Relative indices of abundance for Red drum (*Sciaenops ocellatus*) inhabiting inland waters along the Atlantic coast based on 1991-2013 angler catch rate data

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Introduction

Indices of relative abundance were developed from MRFSS and MRIP recreational intercepts for each state from North Virginia south through Florida and a composites for the northern (North Carolina north) and southern stocks (South Carolina through Florida).

Methods

Spatial and Temporal Extent

Separate indices were estimated for each state and for the composite sample of interviews within the the stock region. MRFSS intercepts were used for the period of 1981-2003, while MRIP was used for 2004-2013 to develop criteria for choosing fishing trips categorized as trips that had caught species associated with red drum (defined as red drum fishing trips). Only those data for the years from 1991-2013 were used for the estimating standardized total catch per trip because before 1991 interviews done on multiple individuals from the same trip could not be assigned to the same trip.

Identification of Appropriate Survey Samples

This analysis included selected inland fishing trips made using hook-and-line gear. Fishing trips that were deemed appropriate for measuring subadult red drum abundance trends were identified using a cluster analysis. By identifying those trips that caught associated species but failed to catch red drum, one can infer zero-catch trips that were appropriate to include in the analysis (Stephens and MacCall 2004). Affinity propagation clustering (APC) was chosen to determine associated species, because it has been shown to perform well relative to other cluster techniques and does not require that the number of cluster be pre-specified (Frey and Dueck 2007). APC automatically chooses an optimal number of clusters in the dataset, thereby providing an objective criterion for which to group associated species. To conduct the cluster analysis, the data were first filtered to remove all uncommon species that occurred on only a small proportion (<1.0%) of the total fishing trips made in a given state. The APC procedure was then applied using the Morisita measure of similarity, since this measure is recommended for count data and is insensitive to sample sizes (Krebs 1999). Once the associated species within the red drum cluster were identified for each state, all trips on which red drum of these associated species were caught were used as representative trips in the subsequent analyses. The APC technique was done in R 3.0.1 (R Core Team 2013) using the apcluster package (Bodenhofer et al. 2011).

Standardization Model

Standardized indices of abundance were calculated using a generalized linear modeling procedure that combined the analysis of the binomial information on presence/absence with the lognormal-distributed positive catch data (also known as two-part, hurdle, or zero-adjusted models, Zuur et al. 2009) as:

$$I_y = c_y p_y \quad [1]$$

where c_y are estimated annual mean CPUEs of non-zero catches modeled as lognormal distributions and p_y are estimated annual mean probabilities of capture modeled as binomial distributions. The lognormal submodel considers only trips in which a red drum was caught (*i.e.*, non-zero catches). The binomial model considers all trips in which red drum or associated species were caught. To determine the most appropriate submodels, categorical variables (2-month wave, mode of fishing, area fished, time period of day, angler avidity, and state [in multi-state models]) and covariates (hours fished and number of anglers on trip) were sequentially added to a null model which included year. The factor resulting in the largest decline in deviance per degree of freedom (dev/df) was added to the model for the next step in the evaluation if the dev/df was reduced by at least 0.5% of the base model dev/df. We assume that there were no significant interaction terms with year in this model and consider only the main effects. The final year-specific marginal means estimates and standard errors of the two sub-models were used to generate distributions of estimates for each sub-model from a Monte Carlo simulation (5000 Student's t distributed realizations). The product of these distributions (eq. 1) provided an estimate of the median catch rate with year-specific variability.

Results and Discussion

Identification of Appropriate Trips

The APC technique was performed separately for each state but in all states fishing trips where two species, spotted seatrout and southern flounder, were caught clustered with trips catching red drum. Of the 18 commonly caught inshore species in east Florida, five clusters were delineated by APC with three species in the cluster occupied by red drum (Table 2). In Georgia, trips where five of the twelve common inshore species were caught were categorized as trips with the potential to catch red drum. In North and South Carolina, three species were associated with trips that reported red drum catches (Table 2).

Standardization Model

Standardized indices of abundance were developed for Florida, Georgia, South Carolina, North Carolina, and Virginia. Diagnostics for the model components of the combined south (FL-SC) and north (NC-VA) regions are shown in Figs. 5 and 6. Within each region the state-specific trends in catch rate were quite similar so the combined regional models were used for the assessment. In the northern model, significant factors were: binomial model, fishing mode, wave, area, and hours fished; lognormal, fishing mode, wave, hours fished, avidity, and number of anglers. In the southern region the significant factors accounted for were: binomial, fishing mode, wave, hours fished, state, avidity, and area fished; lognormal, , fishing mode, wave, hours fished, state, avidity, area fished, number of anglers, and time period of day.

The standardized trip catch rates show fluctuations in the South but with an overall increase between 1991 and 2013. Significant peaks occurred in 1995 and 2010. In the northern region, there was also a general increase over the time period with peak catch rates in 2002 and 2012 and significant lows in 1996, 2003-4, and 2011.

References

Bodenhofer U, A Kothmeier, and S Hochreiter. 2011. APCluster: an R package for affinity propagation clustering. Bioinformatics 27:2463-2464. DOI: 10.1093/bioinformatics/btr406.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Zuur, AF, EN Ieno, NJ Walker, AA Saveliev, GM Smith. 2009. Mixed effects models and extensions in ecology with R. Springer Science+Business Media, New York NY. 574pp.

Tables

Table 1. Species clusters used to select those trips where a red drum was likely to occur.

Florida East	Georgia	South Carolina	North Carolina	Virginia
SPOTTED SEATROUT	SILVER PERCH	SPOTTED SEATROUT	STRIPED BASS	SPOTTED SEATROUT
SOUTHERN FLOUNDER	SPOTTED SEATROUT	SOUTHERN FLOUNDER	SPOTTED SEATROUT	RED DRUM
BLACK DRUM	SOUTHERN FLOUNDER	BLACK DRUM	RED DRUM	
RED DRUM	BLUEFISH	RED DRUM	SOUTHERN FLOUNDER	
	RED DRUM			

Table 3. Observed number of trips, mean total catch rate, and its standard error for trips chosen as likely red drum fishing trips in each of the states.

	Number of Trips					Mean Total Catch of Red Drum					Standard Error of Catch Rate				
	FL	GA	SC	NC	VA	FL	GA	SC	NC	VA	FL	GA	SC	NC	VA
1991	294	258	95	593	38	1.44	1.55	1.83	0.89	0.45	0.386	0.285	0.593	0.119	0.129
1992	471	421	215	321	50	0.91	1.73	1.26	0.57	1.20	0.097	0.182	0.138	0.113	0.454
1993	647	229	171	455	66	1.14	1.91	2.03	1.15	1.61	0.147	0.256	0.375	0.205	1.134
1994	895	224	152	647	186	1.08	2.35	2.82	0.66	0.13	0.109	0.352	0.380	0.078	0.046
1995	850	224	231	934	177	1.12	2.79	4.09	0.90	0.31	0.102	0.384	0.519	0.068	0.143
1996	740	174	324	781	109	1.12	1.89	2.35	0.36	0.06	0.086	0.297	0.242	0.043	0.022
1997	762	166	376	865	104	0.96	1.01	2.14	0.95	1.10	0.085	0.139	0.331	0.090	0.335
1998	898	270	333	952	93	1.06	0.83	1.41	1.38	1.72	0.082	0.121	0.160	0.124	0.364
1999	1,565	212	250	814	103	1.06	1.35	1.42	1.16	1.75	0.068	0.258	0.205	0.091	0.445
2000	1,495	343	306	672	116	1.12	1.80	1.01	0.87	1.86	0.063	0.232	0.133	0.094	0.506
2001	1,558	298	202	691	74	1.42	2.87	2.10	1.15	0.59	0.086	0.337	0.310	0.158	0.130
2002	1,467	315	277	960	195	1.25	2.36	1.54	1.54	5.04	0.082	0.269	0.198	0.114	0.450
2003	1,275	442	165	562	107	1.31	2.41	2.28	0.41	0.64	0.084	0.225	0.278	0.079	0.218
2004	1,154	328	277	695	77	1.73	2.13	2.36	0.41	0.55	0.130	0.285	0.287	0.045	0.184
2005	1,231	348	305	635	37	1.51	2.67	2.10	0.86	0.70	0.100	0.297	0.201	0.139	0.284
2006	1,419	431	423	766	55	1.18	1.18	1.68	1.37	1.64	0.072	0.130	0.181	0.125	0.363
2007	1,336	433	376	639	238	1.06	1.79	2.16	1.54	1.70	0.090	0.223	0.248	0.162	0.294
2008	1,143	401	409	695	220	1.13	2.58	2.55	1.36	2.22	0.080	0.357	0.279	0.124	0.311
2009	1,014	408	421	668	164	1.18	2.06	3.89	1.41	1.76	0.085	0.263	0.321	0.109	0.224
2010	1,153	417	472	1,073	148	1.84	4.26	3.75	1.68	0.67	0.128	0.345	0.287	0.093	0.147
2011	1,083	370	537	1,109	115	1.41	1.91	3.90	0.83	0.42	0.099	0.227	0.240	0.076	0.171
2012	1,259	399	393	1,354	302	1.26	1.07	2.74	2.11	4.78	0.076	0.129	0.228	0.091	0.468
2013	759	224	380	1,136	230	1.34	2.53	2.91	1.86	2.23	0.114	0.399	0.352	0.223	0.278

Table 2. Standardized angler catch rate.

Florida

year	Total num sets	Num positive	Mean	std.dev	CV
1991	294	96	0.822	0.0962	0.117
1992	471	155	0.824	0.0749	0.091
1993	647	200	0.845	0.0692	0.082
1994	895	294	0.920	0.0636	0.069
1995	850	328	0.949	0.0602	0.063
1996	740	302	0.942	0.0623	0.066
1997	762	270	0.837	0.0606	0.072
1998	898	343	0.879	0.0554	0.063
1999	1,565	586	0.793	0.0414	0.052
2000	1,495	629	0.810	0.0404	0.050
2001	1,558	709	0.995	0.0471	0.047
2002	1,467	615	0.857	0.0426	0.050
2003	1,275	516	0.925	0.0484	0.052
2004	1,154	549	1.166	0.0588	0.050
2005	1,231	563	1.053	0.0533	0.051
2006	1,419	585	0.901	0.0466	0.052
2007	1,336	488	0.781	0.0449	0.057
2008	1,143	451	0.851	0.0496	0.058
2009	1,014	432	0.918	0.0528	0.057
2010	1,153	582	1.250	0.0611	0.049
2011	1,083	536	1.074	0.0547	0.051
2012	1,259	561	0.976	0.0502	0.051
2013	759	345	1.013	0.0616	0.061

Table 2. Standardized angler catch rate.

Georgia

year	Total num sets	Num positive	Mean	std.dev	CV
1991	258	74	0.401	0.0839	0.209
1992	421	149	0.526	0.0791	0.151
1993	229	94	0.556	0.1055	0.190
1994	224	95	0.675	0.1249	0.185
1995	224	97	0.888	0.1595	0.180
1996	174	70	0.595	0.1270	0.214
1997	166	62	0.448	0.1004	0.224
1998	270	88	0.363	0.0679	0.187
1999	212	71	0.450	0.0927	0.206
2000	343	118	0.528	0.0880	0.167
2001	298	125	0.795	0.1330	0.167
2002	315	141	0.805	0.1211	0.151
2003	442	193	0.844	0.1104	0.131
2004	328	129	0.664	0.1052	0.158
2005	348	167	0.792	0.1096	0.138
2006	431	139	0.421	0.0643	0.153
2007	433	152	0.480	0.0709	0.148
2008	401	175	0.642	0.0894	0.139
2009	408	146	0.579	0.0872	0.150
2010	417	241	1.360	0.1545	0.114
2011	370	166	0.624	0.0872	0.140
2012	399	137	0.374	0.0583	0.156
2013	224	98	0.886	0.1565	0.177

Table 2. Standardized angler catch rate.

South Carolina

year	Total num sets	Num positive	Mean	std.dev	CV
1991	95	35	0.920	0.3137	0.341
1992	215	100	0.844	0.2111	0.250
1993	171	69	0.820	0.2405	0.293
1994	152	83	1.662	0.4103	0.247
1995	231	138	2.019	0.4281	0.212
1996	324	181	1.349	0.2884	0.214
1997	376	192	1.140	0.2474	0.217
1998	333	136	0.854	0.2073	0.243
1999	250	108	0.956	0.2303	0.241
2000	306	103	0.533	0.1467	0.276
2001	202	97	1.155	0.2660	0.230
2002	277	116	1.021	0.2527	0.248
2003	165	96	1.336	0.3007	0.225
2004	277	146	1.120	0.2559	0.229
2005	305	177	1.323	0.2750	0.208
2006	423	175	1.069	0.2435	0.228
2007	376	165	1.220	0.2853	0.234
2008	409	210	1.036	0.2350	0.227
2009	421	265	1.749	0.3464	0.198
2010	472	315	1.844	0.3365	0.183
2011	537	403	2.135	0.3397	0.159
2012	393	245	1.333	0.2670	0.200
2013	380	217	1.457	0.2988	0.205

Table 2. Standardized angler catch rate.

South Region

year	Total num sets	Num positive	Mean	std.dev	CV
1991	647	205	0.747	0.0642	0.086
1992	1,107	404	0.784	0.0473	0.060
1993	1,047	363	0.864	0.0536	0.062
1994	1,271	472	1.042	0.0565	0.054
1995	1,305	563	1.171	0.0566	0.048
1996	1,238	553	0.998	0.0499	0.050
1997	1,304	524	0.829	0.0432	0.052
1998	1,501	567	0.753	0.0381	0.051
1999	2,027	765	0.747	0.0328	0.044
2000	2,144	850	0.736	0.0309	0.042
2001	2,058	931	0.990	0.0394	0.040
2002	2,059	872	0.855	0.0355	0.042
2003	1,882	805	0.976	0.0409	0.042
2004	1,759	824	1.062	0.0439	0.041
2005	1,884	907	1.046	0.0410	0.039
2006	2,273	899	0.815	0.0330	0.040
2007	2,145	805	0.789	0.0338	0.043
2008	1,953	836	0.868	0.0359	0.041
2009	1,843	843	1.021	0.0417	0.041
2010	2,042	1,138	1.417	0.0489	0.034
2011	1,990	1,105	1.217	0.0415	0.034
2012	2,051	943	0.912	0.0354	0.039
2013	1,363	660	1.116	0.0503	0.045

Table 2. Standardized angler catch rate.

North Carolina

year	Total num sets	Num positive	Mean	std.dev	CV
1991	593	140	0.436	0.0593	0.136
1992	321	74	0.296	0.0541	0.183
1993	455	164	0.549	0.0686	0.125
1994	647	166	0.337	0.0422	0.125
1995	934	389	0.586	0.0499	0.085
1996	781	155	0.214	0.0280	0.131
1997	865	262	0.527	0.0541	0.103
1998	952	400	0.699	0.0565	0.081
1999	814	364	0.742	0.0624	0.084
2000	672	235	0.448	0.0475	0.106
2001	691	215	0.504	0.0545	0.108
2002	960	491	0.949	0.0715	0.075
2003	562	100	0.269	0.0417	0.155
2004	998	215	0.294	0.0320	0.109
2005	799	216	0.548	0.0579	0.106
2006	958	318	0.644	0.0575	0.089
2007	917	301	0.625	0.0571	0.091
2008	1,038	431	0.733	0.0567	0.077
2009	895	366	0.711	0.0583	0.082
2010	1,473	662	0.766	0.0508	0.066
2011	1,502	315	0.356	0.0332	0.093
2012	2,316	1,273	1.271	0.0647	0.051
2013	1,497	703	0.864	0.0543	0.063

Table 2. Standardized angler catch rate.

Virginia

year	Total num sets	Num positive	Mean	std.dev	CV
1991	38	13	0.430	0.2000	0.465
1992	50	17	0.749	0.2941	0.393
1993	66	20	0.516	0.1976	0.383
1994	186	12	0.102	0.0551	0.541
1995	177	21	0.194	0.0776	0.401
1996	109	6	0.070	0.0554	0.791
1997	104	23	0.625	0.2313	0.370
1998	93	52	1.081	0.2501	0.231
1999	103	44	1.020	0.2593	0.254
2000	116	56	0.929	0.2052	0.221
2001	74	22	0.545	0.1991	0.366
2002	195	157	3.289	0.4323	0.131
2003	107	26	0.415	0.1404	0.338
2004	77	14	0.359	0.1744	0.486
2005	37	12	0.676	0.3192	0.472
2006	55	27	1.310	0.3991	0.305
2007	238	104	0.977	0.1792	0.183
2008	220	114	1.579	0.2702	0.171
2009	164	91	1.356	0.2344	0.173
2010	148	38	0.546	0.1591	0.292
2011	115	10	0.336	0.1952	0.582
2012	302	213	2.859	0.3504	0.123
2013	230	137	1.641	0.2527	0.154

Table 2. Standardized angler catch rate.

North Region

year	Total num sets	Num positive	Mean	std.dev	CV
1991	631	153	0.414	0.0560	0.135
1992	371	91	0.329	0.0567	0.172
1993	521	184	0.525	0.0649	0.124
1994	833	178	0.270	0.0341	0.126
1995	1,111	410	0.504	0.0440	0.087
1996	890	161	0.190	0.0261	0.138
1997	969	285	0.514	0.0531	0.103
1998	1,045	452	0.709	0.0574	0.081
1999	917	408	0.733	0.0614	0.084
2000	788	291	0.488	0.0491	0.101
2001	765	237	0.491	0.0536	0.109
2002	1,155	648	1.219	0.0844	0.069
2003	669	126	0.275	0.0410	0.149
2004	1,075	229	0.288	0.0327	0.114
2005	836	228	0.536	0.0585	0.109
2006	1,013	345	0.662	0.0599	0.091
2007	1,155	405	0.664	0.0557	0.084
2008	1,258	545	0.802	0.0597	0.074
2009	1,059	457	0.767	0.0606	0.079
2010	1,621	700	0.727	0.0497	0.068
2011	1,617	325	0.340	0.0332	0.098
2012	2,618	1,486	1.368	0.0686	0.050
2013	1,727	840	0.910	0.0556	0.061

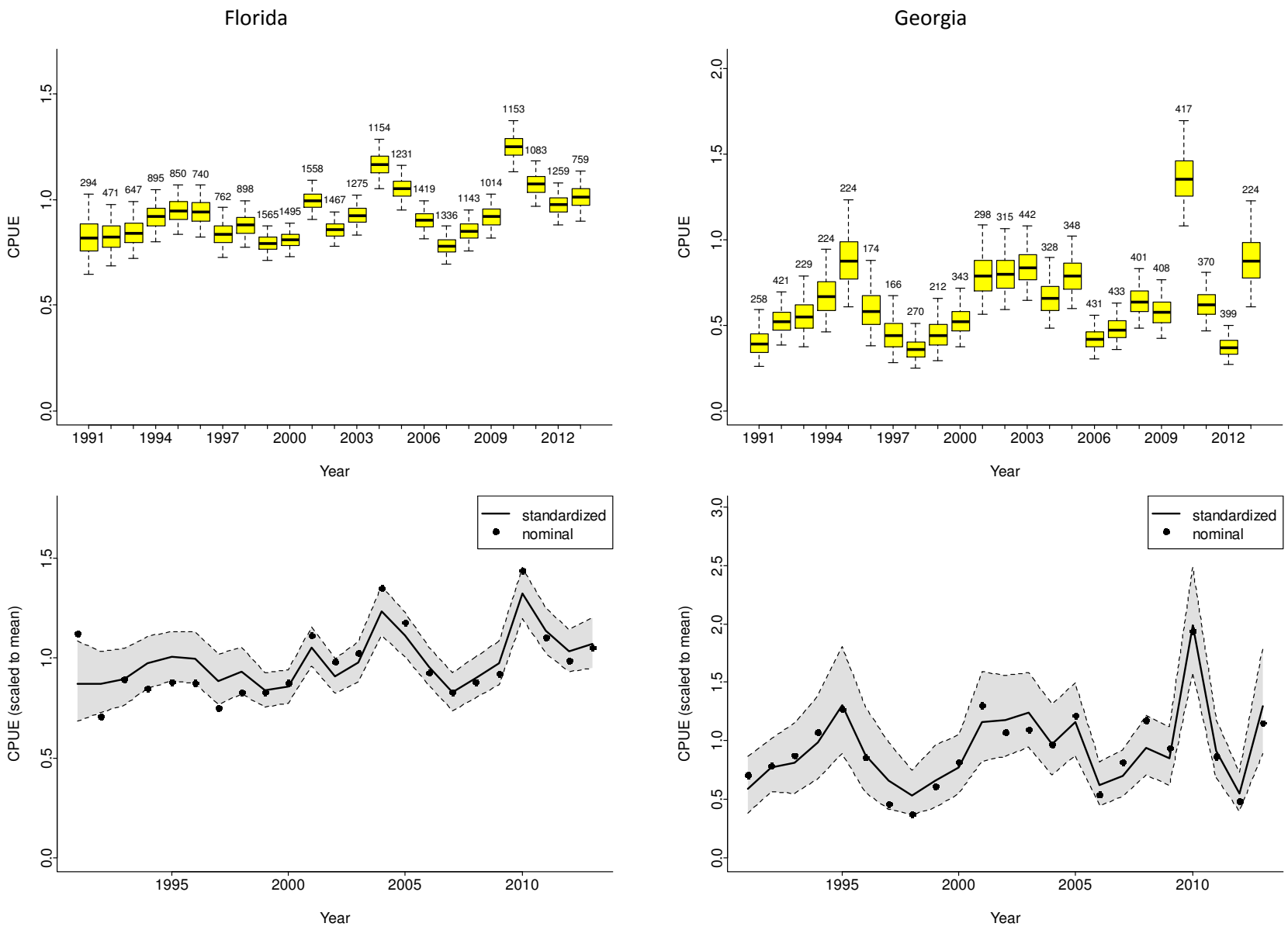

Figure 4. Standardized angler catch rates for selected (as potential red drum trips) estuarine fishing trips made in Florida and Georgia during 1991-2013. Top graph shows Monte Carlo distribution of index and sample size. Lower graphs show the standardized index (line) with 95% confidence bounds (shaded) and the nominal means (points) relative to the overall time series mean.

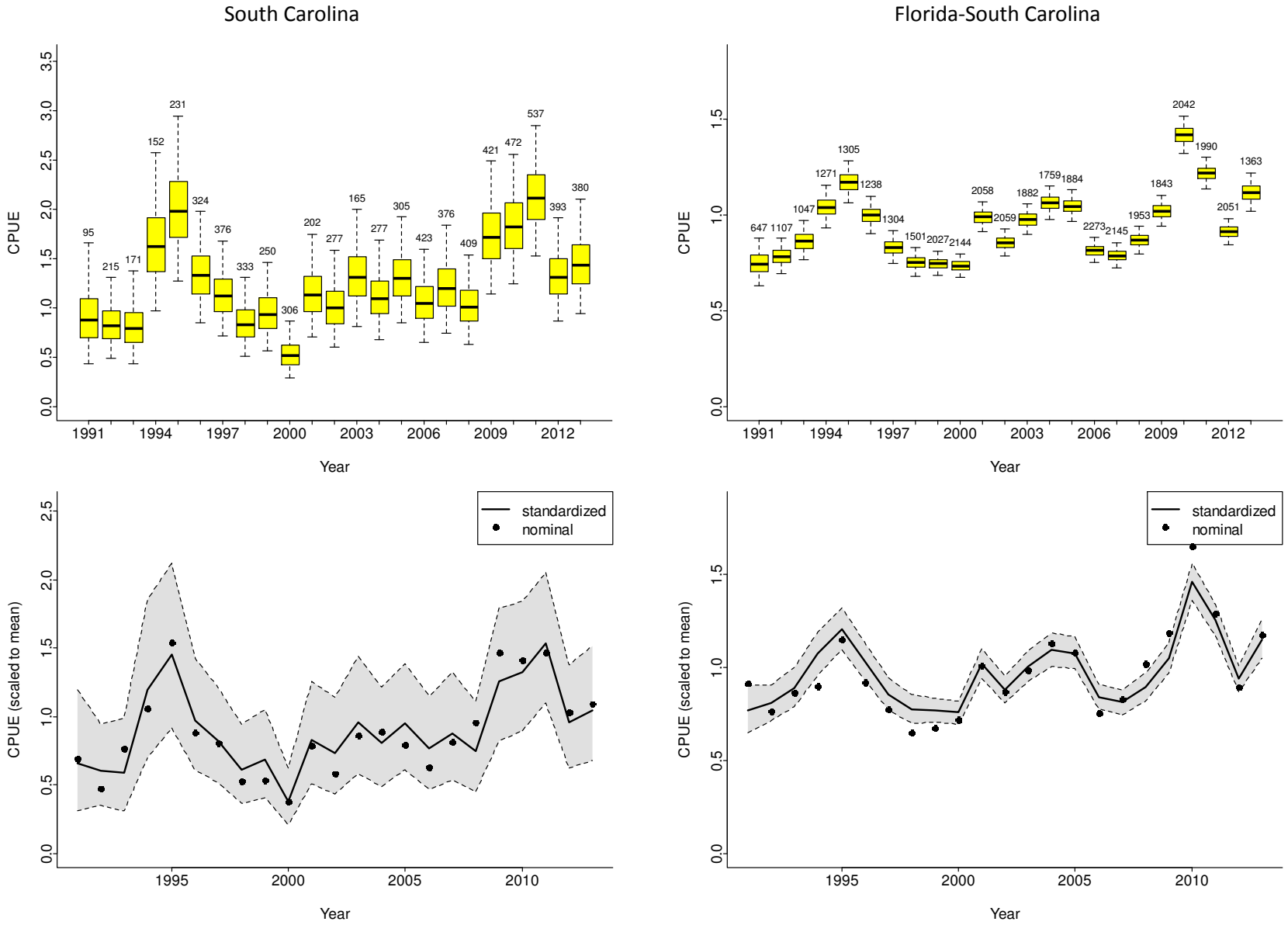

Figure 4. Standardized angler catch rates for selected (as potential red drum trips) estuarine fishing trips made in South Carolina and entire southern region during 1991-2013. Top graph shows Monte Carlo distribution of index and sample size. Lower graphs show the standardized index (line) with 95% confidence bounds (shaded) and the nominal means (points) relative to the overall time series mean.

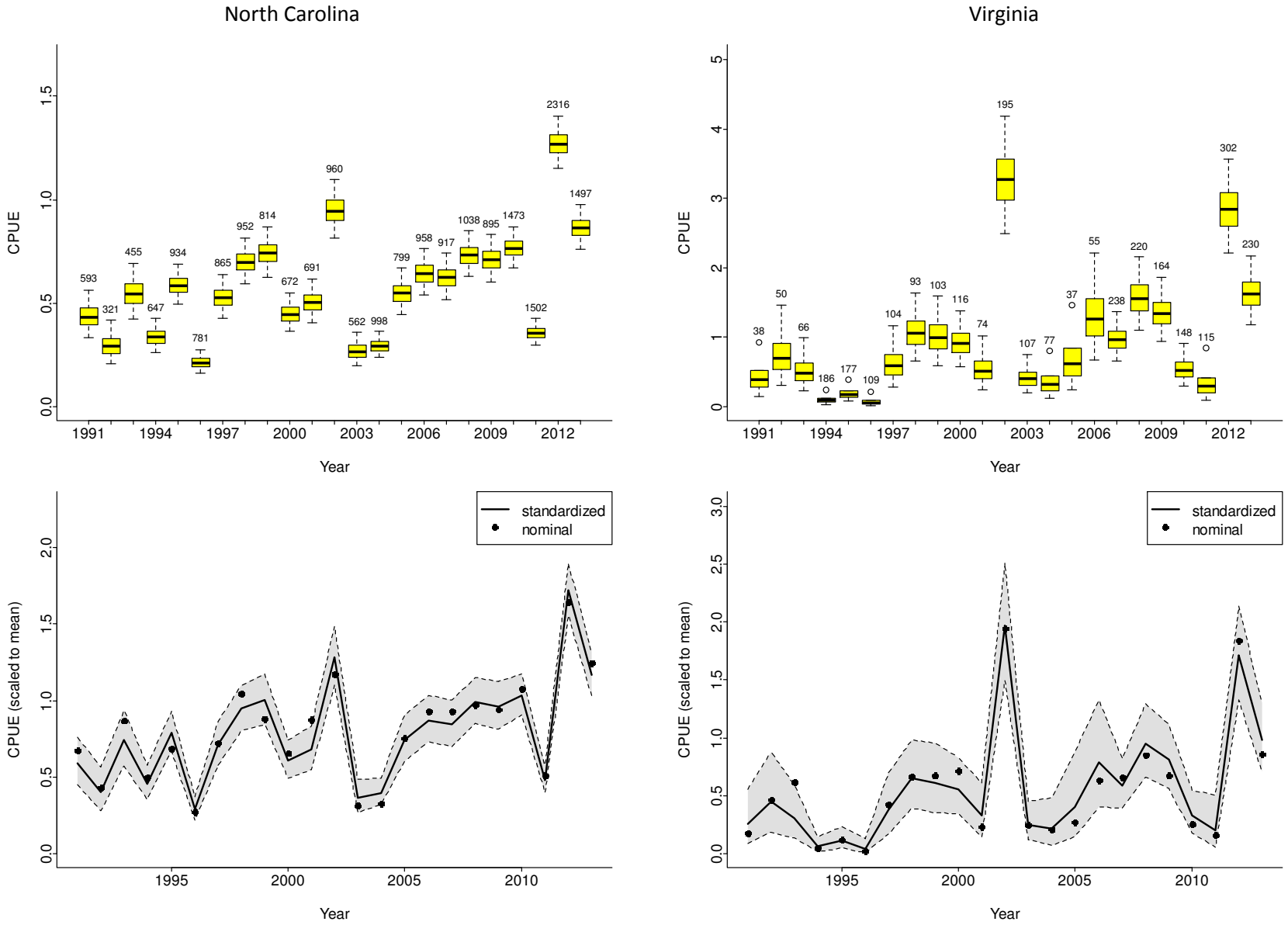

Figure 4. Standardized angler catch rates for selected (as potential red drum trips) estuarine fishing trips made in North Carolina and Virginia during 1991-2013. Top graph shows Monte Carlo distribution of index and sample size. Lower graphs show the standardized index (line) with 95% confidence bounds (shaded) and the nominal means (points) relative to the overall time series mean.

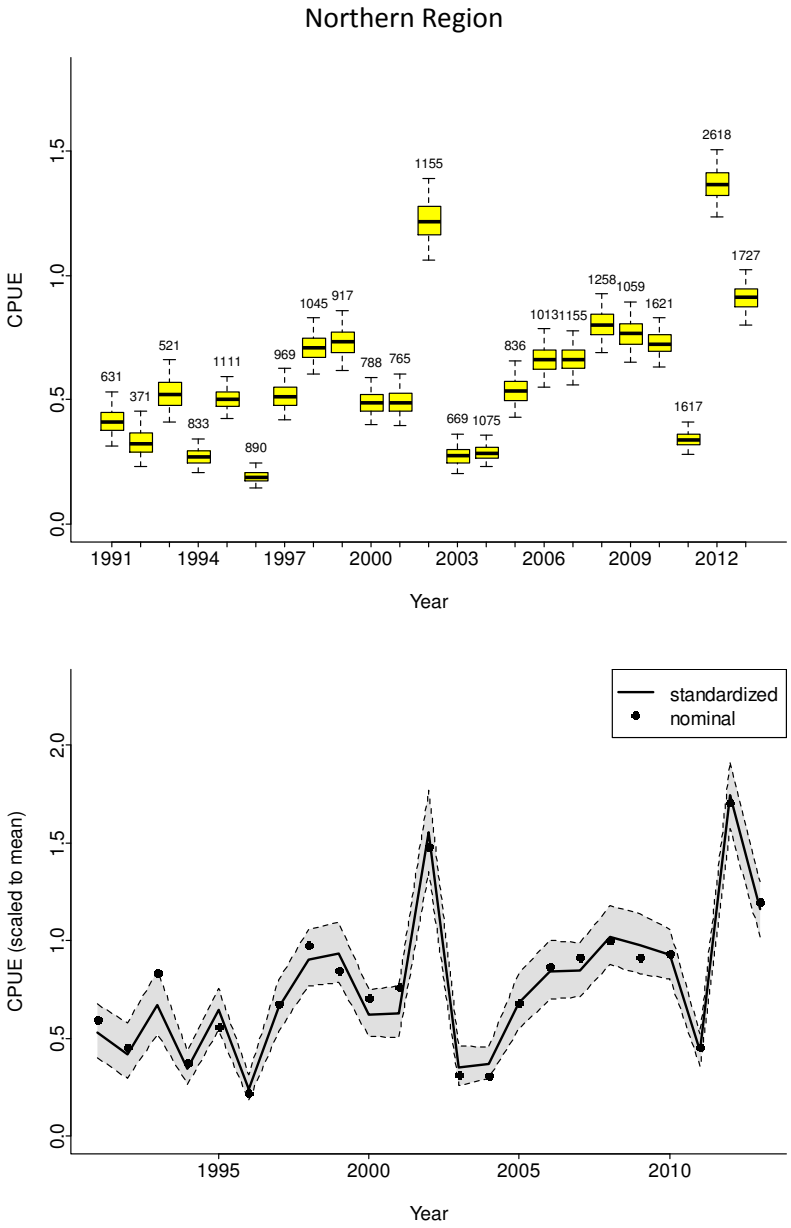

Figure 4. Standardized angler catch rates for selected (as potential red drum trips) estuarine fishing trips made in the entire northern region during 1991-2013. Top graph shows Monte Carlo distribution of index and sample size. Lower graphs show the standardized index (line) with 95% confidence bounds (shaded) and the nominal means (points) relative to the overall time series mean.

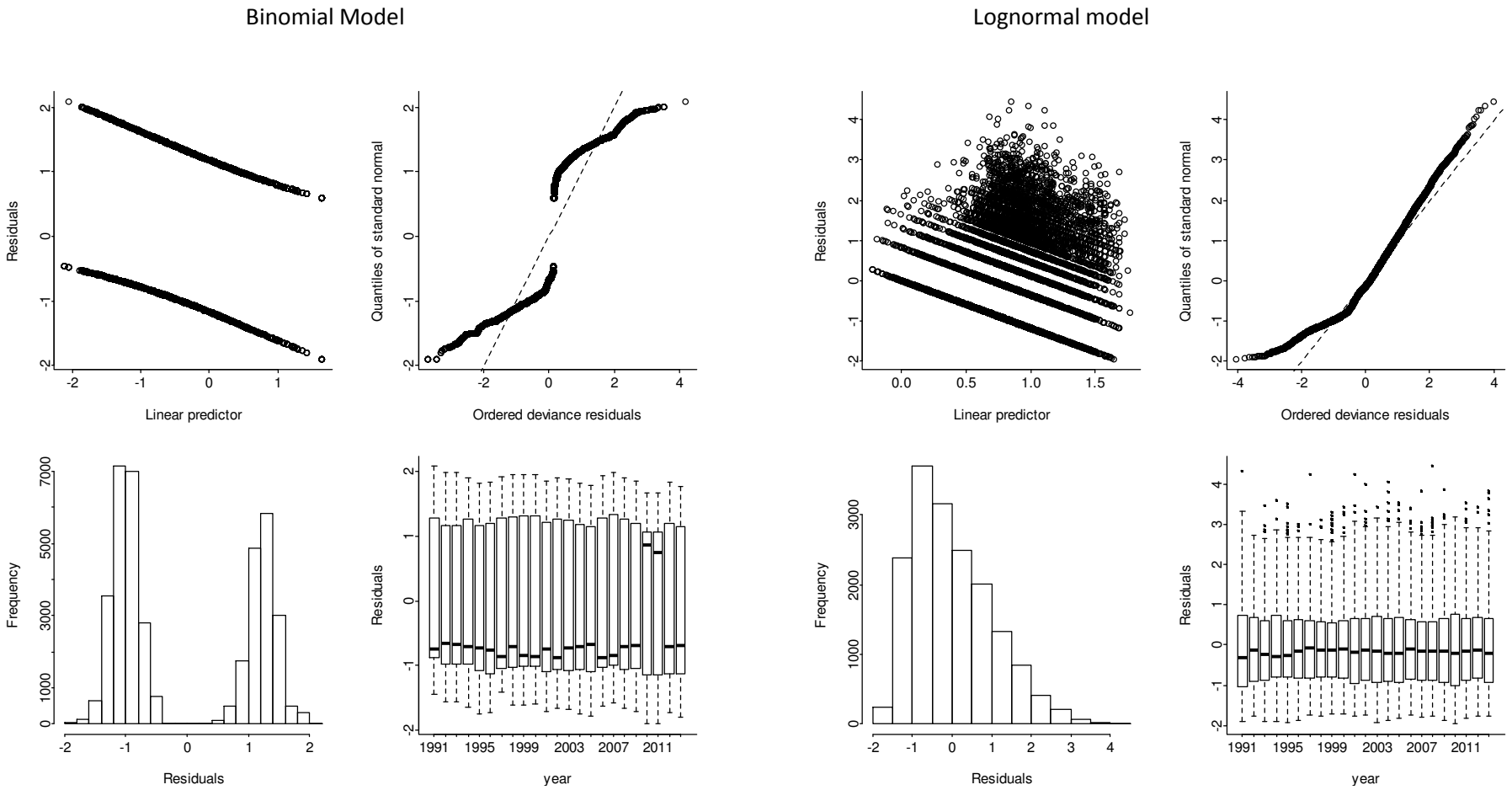

Figure 5. Diagnostic plots from the binomial and lognormal components of the delta lognormal model used to estimate year-specific marginal means (lsmeans) for angler total-catch rates for red drum in the southern stock region.

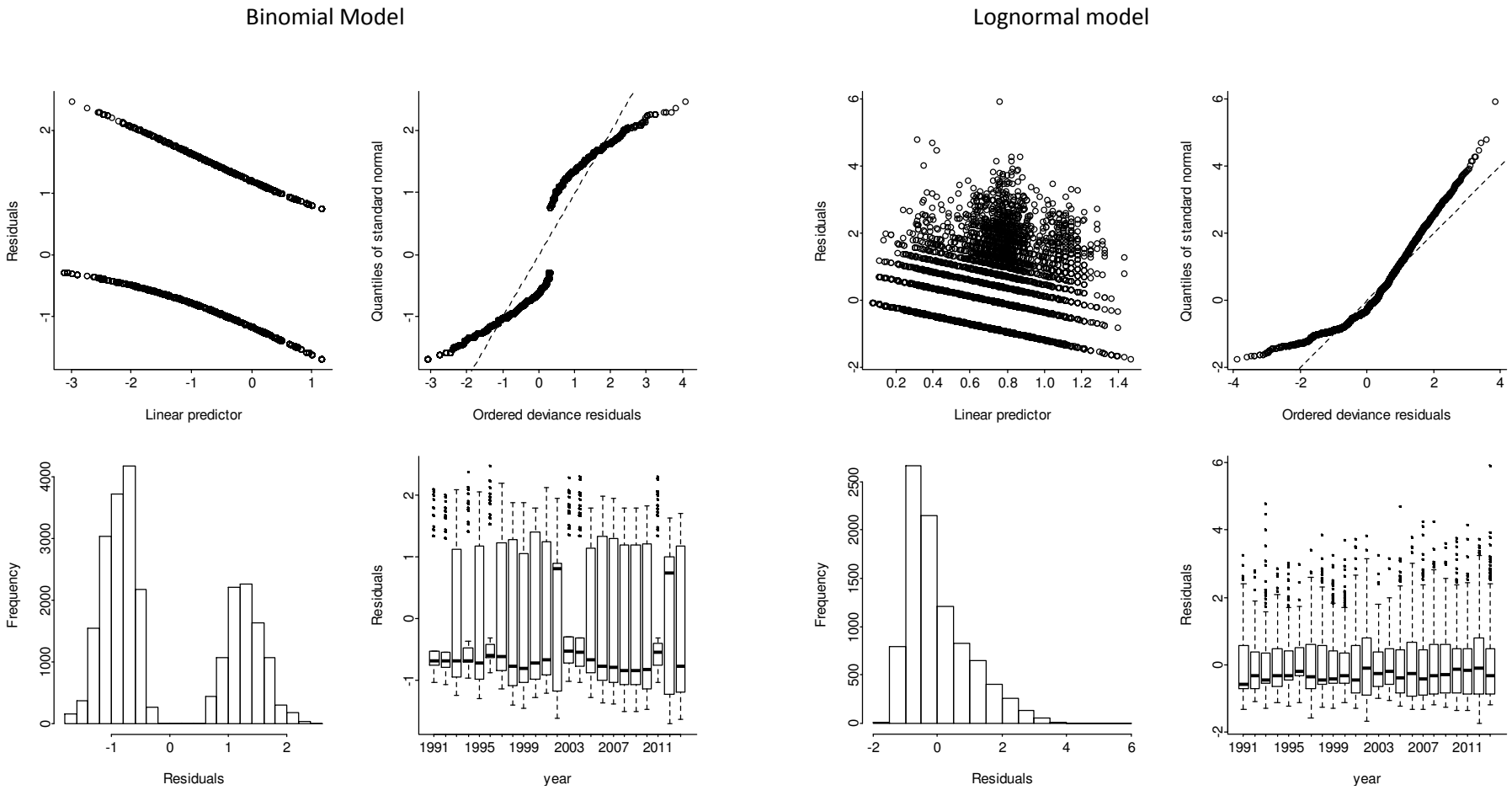

Figure 6. Diagnostic plots from the binomial and lognormal components of the delta lognormal model used to estimate year-specific marginal means (lsmeans) for angler total-catch rates for red drum in the northern stock region.