A New Proposed Methodology for Conducting Bag and Size Limit Analyses

Using Black Sea Bass as an Example

Introduction

Analyzing the effect of reducing a bag limit on the estimated landings of a particular stock has become a fairly routine procedure in fisheries management. One simply analyzes the data on a trip-by-trip basis and reduces the catch of each trip that originally landed more than the proposed bag limit. However, analyzing bag limit increases isn't as straight forward. The problem is estimating by how much to increase the landings as the bag limit increases.

It may be safe to assume that if a trip did not reach the current bag limit, it would not reach a proposed bag limit that is higher than the current one. However, what about the trips that did reach the bag limit? One possible assumption of the bag limit increase analysis is that if a trip reached the current bag limit, it would reach whatever proposed increases were made to that bag limit without any limitations. Another, more refined approach limited the increase in landings to the reported discards per trip. However, there was no way to distinguish whether a fish was discarded because it was under the legal size-limit or because the angler reached the bag limit.

Another related analysis is to look at changes in the size limit for a species. Analyses looking at increases in the minimum size limit for a species are also fairly common in fisheries management. Much of the available trip-level data has size information associated with it, which is used to trim the landings of each trip by the fish that exceed the proposed minimum size.

However, analyzing size limit decreases is much more complex. Any trip, whether it reached its bag limit or not, may have landed more fish if the size limit was lower in a given year. We could look at the discards on each trip to give us an idea of the maximum number of fish we could increase the landings by, but there is no way to distinguish between fish that are above the new minimum size versus those that are below it.

The new method proposed here is an attempt to solve these two problems using the available information from the most recent stock assessment. The abundance at age, recreational selectivity, discard selectivity, and proportion of fish above and below the size limit at age are all used to estimate the proportion of the discards that are above and below the size limit being considered. This information allows us to determine how many fish to add to the landings for each size limit being looked at. It also tells us which discards were due to the size limit versus

those that were due to reaching the bag limit, which together with the size information on discards, allows for the analysis of increasing bag limits.

This analysis examines increasing the recreational bag limit for Black Sea Bass from the current bag limit of 5 fish per angler to proposed bag limits ranging from 6 to 10 fish per angler. It also examines decreasing the size limit for Black Sea Bass from the current 13" minimum size to either 12" or 11" minimum size limits. Two data sources are used in this analysis: the MRIP intercept data (Marine Recreational Information Program, which includes private recreational trips and charter boat trips) from 2013 and 2014, and the headboat data (obtained from the Southeast Region Headboat Survey) from 2013 and 2014. The data ranges from Cape Hatteras, NC down to the Miami Dade – Monroe County line in FL and includes all trips that encountered at least one Black Sea Bass (either landed, discarded, or both).

2013 and 2014 were chosen because of the change in minimum size from 12" to 13" that went into effect in 2013. Also, 2013 was the first year the new MRIP sampling protocol was used. MRIP began using a new Access Point Angler Intercept Survey (APAIS) in Wave 2 of 2013 that was designed to better sample times of day outside of the peak activity times. Each year was analyzed individually and the average of 2013 and 2014 was also looked at to get a range of estimated landings values under each of the proposed bag limits. All assessment data came from the SEDAR 25 update for Black Sea Bass completed in 2013.

New Proposed Methodology and Assumptions

1. Assumption: All discarded fish reported on trips that did not reach the bag limit at the trip level are below the minimum size limit.
2. Assumption: Fish discarded on trips that reached the bag limit could be both above and below the minimum size limit. In other words, discards on these trips could be due to the bag limit or the size limit.
3. Population estimates from the most recent stock assessment were used to estimate the size composition of discarded fish for trips that reached the bag limit. The intent is to determine the proportion of discarded fish above and below the size limit, which can be used to determine how many of the discarded fish can contribute to landings if the bag limit is increased or the size limit is decreased.
4. Assumption: Trips that reach the bag limit discard some fish due to the bag limit. Therefore, some legal-sized Black Sea Bass are discarded.
5. Discard selectivities for MRIP and Headboat needed to be estimated for fish above and below each of the proposed minimum size limits. Once these were calculated, the

proportion of discarded fish above the minimum size limit on trips that reached the bag limit could be calculated.

6. As increasing bag limit alternatives were evaluated, the catch increased by the number of discarded Black Sea Bass reported on trips that reached the bag limit multiplied by the proportion of discards from those trips that are greater than the minimum size.
7. All the formulas used to perform the calculations and more detailed methods are described in the Appendix.

Appendix

Formulas, Calculations, and Detailed Methods Used in the New Proposed Analysis

Given:

$S_{a,f}^{D,<min}$ – Discard selectivity for fish less than the minimum size at age a for fishery f.

$S_{a,f}^{D,>min}$ – Discard selectivity for fish greater than the minimum size at age a for fishery f.

$E_{f,y}^{D}$ – Exploitation rate for dead discards in year y for fishery f.

$N_{a,y}$ – Total abundance at age a for year y.

M^{D} – Discard mortality.

We can estimate the proportion of total fish discarded that are above the minimum size limit for a given fishery f in a given year y:

$$\frac{\sum_a \left(S_a^{D,>min} E^D N_a\right) \Big/ M^D}{\left(\sum_a \left(S_a^{D,<min} E^D N_a\right) \Big/ M^D\right) + \left(\sum_a \left(S_a^{D,>min} E^D N_a\right) \Big/ M^D\right)}$$

Since this proportion is being calculated for a given fishery in a given year, the discard exploitation rate and the discard mortality both become constants and can be removed from the above equation. (It should be noted that this analysis can also be used for assessments where there is a single selectivity for the recreational fleet, but different exploitation rates for harvest versus discards. The exploitation rate in the equation above would need to remain in the equation in these circumstances. This is a common approach in the Stock Synthesis modeling framework.) After removing these constant terms, the above equation reduces to:

$$\frac{\sum_a \left(S_a^{D,>min} N_a\right)}{\sum_a \left(S_a^{D,<min} N_a\right) + \sum_a \left(S_a^{D,>min} N_a\right)}$$

For this analysis, the discard selectivities for fish below the size limit were calculated using the same methodology as was used in both SEDAR 25 and the 2013 update. Below is an excerpt from the SEDAR 25 assessment report.

Selectivities of discards were assumed to be dome-shaped. They were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken was that age-specific values for ages 0–2 were estimated, age 3 was assumed to have full selection, and selectivity for each age 4+ was set equal to the age-specific probability of being below the size limit, given the estimated normal distribution of size at age. In this way, the descending limb of discard selectivities would change with modification in the size limit.

However, the discard selectivity for fish under the minimum size could not simply be taken from the 2013 update because the 2013 update corrected for closed seasons in the descending limb of the discard selectivity, meaning that during the closed season there was an assumption of legal sized fish being discarded on all trips. After the new ACL was implemented from the results of the update, the recreational fishery was not subject to a regulatory closure. Also, we needed a way to calculate new selectivity curves for different minimum sizes to be analyzed.

The SEDAR 25 update assumed no fish age 3 or less had yet reached the minimum size, therefore the model estimated discard selectivity was used to estimate the proportion of fish age 3 and less that would be selected by the fishery to be discarded. Discards were assumed to be zero for fish above the minimum size in these age classes. For ages 4^{+}, the selectivity at age for discards below the minimum size was estimated by using the length at age calculated from the von Bertalanffy growth equation estimated in SEDAR 25 to estimate the probability at age that a fish is below the minimum size. It was assumed the distribution of size at age was normal with a mean of the von Bert calculated length and a CV of 1. Those probabilities at age for ages 4+ were used to fill in the descending limb of the discard selectivity to produce new discard selectivities at age.

This method of adjusting for the size limit allowed for analyzing the effects of lowering the size limit for Black Sea Bass. The Council has proposed lowering the recreational size limit to 12” or 11”. The bag limit analysis can easily be done for each of these size limits by adjusting the selectivity pattern using the procedure described above. These methods will continue describing the analysis using the 13” size limit as an example, but the same procedure was used to analyze each bag limit alternative for a 12” and 11” minimum size limit.

Discard selectivity for fish greater than the minimum size also needed to be calculated for trips that reached the bag limit of 5 fish per person. To accomplish this, the probability of a fish being greater than 13 inches at age was calculated by setting the selectivity of fish ages 0-3 equal to zero (as was assumed above) and taking the inverse of the probability at age that a fish is below the minimum size for ages 4^{+}. That inverse probability at age was then multiplied by the proportion of trips that reached the bag limit, on average, between 2013 and 2014. This step is done because one of the assumptions of this analysis is that only trips where the bag limit is reached can fish greater than the minimum size be discarded. Calculating the number of fish available to the fishery that are greater than the minimum allows for analyses of increasing bag limits and decreasing size limits for management purposes.

One small addition was made when looking at multiple size limits together with multiple bag limits. Rather than recalculate all the discards for each size limit and then proceeding with each bag limit analysis, it is possible to calculate the number of discards between 2 size limits. This allows for incrementally adding discards into the catch as the size limit changes. The procedure is quite simple and follows the methods described above. For example, following along with the 13" size limit, if we were to then look at a 12" size limit we would only need to calculate the number of discards between 12" and 13". This is done by first calculating the probability of a fish being above and below 12" at each size class using the procedure described above. Then simply subtract the probability of being greater than 13" from the probability of being greater than 12". This gives you the probability of being between 12" and 13". The discard selectivity is calculated using a mix of that used to calculate the discard selectivity for fish <13" and those >13". Since fish 0-3 years of age are always below the minimum size, those age classes are set to zero, as they were for fish >13" above. However, since the data being used were collected under a minimum size limit of 13", the assumption of only trips that hit the bag limit being able to discard fish between 12" and 13" does not hold. Therefore, the probability of being between 12" and 13" becomes the new discard selectivity (without having to multiply by the proportion of trips that hit the bag limit).

The formulas to calculate these discard selectivities are:

$$S_a^{D,<min} \begin{cases} S_a^D \, from\ 2013\ update, a = 0-3 \\ P(x \le min)_a \, , a = 4^+ \end{cases}$$

$$S_a^{D,>min} \begin{cases} 0, a = 0-3 \\ (1 - P(x \le min)_a) * \%Trips^{Hit\ Bag}, a = 4^+ \end{cases}$$

$$S_a^{min1 \le D < min2} \begin{cases} 0, a = 0-3 \\ P(x > min1)_a - P(x > min2)_a \, , a = 4^+ \end{cases}$$

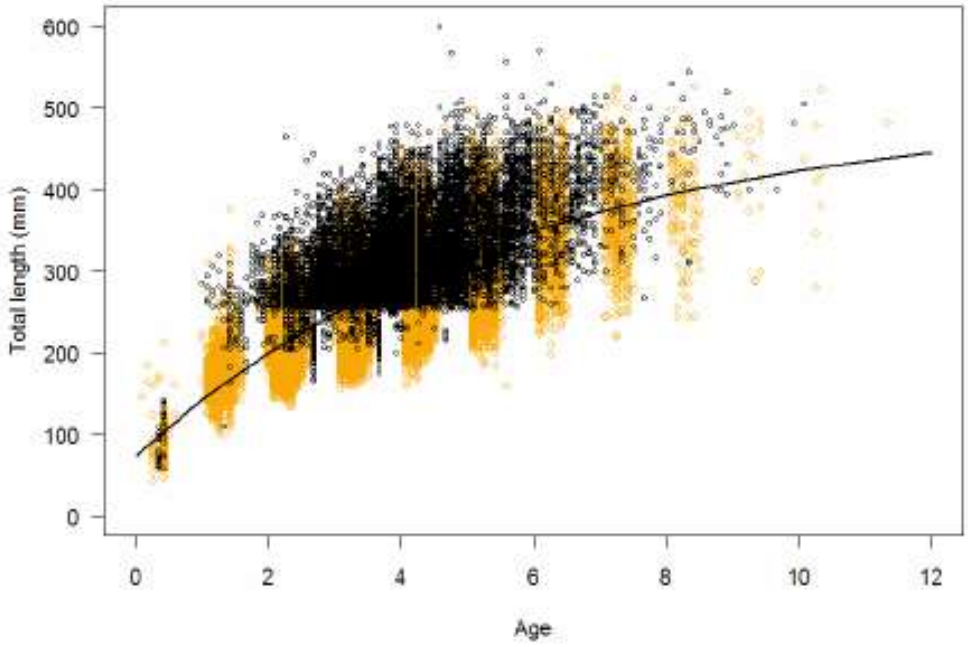
where $P(x \le min)_a$ is the probability that a fish is less than or equal to the minimum size at a given age a, $\%Trips^{Hit\ Bag}$ is the percent of trips averaged across 2013 and 2014 that hit the bag limit, $S_a^{min1 \le D < min2}$ is the discard selectivity for fish between 2 minimum sizes, and $P(x>min1)_a$ and $P(x>min1)_a$ are the probabilities that a fish is greater than one of two minimum sizes (min1 and min2) where min1<min2.

Appendix Table 1. All necessary quantities to calculate the discard selectivities of Black Sea Bass both greater than and less than or equal to 13 inches, including the estimated discard selectivity from the 2013 SEDAR 25 update, the probabilities of a fish being above and below the 13-inch minimum size limit at age, and the final selectivities at age. This table is for MRIP, the only difference being the percent of trips that hit the bag limit. For MRIP, the percent of trips that hit the bag limit averaged across 2013 and 2014 is 1.05%, which is used for these calculations. In contrast, for headboat is was 3.2%.

Age	Est Discard Selectivity	P(x≤13)	P(x>13)	Discard Selectivity	
				<13 in	>13 in
0	0.001	0.999699327	0.0003007	0.001	0
1	0.093	0.905085467	0.0949145	0.093	0
2	0.63	0.742092819	0.2579072	0.63	0
3	1	0.629601623	0.3703984	1	0
4	0.818	0.557751028	0.442249	0.557751028	0.442249
5	0.64	0.510170201	0.4898298	0.510170201	0.4898298
6	0.549	0.477226287	0.5227737	0.477226287	0.5227737
7	0.508	0.453537716	0.5464623	0.453537716	0.5464623
8	0.488	0.435984062	0.5640159	0.435984062	0.5640159
9	0.479	0.422665013	0.577335	0.422665013	0.577335
10	0.473	0.412368621	0.5876314	0.412368621	0.5876314
11	0.47	0.404290062	0.5957099	0.404290062	0.5957099

Appendix Table 2. All the necessary information to calculate the proportion of discarded Black Sea Bass above 13 inches, including the discard selectivities for MRIP calculated in the above table, the estimated abundance at age in 2012 (the terminal year) from the 2013 SEDAR 25 update, and the calculated numbers of discards above and below 13 inches at age.

Age	Discard Selectivity		2012 Abundance (num)	Discards ≤13"	Discards >13"
	≤13"	>13"			
0	0.001	0	33,042,170	49,563	0
1	0.093	0	13,459,560	1,184,441	0
2	0.63	0	8,842,770	5,296,819	0
3	1	0	4,277,590	4,277,590	0
4	0.557751028	0.442249	1,542,900	860,554	7,145
5	0.510170201	0.4898298	516,580	263,544	2,650
6	0.477226287	0.5227737	145,210	69,298	795
7	0.453537716	0.5464623	33,720	15,293	193
8	0.435984062	0.5640159	8,310	3,623	49
9	0.422665013	0.577335	3,840	1,623	23
10	0.412368621	0.5876314	1,490	614	9
11	0.404290062	0.5957099	900	364	6
Total				12,023,327	10,869
Proportion				**0.999096783**	**0.000903217**



Appendix Figure 1. von Bertalanffy growth model for all combined length/age data from the SEDAR 25 update, corrected for minimum size limit bias (black line). Black circles represent fishery dependent age samples, orange circles represent fishery-independent age samples.