Summary of Discard Estimates for Atlantic Sturgeon

Prepared by Tim Miller and Gary Shepherd
Population Dynamics Branch
Northeast Fisheries Science Center

August 19, 2011

Major Summary Points

1. This report provides a summary of sturgeon discard estimates from 2006 to 2010 for otter trawl and sink gillnet fisheries. A secondary objective was to establish an association between the sturgeon encounters and species groups within fishery management plans. This led to a model-based, rather than a design-based estimator of discards.

2. The spatial coverage of observed trips is not sufficient to support precise estimation of discards at the level of 3-digit Statistical Area and monthly resolution

3. The spatial coverage of observed trips is sufficient to support discard estimation at the level of 2 digit Statistical Areas {51,52,53,56,61,62,63}.

4. Given this spatial resolution it is possible to estimate discards at the quarterly level in most years (2006-2010) but the precision of these estimates is expected to be low.

5. Within federal waters, sturgeon were captured primarily in small and large mesh trawls, and small, large and extra large mesh sink gillnets. Captures observed in state waters or observed by state observers are not included in this report.

6. Estimates of discards at the finest level of resolution (Stat Area x Quarter x gear) are expected to be imprecise.

7. Two estimators were examined.

    a. A design based ratio estimator expands the ratio of total sturgeon takes to total landings by the total landings within a cell
    b. A model based estimator incorporates the mixture of species associated with the observed trips. Other factors in the model include year and year x FMP interactions. Separate models were developed for sink gillnets and trawls. Mesh size was not included, but to some extent, the species mixtures will alias the mesh effect, e.g., silver and red hake, butterfish and squid alias small mesh gear.

8. The design based ratio estimator relies on the assumption that discards are proportional to the total amount landed. While this has been observed for many species, the rarity of sturgeon makes it difficult to satisfy this assumption. Variance estimates for the ratio estimator were not computed.

9. The model based estimator takes additional biological information into account and provides some information about the species associations that may influence sturgeon encounter rates. Standard error estimates of the total discards by year and gear are about 25%?

10. The partitioning of discard encounters to FMPs is not a particularly informative exercise because of the high likelihood of inappropriately attributing associations/responsibilities.

11. An application of the method of Warden (2010) to the design based estimator was difficult to interpret. Heterogeneity of fishing activities within each gear* area* year strata led to inappropriate conclusions about the FMP associations.

12. Alternatively, the model based approach led to somewhat more sensible FMP associations and allowed for a comprehensive approach, rather than a two stage process (ie. Ratio estimator, followed by the Warden method).

13. Important caveats for the interpretation of the FMP associations include:
    a. The NEFOP data do not include takes by inshore state water fisheries. These are reliant on state-specific observer programs or programs designed for marine mammals or turtles.
    b. A significant fraction of the sturgeon takes are associated with non FMP species (eg. ASMFC plans or state fisheries).
    c. The influence of an FMP is a measure of association that sums to one across all species groups. HOWEVER, it is not a measure of the incidence rate or probability of capture.
    d. Most trips capture one or more FMP species and the specific gear or deployment patterns within a trip may change. At the trip level it is not possible to identify these finer scale patterns. At the tow level within trip the ability to resolve potential causes may be higher, but it is not possible to expand such inferences to the total database. In other words, the VTR data cannot support such expansions.
    e. Most of the FMPs have multiple species. The bycatch of sturgeon may be more closely associated with one species than the other (eg. fluke, scup, sea bass). Hence the multispecies associations may be too coarse.
    f. Observer coverage for mid Atlantic species is generally lower than coverage rates on Georges Bank and Gulf of Maine.
    g. Recent changes in skate and dogfish fisheries with increased directed fishing may have important temporal effects on associations.
    h. Estimates are based on landings only. The FMPs in question may (will) influence the quantity of landings and consequently the FMP attributable to sturgeon bycatch.

Part 1. Design Based Estimation--Summary of Atlantic sturgeon by-catch in otter trawl and sink gillnet fisheries.

The intent of this analysis was to update previous estimates from 2006 through 2010. Data were limited by observer coverage to waters outside the coastal boundary (fzone>0) and north of Cape Hatteras, NC. Sturgeon included in the data set were those identified by federal observers as Atlantic sturgeon, as well as those categorized as unknown sturgeon. At this time, data were limited to information collected by the Northeast Fishery Observer program. Limited data collected in the At-Sea monitoring program were not included, although preliminary views suggest the incidence of sturgeon encounters was low.

The frequency of encounters in the observer programs were expanded by total landings recorded in vessel trip reports rather than dealer data, since the dealer data does not include information on mesh sizes. Generally the VTR data represents greater than 90% of total landings. Originally the data was to be evaluated by year, month, 3-digit statistical area, gear type and mesh size. Unfortunately the level of observer coverage did not support that degree of partitioning in the data. Tables 1-4 illustrate the sparse data available to support discard estimation at this level of resolution.

Therefore data were combined into division (identified as the first 2 digits in area codes), quarter, gear type (otter trawl (fish) and sink gillnet) and mesh categories. Mesh sizes were categorized for otter trawl as small (<5.5”) or large (greater than or equal to 5.5”) and small (<5.5”), large (between 5.5” and 8”) and extra large (>8”) in sink gillnets.

For each cell (year, division, qtr, gear, mesh) the ratio of sturgeon count to total kept weight of all species was calculated. This ratio was then applied to total landed weight in the cell as recorded in VTR data. No imputation was done to estimate sturgeon in missing cells. Total discard estimates for all encounters (alive + dead at capture) for gill nets and trawls in Tables 5 and 6, respectively. Total discards for sturgeon encounters where the observer recorded the fish as dead (a subset of total encounters) are summarized in Table 7 (gill nets) and Table 8 (trawls). The two categories represent bounds of possible sturgeon mortalities. A composite summary across gears is provided in Table 9. Using the ratio estimator the overall fraction of dead discards to total encounters is about 12% for both gears combined. About 20% of the sink gill net encounters were dead at capture while only about 5% of the otter trawl encounters were dead at capture. It must be emphasized that these conclusions are dependent on the validity of the ratio estimator model. Moreover, results should not be considered definitive estimates of Atlantic sturgeon losses because the estimates do not address the issue of missing cells.

Further analyses, not presented here suggested that the ratio estimator may not be sufficient to provide appropriate expansions to total encounters. Attempts to apply the method of Warden (2011) to identify the degree of association by FMP suggested that the total kept estimate within a strata was more heterogeneous than desirable for a ratio estimator. Examination of the actual observer data for trips that caught sturgeon suggested that the species mix within the trip, rather than the mesh within gear, may be a better predictor of encounter rate. Moreover, a model based estimator may help resolve some of the remaining heterogeneity within a stratum. This led to an alternative model described in the next section.

Part 2. Model-Based Estimates of Atlantic Sturgeon Encounters

Concerns about the utility of the design-based ratio estimator for sturgeon encounters led to the development of a model based approach. The model-based estimator attempts to resolve the heterogeneity within spatial and temporal strata by considering the mix of species on a given trip. The basic idea is that mix of species can improve predictions better than the strata x gear x mesh x quarter.

A generalized linear model was used with the sturgeon takes on each trip as the response. A quasi-Poisson assumption was made for the distribution of the response which allows the variance to be greater than that associated with the Poisson distribution. There was necessary because there was substantially greater dispersion in the residuals than expected under the Poisson model.

A variety of candidate models were evaluated with the following factors as predictor variables:

a. Presence/Absence of a species within an FMP (e.g., 1 if bluefish caught, 0 otherwise, 1 if a fluke, scup or seabass was caught, 0 otherwise, and so forth.) Each FMP was included as a binary (0/1) predictor variable.
b. Year as a factor {2007-2011}
c. FMP X Year interactions.
d. Quarter as a factor
e. FMP X Quarter interactions

Separate models were developed for all mesh sizes of gill nets and all mesh sizes of otter trawl. The rationale for ignoring the differences in mesh size is that differences in species composition alias the effects of mesh differences.

The general model for the log-mean take on trip i is

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

where $\hat{\beta}$ are the estimated coefficients and $X_{1i}, \ldots, X_{pi}$ are the covariates that represent FMP, year, quarter and any interactions. For the models we consider here the covariates for each trip are either 0 or 1 depending on whether a particular FMP was landed and what quarter or year the trip took place.

Model fitting is based on observer hauls and landings of each species and takes of any sturgeon on those hauls since 2006. FMP landings are determined by aggregating species landings attributable to each FMP.

To predict sturgeon take for all landings, we are primarily interested in data aggregated to the trip level since VTR data are recorded at this level. Similar to the observer data, FMP landings for each trip in the VTR data since 2006 are determined by aggregating species landings attributable to each FMP. Otter trawl and sink gillnet based landings are discussed separately below, but the general methodologies are the same.

Given estimated coefficients from fitting the model to observer data, we make predictions of the expected sturgeon take for each VTR trip where we have the same information on whether the FMP was landed, and, if necessary, year and quarter. The predictions are made using the anti-log of the same equation above, but where the covariates are for VTR trip i. The total discard estimates represent the sum of all the model predictions over the relevant year, quarter and statistical division. The final models and predicted discards are provided in Appendix A for otter trawls and in Appendix B for sink gillnets.

Model Based Otter Trawl Estimates

In all observed trawl gear (gear code = 50) records from 2006 to 2010, there were no landings attributable to herring, river herring, salmon, tilefish, red crab and surf clams/ocean quahog FMPs when sturgeon were taken. So those FMPs are not considered in further analysis.

When fitting the quasi-poisson generalized linear model to trip-aggregated data on sturgeon takes and FMP catches (model 0), there is a declining trend (significant or not) in mean sturgeon numbers with increased catches for most FMPs. For those where positive trends occur they are not significant except the “other” category of catches that does not include any of the FMPs. Fitting the same type of model with indicator covariates of whether the FMP landed rather than the actual amount landed on the trip (model 1), there is only a significant positive effects for FSB.

When fitting the same type of model as model 1, but with quarterly differences in the effects of the FMP landings indicators (model 2), the determination of meaningful positive effects is complicated because the reference class of trips needs to be defined. The default in the model fitting is a trip without any of the FMPs in the first quarter of the year. Note that the quarterly effects are constant across years in this model (i.e, “year” is not in the model). Other models that we fit allowed effects of the FMPs to be unique for all 20 quarters (year*qtr) (model 3), to differ by year (model 4), to differs by each of the 20 quarters but not affected by FMP (model 5), and to differ by year only (model 6) or by quarter only (model 7). The best performing model of those fitted to the trip specific data based on $QAIC_c$ was model 3 that allowed quarterly effects of the FMPs on sturgeon take.

Model Based Gill Net Estimates

In all observed gillnet gear (gear code = 100, 105,116,117) records from 2006 to 2010, there were no landings attributable to herring, river herring, salmon, tilefish, red crab and surf clams/ocean quaohog FMPs when sturgeon were taken. So those FMPs are not considered in further analysis.

When fitting the quasi-poisson generalized linear model to trip-aggregated data on sturgeon takes and FMP catches for gillnet gear (model 0.gn), there is a declining trend (significant or not) in mean sturgeon numbers with increased catches for most FMPs. For those where positive trends occur they are not significant. Fitting the same type of model with indicator covariates of whether the FMP landed rather than the actual amount landed on the trip (model 1.gn), there is a significant positive effect of presence of for monkfish and striped bass FMPs, and the "other" category.

As for otter trawl gear, we fit models allowing effects of the FMP landings indicators to differ quarterly (model 2.gn), to be unique for all 20 quarters (year*qtr) (model 3.gn), to differ by year (model 4.gn), to differ by each of the 20 quarters but not affected by FMP (model 6.gn), and to differ by year only (model 6.gn) or by quarter only (model 7.gn). The best performing model of those fitted to the trip specific data based on $QAIC_c$ was model 4.gn that allowed yearly effects of the FMPs on sturgeon take.

Part 3. Allocation to FMP from Final Model

Trying to measure the effect of different FMPs on the sturgeon take is complicated because landings attributable to multiple FMPs can occur on the same trip, whether sturgeon are taken or not. Below, we propose a possible method based on the above models.

The method for predicting the take on a given VTR trip is given above. Given the indicators of presence for FMPs for all of the VTR trips, we can predict the total take of sturgeon for all fishing effort in the given year/quarter/mesh-size category k as

$$\hat{T}_{k,i} = \sum_{i=1}^{N_k} \hat{T}_{k,i}$$

The proposed measure of effect for each FMP is the predicted total take on trips where FMP f is present:

$$\hat{T}_f = \sum_{i=1}^{N_f} \hat{T}_{f,i} \, .$$

When there is a combination of strong association of sturgeon take with an FMP or a large number of trips where the FMP is present, this measure will be large. When there is no effect or when the FMP is always absent, this measure will be 0. A possible relative weight for the FMPs is

$$W_{y,q,f} = \frac{\hat{T}_{y,q,f}}{\sum_{f=1}^{F} \hat{T}_{y,q,f}} \, .$$

The weights sum to 1 and can be used to attribute proportions of the total take to each FMP.

For trawl data we could not use the best model (model 5) for predicting sturgeon take from the VTR data because of the inability to predict sturgeon take due to lack of observations of some types of interactions and the presence of those types of trips in the VTR data., Instead we used the next best model with respect to $QAIC_c$ (model 2, see Appendix A for estimated coefficients) to determined the predicted yearly total takes, the weights $W_{y,f}$ for each FMP in years 2006-2010, and also the total take across all years and corresponding weights determined by the sum of the predicted takes for all trips across years (Table 10). The weights indicate that for otter trawl gear the correlation of FMP landings to sturgeon take are consistently highest for FSB.

Skate and SMB FMPs have the next largest weights which are similar to the "other" category that accounts for landings of fish not attributable any of the FMPs (e.g., lobster and croaker).

For gill net data and using model 4.gn (see Appendix B for estimated coefficients), I determined the predicted yearly total takes, the weights $W_{y,f}$ for each FMP in years 2006-2010, and also the total take across all years and corresponding weights determined by the sum of the predicted takes for all trips across years (Table 11). The weights indicate that for gillnet gear the correlation of FMP landings to sturgeon take are consistently highest for monkfish, but the skate FMP had a similar weight in 2009 and 2010 which resulted in it having the next largest weight among all FMPs when looking at all years (2006-2010) combined. The "other" category has the next largest weight for all data combined and all others are less than 0.1.

References

Warden, ML. 2011. Proration of loggerhead sea turtle (*Caretta caretta*) interactions in US Mid-Atlantic bottom otter trawls for fish and scallops, 2005–2008, by managed species landed. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 11-04; 8 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026

Figure 1. Estimated annual sturgeon take by trawl gear. Vertical bars represent approximate 95% confidence intervals.

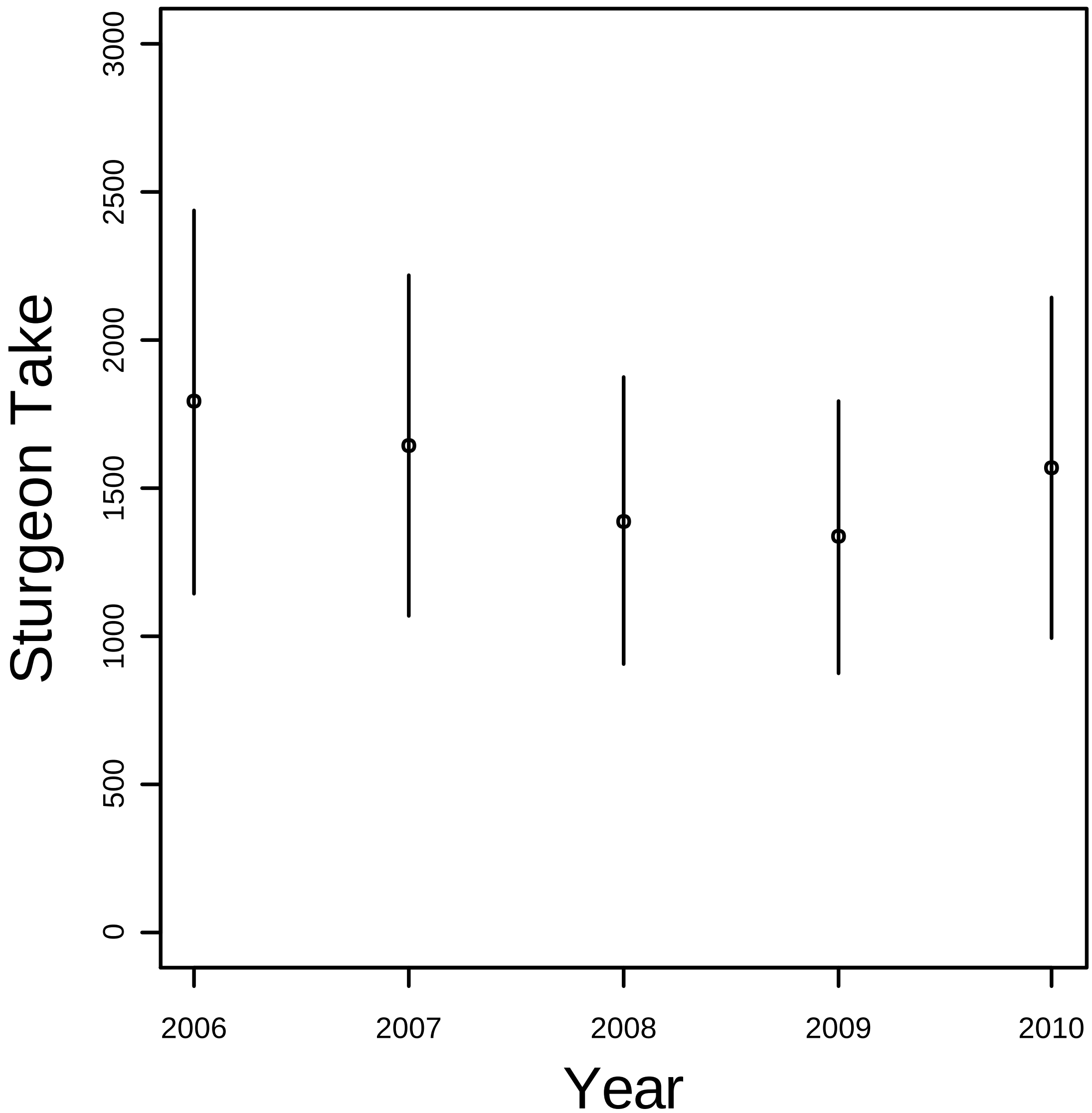

Figure 2. Estimated annual sturgeon take by gillnet gear. Vertical bars represent approximate 95% confidence intervals.

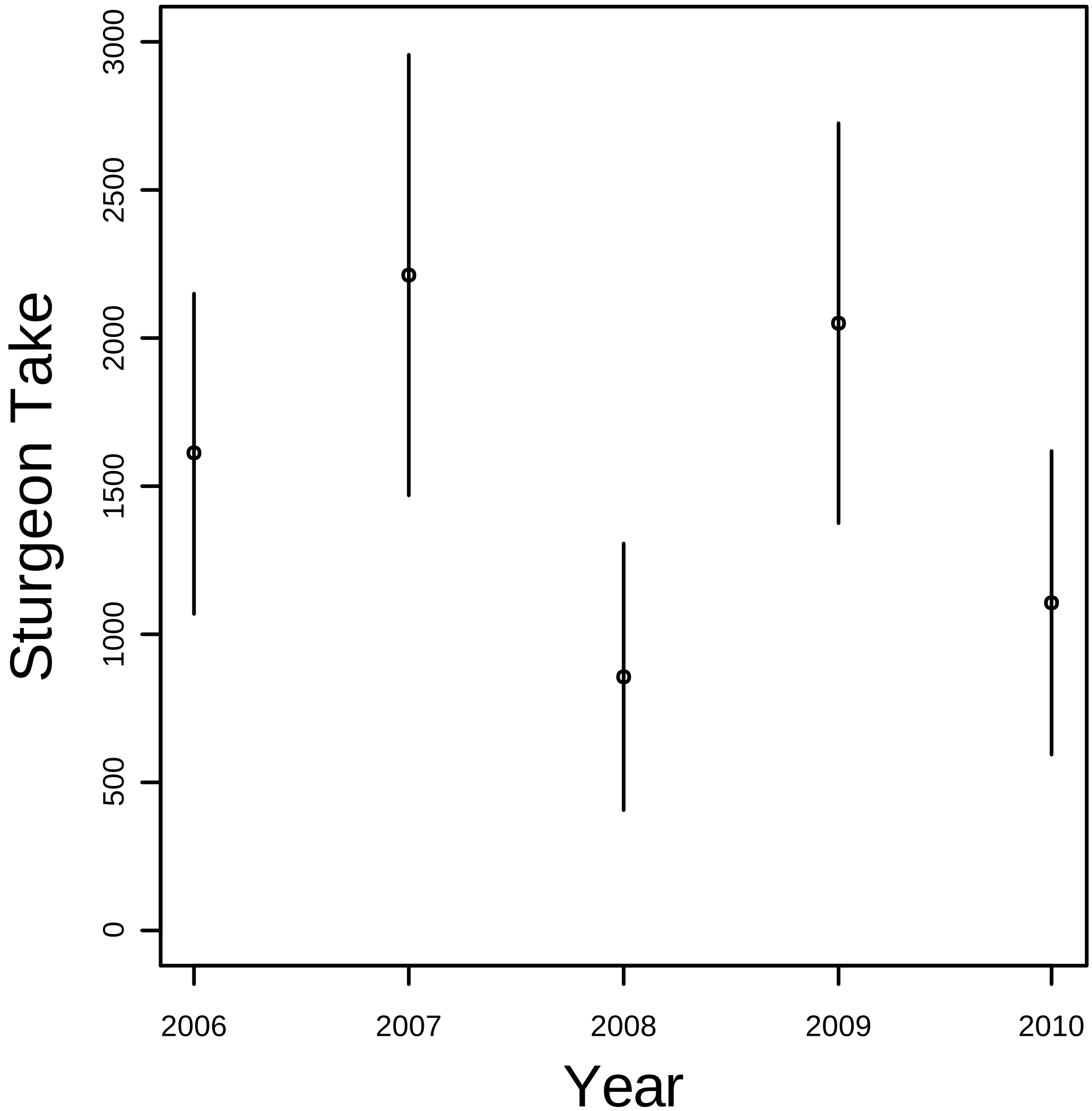

Figure 3. Annual relative influence of FMP on sturgeon take for trawl effort. Vertical bars represent approximate 95% confidence intervals.

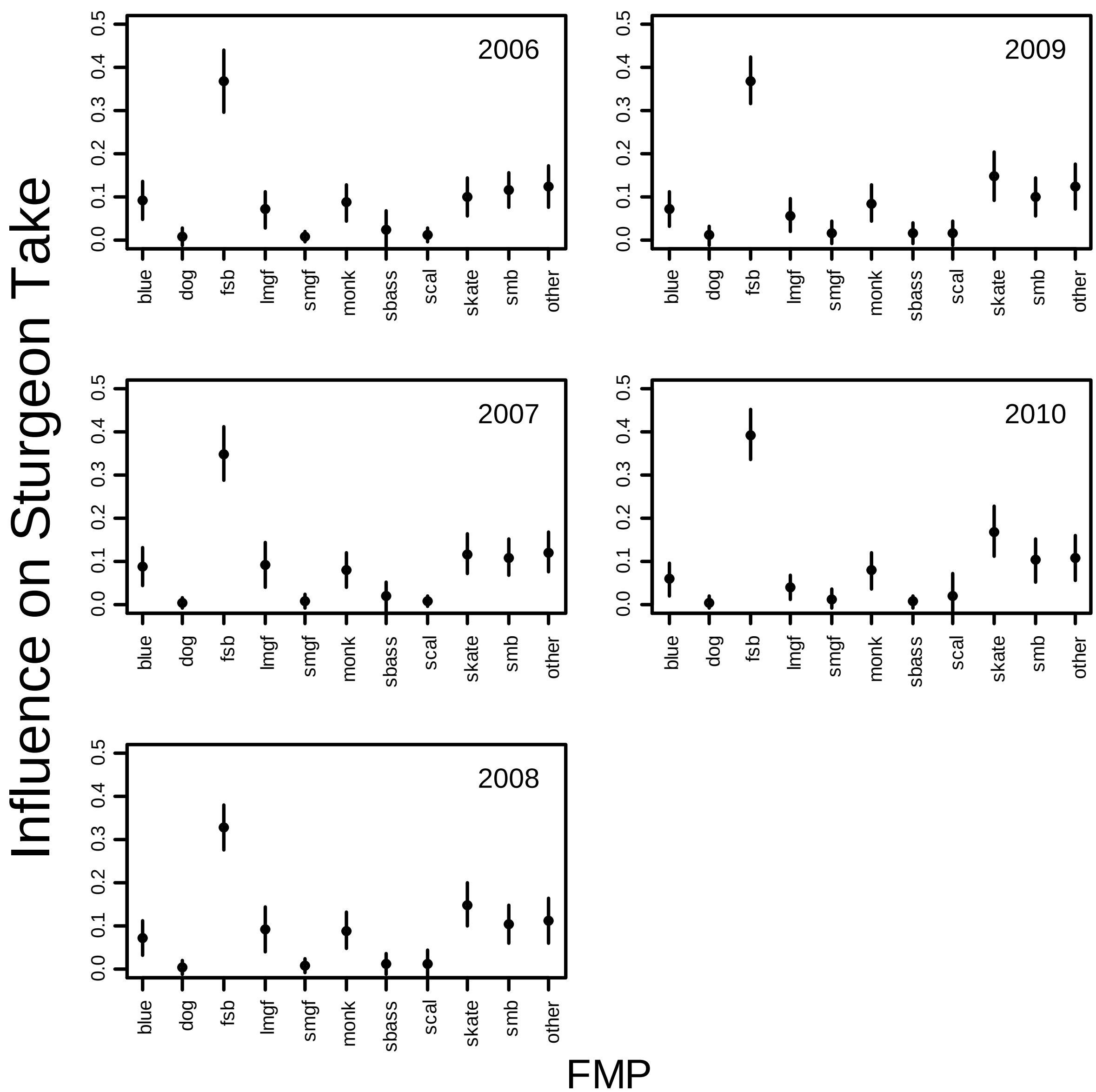

Figure 4. Annual relative influence of FMP on sturgeon take for gillnet effort. Vertical bars represent approximate 95% confidence intervals.

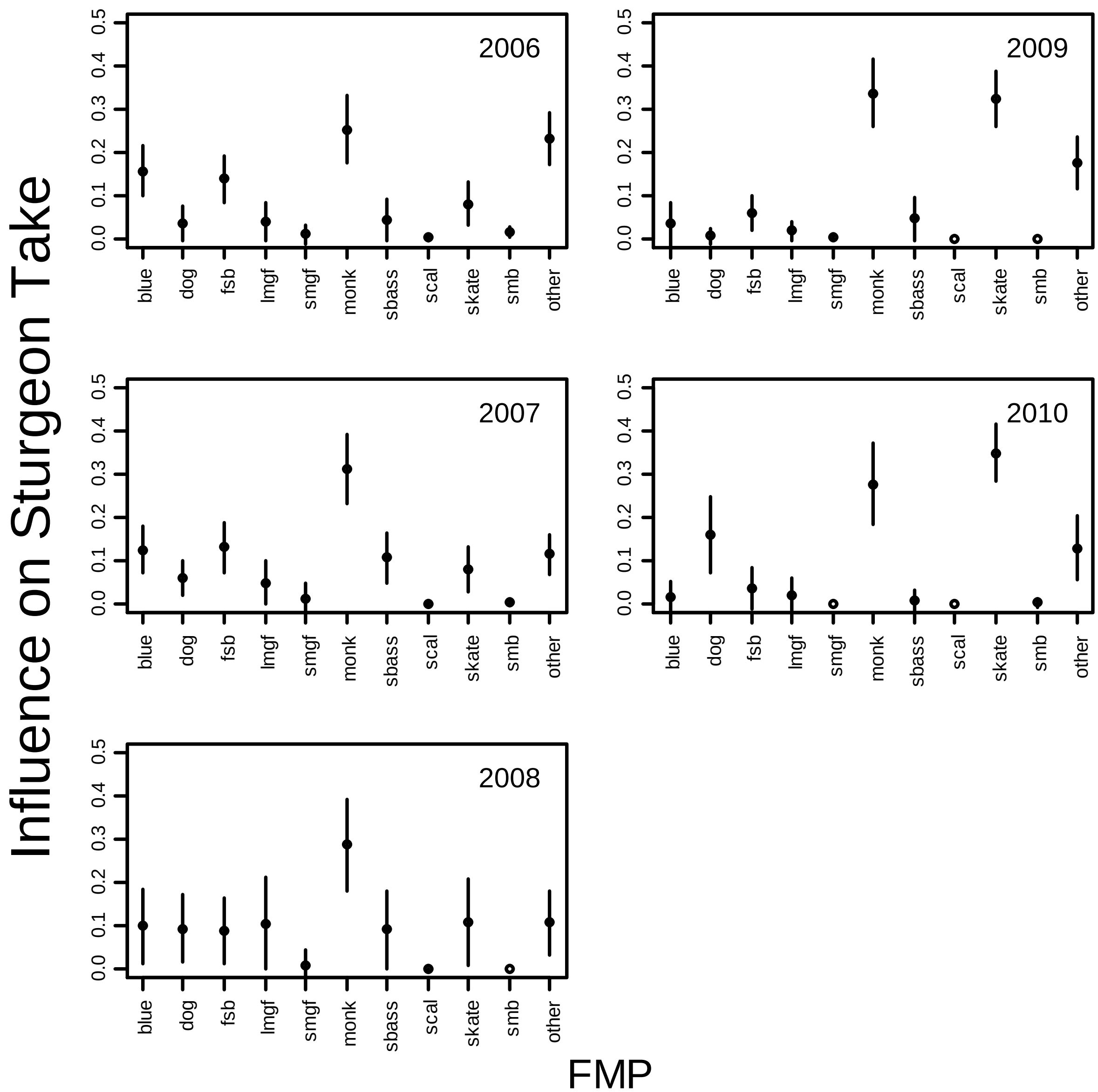

Table 1. Encounters of Atlantic sturgeon and sturgeon, unknown by month, area and mesh size in otter trawl gear, 2006-2010 combined.

Large mesh otter trawl

area	month 1	2	3	4	5	6	7	8	9	10	11	12
464	0		0		0					0	0	
465	0		0	0		0	0				0	0
511	0			0								0
512	0		0	0	0	0	0	0	0	0	0	0
513	0	0	0	0		0	0	0	0	0	0	0
514	3	0	0	0	0	0	0	0	0	0	0	0
515	0	0	0	0	0	0	0	0	0	0	0	0
521	0	0	0	0	0	0	0	0	0	0	0	0
522	0	0			0			0	0	0	0	
525			0	0	0	0	0	0				
526	0	0	0	0	0	0	0	0	0	0	0	0
537	0	0	0	0	0	0	0	0	0	0	1	0
538				0	0	0	0	0	0	0	0	
539	0	0	0	0	0	0	0	0	0	0	0	0
562					0	0	0	0				
611	0	0	0	0	0	0	0	0	0	0	0	0
612		1		0	25	5	5	0	33	1	0	0
613	0	0	0	1	0			0	0	0	0	0
614				1	0		0		0			
615	0				0		0	0	0		0	0
616	0	0	0	0					0	0	0	0
621	0	0	0		0	2	0	0	18	0	0	1
622	0	0	0								0	0
625							0			0	0	0
626	0	0		0							0	0
631	0	2										0
632										0		
635	0											0
636										0		

Small mesh otter trawl

area	month 1	2	3	4	5	6	7	8	9	10	11	12
465									0			
512							0		0		0	
513	0	0				0	0	0	0		0	
514	0	0	0				0	0	0	0	1	0
515	0		0			0	0		0		0	
521	0	0	0				0	0	0	0	0	0
522							0	0	0	0		
525	0	0	0		0	0	0	0	0	0	0	0
526	0	0	0					0	0	0	0	0
533				0								
537	0	0	0	0	0	1	1	0	0	0	0	0
538				0	0	0	0	0	0	0		
539	0	0	0	0	0	1	0	0	0	0	0	0
562	0	0			0	0	0	0	0	0	0	0
611	0	0		0	1	0	0	0	0	0	0	0
612	0		0	6	14	13	0	0	1	0	0	0
613	0	0	0	0	0	0	1	0	0	1	4	0
614					1	3	0	0	0	0	0	
615	0	0	0	0	0	0	0	0	0	0	0	0
616	0	0	0	0	0	0		0	0	0	0	0
621	0	0	0	0	3	1	1	0	3	9	2	1
622	0	0	0	0	0	0	0	0	0	0	0	0
623	0	0	0					0	0		0	0
625	4		0			0				1	12	18
626	0	0	0	0		0	0	0	0	0	0	0
627	0	0		0			0	0				
631	2	2	22	7						1	4	3
632				0		0	0	0	0	0	0	0
635	10	4	8	1						0	0	0
636	0	0		0		0		0			0	0

Table 2. Encounters of Atlantic sturgeon and sturgeon, unknown by month, area in small mesh sink gillnet gear, 2006-2010 combined.

small mesh sink gillnet

	month											
area	1	2	3	4	5	6	7	8	9	10	11	12
464			0									
513								0	0	0		
514	0	0	0				0	0				
515			0									
521	0	0	0		0	0	0	0	0	0	0	**1**
522	0											
526					0							
537	0		0	0	0				0		0	
539					**1**							
611					0		0				0	
612				0	0	0	0	**1**	**1**	0		
613				0		0	0	0	0	0	0	
614				**5**	0	0		**1**	0	0	0	
615						0			0	0		
621			0	0	0			0	0	0	0	
625		0	0	**1**	0	**1**	0	0	0	**1**	0	0
626			0	0								
631	**1**	**6**	**8**	**2**	0				0	0	0	0
632				0								
635	**2**	0	**12**	**2**	0	0	0	0	0	0	**1**	**1**
636	0	0	0	0							0	
637	0											
638				0								

Table 3. Encounters of Atlantic sturgeon and sturgeon, unknown by month, area in large mesh sink gillnet gear, 2006-2010 combined.

large mesh sink gillnet

area	month 1	2	3	4	5	6	7	8	9	10	11	12
464		0	0						0			0
513	0		0	0	0	0	0	0	0	0	0	0
514	**6**	**5**	**2**	0	**1**	0	0	0	0	0	0	**2**
515	0	0	0	0	0	0	0	0	0	0	0	0
521	0	0		0	0	**1**	0	0	0	0	0	0
522		0			0							
525											0	
537	0	0		0	0		0					
538					0	0			0		0	
539		0		0	**4**	0	0	0	0	0	0	0
611				0	0			0			0	
612				**5**	0	0	**5**	**9**	0	0	**2**	0
613		0		0	4		0	0	0	0	0	0
614				**9**	**5**	**3**	**4**	**1**	0	0	0	0
615					0				0	0	0	0
621	0		0	**4**	0						0	0
625	**2**	**1**	0	**3**	**7**	**1**			0		**2**	**2**
631	**4**	**4**	0	0	**1**				0	0	0	**4**
632		0										
635	0	**1**	0	0	0	0	0	0	0	0	0	0
636	0	0	0	0								

Table 4. Encounters of Atlantic sturgeon and sturgeon, unknown by month, area in extra large mesh sink gillnet gear, 2006-2010 combined.

X-large sink gillnet

	month											
area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
464												0
512										0		
513				0		0	0	0	0	0	0	0
514	0	0	0		0	0	0	0	1	0	0	0
515					0		0		0	0	0	0
521	**1**			0	0	0	**1**	0	**1**	**1**	**2**	**1**
522				0			0					0
526		0	0	0	0							
537	**1**	0	**1**	**1**	**5**	0	0	0	0	**1**	0	**1**
538					0							
539	0	0		0	**4**	0	0		0	0	0	0
611					0	**1**						
612	**5**	0	0	0	**1**	**3**	0			0	0	**1**
613	0	0		0	**2**	**1**		0	0	0	**7**	0
614	0			0	**5**	0					0	
615	0	0	0	0	**2**	**2**	0			0	0	**1**
616	0		0	0	0	0				0	0	0
621		0	0	0	**2**						0	
622					0							
625		**2**	**2**	**2**	**4**	0					**1**	**3**
626	0	0	0	**1**	**5**						0	0
631	**2**	**6**	**1**	**5**						0	0	**2**
635	0		**58**	**69**								

Table 5. All Atlantic sturgeon encounters expanded by VTR landings by division, mesh size and year for sink gillnets. 2006 across top row to 2010 across bottom row.

small mesh sink gillnet
All sturgeon
expanded to VTR landings

division	1	2	3	4	
51					
52	0				
53			0		
61		157	9	0	
62		4	0	9	
63	0	14	0	6	198
51	0	0	0	0	
52			0	0	
53		12	0	0	
61	0	0	24	0	
62	0	15	0	0	
63	83	0	0	0	135
51	0	0	0	0	
52	0			0	
53		0	0	0	
61	0	0	0	0	
62	0	0	0	0	
63	0	0	0	0	0
51	0		0		
52	0		0		
53	0	0			
61	0	0	0	0	
62	0	0	0	0	
63	98	0	0	0	98
51			0		
52					
53				0	
61			0	0	
62		0	0	0	
63	81	13	0	0	94

large mesh sink gillnet
All sturgeon
expanded to VTR landings

division	1	2	3	4	
51	54	0	0	0	
52	0	0	0	0	
53		11	0	0	
61		638	72	0	
62	206	114	0	20	
63	0	0		3	1117
51	29	0	0	0	
52	0	0	0	0	
53	0	27	0	0	
61		0	184	87	
62	0	15		0	
63	34	17		24	416
51	47	0	0	65	
52	0	79	0	0	
53	0	17	0	0	
61		0	0		
62	189	22		20	
63	17	0	0	22	478
51	34	0	0	0	
52	0	0	0	0	
53		0	0	0	
61		0	453	0	
62		193		22	
63	0	0		0	702
51	39	12	0	0	
52	0	0	0	0	
53		0	0	0	
61	0	46	0	0	
62	0	24			
63	0	0	0	0	121

x-large mesh sink gillnet
All sturgeon
expanded to VTR landings

division	1	2	3	4	
51	0	0	63	0	
52	0	0	22	44	
53	0	14	0	0	
61	17	62	0	0	
62	0	54		0	
63	13	10			299
51	0	0	0	0	
52	0	0	23	14	
53	0	47	0	14	
61	0	131	0	0	
62	41	128		28	
63	51	17			493
51	0	0	0	0	
52	0	0	0	0	
53	10	0	0	0	
61	0	67	0	84	
62	0	14		0	
63	15	11		0	200
51	0	0	0	0	
52	0	0	0	13	
53	10	104	0	40	
61	40	66	0	136	
62	9	8		26	
63	18	158			628
51	0	0	0	0	
52	12	0	0		
53	0	0			
61	28	66	0	0	
62	0	6			
63		20			132

Table 6. All Atlantic sturgeon encounters expanded by VTR landings by division, mesh size and year for otter trawls. 2006 across top row to 2010 across bottom row.

small mesh otter trawl
All sturgeon
Expanded by ratio to VTR landings

	1	2	3	4	Total
51	0		0	0	
52	0	0	0	0	
53	0	0	0	0	
56					
61	0	996	0	184	
62	29	0	8	309	
63	20	0	0	0	1546

	1	2	3	4	Total
51	0		0	0	
52	0	0	0	0	
53	0	0	0	0	
56					
61	0	0	0	0	
62	0	0	0	449	
63	47			40	536

	1	2	3	4	Total
51	0	0	0	0	
52	0	0	0	0	
53	0	0	0	0	
56					
61	0	279	80	0	
62	0	21	0	19	
63	19		0	36	454

	1	2	3	4	Total
51	0		0	22	
52	0	0	0	0	
53	0	0	17	0	
56					
61	0	336	9	0	
62	0	9	48	24	
63	435	0	0	6	907

	1	2	3	4	Total
51	0	0	0	0	
52	0	0	0	0	
53	0	39	0	0	
56	0	0	0	0	
61	0	317	0	0	
62	0	0	0	84	
63	41	36	0	24	541

Large mesh otter trawl
All sturgeon
Expanded by ratio to VTR landings

	1	2	3	4	Total
51	33				
52	0	0	0	0	
53	0	0	0	0	
61		0	0		
62	0	28	0	0	
63	0	0	0		61

	1	2	3	4	Total
51	19	0	0	0	
52	0	0	0	0	
53	0	0	0	0	
56					
61	0	0	0	0	
62	0	0	252	0	
63	0			0	271

	1	2	3	4	Total
51		0		0	
52	0	0	0	0	
53	0	0	0	0	
61	44	218	108	22	
62	0	12	0	0	
63	0	0	0	0	404

	1	2	3	4	Total
51	0	0		0	
52	0	0	0	0	
53	0	0	0	0	
56		0		0	
61	0	113	23	0	
62	0	0	7	0	
63	0				143

	1	2	3	4	Total
51	0	0	0	0	
52	0	0	0	0	
53	0	0	0	0	
56		0	0		
61	0	437	601	0	
62	0	0	0	0	
63	172			0	1211

Table 7. Dead Atlantic sturgeon encounters expanded by VTR landings by division, mesh size and year for sink gillnets. 2006 across top row to 2010 across bottom row.

small mesh sink gillnet
dead sturgeon expanded by VTR

Year	Division	1	2	3	4	Total
2006	51					
	52	0				
	53			0		
	61		0	0	0	
	62		0	0	0	
	63	0	0	0	0	0
2007	51	0		0		
	52	0	0	0	1	
	53	0	0		0	
	61		0	0	0	
	62	0	0		0	
	63	0	0		0	1
2008	51	0		0		
	52	0	0	0	0	
	53		0			
	61		0	0		
	62	0	0		0	
	63	0	0	0	0	0
2009	51	0		0	0	
	52	0		0		
	53		0			
	61		0	0	0	
	62		0		0	
	63	0	0		0	0
2010	51			0	0	
	52			0	0	
	53					
	61		0	0	0	
	62		0			
	63	0	0	0	0	0

large mesh sink gillnet
dead sturgeon expanded

Year	Division	1	2	3	4	Total
2006	51	0	0	0	0	
	52	0	0	0	0	
	53		0	0	0	
	61	0	28	0	0	
	62	0	38	0	0	
	63	0	0		0	66
2007	51	15	0	0	0	
	52	0	0	0	0	
	53	0	0	0	0	
	61		0	20	0	
	62	0	0		0	
	63	0	0		0	35
2008	51	16	0	0	0	
	52	0	79	0	0	
	53	0	0	0	0	
	61		0	0		
	62	0	0		0	
	63	6	0	0	0	100
2009	51	0	0	0	0	
	52	0	0	0	0	
	53		0	0	0	
	61		0	0	0	
	62		0		0	
	63	0	0		0	0
2010	51	0	0	0	0	
	52	0	0	0	0	
	53		0	0	0	
	61	0	0	0	0	
	62	0	24			
	63	0	0	0	0	24

x-large mesh sink gillnet
dead sturgeon expanded

Year	Division	1	2	3	4	Total
2006	51	0	0	63	0	
	52	0	0	22	44	
	53	0	0	0	0	
	61	17	31	0	0	
	62	0	0	0	0	
	63	0	3		0	180
2007	51	0	0	0	0	
	52	0	0	0	0	
	53	0	31	0	14	
	61	0	112		0	
	62	0	107		9	
	63	0	0		0	273
2008	51	0	0	0	0	
	52	0	0	0	0	
	53	0	0	0	0	
	61	0	67	0	42	
	62	0	14		0	
	63	4	4		0	131
2009	51	0	0	0	0	
	52	0	0	0	13	
	53	10	69	0	0	
	61	0	33	0	82	
	62	0	8		0	
	63	0	11		0	226
2010	51	0	0	0	0	
	52	0	0	0	0	
	53	0	0			
	61	0	0	0	0	
	62	0	6			
	63		0			6

Table 8. Dead Atlantic sturgeon encounters expanded by VTR landings by division, mesh size and year for otter trawl. 2006 across top row to 2010 across bottom row.

small mesh otter trawl
Expanded by ratio to VTR landings
dead sturgeon expanded

		1	2	3	4	
2006	51	0		0	0	
	52	0	0	0	0	
	53	0	0	0	0	
	56					
	61	0	0	0	61	
	62	29	0	0	0	
	63	0	0	0	0	90
2007	51	0		0	0	
	52	0	0	0	0	
	53	0	0	0	0	
	56					
	61	0	0	0	0	
	62	0	0	0	0	
	63	4			0	4
2008	51	0	0	0	0	
	52	0	0	0	0	
	53	0	0	0	0	
	56					
	61	0	0	0	0	
	62	0	0	0	0	
	63	0		0	0	0
2009	51	0		0	0	
	52	0	0	0	0	
	53	0	0	0	0	
	56					
	61	0	0	0	0	
	62	0	0	0	0	
	63	19	0	0	0	19
2010	51	0		0	0	
	52	0	0	0	0	
	53	0	0	0	0	
	56					
	61	0	0	0	0	
	62	0	0	0	0	
	63	7	0	0	0	7

large mesh otter trawl
dead sturgeon expanded
to VTR all kept

51	0	0	0	0	
52	0	0	0	0	
53	0	0	0	0	
61	0	0	0	0	
62	0	0	0	0	
63	0	0	0	0	0
51	0	0	0	0	
52	0	0	0	0	
53	0	0	0	0	
56	0	0	0	0	
61	0	0	0	0	
62	0	0	59	0	
63	0	0	0	0	59
51	0	0	0	0	
52	0	0	0	0	
53	0	0	0	0	
61	0	36	108	0	
62	0	0	0	0	
63	0	0	0	0	145
51	0	0	0	0	
52	0	0	0	0	
53	0	0	0	0	
56	0	0	0	0	
61	0	0	0	0	
62	0	0	0	0	
63	0	0	0	0	0
51	0	0	0	0	
52	0	0	0	0	
53	0	0	0	0	
56	0	0	0	0	
61	0	0	0	0	
62	0	0	0	0	
63	0			0	0

Table 9. Summary of Atlantic sturgeon encounters of all fish and total dead , by gear type and year.

Estimated encounters

	sink gillnet	otter trawl	total
2006	1614	1606	3221
2007	1044	807	1851
2008	678	857	1536
2009	1428	1050	2478
2010	347	1752	2099

Estimated dead encounters

	sink gillnet	otter trawl	total
2006	246	90	336
2007	309	63	373
2008	231	145	376
2009	223	19	245
2010	30	7	37

Total

	encounter	dead
2006	3221	336
2007	1851	373
2008	1536	376
2009	2478	245
2010	2099	37

Table 10. Yearly and total predicted sturgeon take and FMP weights for otter trawl gear based on VTR data and model 4 fit to observer data. FMPs not listed have weights of zero.

Year	Total take	blue	dog	fsb	lmgf	smgf	monk	sbass	scal	skate	smb	other
2006	1793.687	0.092	0.008	0.368	0.069	0.007	0.085	0.024	0.011	0.097	0.115	0.123
2007	1645.893	0.089	0.005	0.349	0.092	0.010	0.079	0.020	0.008	0.118	0.109	0.121
2008	1392.025	0.074	0.006	0.328	0.093	0.009	0.092	0.013	0.014	0.151	0.106	0.114
2009	1338.139	0.070	0.010	0.367	0.057	0.017	0.084	0.013	0.014	0.146	0.099	0.122
2010	1570.297	0.059	0.006	0.393	0.040	0.014	0.078	0.007	0.021	0.170	0.103	0.109
2006-2010	7740.041	0.078	0.007	0.361	0.071	0.011	0.084	0.016	0.013	0.134	0.107	0.118

Table 11. Yearly and total predicted sturgeon take and FMP weights for sink gillnet gear based on VTR data and model 6.gn fit to observer data. FMPs not listed have weights of zero.

Year	Total take	blue	dog	fsb	lmgf	smgf	monk	sbass	scal	skate	smb	other
2006	1612.001	0.156	0.035	0.138	0.039	0.010	0.252	0.043	0.002	0.080	0.015	0.230
2007	2216.112	0.126	0.060	0.132	0.049	0.012	0.312	0.107	0.002	0.082	0.003	0.115
2008	858.155	0.100	0.095	0.089	0.106	0.012	0.288	0.092	0.001	0.110	0.000	0.108
2009	2053.346	0.034	0.006	0.059	0.017	0.002	0.336	0.045	0.000	0.323	0.000	0.176
2010	1107.961	0.018	0.159	0.035	0.022	0.000	0.277	0.008	0.000	0.348	0.003	0.130
2006-2010	7847.576	0.089	0.059	0.095	0.040	0.007	0.299	0.062	0.001	0.188	0.004	0.156

Appendix A. Summary of model parameters and discard estimates for Atlantic sturgeon in otter trawls.

Table A1. Estimated parameters for model 4 fitted to the trip-specific observer otter trawl data from 2006-2010.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-4.540	1.643	-2.762	0.006
blue.ocTRUE	-0.059	0.748	-0.080	0.937
dog.ocTRUE	-15.302	5032.761	-0.003	0.998
fsb.ocTRUE	1.826	1.034	1.767	0.077
lmgf.ocTRUE	-1.662	1.107	-1.501	0.133
smgf.ocTRUE	-2.247	1.774	-1.266	0.205
monk.ocTRUE	-1.063	0.673	-1.578	0.115
sbass.ocTRUE	-0.481	1.423	-0.338	0.736
scal.ocTRUE	-0.342	0.961	-0.356	0.722
skate.ocTRUE	-0.829	1.489	-0.557	0.578
smb.ocTRUE	-0.974	0.750	-1.299	0.194
other.ocTRUE	3.136	1.412	2.221	0.026
factor(QTR)2	-0.429	2.936	-0.146	0.884
factor(QTR)3	-12.762	1133.424	-0.011	0.991
factor(QTR)4	0.386	2.488	0.155	0.877
blue.ocTRUE:factor(QTR)2	0.678	1.040	0.652	0.514
blue.ocTRUE:factor(QTR)3	-1.173	1.625	-0.722	0.470
blue.ocTRUE:factor(QTR)4	-0.162	1.006	-0.161	0.872
dog.ocTRUE:factor(QTR)2	14.189	5032.761	0.003	0.998
dog.ocTRUE:factor(QTR)3	14.887	5032.761	0.003	0.998
dog.ocTRUE:factor(QTR)4	14.743	5032.761	0.003	0.998
fsb.ocTRUE:factor(QTR)2	1.150	2.616	0.440	0.660
fsb.ocTRUE:factor(QTR)3	14.226	1133.423	0.013	0.990
fsb.ocTRUE:factor(QTR)4	0.838	2.113	0.397	0.692
lmgf.ocTRUE:factor(QTR)2	1.514	1.235	1.225	0.221
lmgf.ocTRUE:factor(QTR)3	-0.804	2.652	-0.303	0.762
lmgf.ocTRUE:factor(QTR)4	0.050	1.900	0.027	0.979
smgf.ocTRUE:factor(QTR)2	0.963	2.170	0.444	0.657
smgf.ocTRUE:factor(QTR)3	2.604	3.057	0.852	0.394
smgf.ocTRUE:factor(QTR)4	-0.230	2.477	-0.093	0.926
monk.ocTRUE:factor(QTR)2	0.917	0.877	1.045	0.296
monk.ocTRUE:factor(QTR)3	-1.037	2.396	-0.433	0.665

monk.ocTRUE:factor(QTR)4	0.914	0.992	0.921	0.357
sbass.ocTRUE:factor(QTR)2	-16.830	6566.465	-0.003	0.998
sbass.ocTRUE:factor(QTR)3	-14.623	3941.823	-0.004	0.997
sbass.ocTRUE:factor(QTR)4	1.399	1.802	0.777	0.437
scal.ocTRUE:factor(QTR)2	-1.174	2.591	-0.453	0.651
scal.ocTRUE:factor(QTR)3	1.542	3.359	0.459	0.646
scal.ocTRUE:factor(QTR)4	1.215	1.253	0.970	0.332
skate.ocTRUE:factor(QTR)2	1.850	1.605	1.152	0.249
skate.ocTRUE:factor(QTR)3	1.989	1.609	1.236	0.217
skate.ocTRUE:factor(QTR)4	-1.548	2.284	-0.678	0.498
smb.ocTRUE:factor(QTR)2	0.359	0.958	0.375	0.708
smb.ocTRUE:factor(QTR)3	-0.713	1.484	-0.480	0.631
smb.ocTRUE:factor(QTR)4	1.060	1.006	1.054	0.292
other.ocTRUE:factor(QTR)2	-3.446	1.507	-2.286	0.022
other.ocTRUE:factor(QTR)3	-5.512	1.701	-3.240	0.001
other.ocTRUE:factor(QTR)4	-2.943	1.573	-1.871	0.061

Table A2. Estimated sturgeon takes by otter trawl gear in 2006 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.04	0.06	0	0.02
51	12.17	9.04	0.05	4.7
52	7.28	22.84	1.56	1.82
53	17.39	170.75	189.27	106.73
54	0.01	NA	0	NA
55	NA	NA	NA	NA
56	NA	12.85	0.04	0.15
61	92.61	373.32	359.15	225
62	24.19	26.29	21.04	72.39
63	27.41	0.45	0.1	14.95

Table A3. Estimated sturgeon takes by otter trawl gear in 2007 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.03	0.05	0	0.01
51	12.95	5.95	0.04	5.25
52	6.81	26.1	2.32	1.33
53	15.97	183.85	120.22	57.2
54	0.02	NA	NA	NA
55	NA	NA	NA	NA
56	0.78	8.37	0.08	0.68
61	73.74	449.59	294.77	201.41
62	15.05	20.88	18.83	47.84
63	55.15	0.72	0.14	19.77

Table A4. Estimated sturgeon takes by otter trawl gear in 2008 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.04	0.05	0	0.01
51	52.72	7.05	0.05	4.87
52	6.98	30.51	2.59	1.21
53	14.07	205.33	131.47	36.89
54	0.04	NA	NA	NA
55	NA	NA	NA	0.02
56	0.51	1.27	0	0.25
61	49.16	323.76	255.95	113.49
62	41.51	7.74	6.51	36.71
63	39.71	0.14	0.12	21.31

Table A5. Estimated sturgeon takes by otter trawl gear in 2009 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.09	0.05	0	0.1
51	31.39	6.82	0.05	5.67
52	6.22	26.38	1.86	0.63
53	10.59	158.74	105.15	49.39
54	0	0.88	0.87	NA
55	NA	0.01	NA	NA
56	1.41	1.89	0.06	0.22
61	63.28	258.26	293.27	147.71
62	21.58	8.5	10.36	46.56
63	55.65	1.77	0.05	22.68

Table A6. Estimated sturgeon takes by otter trawl gear in 2010 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.05	0.04	0	0.02
51	47.06	3.79	0.04	2.61
52	6.72	28.02	3.23	0.44
53	12.13	196.87	198.23	43.85
54	0	NA	NA	NA
55	NA	NA	NA	NA
56	0.53	1.92	0.06	0.16
61	52.9	335.08	370.45	116.7
62	37.49	19.04	6.74	52.02
63	21.29	0.46	0.55	11.8

Table A7. Observed sturgeon takes by otter trawl gear in 2006 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	NA	NA	NA	NA
51	1	0	0	0
52	1	0	0	0
53	0	0	0	0
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	0	0	NA
61	0	11	0	3
62	4	0	1	2
63	5	NA	0	0

Table A8. Observed sturgeon takes by otter trawl gear in 2007 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	NA	NA	NA	NA
51	1	0	0	0
52	0	0	0	0
53	0	0	0	0
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	0	0	NA	0
61	6	2	0	2
62	3	0	17	24
63	3	NA	NA	0

Table A9. Observed sturgeon takes by otter trawl gear in 2008 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	NA	NA	NA	NA
51	0	0	0	0
52	0	0	0	0
53	0	0	0	0
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	0	0	NA	NA
61	1	13	5	1
62	2	3	0	3
63	0	NA	0	0

Table A10. Observed sturgeon takes by otter trawl gear in 2009 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	NA	NA	NA	NA
51	0	0	0	1
52	0	0	0	0
53	0	0	1	0
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	0	NA	0
61	0	13	2	0
62	0	1	4	3
63	23	0	0	0

Table A11. Observed sturgeon takes by otter trawl gear in 2010 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	NA	NA	NA	NA
51	0	0	0	0
52	0	0	0	0
53	0	2	0	0
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	0	0	0	0
61	1	33	33	1
62	0	0	0	18
63	7	8	0	2

Table A12. Number of VTR trips using otter trawl gear in 2006 by division and quarter.

	1	2	3	4
46	4	10	9	4
51	1494	959	2237	1764
52	533	513	474	449
53	1040	1695	1913	1340
54	3	0	1	0

55	0	0	0	0
56	0	123	23	27
61	1324	3371	3591	2394
62	475	795	660	455
63	78	9	52	109

Table A13. Number of VTR trips using otter trawl gear in 2007 by division and quarter.

	1	2	3	4
46	6	10	4	3
51	1552	890	2246	1508
52	441	503	481	500
53	948	1715	1432	1310
54	1	0	0	0
55	0	0	0	0
56	70	119	23	75
61	1426	3489	3641	2115
62	215	242	314	298
63	181	10	20	150

Table A14. Number of VTR trips using otter trawl gear in 2008 by division and quarter.

	1	2	3	4
46	4	7	3	6
51	2197	1151	2069	1544
52	424	493	370	299
53	970	1715	1450	1110
54	1	0	0	0
55	0	0	0	1
56	40	19	92	147
61	1163	3071	2942	1481
62	390	131	303	265
63	131	8	30	135

Table A15. Number of VTR trips using otter trawl gear in 2009 by division and quarter.

	1	2	3	4
46	4	10	1	10
51	1921	1008	2428	1704

52	392	429	301	341
53	909	1584	1241	946
54	1	8	14	0
55	0	1	0	0
56	44	73	116	78
61	1046	2953	2804	1800
62	430	164	306	319
63	229	24	22	154

Table A16. Number of VTR trips using otter trawl gear in 2010 by division and quarter.

	1	2	3	4
46	4	7	1	3
51	2255	624	1040	810
52	363	445	355	268
53	862	1826	1657	1032
54	1	0	0	0
55	0	0	0	0
56	60	87	61	70
61	833	2705	2707	1688
62	414	199	272	333
63	165	23	83	78

Table A17. Proportion of VTR trips using otter trawl gear with observers in 2006 by division and quarter.

	1	2	3	4
46	0.000	0.000	0.000	0.000
51	0.086	0.011	0.018	0.015
52	0.038	0.019	0.030	0.016
53	0.060	0.013	0.015	0.019
54	0.000	NA	0.000	NA
55	NA	NA	NA	NA
56	NA	0.008	0.043	0.000
61	0.021	0.011	0.015	0.016
62	0.021	0.013	0.024	0.013
63	0.090	0.000	0.038	0.009

Table B18. Proportion of VTR trips using otter trawl gear with observers in 2007 by division and quarter.

	1	2	3	4
46	0.000	0.000	0.000	0.000
51	0.028	0.034	0.023	0.042
52	0.020	0.038	0.040	0.032
53	0.028	0.022	0.036	0.010
54	0.000	NA	NA	NA
55	NA	NA	NA	NA
56	0.071	0.017	0.000	0.013
61	0.015	0.021	0.043	0.020
62	0.014	0.021	0.070	0.070
63	0.094	0.000	0.000	0.073

Table B19. Proportion of VTR trips using otter trawl gear with observers in 2008 by division and quarter.

	1	2	3	4
46	0.000	0.000	0.000	0.000
51	0.024	0.023	0.022	0.052
52	0.059	0.024	0.035	0.054
53	0.021	0.020	0.012	0.027
54	0.000	NA	NA	NA
55	NA	NA	NA	0.000
56	0.075	0.053	0.000	0.000
61	0.017	0.024	0.022	0.024
62	0.044	0.099	0.040	0.057
63	0.053	0.000	0.033	0.074

Table B20. Proportion of VTR trips using otter trawl gear with observers in 2009 by division and quarter.

	1	2	3	4
46	0.000	0.000	0.000	0.000
51	0.084	0.019	0.055	0.053
52	0.033	0.021	0.056	0.053
53	0.031	0.061	0.084	0.071
54	0.000	0.000	0.000	NA

55	NA	0.000	NA	NA
56	0.000	0.041	0.000	0.038
61	0.020	0.024	0.031	0.037
62	0.063	0.085	0.098	0.154
63	0.061	0.042	0.045	0.156

Table B21. Proportion of VTR trips using otter trawl gear with observers in 2010 by division and quarter.

	1	2	3	4
46	0.000	0.000	0.000	0.000
51	0.023	0.045	0.044	0.086
52	0.058	0.011	0.045	0.037
53	0.031	0.045	0.025	0.046
54	0.000	NA	NA	NA
55	NA	NA	NA	NA
56	0.033	0.046	0.033	0.043
61	0.055	0.060	0.039	0.030
62	0.140	0.106	0.118	0.090
63	0.085	0.174	0.120	0.115

Appendix B. Summary of model parameters and discard estimates for Atlantic sturgeon in gill nets.

Table B1. Estimated parameters for model 6gn fitted to the trip-specific observer sink gillnet data from 2006-2010.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.379	0.385	-6.173	0.000
blue.ocTRUE	-0.071	0.330	-0.214	0.830
dog.ocTRUE	-0.512	0.700	-0.732	0.464
fsb.ocTRUE	0.978	0.316	3.095	0.002
lmgf.ocTRUE	-2.354	0.723	-3.256	0.001
smgf.ocTRUE	0.598	1.136	0.526	0.599
monk.ocTRUE	1.139	0.350	3.258	0.001
sbass.ocTRUE	0.205	0.665	0.308	0.758
scal.ocTRUE	-0.780	1.567	-0.498	0.619
skate.ocTRUE	-1.475	0.433	-3.409	0.001
smb.ocTRUE	-0.906	0.501	-1.809	0.070
other.ocTRUE	0.553	0.359	1.537	0.124
factor(YEAR)2007	-0.657	0.585	-1.122	0.262
factor(YEAR)2008	-0.795	0.697	-1.140	0.254
factor(YEAR)2009	-1.051	0.662	-1.588	0.112
factor(YEAR)2010	-1.164	0.729	-1.596	0.110
factor(YEAR)2011	-2.295	1.470	-1.561	0.119
blue.ocTRUE:factor(YEAR)2007	0.127	0.498	0.255	0.799
blue.ocTRUE:factor(YEAR)2008	0.265	0.703	0.376	0.707
blue.ocTRUE:factor(YEAR)2009	-1.102	0.888	-1.240	0.215
blue.ocTRUE:factor(YEAR)2010	-1.075	1.000	-1.075	0.282
blue.ocTRUE:factor(YEAR)2011	1.260	1.490	0.845	0.398
dog.ocTRUE:factor(YEAR)2007	1.003	0.814	1.232	0.218
dog.ocTRUE:factor(YEAR)2008	0.845	0.925	0.914	0.361
dog.ocTRUE:factor(YEAR)2009	-2.369	1.697	-1.396	0.163
dog.ocTRUE:factor(YEAR)2010	1.775	0.838	2.117	0.034
dog.ocTRUE:factor(YEAR)2011	-13.918	1148.485	-0.012	0.990
fsb.ocTRUE:factor(YEAR)2007	-0.136	0.481	-0.283	0.777
fsb.ocTRUE:factor(YEAR)2008	-0.518	0.664	-0.780	0.435
fsb.ocTRUE:factor(YEAR)2009	-1.294	0.541	-2.391	0.017
fsb.ocTRUE:factor(YEAR)2010	-1.844	0.808	-2.282	0.023

fsb.ocTRUE:factor(YEAR)2011	0.761	1.485	0.513	0.608
lmgf.ocTRUE:factor(YEAR)2007	-0.086	0.947	-0.091	0.928
lmgf.ocTRUE:factor(YEAR)2008	0.838	1.078	0.778	0.437
lmgf.ocTRUE:factor(YEAR)2009	-0.032	1.037	-0.031	0.975
lmgf.ocTRUE:factor(YEAR)2010	-0.250	1.190	-0.210	0.834
lmgf.ocTRUE:factor(YEAR)2011	3.816	1.453	2.626	0.009
smgf.ocTRUE:factor(YEAR)2007	-0.064	1.977	-0.033	0.974
smgf.ocTRUE:factor(YEAR)2008	-0.909	1.999	-0.455	0.649
smgf.ocTRUE:factor(YEAR)2009	-1.390	1.604	-0.867	0.386
smgf.ocTRUE:factor(YEAR)2010	-14.082	726.818	-0.019	0.985
smgf.ocTRUE:factor(YEAR)2011	-16.371	1489.100	-0.011	0.991
monk.ocTRUE:factor(YEAR)2007	1.253	0.573	2.188	0.029
monk.ocTRUE:factor(YEAR)2008	0.181	0.767	0.236	0.814
monk.ocTRUE:factor(YEAR)2009	0.192	0.676	0.285	0.776
monk.ocTRUE:factor(YEAR)2010	-1.467	0.830	-1.767	0.077
monk.ocTRUE:factor(YEAR)2011	-1.359	1.190	-1.141	0.254
sbass.ocTRUE:factor(YEAR)2007	2.014	0.814	2.475	0.013
sbass.ocTRUE:factor(YEAR)2008	1.738	0.947	1.835	0.067
sbass.ocTRUE:factor(YEAR)2009	2.579	0.948	2.721	0.007
sbass.ocTRUE:factor(YEAR)2010	0.094	1.794	0.052	0.958
sbass.ocTRUE:factor(YEAR)2011	-14.334	1516.644	-0.009	0.992
scal.ocTRUE:factor(YEAR)2007	1.405	1.945	0.723	0.470
scal.ocTRUE:factor(YEAR)2008	1.877	2.271	0.827	0.408
scal.ocTRUE:factor(YEAR)2009	-15.208	2095.281	-0.007	0.994
scal.ocTRUE:factor(YEAR)2010	0.816	1.942	0.420	0.674
scal.ocTRUE:factor(YEAR)2011	-13.424	6203.050	-0.002	0.998
skate.ocTRUE:factor(YEAR)2007	-0.413	0.615	-0.670	0.503
skate.ocTRUE:factor(YEAR)2008	0.349	0.861	0.405	0.685
skate.ocTRUE:factor(YEAR)2009	2.720	0.675	4.031	0.000
skate.ocTRUE:factor(YEAR)2010	3.569	0.971	3.675	0.000
skate.ocTRUE:factor(YEAR)2011	2.269	0.997	2.276	0.023
smb.ocTRUE:factor(YEAR)2007	-0.892	1.218	-0.732	0.464
smb.ocTRUE:factor(YEAR)2008	-13.967	974.928	-0.014	0.989
smb.ocTRUE:factor(YEAR)2009	-14.084	892.049	-0.016	0.987
smb.ocTRUE:factor(YEAR)2010	-0.110	1.642	-0.067	0.946
smb.ocTRUE:factor(YEAR)2011	2.196	1.072	2.048	0.041
other.ocTRUE:factor(YEAR)2007	-0.734	0.508	-1.444	0.149
other.ocTRUE:factor(YEAR)2008	-0.841	0.616	-1.365	0.172
other.ocTRUE:factor(YEAR)2009	0.773	0.490	1.578	0.115
other.ocTRUE:factor(YEAR)2010	-0.213	0.606	-0.351	0.726
other.ocTRUE:factor(YEAR)2011	-0.249	0.913	-0.272	0.785

Table B2. Estimated sturgeon takes by sink gillnet gear in 2006 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.18	1.96	4.1	0.03
51	14.42	20.16	81.57	46.89
52	8.78	12.7	35.29	17.8
53	51.12	197.56	71.71	45.49
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	0.13	1.51	0.05
61	47.1	204.16	202.7	213.33
62	26.38	114.62	41.94	49.93
63	73.5	13.45	1.55	10.63
70	1.07	0.21	NA	NA

Table B3. Estimated sturgeon takes by sink gillnet gear in 2007 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.18	0.26	0.48	0
51	16.65	36.46	132.65	77.12
52	5.79	19.09	50.14	16.44
53	31.48	238.49	77.79	62.94
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	0.04	NA	NA
61	81.71	223.25	243.63	579.41
62	43.76	105.53	12	90.71
63	44.2	8.32	0.48	16.98
70	0.12	NA	NA	NA

Table B4. Estimated sturgeon takes by sink gillnet gear in 2008 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.06	0.14	0.03	NA
51	17.77	27.7	91.56	46.64
52	2.88	7.93	26.14	10.07
53	16.47	94.23	21.34	18.85
54	0.01	NA	0	NA
55	NA	0	NA	NA
56	NA	0.13	1.51	0.05
61	35.06	80.31	60.84	117.6
62	31.41	46.17	9.55	48.92
63	16.65	7.53	0.03	22.24
70	0.04	NA	NA	NA

Table B5. Estimated sturgeon takes by sink gillnet gear in 2009 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.09	0.05	0.13	NA
51	15.1	16.57	33.4	43.35
52	15.32	15.14	67.15	132.07
53	105.12	266.69	41.04	107.5
54	NA	0.43	0.04	NA
55	NA	NA	NA	NA
56	0.01	0.2	NA	NA
61	135.53	354.75	137.4	241.77
62	56.2	138.64	26.53	39.11
63	33.72	24.52	0.58	4.21
70	0.37	NA	NA	0.61

Table B6. Estimated sturgeon takes by sink gillnet gear in 2010 by division and quarter. NA is given in cells where no trips were present in VTR records for a quarter and division.

	1	2	3	4
46	0.01	0	0	NA
51	9.45	23.11	67.63	7.91
52	5.31	25.88	140.93	24.99
53	35.77	156.08	50.72	38.1
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	0	0	NA	NA
61	56.8	120.79	33.18	179.89
62	4.12	53.19	12.53	20.03
63	22.41	7.08	0.32	11.04
70	0.5	0.04	NA	0.13

Table B7. Observed sturgeon takes by sink gillnet gear in 2006 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	0	NA	NA	0
51	3	0	1	0
52	0	0	1	2
53	0	2	0	0
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	NA	NA	NA
61	2	32	6	0
62	1	13	0	2
63	31	6	0	3
70	0	16	NA	0

Table B8. Observed sturgeon takes by sink gillnet gear in 2007 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	0	NA	NA	NA
51	2	0	0	0
52	0	0	1	2
53	0	9	0	1
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	NA	NA	NA
61	1	7	11	2
62	2	9	0	3
63	50	8	0	1
70	0	0	0	0

Table B9. Observed sturgeon takes by sink gillnet gear in 2008 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	0	NA	NA	NA
51	3	0	0	2
52	0	1	0	0
53	1	1	0	0
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	NA	NA	NA
61	0	2	0	10
62	2	2	0	2
63	10	5	0	2
70	0	0	0	0

Table B10. Observed sturgeon takes by sink gillnet gear in 2009 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	NA	NA	NA	NA
51	4	0	0	0
52	0	0	0	1
53	1	3	0	1
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	NA	NA	NA
61	2	2	5	5
62	2	4	0	1
63	11	56	0	3
70	0	0	0	0

Table B11. Observed sturgeon takes by sink gillnet gear in 2010 by division and quarter. NA is given in cells where no trips were observed for a quarter and division.

	1	2	3	4
46	NA	NA	NA	NA
51	1	1	0	1
52	1	0	0	0
53	0	0	0	1
54	NA	NA	NA	NA
55	NA	NA	NA	NA
56	NA	NA	NA	NA
61	1	5	0	27
62	0	4	0	1
63	3	4	0	0
70	0	0	0	0

Table B12. Number of VTR trips using sink gillnet gear in 2006 by division and quarter.

	1	2	3	4
46	3	7	9	1
51	956	718	2422	2009
52	118	205	752	434
53	324	1166	278	317

54	0	0	0	0
56	0	2	3	1
61	369	1355	1221	1394
62	164	483	296	357
63	440	78	15	85
70	10	3	0	0

Table B13. Number of VTR trips using sink gillnet gear in 2007 by division and quarter.

	1	2	3	4
46	4	6	2	1
51	1259	831	2562	2050
52	109	257	939	427
53	201	990	395	513
54	0	0	0	0
56	0	1	0	0
61	368	1515	1421	1844
62	209	583	344	422
63	396	66	21	90
70	8	0	0	0

Table B14. Number of VTR trips using sink gillnet gear in 2008 by division and quarter.

	1	2	3	4
46	2	5	1	0
51	1739	1148	3030	2326
52	104	264	798	425
53	305	1260	333	381
54	0	1	0	0
56	0	0	0	0
61	422	1337	844	1083
62	246	561	280	356
63	288	79	1	199
70	2	0	0	0

Table B15. Number of VTR trips using sink gillnet gear in 2009 by division and quarter.

	1	2	3	4
46	4	2	3	0

51	1746	1356	3573	2278
52	66	213	691	271
53	296	1147	446	363
54	0	1	1	0
56	1	3	0	0
61	412	1262	1082	1127
62	145	612	435	523
63	375	101	41	130
70	8	0	0	5

Table B16. Number of VTR trips using sink gillnet gear in 2010 by division and quarter.

	1	2	3	4
46	5	2	1	0
51	2538	961	2150	1086
52	70	203	792	226
53	262	1175	402	302
54	0	0	0	0
56	2	1	0	0
61	350	1127	977	1066
62	70	571	354	390
63	492	178	25	212
70	13	1	0	4

Table B17. Proportion of VTR trips using sink gillnet gear with observers in 2006 by division and quarter.

	1	2	3	4
46	0.333	0.000	0.000	1.000
51	0.093	0.015	0.026	0.038
52	0.119	0.098	0.028	0.032
53	0.040	0.077	0.036	0.069
54	NA	NA	NA	NA
56	NA	0.000	0.000	0.000
61	0.117	0.043	0.045	0.032
62	0.006	0.106	0.139	0.106
63	0.164	0.462	1.133	0.659
70	0.900	6.000	NA	Inf

Table B18. Proportion of VTR trips using sink gillnet gear with observers in 2007 by division and quarter.

	1	2	3	4
46	0.250	0.000	0.000	0.000
51	0.076	0.016	0.028	0.038
52	0.037	0.066	0.026	0.089
53	0.129	0.086	0.025	0.047
54	NA	NA	NA	NA
56	NA	0.000	NA	NA
61	0.027	0.054	0.059	0.038
62	0.072	0.070	0.052	0.073
63	0.331	0.561	0.524	0.489
70	1.500	Inf	Inf	Inf

Table B19. Proportion of VTR trips using sink gillnet gear with observers in 2008 by division and quarter.

	1	2	3	4
46	0.500	0.000	0.000	NA
51	0.048	0.021	0.029	0.031
52	0.058	0.049	0.035	0.064
53	0.085	0.033	0.036	0.042
54	NA	0.000	NA	NA
56	NA	NA	NA	NA
61	0.031	0.030	0.033	0.035
62	0.057	0.096	0.071	0.104
63	0.184	0.203	12.000	0.226
70	2.500	Inf	Inf	Inf

Table B20. Proportion of VTR trips using sink gillnet gear with observers in 2009 by division and quarter.

	1	2	3	4
46	0.000	0.000	0.000	NA
51	0.089	0.012	0.031	0.031
52	0.076	0.023	0.036	0.089
53	0.095	0.016	0.011	0.033
54	NA	0.000	0.000	NA

56	0.000	0.000	NA	NA
61	0.041	0.037	0.018	0.038
62	0.069	0.062	0.037	0.034
63	0.104	0.287	0.268	0.262
70	0.625	Inf	Inf	2.800

Table B21. Proportion of VTR trips using sink gillnet gear with observers in 2010 by division and quarter.

	1	2	3	4
46	0.000	0.000	0.000	NA
51	0.020	0.054	0.023	0.101
52	0.071	0.039	0.051	0.066
53	0.046	0.025	0.002	0.043
54	NA	NA	NA	NA
56	0.000	0.000	NA	NA
61	0.051	0.031	0.016	0.060
62	0.071	0.109	0.048	0.085
63	0.079	0.191	0.920	0.189
70	0.538	12.000	Inf	7.500

Appendix C. Variance and Confidence intervals for yearly predicted sturgeon takes and proportions by FMP.

Let $\hat{\mathbf{B}}$ be the p x1 vector of coefficients estimated from the best fitted model (trawl or gillnet) and $\hat{\mathbf{V}}$ (p x p) be the estimated covariance matrix of the estimated coefficients (p is the number of estimated coefficients). Also, let $\mathbf{X}_y$ be the n_y x p matrix of covariates for the VTR trips in year y where n_y is the number of trips. Then the log estimated predictions for the n_y VTR trips is $\log(\mathbf{T}_y) = \mathbf{X}_y\hat{\mathbf{B}}$ and the estimated takes are $\mathbf{T}_y = e^{\mathbf{X}_y\hat{\mathbf{B}}}$. The n_y x n_y covariance matrix for the log predictions is

$$\hat{\mathbf{V}}_{\log(\mathbf{T}_y)} = \mathbf{X}_y\hat{\mathbf{V}}\mathbf{X}_y'$$

and the approximate (delta method) covariance matrix for the estimated takes is

$$\hat{\mathbf{V}}_{\mathbf{T}_y} = \text{diag}(\hat{\mathbf{T}}_y)\hat{\mathbf{V}}_{\log(\mathbf{T}_y)}\text{diag}(\hat{\mathbf{T}}_y).$$

The variance of the total take estimate for year y is just the sum of all n_y^2 elements of $\hat{\mathbf{V}}_{\mathbf{T}_y}$:

$$\hat{V}(\hat{T}_y) = \mathbf{1}_y'\hat{\mathbf{V}}_{\mathbf{T}_y}\mathbf{1}_y.$$

where $\mathbf{1}_y$ is a n_y x1 vector of ones. Similarly letting $\mathbf{1}_{f,y}$ be a n_y x1 vector of ones where FMP f is present and zero otherwise, the variance of the total take where FMP f is present is

$$\hat{V}(\hat{T}_{f,y}) = \mathbf{1}_{f,y}'\hat{\mathbf{V}}_{\mathbf{T}_y}\mathbf{1}_{f,y}.$$

Likewise, the covariance of estimated takes where FMPs f and g are present is

$$Cov(\hat{T}_{f,y},\hat{T}_{g,y}) = \mathbf{1}_{f,y}'\hat{\mathbf{V}}_{\mathbf{T}_y}\mathbf{1}_{g,y}.$$

The measure of FMP influence on sturgeon take, is the ratio of two values, the total take where FMP f is present to the sum of those estimates across all FMPs. The variance of the numerator $\hat{V}(\hat{T}_{f,y})$ is given above and the variance of the denominator is

$$\hat{V}(D) = \hat{V}\left(\sum_{f=1}^{F}\hat{T}_{f,y}\right) = \sum_{f=1}^{F}\hat{V}(\hat{T}_{f,y}) + \sum_{f=1}^{F}\sum_{g\neq f}^{F}Cov(\hat{T}_{f,y},\hat{T}_{g,y})$$

and the covariance of the numerator and denominator is

$$Cov(N,D) = Cov\left(\hat{T}_{f,y},\sum_{g=1}^{F}\hat{T}_{g,y}\right) = \sum_{g=1}^{F}Cov(\hat{T}_{f,y},\hat{T}_{g,y}) = \hat{V}(\hat{T}_{f,y}) + \sum_{g\neq f}^{F}Cov(\hat{T}_{f,y},\hat{T}_{g,y})$$

The approximate variance estimate (delta method) for the ratio ($R = N / D$) is

$$\hat{V}(R) = R^2\left[\frac{\hat{V}(N)}{N^2} + \frac{\hat{V}(D)}{D^2} + \frac{Cov(N,D)}{ND}\right].$$

Confidence intervals are based on standard errors (square root of variance) and approximate normality of the point estimates.