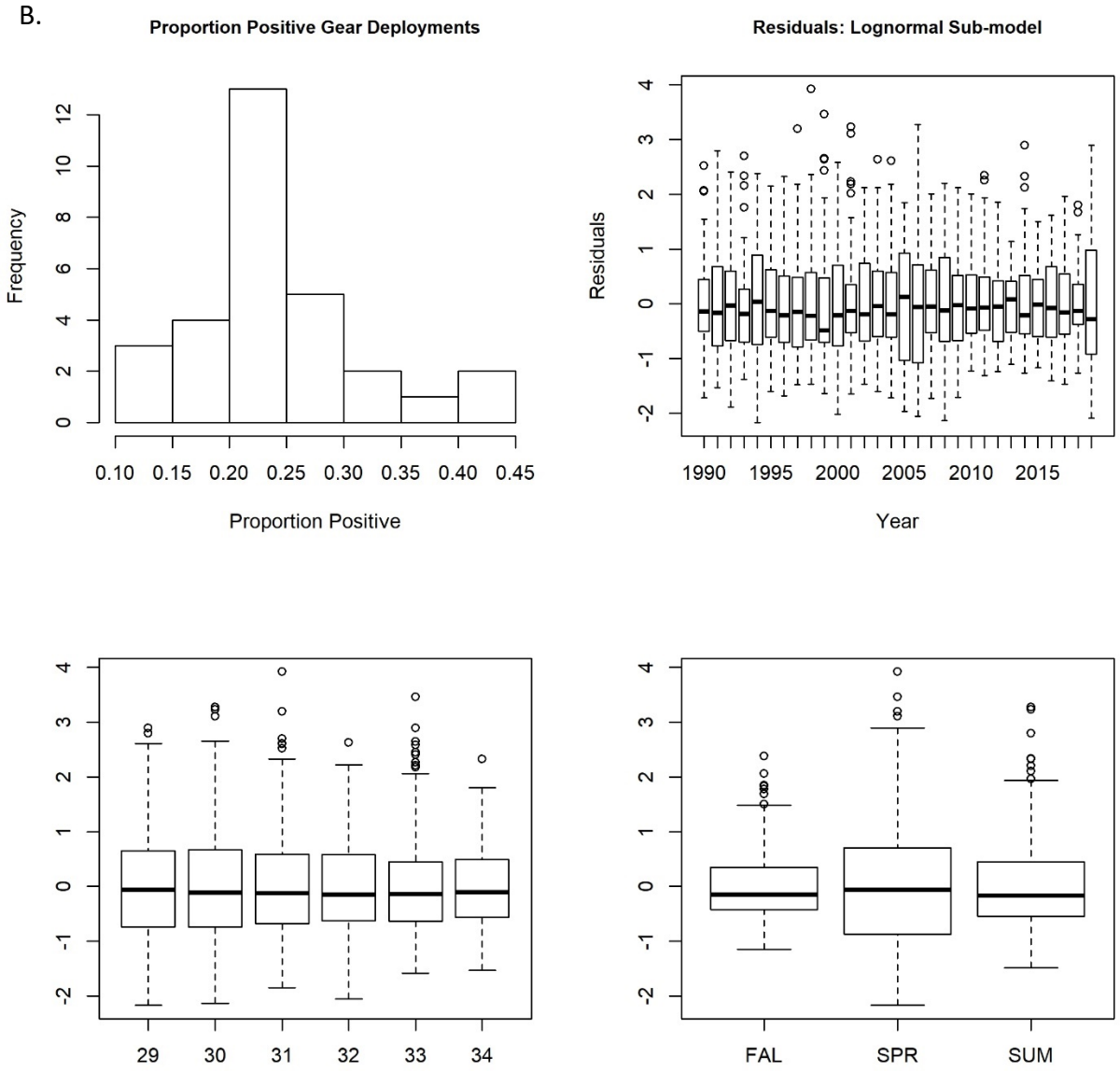


Figure 11. Residuals for A) the Bernoulli sub-model and B) the lognormal sub-model of the dGLM standardized index for Age 1 Spanish Mackerel.

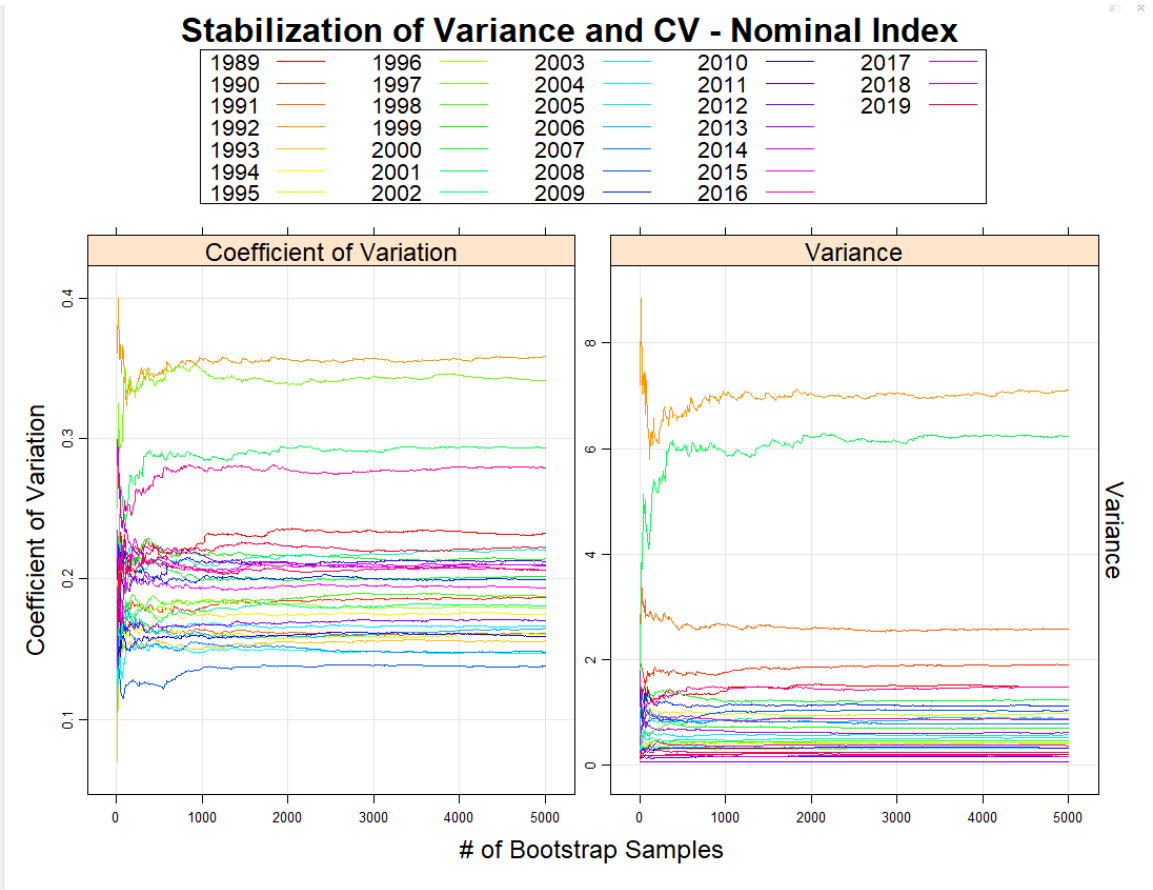


Figure 12. Impact of number of bootstrap iterations during the ZINB index development of coefficient of variation for Age 0 Spanish Mackerel.

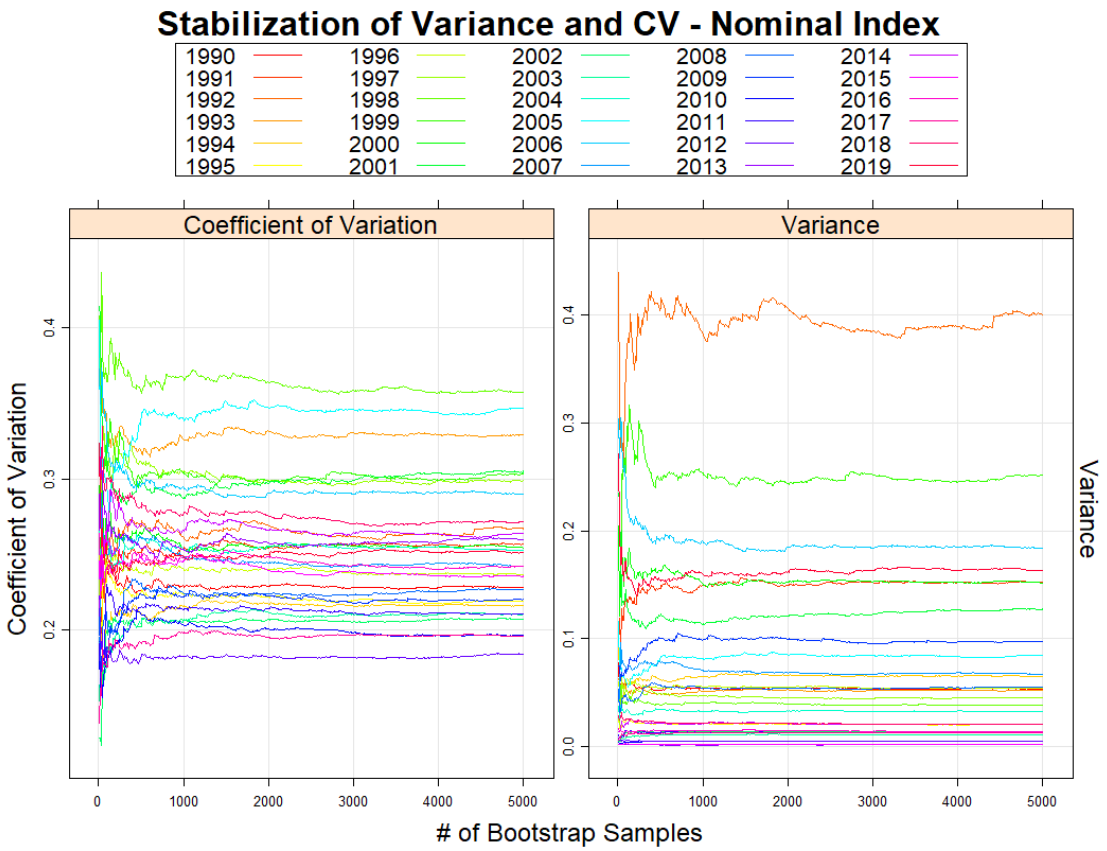


Figure 13. Impact of number of bootstrap iterations during the ZINB index development of coefficient of variation for Age 1 Spanish Mackerel.