Discard Estimates for Atlantic Sturgeon through 2021

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Figure 1: Atlantic Sturgeon, Acipsener oxyrinchus oxyrinchus

Model-Based Estimates of Atlantic Sturgeon Encounters

Following the approach used by Miller and Shepherd (2011), Miller (2015), and Curti (2016), the same generalized linear model framework with quasi-poisson assumption was used for modeling sturgeon takes as a function of the trip-specific species mix, year and quarter factors. In Miller and Shepherd (2011), the "species mix" was comprised of those species currently managed with federal fishery management plans. In this analysis we follow the modifications applied in the most recent ASMFC Sturgeon Benchmark Assessment (ASMFC 2017), where the "species mix" covariates were those species caught most on observed hauls encountering sturgeon. The total hail weights were estimated for all individual species on hauls that encountered sturgeon and the species included as covariates were those whose cumulative sums represented 95% of the total hail weights on these hauls. ASMFC (2017) examined depth and mesh as potential covariates and determined that these variables were often missing and can change substantially over the course of a trip, while the composition of species landed on a trip could be used as a proxy for differences in mesh size and depth.

Following Miller and Shepherd (2011), a quasi-Poisson assumption was used for modeling sturgeon takes as a function of species landed, year, and quarter factors, permitting the variance to be greater than that associated with a Poisson distribution. Each species was included as a binary predictor variable because runs that included species landed weights as continuous variables had convergence problems. The general model for the log-average take on trip i was:

$$\ln(\hat{T}_i) = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + ... + \hat{\beta}_p X_{pi}$$

where $X_{1i}, ..., X_{pi}$ represents p species, gear, quarter covariates including any modeled interactions, and $\hat{\beta}_p$ represent estimated parameters.

Candidate models were fit separately to all observed bottom otter trawl and gillnet (sink and drift) trips. Models were fit to an appropriate subset of observer trips between 2000 and 2021. Analyses for 2020 were not possible because of reductions in observer coverage in that year due to the COVID-19 pandemic. The subset of observed trips included all coastal statistical areas (Figure 2) and those observer programs that

encountered sturgeon and had a representative geographic range. Model selection was robust to the choice of included areas and observer programs. The species included as covariates for each gear are detailed in Tables 1 and 2 for otter trawls and gillnets, respectively.

The full time series of discard estimates may change as the models are updated in subsequent years because model parameter estimates will change when data from additional years are incorporated into the model. Consequently, the discard estimates presented in this report differ from those of the previous updates.

Candidate models included the following factors and interactions:

1. No covariates
2. Quarter
3. Year
4. Quarter + Year + Quarter:Year
5. Species
6. Species + Quarter + Species:Quarter
7. Species + Year + Species:Year
8. Species + Year + Quarter + Species:Quarter + Species:Year
9. Species + Year + Quarter + Species:Quarter + Species:Year + Year:Quarter
10. Species + Year + Quarter + Species:Quarter + Species:Year + Year:Quarter + Species:Quarter:Year

For each gear (otter trawl and gillnet), the best performing model was selected based on $QAIC_c$; the preferred model was the one with the minimum $QAIC_c$ value.

To predict sturgeon take for all commercial landings, landings for each trip between 2000 and 2021 (except 2020) in the VTR database were determined for each species covariate. Using the estimated coefficients from the best performing model for each gear, the expected sturgeon take was predicted for each VTR trip where information was available on whether the species was landed, and, if necessary, year and quarter. Total annual discard estimates were the sums of all predictions from the best-performing model for trips made in the relevant year.

To estimate dead bycatch, GLMs were fit to data based only on those sturgeon encounters where individuals were recorded as dead. These models, however, resulted in nonsensical estimates for the total expected sturgeon take when expanded to the VTR trips, presumably due to low sample sizes. As a result, dead discards were estimated by calculating the proportion of observed sturgeon recorded as dead and applying this proportion to the total take estimate.

The best performing model fitted to trip-specific observer otter trawl data was model 8, but it produced unrealistic estimates of sturgeon bycatch (10^{37} sturgeon) and was not used. The next best was model 6, which allowed quarterly effects of the species mix on sturgeon take (Table 3 and Table 4) was selected instead. Model 10 failed to converge. The best performing model fitted to trip-specific observer gillnet data was model 9, which allowed yearly and quarterly effects of the species mix on sturgeon take with interaction between year and quarter (Table 5, Table 6). Model 10 again failed to converge.

The selected model for each gear type was applied to vessel trip reports to predict sturgeon take for all trips. The total bycatch of sturgeon from bottom otter trawls ranged between 638 – 1,434 fish over the time series (Table 7). The proportion of the encountered sturgeon recorded as dead ranged between 0 – 18% and averaged 4%. This resulted in annual dead discards ranging from 0 – 203 fish. Likewise, the total bycatch of sturgeon from sink and drift gillnets ranged from 281 – 3,326 fish (Table 8). The proportion of sturgeon recorded as dead ranged between 12 – 51% and averaged 30%, resulting in annual dead discards ranging from 122 – 774 fish.

References

Atlantic States Marine Fisheries Commission (ASMFC). 2017. 2017 Atlantic Sturgeon Benchmark Stock Assessment and Peer Review Report.

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Miller, T. J., and Shepherd, G.R. 2011. Summary of discard estimates for Atlantic sturgeon (White paper). NOAA/NMFS, Woods Hole, MA: Population Dynamics Branch.

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Tables

Table 1: Species that represented 95% of the total landings on otter trawl trips that encountered sturgeon.

Common Name	Scientific Name	Cumulative Proportion
Croaker, Atlantic	*Micropogonias undulatus*	0.30
Squid, Atl Long-Fin	*Loligo pealeii*	0.45
Skate, Nk	*Rajidae*	0.59
Crab, Horseshoe	*Limulus polyphemus*	0.69
Flounder, Summer (Fluke)	*Paralichthys dentatus*	0.76
Skate, Little	*Leucoraja erinacea*	0.81
Scup	*Stenotomus chrysops*	0.84
Skate, Winter (Big)	*Raja ocellata*	0.86
Dogfish, Spiny	*Squalus acanthias*	0.88
Butterfish	*Peprilus triacanthus*	0.90
Cod, Atlantic	*Gadus morhua*	0.91
Skate, Clearnose	*Raja eglanteria*	0.92
Flounder, Yellowtail	*Limanda ferruginea*	0.93
Bass, Striped	*Morone saxatilis*	0.94
Dogfish, Smooth	*Mustelus canis*	0.94
Flounder, Winter (Blackback)	*Pseudopleuronectes americanus*	0.95

Table 2: Species that represented 95% of the total landings on gillnet trips that encountered sturgeon.

Common Name	Scientific Name	Cumulative Proportion
Monkfish (Goosefish)	*Lophius americanus*	0.28
Skate, Winter (Big)	*Raja ocellata*	0.55
Dogfish, Spiny	*Squalus acanthias*	0.79
Dogfish, Smooth	*Mustelus canis*	0.88
Bluefish	*Pomatomus saltatrix*	0.90
Cod, Atlantic	*Gadus morhua*	0.92
Skate, Nk	*Rajidae*	0.94
Bass, Striped	*Morone saxatilis*	0.95

Table 3: QAICc values for each successfully converged candidate model fitted to trip-specific observer otter trawl data from 2006-2021 without 2020 data.

Model	QAICc
1	3,469.91
2	3,379.32
3	3,368.01
4	3,232.55
5	2,926.76
6	2,743.15
7	2,888.25
8	2,721.50
9	2,750.89

Table 4: Estimated parameters for model 6 fitted to trip-specific observer otter trawl data from 2006-2021 without 2020 data.

Parameter	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-5.100	0.942	-5.413	0.000
butt.bTRUE	-0.513	0.577	-0.890	0.373
cl.sk.bTRUE	-14.636	3,876.134	-0.004	0.997
cod.bTRUE	-0.855	0.901	-0.950	0.342
croak.bTRUE	3.778	0.575	6.567	0.000

Parameter	Estimate	Std Error	t value	Pr(>|t|)
hsh.crb.bTRUE	3.346	1.123	2.981	0.003
lit.sk.bTRUE	1.528	1.310	1.167	0.243
loligo.bTRUE	-0.309	0.517	-0.598	0.550
other.bTRUE	0.630	0.853	0.738	0.460
sbass.bTRUE	-0.227	1.050	-0.216	0.829
scup.bTRUE	-1.939	1.415	-1.370	0.171
sm.dog.bTRUE	-0.369	0.953	-0.387	0.698
sp.dog.bTRUE	0.831	1.250	0.664	0.506
su.fl.bTRUE	1.136	0.567	2.005	0.045
unk.sk.bTRUE	-1.422	2.007	-0.708	0.479
win.fl.bTRUE	0.262	0.851	0.308	0.758
wint.sk.bTRUE	-1.779	1.085	-1.639	0.101
yt.fl.bTRUE	-0.172	1.069	-0.161	0.872
factor(QTR)2	1.987	1.025	1.938	0.053
factor(QTR)3	0.248	1.170	0.212	0.832
factor(QTR)4	1.255	1.094	1.147	0.251
butt.bTRUE:factor(QTR)2	0.632	0.617	1.025	0.305
butt.bTRUE:factor(QTR)3	1.098	0.661	1.660	0.097
butt.bTRUE:factor(QTR)4	1.085	0.650	1.670	0.095
cl.sk.bTRUE:factor(QTR)2	14.463	3,876.134	0.004	0.997
cl.sk.bTRUE:factor(QTR)3	16.177	3,876.134	0.004	0.997
cl.sk.bTRUE:factor(QTR)4	14.495	3,876.134	0.004	0.997
cod.bTRUE:factor(QTR)2	-2.032	1.181	-1.720	0.085
cod.bTRUE:factor(QTR)3	-12.203	363.802	-0.034	0.973
cod.bTRUE:factor(QTR)4	0.277	1.039	0.267	0.790
croak.bTRUE:factor(QTR)2	-0.489	0.703	-0.696	0.487
croak.bTRUE:factor(QTR)3	-1.395	0.665	-2.099	0.036
croak.bTRUE:factor(QTR)4	-2.203	0.676	-3.260	0.001
hsh.crb.bTRUE:factor(QTR)2	-3.751	1.290	-2.907	0.004
hsh.crb.bTRUE:factor(QTR)3	-4.541	1.252	-3.626	0.000
hsh.crb.bTRUE:factor(QTR)4	-2.085	1.187	-1.756	0.079
lit.sk.bTRUE:factor(QTR)2	-1.334	1.351	-0.987	0.324
lit.sk.bTRUE:factor(QTR)3	-1.443	1.372	-1.051	0.293
lit.sk.bTRUE:factor(QTR)4	-1.556	1.383	-1.125	0.261
loligo.bTRUE:factor(QTR)2	0.469	0.577	0.814	0.416

Parameter	Estimate	Std Error	t value	Pr(>|t|)
loligo.bTRUE:factor(QTR)3	-0.207	0.604	-0.342	0.732
loligo.bTRUE:factor(QTR)4	-0.245	0.592	-0.413	0.679
other.bTRUE:factor(QTR)2	0.162	0.934	0.174	0.862
other.bTRUE:factor(QTR)3	-1.115	0.907	-1.228	0.219
other.bTRUE:factor(QTR)4	-0.724	0.984	-0.736	0.462
sbass.bTRUE:factor(QTR)2	1.650	1.077	1.532	0.126
sbass.bTRUE:factor(QTR)3	-0.116	1.446	-0.080	0.936
sbass.bTRUE:factor(QTR)4	0.756	1.138	0.664	0.507
scup.bTRUE:factor(QTR)2	2.112	1.437	1.470	0.141
scup.bTRUE:factor(QTR)3	2.150	1.450	1.483	0.138
scup.bTRUE:factor(QTR)4	1.335	1.449	0.921	0.357
sm.dog.bTRUE:factor(QTR)2	0.963	0.978	0.985	0.325
sm.dog.bTRUE:factor(QTR)3	0.227	1.019	0.223	0.824
sm.dog.bTRUE:factor(QTR)4	0.303	1.082	0.280	0.780
sp.dog.bTRUE:factor(QTR)2	-2.291	1.414	-1.620	0.105
sp.dog.bTRUE:factor(QTR)3	-2.488	2.321	-1.072	0.284
sp.dog.bTRUE:factor(QTR)4	-0.204	1.303	-0.157	0.876
su.fl.bTRUE:factor(QTR)2	-1.625	0.619	-2.626	0.009
su.fl.bTRUE:factor(QTR)3	1.028	0.890	1.155	0.248
su.fl.bTRUE:factor(QTR)4	0.191	0.691	0.276	0.782
unk.sk.bTRUE:factor(QTR)2	1.895	2.032	0.932	0.351
unk.sk.bTRUE:factor(QTR)3	0.830	2.099	0.395	0.693
unk.sk.bTRUE:factor(QTR)4	2.159	2.037	1.060	0.289
win.fl.bTRUE:factor(QTR)2	-0.930	0.906	-1.027	0.305
win.fl.bTRUE:factor(QTR)3	-1.003	1.363	-0.736	0.462
win.fl.bTRUE:factor(QTR)4	0.006	0.933	0.006	0.995
wint.sk.bTRUE:factor(QTR)2	2.184	1.104	1.978	0.048
wint.sk.bTRUE:factor(QTR)3	1.064	1.201	0.885	0.376
wint.sk.bTRUE:factor(QTR)4	1.873	1.130	1.657	0.098
yt.fl.bTRUE:factor(QTR)2	-0.295	1.233	-0.239	0.811
yt.fl.bTRUE:factor(QTR)3	-0.394	2.357	-0.167	0.867
yt.fl.bTRUE:factor(QTR)4	-1.093	1.221	-0.895	0.371

Table 5: QAICc values for each successfully converged candidate model fitted to trip-specific observer gillnet data from 2006-2021 without 2020 data.

Model	QAICc
1	8,078.96
2	7,501.43
3	7,788.71
4	7,190.84
5	7,032.43
6	6,434.20
7	6,599.43
8	6,104.04
9	6,063.87

Table 6: Estimated parameters for model 6 fitted to trip-specific observer gillnet data from 2006-2021 without 2020 data.

Parameter	Estimate	Std Error	t value	Pr(>|t|)
(Intercept)	-2.656	0.463	-5.737	0.000
blue.bTRUE	-1.021	0.589	-1.734	0.083
cod.bTRUE	-0.530	0.485	-1.093	0.275
monk.bTRUE	0.788	0.397	1.985	0.047
other.bTRUE	-0.175	0.344	-0.511	0.610
sbass.bTRUE	1.570	0.379	4.143	0.000
sm.dog.bTRUE	0.957	0.384	2.494	0.013
sp.dog.bTRUE	1.617	0.366	4.419	0.000
unk.sk.bTRUE	1.051	0.702	1.496	0.135
wint.sk.bTRUE	-1.438	0.568	-2.532	0.011
factor(QTR)2	-0.504	0.502	-1.004	0.315
factor(QTR)3	-1.736	0.979	-1.774	0.076
factor(QTR)4	0.301	0.478	0.629	0.529
factor(YEAR)2001	-0.477	0.739	-0.646	0.519
factor(YEAR)2002	-2.323	1.077	-2.156	0.031
factor(YEAR)2003	0.464	0.645	0.719	0.472
factor(YEAR)2004	-0.553	0.635	-0.870	0.384
factor(YEAR)2005	-0.612	0.726	-0.843	0.399

Parameter	Estimate	Std Error	t value	Pr(>|t|)
factor(YEAR)2006	0.459	0.633	0.725	0.469
factor(YEAR)2007	-0.046	0.604	-0.076	0.940
factor(YEAR)2008	-0.498	0.745	-0.668	0.504
factor(YEAR)2009	-0.796	0.729	-1.092	0.275
factor(YEAR)2010	-0.832	0.808	-1.030	0.303
factor(YEAR)2011	-1.360	0.701	-1.941	0.052
factor(YEAR)2012	-0.250	0.699	-0.357	0.721
factor(YEAR)2013	-0.837	0.839	-0.998	0.318
factor(YEAR)2014	-0.531	0.669	-0.793	0.428
factor(YEAR)2015	-2.046	0.867	-2.359	0.018
factor(YEAR)2016	-0.190	0.529	-0.360	0.719
factor(YEAR)2017	-0.120	0.582	-0.205	0.837
factor(YEAR)2018	0.120	0.584	0.205	0.838
factor(YEAR)2019	0.109	0.536	0.204	0.838
factor(YEAR)2021	-14.812	1,012.168	-0.015	0.988
blue.bTRUE:factor(QTR)2	1.404	0.470	2.988	0.003
blue.bTRUE:factor(QTR)3	0.956	0.585	1.633	0.102
blue.bTRUE:factor(QTR)4	1.222	0.484	2.522	0.012
blue.bTRUE:factor(YEAR)2001	0.171	0.614	0.278	0.781
blue.bTRUE:factor(YEAR)2002	-0.387	0.778	-0.497	0.619
blue.bTRUE:factor(YEAR)2003	-1.488	0.733	-2.030	0.042
blue.bTRUE:factor(YEAR)2004	-0.278	0.514	-0.541	0.589
blue.bTRUE:factor(YEAR)2005	0.503	0.593	0.848	0.397
blue.bTRUE:factor(YEAR)2006	0.040	0.557	0.071	0.943
blue.bTRUE:factor(YEAR)2007	0.449	0.582	0.771	0.441
blue.bTRUE:factor(YEAR)2008	0.123	0.757	0.162	0.871
blue.bTRUE:factor(YEAR)2009	-1.720	0.852	-2.019	0.043
blue.bTRUE:factor(YEAR)2010	-0.516	0.790	-0.653	0.514
blue.bTRUE:factor(YEAR)2011	-1.191	0.933	-1.277	0.202
blue.bTRUE:factor(YEAR)2012	0.080	0.886	0.090	0.928
blue.bTRUE:factor(YEAR)2013	0.155	0.594	0.261	0.794
blue.bTRUE:factor(YEAR)2014	-0.028	0.657	-0.042	0.966
blue.bTRUE:factor(YEAR)2015	-0.516	0.504	-1.024	0.306
blue.bTRUE:factor(YEAR)2016	-0.032	0.479	-0.066	0.947
blue.bTRUE:factor(YEAR)2017	-0.135	0.497	-0.272	0.786

Parameter	Estimate	Std Error	t value	Pr(>|t|)
blue.bTRUE:factor(YEAR)2018	-1.619	0.692	-2.338	0.019
blue.bTRUE:factor(YEAR)2019	-0.274	0.521	-0.526	0.599
blue.bTRUE:factor(YEAR)2021	-1.150	1.008	-1.141	0.254
cod.bTRUE:factor(QTR)2	-0.535	0.315	-1.698	0.090
cod.bTRUE:factor(QTR)3	0.418	0.584	0.716	0.474
cod.bTRUE:factor(QTR)4	-0.929	0.305	-3.041	0.002
cod.bTRUE:factor(YEAR)2001	-0.125	0.730	-0.171	0.864
cod.bTRUE:factor(YEAR)2002	0.130	0.771	0.169	0.866
cod.bTRUE:factor(YEAR)2003	0.380	0.642	0.592	0.554
cod.bTRUE:factor(YEAR)2004	0.370	0.557	0.664	0.507
cod.bTRUE:factor(YEAR)2005	-0.008	0.686	-0.011	0.991
cod.bTRUE:factor(YEAR)2006	-1.650	0.816	-2.023	0.043
cod.bTRUE:factor(YEAR)2007	-1.339	0.787	-1.700	0.089
cod.bTRUE:factor(YEAR)2008	-0.051	0.836	-0.061	0.951
cod.bTRUE:factor(YEAR)2009	-0.813	0.844	-0.962	0.336
cod.bTRUE:factor(YEAR)2010	0.437	0.669	0.654	0.513
cod.bTRUE:factor(YEAR)2011	1.870	0.639	2.925	0.003
cod.bTRUE:factor(YEAR)2012	0.879	0.661	1.330	0.184
cod.bTRUE:factor(YEAR)2013	1.380	0.745	1.852	0.064
cod.bTRUE:factor(YEAR)2014	1.729	0.645	2.680	0.007
cod.bTRUE:factor(YEAR)2015	-1.192	0.820	-1.454	0.146
cod.bTRUE:factor(YEAR)2016	-0.311	0.678	-0.458	0.647
cod.bTRUE:factor(YEAR)2017	0.060	0.755	0.080	0.936
cod.bTRUE:factor(YEAR)2018	0.554	0.705	0.786	0.432
cod.bTRUE:factor(YEAR)2019	-1.260	0.944	-1.335	0.182
cod.bTRUE:factor(YEAR)2021	-0.023	0.955	-0.024	0.981
monk.bTRUE:factor(QTR)2	-0.565	0.227	-2.488	0.013
monk.bTRUE:factor(QTR)3	-1.261	0.546	-2.311	0.021
monk.bTRUE:factor(QTR)4	0.006	0.269	0.021	0.983
monk.bTRUE:factor(YEAR)2001	0.913	0.588	1.553	0.120
monk.bTRUE:factor(YEAR)2002	1.614	0.803	2.009	0.045
monk.bTRUE:factor(YEAR)2003	-0.488	0.597	-0.818	0.413
monk.bTRUE:factor(YEAR)2004	-0.133	0.534	-0.248	0.804
monk.bTRUE:factor(YEAR)2005	0.702	0.633	1.110	0.267
monk.bTRUE:factor(YEAR)2006	0.657	0.514	1.280	0.201

Parameter	Estimate	Std Error	t value	Pr(>|t|)
monk.bTRUE:factor(YEAR)2007	1.979	0.561	3.529	0.000
monk.bTRUE:factor(YEAR)2008	0.820	0.701	1.169	0.242
monk.bTRUE:factor(YEAR)2009	0.443	0.664	0.668	0.504
monk.bTRUE:factor(YEAR)2010	0.242	0.699	0.346	0.729
monk.bTRUE:factor(YEAR)2011	-0.470	0.576	-0.816	0.414
monk.bTRUE:factor(YEAR)2012	-0.304	0.589	-0.516	0.606
monk.bTRUE:factor(YEAR)2013	-0.127	0.658	-0.194	0.847
monk.bTRUE:factor(YEAR)2014	-1.508	0.583	-2.588	0.010
monk.bTRUE:factor(YEAR)2015	-0.883	0.522	-1.693	0.090
monk.bTRUE:factor(YEAR)2016	0.265	0.482	0.551	0.582
monk.bTRUE:factor(YEAR)2017	-1.093	0.533	-2.050	0.040
monk.bTRUE:factor(YEAR)2018	-1.621	0.522	-3.106	0.002
monk.bTRUE:factor(YEAR)2019	-0.128	0.523	-0.245	0.806
monk.bTRUE:factor(YEAR)2021	-0.204	0.755	-0.270	0.787
other.bTRUE:factor(QTR)2	0.047	0.193	0.243	0.808
other.bTRUE:factor(QTR)3	0.028	0.499	0.057	0.955
other.bTRUE:factor(QTR)4	-0.332	0.209	-1.591	0.112
other.bTRUE:factor(YEAR)2001	-0.028	0.514	-0.054	0.957
other.bTRUE:factor(YEAR)2002	0.263	0.641	0.410	0.682
other.bTRUE:factor(YEAR)2003	0.254	0.550	0.463	0.643
other.bTRUE:factor(YEAR)2004	0.431	0.442	0.975	0.330
other.bTRUE:factor(YEAR)2005	0.021	0.523	0.040	0.968
other.bTRUE:factor(YEAR)2006	0.841	0.490	1.717	0.086
other.bTRUE:factor(YEAR)2007	0.042	0.455	0.091	0.927
other.bTRUE:factor(YEAR)2008	0.412	0.593	0.694	0.487
other.bTRUE:factor(YEAR)2009	0.607	0.446	1.361	0.173
other.bTRUE:factor(YEAR)2010	-0.223	0.505	-0.442	0.658
other.bTRUE:factor(YEAR)2011	-0.105	0.585	-0.179	0.858
other.bTRUE:factor(YEAR)2012	-0.530	0.561	-0.944	0.345
other.bTRUE:factor(YEAR)2013	-1.038	0.513	-2.022	0.043
other.bTRUE:factor(YEAR)2014	-0.239	0.527	-0.452	0.651
other.bTRUE:factor(YEAR)2015	1.319	0.460	2.866	0.004
other.bTRUE:factor(YEAR)2016	0.523	0.380	1.379	0.168
other.bTRUE:factor(YEAR)2017	0.709	0.420	1.687	0.092
other.bTRUE:factor(YEAR)2018	0.470	0.414	1.135	0.256

Parameter	Estimate	Std Error	t value	Pr(>|t|)
other.bTRUE:factor(YEAR)2019	0.742	0.393	1.886	0.059
other.bTRUE:factor(YEAR)2021	-0.813	0.647	-1.256	0.209
sbass.bTRUE:factor(QTR)2	-0.151	0.444	-0.341	0.733
sbass.bTRUE:factor(QTR)3	0.719	0.659	1.091	0.275
sbass.bTRUE:factor(QTR)4	0.214	0.385	0.554	0.579
sbass.bTRUE:factor(YEAR)2001	0.843	0.632	1.334	0.182
sbass.bTRUE:factor(YEAR)2002	0.545	0.775	0.704	0.482
sbass.bTRUE:factor(YEAR)2003	0.343	0.606	0.567	0.571
sbass.bTRUE:factor(YEAR)2004	-0.602	0.640	-0.940	0.347
sbass.bTRUE:factor(YEAR)2005	-0.647	0.823	-0.786	0.432
sbass.bTRUE:factor(YEAR)2006	-0.768	0.754	-1.019	0.308
sbass.bTRUE:factor(YEAR)2007	0.738	0.582	1.267	0.205
sbass.bTRUE:factor(YEAR)2008	0.176	0.737	0.239	0.811
sbass.bTRUE:factor(YEAR)2009	1.454	0.736	1.975	0.048
sbass.bTRUE:factor(YEAR)2010	-1.936	1.505	-1.286	0.198
sbass.bTRUE:factor(YEAR)2011	-15.596	1,321.489	-0.012	0.991
sbass.bTRUE:factor(YEAR)2012	-16.244	1,650.057	-0.010	0.992
sbass.bTRUE:factor(YEAR)2013	-17.866	2,182.583	-0.008	0.993
sbass.bTRUE:factor(YEAR)2014	-17.737	3,779.097	-0.005	0.996
sbass.bTRUE:factor(YEAR)2015	-2.296	1.463	-1.569	0.117
sbass.bTRUE:factor(YEAR)2016	-17.213	1,061.776	-0.016	0.987
sbass.bTRUE:factor(YEAR)2017	-1.304	0.825	-1.581	0.114
sbass.bTRUE:factor(YEAR)2018	-3.088	1.105	-2.795	0.005
sbass.bTRUE:factor(YEAR)2019	-2.839	0.859	-3.306	0.001
sbass.bTRUE:factor(YEAR)2021	-17.053	1,822.219	-0.009	0.993
sm.dog.bTRUE:factor(QTR)2	1.536	0.310	4.956	0.000
sm.dog.bTRUE:factor(QTR)3	2.129	0.511	4.169	0.000
sm.dog.bTRUE:factor(QTR)4	-0.188	0.357	-0.526	0.599
sm.dog.bTRUE:factor(YEAR)2001	-2.095	0.685	-3.061	0.002
sm.dog.bTRUE:factor(YEAR)2002	-1.428	0.878	-1.627	0.104
sm.dog.bTRUE:factor(YEAR)2003	-0.886	0.691	-1.281	0.200
sm.dog.bTRUE:factor(YEAR)2004	-1.623	0.742	-2.187	0.029
sm.dog.bTRUE:factor(YEAR)2005	-2.610	1.108	-2.357	0.018
sm.dog.bTRUE:factor(YEAR)2006	-1.007	0.522	-1.929	0.054
sm.dog.bTRUE:factor(YEAR)2007	-1.900	0.587	-3.238	0.001

Parameter	Estimate	Std Error	t value	Pr(>|t|)
sm.dog.bTRUE:factor(YEAR)2008	-0.194	0.914	-0.212	0.832
sm.dog.bTRUE:factor(YEAR)2009	-1.435	0.609	-2.356	0.018
sm.dog.bTRUE:factor(YEAR)2010	-0.071	0.774	-0.092	0.927
sm.dog.bTRUE:factor(YEAR)2011	-0.874	1.145	-0.763	0.445
sm.dog.bTRUE:factor(YEAR)2012	-1.018	0.714	-1.427	0.154
sm.dog.bTRUE:factor(YEAR)2013	0.720	0.563	1.279	0.201
sm.dog.bTRUE:factor(YEAR)2014	-0.940	0.715	-1.315	0.189
sm.dog.bTRUE:factor(YEAR)2015	-0.567	0.474	-1.197	0.231
sm.dog.bTRUE:factor(YEAR)2016	0.064	0.435	0.146	0.884
sm.dog.bTRUE:factor(YEAR)2017	-0.687	0.466	-1.472	0.141
sm.dog.bTRUE:factor(YEAR)2018	0.378	0.478	0.790	0.430
sm.dog.bTRUE:factor(YEAR)2019	-0.356	0.474	-0.751	0.453
sm.dog.bTRUE:factor(YEAR)2021	-0.368	0.745	-0.494	0.621
sp.dog.bTRUE:factor(QTR)2	-1.039	0.243	-4.279	0.000
sp.dog.bTRUE:factor(QTR)3	-0.482	0.470	-1.026	0.305
sp.dog.bTRUE:factor(QTR)4	0.037	0.252	0.147	0.883
sp.dog.bTRUE:factor(YEAR)2001	-1.009	0.927	-1.088	0.277
sp.dog.bTRUE:factor(YEAR)2002	-0.592	0.790	-0.749	0.454
sp.dog.bTRUE:factor(YEAR)2003	-1.344	1.148	-1.171	0.242
sp.dog.bTRUE:factor(YEAR)2004	-2.155	0.573	-3.760	0.000
sp.dog.bTRUE:factor(YEAR)2005	-2.042	0.671	-3.044	0.002
sp.dog.bTRUE:factor(YEAR)2006	-1.456	0.738	-1.974	0.048
sp.dog.bTRUE:factor(YEAR)2007	-0.589	0.516	-1.142	0.253
sp.dog.bTRUE:factor(YEAR)2008	-0.309	0.722	-0.428	0.669
sp.dog.bTRUE:factor(YEAR)2009	-3.678	1.501	-2.450	0.014
sp.dog.bTRUE:factor(YEAR)2010	-0.016	0.517	-0.032	0.975
sp.dog.bTRUE:factor(YEAR)2011	-0.598	0.569	-1.051	0.293
sp.dog.bTRUE:factor(YEAR)2012	-1.292	0.611	-2.116	0.034
sp.dog.bTRUE:factor(YEAR)2013	-1.534	0.520	-2.952	0.003
sp.dog.bTRUE:factor(YEAR)2014	-1.180	0.529	-2.233	0.026
sp.dog.bTRUE:factor(YEAR)2015	-0.143	0.477	-0.300	0.764
sp.dog.bTRUE:factor(YEAR)2016	-0.749	0.422	-1.777	0.076
sp.dog.bTRUE:factor(YEAR)2017	-1.056	0.452	-2.336	0.020
sp.dog.bTRUE:factor(YEAR)2018	-1.045	0.461	-2.265	0.024
sp.dog.bTRUE:factor(YEAR)2019	-0.563	0.434	-1.298	0.194

Parameter	Estimate	Std Error	t value	Pr(>|t|)
sp.dog.bTRUE:factor(YEAR)2021	-0.992	0.745	-1.332	0.183
unk.sk.bTRUE:factor(QTR)2	-0.082	0.510	-0.161	0.872
unk.sk.bTRUE:factor(QTR)3	-0.178	1.129	-0.158	0.874
unk.sk.bTRUE:factor(QTR)4	-0.304	0.539	-0.565	0.572
unk.sk.bTRUE:factor(YEAR)2001	-0.836	1.547	-0.540	0.589
unk.sk.bTRUE:factor(YEAR)2002	0.839	1.081	0.776	0.438
unk.sk.bTRUE:factor(YEAR)2003	-16.203	1,503.930	-0.011	0.991
unk.sk.bTRUE:factor(YEAR)2004	-0.314	0.774	-0.405	0.685
unk.sk.bTRUE:factor(YEAR)2005	-2.111	1.530	-1.380	0.168
unk.sk.bTRUE:factor(YEAR)2006	-1.351	0.810	-1.667	0.095
unk.sk.bTRUE:factor(YEAR)2007	-2.361	1.172	-2.014	0.044
unk.sk.bTRUE:factor(YEAR)2008	-0.942	1.584	-0.595	0.552
unk.sk.bTRUE:factor(YEAR)2009	-1.597	1.530	-1.043	0.297
unk.sk.bTRUE:factor(YEAR)2010	-15.320	1,286.389	-0.012	0.990
unk.sk.bTRUE:factor(YEAR)2011	0.063	1.172	0.054	0.957
unk.sk.bTRUE:factor(YEAR)2012	-15.869	1,595.745	-0.010	0.992
unk.sk.bTRUE:factor(YEAR)2013	0.162	0.913	0.178	0.859
unk.sk.bTRUE:factor(YEAR)2014	0.531	0.809	0.657	0.511
unk.sk.bTRUE:factor(YEAR)2015	-15.723	767.893	-0.020	0.984
unk.sk.bTRUE:factor(YEAR)2016	-2.195	1.158	-1.894	0.058
unk.sk.bTRUE:factor(YEAR)2017	-0.804	0.821	-0.980	0.327
unk.sk.bTRUE:factor(YEAR)2018	-0.066	0.805	-0.082	0.935
unk.sk.bTRUE:factor(YEAR)2019	-1.050	0.784	-1.340	0.180
unk.sk.bTRUE:factor(YEAR)2021	-0.006	0.988	-0.006	0.995
wint.sk.bTRUE:factor(QTR)2	0.868	0.268	3.234	0.001
wint.sk.bTRUE:factor(QTR)3	0.563	0.495	1.138	0.255
wint.sk.bTRUE:factor(QTR)4	1.409	0.290	4.852	0.000
wint.sk.bTRUE:factor(YEAR)2001	0.980	0.676	1.449	0.147
wint.sk.bTRUE:factor(YEAR)2002	0.765	0.747	1.024	0.306
wint.sk.bTRUE:factor(YEAR)2003	0.707	0.774	0.913	0.361
wint.sk.bTRUE:factor(YEAR)2004	1.610	0.627	2.567	0.010
wint.sk.bTRUE:factor(YEAR)2005	0.725	0.687	1.055	0.291
wint.sk.bTRUE:factor(YEAR)2006	-0.834	0.732	-1.140	0.254
wint.sk.bTRUE:factor(YEAR)2007	-0.473	0.670	-0.706	0.480
wint.sk.bTRUE:factor(YEAR)2008	-0.057	0.859	-0.066	0.947

Parameter	Estimate	Std Error	t value	Pr(>|t|)
wint.sk.bTRUE:factor(YEAR)2009	2.020	0.741	2.727	0.006
wint.sk.bTRUE:factor(YEAR)2010	1.476	0.780	1.891	0.059
wint.sk.bTRUE:factor(YEAR)2011	2.232	0.670	3.333	0.001
wint.sk.bTRUE:factor(YEAR)2012	1.652	0.714	2.313	0.021
wint.sk.bTRUE:factor(YEAR)2013	2.102	0.746	2.815	0.005
wint.sk.bTRUE:factor(YEAR)2014	1.743	0.684	2.549	0.011
wint.sk.bTRUE:factor(YEAR)2015	0.743	0.625	1.189	0.235
wint.sk.bTRUE:factor(YEAR)2016	1.230	0.610	2.017	0.044
wint.sk.bTRUE:factor(YEAR)2017	0.664	0.650	1.022	0.307
wint.sk.bTRUE:factor(YEAR)2018	2.001	0.622	3.218	0.001
wint.sk.bTRUE:factor(YEAR)2019	0.344	0.651	0.528	0.597
wint.sk.bTRUE:factor(YEAR)2021	0.097	0.812	0.119	0.905
factor(QTR)2:factor(YEAR)2001	0.546	0.659	0.829	0.407
factor(QTR)3:factor(YEAR)2001	-13.895	533.460	-0.026	0.979
factor(QTR)4:factor(YEAR)2001	-1.601	0.743	-2.154	0.031
factor(QTR)2:factor(YEAR)2002	1.695	0.899	1.886	0.059
factor(QTR)3:factor(YEAR)2002	1.923	1.350	1.425	0.154
factor(QTR)4:factor(YEAR)2002	0.670	0.851	0.787	0.431
factor(QTR)2:factor(YEAR)2003	0.796	0.722	1.102	0.270
factor(QTR)3:factor(YEAR)2003	-1.596	1.765	-0.904	0.366
factor(QTR)4:factor(YEAR)2003	-0.757	0.713	-1.063	0.288
factor(QTR)2:factor(YEAR)2004	1.119	0.628	1.781	0.075
factor(QTR)3:factor(YEAR)2004	1.284	1.061	1.211	0.226
factor(QTR)4:factor(YEAR)2004	0.303	0.609	0.497	0.619
factor(QTR)2:factor(YEAR)2005	0.607	0.743	0.817	0.414
factor(QTR)3:factor(YEAR)2005	0.661	1.164	0.568	0.570
factor(QTR)4:factor(YEAR)2005	-0.165	0.675	-0.244	0.807
factor(QTR)2:factor(YEAR)2006	0.086	0.574	0.150	0.881
factor(QTR)3:factor(YEAR)2006	-0.242	1.099	-0.220	0.826
factor(QTR)4:factor(YEAR)2006	-2.025	0.751	-2.697	0.007
factor(QTR)2:factor(YEAR)2007	0.023	0.577	0.040	0.968
factor(QTR)3:factor(YEAR)2007	0.499	1.047	0.477	0.633
factor(QTR)4:factor(YEAR)2007	-2.431	0.667	-3.644	0.000
factor(QTR)2:factor(YEAR)2008	-0.392	0.814	-0.482	0.630
factor(QTR)3:factor(YEAR)2008	-14.429	443.282	-0.033	0.974

Parameter	Estimate	Std Error	t value	Pr(>|t|)
factor(QTR)4:factor(YEAR)2008	-1.095	0.743	-1.474	0.141
factor(QTR)2:factor(YEAR)2009	1.614	0.628	2.569	0.010
factor(QTR)3:factor(YEAR)2009	2.445	1.185	2.064	0.039
factor(QTR)4:factor(YEAR)2009	-1.088	0.675	-1.612	0.107
factor(QTR)2:factor(YEAR)2010	-0.262	0.823	-0.319	0.750
factor(QTR)3:factor(YEAR)2010	-0.841	1.296	-0.649	0.516
factor(QTR)4:factor(YEAR)2010	-0.648	0.777	-0.835	0.404
factor(QTR)2:factor(YEAR)2011	0.149	0.720	0.207	0.836
factor(QTR)3:factor(YEAR)2011	-0.780	1.189	-0.656	0.512
factor(QTR)4:factor(YEAR)2011	-0.767	0.660	-1.162	0.245
factor(QTR)2:factor(YEAR)2012	0.522	0.653	0.801	0.423
factor(QTR)3:factor(YEAR)2012	-13.273	307.997	-0.043	0.966
factor(QTR)4:factor(YEAR)2012	-1.531	0.833	-1.837	0.066
factor(QTR)2:factor(YEAR)2013	0.672	0.821	0.818	0.413
factor(QTR)3:factor(YEAR)2013	0.546	1.203	0.454	0.650
factor(QTR)4:factor(YEAR)2013	0.155	0.795	0.195	0.845
factor(QTR)2:factor(YEAR)2014	0.854	0.700	1.221	0.222
factor(QTR)3:factor(YEAR)2014	-0.171	1.253	-0.137	0.891
factor(QTR)4:factor(YEAR)2014	-0.207	0.694	-0.298	0.766
factor(QTR)2:factor(YEAR)2015	2.244	0.865	2.593	0.010
factor(QTR)3:factor(YEAR)2015	-0.169	1.508	-0.112	0.911
factor(QTR)4:factor(YEAR)2015	1.349	0.856	1.577	0.115
factor(QTR)2:factor(YEAR)2016	0.389	0.533	0.730	0.465
factor(QTR)3:factor(YEAR)2016	-2.006	1.366	-1.469	0.142
factor(QTR)4:factor(YEAR)2016	-1.010	0.536	-1.883	0.060
factor(QTR)2:factor(YEAR)2017	1.599	0.580	2.759	0.006
factor(QTR)3:factor(YEAR)2017	-1.738	1.401	-1.240	0.215
factor(QTR)4:factor(YEAR)2017	-0.327	0.598	-0.547	0.584
factor(QTR)2:factor(YEAR)2018	-0.163	0.597	-0.273	0.785
factor(QTR)3:factor(YEAR)2018	-0.498	1.139	-0.437	0.662
factor(QTR)4:factor(YEAR)2018	-0.034	0.563	-0.061	0.952
factor(QTR)2:factor(YEAR)2019	0.570	0.563	1.012	0.311
factor(QTR)3:factor(YEAR)2019	-1.025	1.195	-0.858	0.391
factor(QTR)4:factor(YEAR)2019	-0.848	0.551	-1.540	0.123
factor(QTR)2:factor(YEAR)2021	16.707	1,012.168	0.017	0.987

Parameter	Estimate	Std Error	t value	Pr(>|t|)
factor(QTR)3:factor(YEAR)2021	15.926	1,012.169	0.016	0.987
factor(QTR)4:factor(YEAR)2021	14.843	1,012.168	0.015	0.988

Table 7: Annual sturgeon bycatch estimates for otter trawl gear based on application of the best performing model (model 6) to otter trawl vessel trip records.

Year	Total Bycatch Estimate	Standard Error	Proportion Dead	Dead Bycatch Estimate
2000	1,309	161	0.000	0
2001	1,207	132	0.000	0
2002	1,434	147	0.000	0
2003	1,191	120	0.000	0
2004	1,317	121	0.000	0
2005	1,164	104	0.143	166
2006	1,138	102	0.179	203
2007	1,031	99	0.086	89
2008	964	145	0.161	155
2009	995	114	0.021	21
2010	962	97	0.009	9
2011	905	100	0.000	0
2012	834	87	0.000	0
2013	860	95	0.000	0
2014	771	79	0.000	0
2015	720	72	0.000	0
2016	748	71	0.000	0
2017	698	71	0.000	0
2018	672	70	0.080	53
2019	836	97	0.000	0
2020				
2021	638	66	0.062	40

Table 8: Annual sturgeon bycatch estimates for gillnet gear based on application of the best performing model (model 9) to gillnet vessel trip records.

Year	Total Bycatch Estimate	Standard Error	Proportion Dead	Dead Bycatch Estimate
2000	2,260	671	0.128	290
2001	943	547	0.298	281
2002	3,226	2,271	0.240	774
2003	997	221	0.212	212
2004	1,418	359	0.487	691
2005	706	222	0.306	216
2006	1,513	332	0.124	187
2007	1,497	377	0.200	299
2008	798	475	0.279	223
2009	1,154	551	0.129	149
2010	283	84	0.507	143
2011	446	230	0.440	196
2012	281	80	0.435	122
2013	1,540	586	0.375	578
2014	670	198	0.333	223
2015	711	112	0.277	197
2016	1,208	149	0.316	381
2017	1,268	210	0.216	274
2018	1,043	146	0.265	276
2019	1,031	131	0.200	206
2020				
2021	1,077	371	0.462	497

Figures

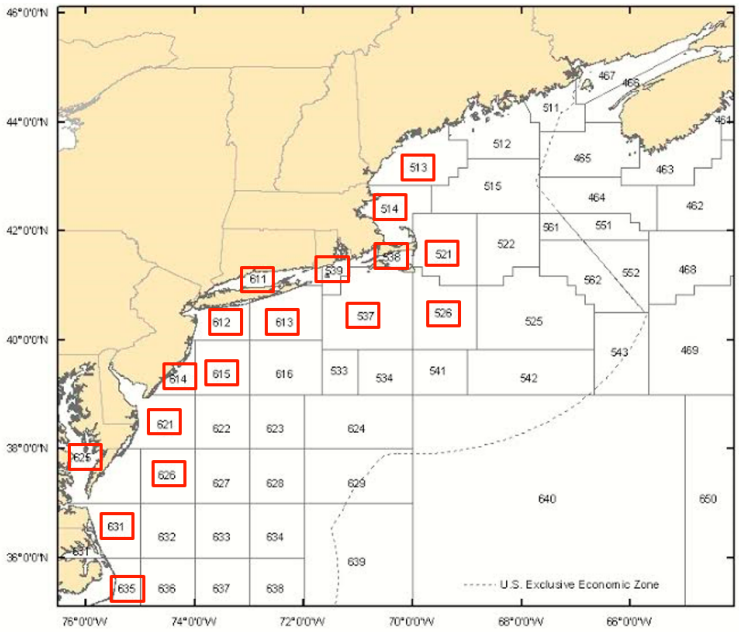

Figure 2: Observed trips used in the estimation of bycatch included coastal statistical areas 513, 514, 521, 526, 537, 538, 539, 611, 612, 613, 614, 615, 621, 625, 626, 631, and 635.