A New Proposed Method for Specifying the FLK/EFL Hogfish OFL, ABC, and ACL in Numbers of Fish While still using the Currently Accepted Allocation Formula in Pounds

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At the Council's request, Amendment 37 specifies the proposed recreational ACL for hogfish in numbers of fish (converted from pounds using average weight) and the commercial ACL in pounds. Issues develop, however, when different size limits are considered for management and the commercial and recreational ACLs are in different units: if the minimum size limit is increased, as the Council proposes to do, the average size and thus weight of fish harvested will also increase. If the method for converting between an ACL in pounds and an ACL in numbers does not address the change in average weight, the expected increase in the average weight of landed fish could lead to the poundage associated with the ACL specified in numbers exceeding the ACL expressed in pounds. This could also result in a perceived shift in allocations when they are compared in the original units across sectors, and if the change in weight landed is great enough, the ABC and OFL in pounds could be exceeded.

The assumption made above is that the conditions input to the model used in projections (certain level of recruitment, selectivity, natural mortality, productivity, etc.) will remain consistent in the fishery after the implementation of Amendment 37, including the change in the minimum size limit. If this assumption is correct, then exceeding the yield of the ABC and OFL in pounds would result in overfishing. However, once the minimum size limit change is implemented by Amendment 37, the selectivity and resulting yield per recruit (YPR) may change from the assumed levels that were input to the model. Therefore, the yield in pounds from fishing at F_{target} will be higher with a higher average fish size. Since the recreational fishery is currently harvesting hogfish at an average size below the Council's preferred minimum size limit of 15 inches (13.9 inches on average 2012-2014) and approximately 70% of the harvested fish are currently below this preferred minimum size, there is a good chance that implementing the preferred minimum size limit will change the selectivity of the recreational fishery.

The most appropriate method to address changes in management measures, such as size limits, that affect fishery selectivity is to update the management parameters, such as MSY and F_{MSY} along with projections of yield and stock size, to reflect the expected selectivity patterns. This is very important because estimates of stock productivity are linked to selectivity and will change when a management action affects future selectivity. Council staff had initial discussions with FWC about the potential to rerun the projections and update productivity measures with selectivity consistent with the proposed size limit increase. However, this will require some modifications to the assessment program. Since SEDAR 37 was conducted using the SS3 assessment model, which is highly complex and there is no one in the region qualified to perform the type of code modification required on the fly, the timing, including review by the SSC for acceptance prior to use, will not fit the statutory timeline for Amendment 37. We will pursue having this modification made for future assessments or updates.

Council staff developed a modified YPR model to investigate the effects of changes in the minimum size on fishing mortality (F) (**Appendix**). The intent was to investigate whether a higher yield could be taken by the fishery, while harvesting the same number of fish, and still not result in overfishing. The results of the modified YPR indicate that the fishery could continue to harvest the same number of fish up to the 20" proposed minimum size alternative with little to no effect on the value of F (**Appendix Table 1**). This is because F is based on numbers killed, so alternatives with the same number of fish killed will have similar F values when you consider F over the same range of ages in all the alternatives. Therefore, the recreational fishery can harvest a higher poundage of hogfish without causing the stock to undergo overfishing.

One method of addressing the change in selectivity due to the change in the minimum size limit would be to specify the OFL, ABC, and ACLs in numbers of fish; however, current sector allocations are based on landings in pounds, so allocations could be impacted if ratios derived from pounds are simply applied to fishing levels expressed in numbers.

For the method proposed here, the OFL and ABC are specified in numbers and each value has an associated yield in pounds based on average weight from the stock assessment projections (**Tables 1-2**). The associated yield in pounds is used to calculate the allocation but is not used for calculating or tracking harvest in the recreational sector. The commercial sector's allocation is calculated in both pounds and numbers; therefore, either can be used to track the harvest for that sector. However, the ABC would still be specified in numbers of fish. A stepwise process to derive the sector ACLs could be:

1. Calculate the total ACL
    - If ABC=ACL, then the total ACL in numbers is provided directly as output from the projections from the stock assessment (**Table 1**).
    - If there is an uncertainty buffer between ACL and ABC, then reduce the ABC (numbers) by the uncertainty buffer to get total ACL (numbers, **Table 2**).
2. Allocate the total ACL- This step allocates the ACL between sectors using the status quo method used for all other stocks managed in the South Atlantic. Using the associated yield (pounds) for the ABC or yield with uncertainty buffer included, calculate the allocation for each sector based on the formula derived in the Comprehensive ACL Amendment. Commercial allocation is 9.63% based on weight and recreational allocation is 90.37% based on weight for the FLK/EFL stock.
3. Convert the commercial allocation from pounds to numbers - Divide the commercial sector allocation in pounds by the average weight of commercially-caught hogfish. The average weight of commercially-caught hogfish for the FLK/EFL stock is 3.21 lbs. (Source: Average of gear-specific average weights from the most recent assessment weighted by the commercial landings in number by gear, Mike Errigo).

    - At this step the commercial allocation has now been calculated in both pounds and numbers and either can be used as the final commercial ACL, depending on the preference of the Council. If pounds are chosen, the ABC will still need to be tracked in numbers, requiring the commercial landings to be converted into numbers at some point.
4. Calculate the Recreational ACL (numbers) - Subtract the commercial allocation in numbers from the total ACL in numbers.

Some benefits of calculating the ACL using this method and specifying the OFL and ABC in numbers include:

- The ABC is not exceeded due to changes in the minimum size and average weights.
- Continues to use the standard method to calculate sector allocations.
- The recreational fishery is tracked in its native units.
- The recreational ACL remains constant in Amendment 37 regardless of what minimum size limit is proposed.
- The harvest reductions needed to rebuild the stock will reduce the number of potential weight observations through the MRIP program, making estimation of landings in weight even more unreliable than they already are for a rarely encountered species. Therefore, uncertainty is reduced by setting the OFL, ABC, and ACL in numbers and tracking the landings in numbers.
        - On average from 2012-2014, 246 hogfish a year are observed (Type A catch) through the MRIP survey in this stock, but only 80 of those are weighed (32.5%).
- The numbers of fish measured in the commercial fishery greatly exceeds the number measured in the recreational fishery (Rec: 0.035% of catch, Comm: 0.58% of catch, Comm samples 16.6 times more of the catch than Rec); therefore, we are using the dataset with less uncertainty to convert from weight to numbers.
- The average size of commercially caught hogfish already exceeds the average size of fish under the preferred size limit and might not shift as much as the recreational fishery likely will.
- Evidence suggests that even if the average weight of landed fish does increase due to an increase in the minimum size that overfishing will not occur (see **Appendix**).

Issues to consider:

- The associated yield in pounds of the ACL in numbers can exceed the SSC approved ABC in pounds if the average weight of landed fish increases due to an increase in the minimum size limit. However, the modified YPR analysis developed by Council staff shows that the yield in pounds from fishing at F_{target} will be higher with a higher average fish size.

- Realized allocation may shift in weight. Allocation in weight will be dependent on average weight estimated for the fisheries. Amendment 37 uses an average weight value of 1.85 lbs. for recreationally caught hogfish, which is slightly above the average weight of a 12-inch hogfish. It is not known what the recreational average weight of hogfish will be under different size limits and how it will change over time. However, this is an issue whenever the ACL for a sector is set in numbers and the allocation is calculated in pounds regardless of the units of the ABC.

This method, developed by Council staff, is designed to keep the numbers of fish harvested constant while allowing the yield to vary based on the possible change in selectivity due to changes in the minimum size limit. Yields above the SSC-approved projections in pounds are possible, but the results of the YPR model developed by Council staff show that as long as the number of fish does not exceed the projected landings then overfishing will not be occurring (see **Appendix**). This proposed method also is consistent with the allocation formula currently in use, which relies on landings in pounds to calculate the sector allocations. The method proposed by SERO staff for calculating the recreational ACL of hogfish in the FLK/EFL stock reduces the number of fish harvested in the recreational sector based on average weight of fish at different size limits and does not consider changes in selectivity due to changes in the minimum size limit. Until a new assessment or new projections can be run to account to changes in selectivity due to changes in the minimum size, Council staff propose this method of specifying the OFL and ABC in numbers and allowing the yield to vary based on changes in selectivity as an interim method for setting the recreational ACL for the FLK/EFL stock of hogfish.

Table 1. Proposed ABC and ACLs for the FLK/EFL hogfish stock. This example is for **Sub-alternative 2a** in **Action 6** (ACL=ABC). The average weight is estimated by the stock assessment model. The average weight of commercially caught hogfish is 3.21 lbs. based on commercial samples.

New Proposed Method To Calculate Hogfish ACL Using Only Comm Avg Wt						
Year	**ABC**	**Model Proj Avg Wt**	**Yield of ABC**	**Yield of Comm ACL**	**Comm ACL**	**Rec ACL**
	(number)	**(lbs/fish)**	**(pounds)**	**(pounds)**	**(number)**	**(number)**
2017	17,930	2.14	38,367	3,695	1,126	16,804
2018	21,421	2.31	49,449	4,762	1,452	19,969
2019	24,996	2.48	61,982	5,969	1,820	23,176
2020	29,200	2.59	75,710	7,291	2,223	26,977
2021	33,965	2.66	90,469	8,712	2,656	31,309
2022	39,027	2.72	106,059	10,213	3,114	35,913
2023	44,162	2.77	122,197	11,768	3,588	40,574
2024	49,254	2.81	138,566	13,344	4,068	45,186
2025	54,183	2.86	154,851	14,912	4,546	49,637
2026	58,878	2.90	170,750	16,443	5,013	53,865
2027	63,295	2.94	186,018	17,914	5,461	57,834

Table 2. Proposed ABC and ACLs for the FLK/EFL hogfish stock. This example is for **Preferred Sub-alternative 2b** in **Action 6** (ACL=95% ABC). The average weight is estimated by the stock assessment model. The average weight of commercially caught hogfish is 3.21 lbs. based on commercial samples.

New Proposed Method To Calculate Hogfish ACL Using Only Comm Avg Wt							
Year	ABC	Total ACL	Model Proj Avg Wt	Yield of Total ACL	Yield of Comm ACL	Comm ACL	Rec ACL
	(number)	(number)	(lbs/fish)	(pounds)	(pounds)	(number)	(number)
2017	17,930	17,032	2.14	36,449	3,510	1,093	15,939
2018	21,421	20,336	2.31	46,977	4,524	1,409	18,927
2019	24,996	23,743	2.48	58,883	5,670	1,766	21,977
2020	29,200	27,770	2.59	71,925	6,926	2,158	25,612
2021	33,965	32,310	2.66	85,946	8,277	2,578	29,732
2022	39,027	37,043	2.72	100,756	9,703	3,023	34,020
2023	44,162	41,909	2.77	116,087	11,179	3,483	38,426
2024	49,254	46,846	2.81	131,638	12,677	3,949	42,897
2025	54,183	51,437	2.86	147,108	14,167	4,413	47,023
2026	58,878	55,935	2.90	162,213	15,621	4,866	51,069
2027	63,295	60,108	2.94	176,717	17,018	5,302	54,806

Table 3. Sector ACLs in pounds and numbers (recreational) for **Sub-alternatives 2a-2c** in **Action 6** and based on ABC projections from **Preferred Alternative 3** in **Action 5** where ABC is equal to the yield at a constant fishing mortality rate and rebuilds the stock in 10 years with a 72.5% probability of rebuilding success. Recreational ACL in numbers of fish is based on an average weight of 1.85 lbs. ww. (Source Amendment 37)

Sub-alternative 2a: ACL=OY=ABC					
Year	**Total ABC (pounds)**	**Total ACL (pounds)**	**Rec ACL (pounds)**	**Rec ACL (number)**	**Commercial ACL (pounds)**
2017	38,367	38,367	34,672	18,742	3,695
2018	49,449	49,449	44,687	24,155	4,762
2019	61,982	61,982	56,013	30,277	5,969
2020	75,710	75,710	68,419	36,983	7,291
2021	90,469	90,469	81,757	44,193	8,712
2022	106,059	106,059	95,846	51,808	10,213
2023	122,197	122,197	110,429	59,692	11,768
2024	138,566	138,566	125,222	67,688	13,344
2025	154,851	154,851	139,939	75,643	14,912
2026	170,750	170,750	154,307	83,409	16,443
2027	186,018	186,018	168,104	90,867	17,914

Preferred Sub-alternative 2b: ACL=OY=95% ABC					
Year	**Total ABC (pounds)**	**Total ACL (pounds)**	**Rec ACL (pounds)**	**Rec ACL (number)**	**Commercial ACL (pounds)**
2017	38,367	36,449	32,939	17,805	3,510
2018	49,449	46,977	42,453	22,947	4,524
2019	61,982	58,883	53,212	28,764	5,670
2020	75,710	71,925	64,998	35,134	6,926
2021	90,469	85,946	77,669	41,983	8,277
2022	106,059	100,756	91,053	49,218	9,703
2023	122,197	116,087	104,908	56,707	11,179
2024	138,566	131,638	118,961	64,303	12,677
2025	154,851	147,108	132,942	71,860	14,167
2026	170,750	162,213	146,591	79,239	15,621
2027	186,018	176,717	159,699	86,324	17,018

Sub-alternative 2c: ACL=OY=90% ABC					
Year	**Total ABC (pounds)**	**Total ACL (pounds)**	**Rec ACL (pounds)**	**Rec ACL (number)**	**Commercial ACL (pounds)**
2017	38,367	34,530	31,205	16,868	3,325
2018	49,449	44,504	40,218	21,740	4,286
2019	61,982	55,784	50,412	27,250	5,372
2020	75,710	68,139	61,577	33,285	6,562
2021	90,469	81,422	73,581	39,774	7,841
2022	106,059	95,453	86,261	46,628	9,192
2023	122,197	109,977	99,386	53,722	10,591
2024	138,566	124,709	112,700	60,919	12,010
2025	154,851	139,366	125,945	68,078	13,421
2026	170,750	153,675	138,876	75,068	14,799
2027	186,018	167,416	151,294	81,781	16,122

APPENDIX

YPR Spreadsheet Description

During development of Amendment 37, concern arose when the weight expected to be harvested from the fishery at different size limits was greater than the projected ABC in pounds at the current12-inch size limit. The best option for developing ABC/ACL recommendations for different size limits would be using projections from a stock assessment. However, statutory time constraints do not allow for the time needed to develop code for such projections. While the stock assessment projections are being developed, a Yield per Recruit (YPR) model is provided to determine if overfishing would occur with an increase in the minimum size limit and the ACL specified in numbers of fish. This YPR model is intended to provide insight into potential changes in fishing mortality (F) and yield in pounds when size limits are changed and ACL in numbers is held constant.

The parameters used in this example are based on model parameters used in the SEDAR 37 stock assessment for the FLK/EFL stock of hogfish (Cells C2-C13, C19-C20) (Cooper et al. 2015). The YPR model is based on the Baranov catch equation (Column S), selectivity (Catch: Column K and Retention: Column L), growth (Length: Column G and Weight: Column H), and mortality (Natural: Column R and Fishing: Column U). Typical YPR models are designed to look at the yield for each recruit at different harvest rates assuming selectivity was constant. Because the F that would be solved for in a typical YPR model only includes the exploited population, the model had to be modified to allow for a comparison across different ages of exploited population. In this model we are assuming that the ACL is specified in numbers and we want to calculate the resulting yield in pounds and F rates (Table 1). This is an example of a hypothetical population for harvest rates, numbers of fish, and discards and should not be considered estimates of sustainable harvest; however, the model does simulate some aspects of the FLK/EFL stock of hogfish in that it uses parameters for growth, natural mortality, and selectivity (catch) from that assessment.

First, fishing mortality on the exploited portion of the population was calculated (the portion of the population above the minimum size, exploited F). Exploited F was calculated by minimizing the squared difference between the yield in numbers (Cell S30) and the ACL in numbers (Cell C26). Yield in numbers was calculated using the Baranov catch equation for each age class in the hypothetical population (Column S) under the assumption that exploitable F is constant for all age classes greater than the selected size limit (Column R). For this F rate estimation, the exploitable age classes can change with a change in the minimum size limit (Cell C17). Retention due to the size limit is determined by the retained selectivity (Column L), which assumes knife-edge selectivity. The total yield in pounds to the fishery (Cell C27) was calculated based on the length and weight-at-age in pounds (Column T). The ages from 3+ were included in the model because that was the size of recruitment to the fishery at the current 12 inch size limit based on SEDAR 37 (Cooper et al. 2015).

Next, the fishing mortality on the entire population above the initial 12 inch minimum size also needed to be calculated for each of the new minimum size limits (population F). This population F is the F rate experienced by the portion of the population that could be selected by the fishery if the size limit was not changed. In the estimation of population F, an average natural mortality is needed. The natural mortality is weighted based on numbers-at-age for an unexploited population (Column N) * selectivity at age (Column K) * scaled Lorenzen mortality estimate (Column U). This resulted in a weighted population natural mortality of 0.180 (Cell V29) for the exploitable age classes based on a 12-inch size limit. The resulting abundance of all exploitable age classes at the current 12-inch size limit (Cell O28) and the weighted average M (Cell V29) were used in a second Baranov equation (Cell P30) where population F (Cell C23) was estimated for the population by minimizing the difference between the catch and the ACL.

$$Number\ harvested = PopSize \times \left(\frac{PopF}{PopF + WeigtedM}\right) \times \left(1 - e^{-(PopF + WeightedM)}\right)$$

Where the number harvested (Cell P30) is the value used to calculate the sum of squared difference for minimization, PopSize is the number of fish in the population age 3 and greater (Cell O28), PopF is the population F (Cell C23), and WeightedM is the average natural mortality for the population age 3 and greater weighted by the number of fish at each age (Cell V29). The population F is changed to minimize the squared difference between the number harvested and the ACL. In this calculation, the original Fs were not changed and only the population F was changed to match the harvest. Although the age classes exposed to fishing mortality changed with different size limits in this estimation, the abundance of all the exploitable age classes at the 12-inch minimum size was used to estimate the population F (ages 3+). The same methods were used to estimate the total fishing mortality (total F) for the population (fishing mortality plus discard mortality, Cell C24) except the difference between the summed total killed (Cell Y29) and the estimated killed (Y30) were minimized. The estimated number killed was derived from the Baranov Catch equation. Total F is the equivalent of what is used in assessments to determine if overfishing is occurring in a population (fishing mortality plus discard mortality).

The total killed (Column Y) is the number of fish landed plus the dead discards. The population that was available for discarding (Column Q) was estimated in the same way the exploitable population size at age (Column P) was estimated with the exception of the use of discard selectivity rather than fishery selectivity (Column M). The discard selectivity was simply estimated as 1 – retained selectivity (if it can be selected for by the fishery, but not retained, then it can be discarded). Number of discards (Column W) was estimated using the Baranov catch equation, which included the exploitable F (Cell C22) multiplied by both the fishery selectivity (Column K) and the discard selectivity (Column M) at age. Finally, number of discards is multiplied by the proportion of the fishery that is hook and line (Cell C 20) since the assumption was there would be negligible discards from the dive sector (<2% since 2010). The hook and line discard mortality rate (Cell C19) was then applied to the number of discards to get dead discards (Column X).

The results indicated that the exploited F increases rapidly for the exploited age classes as size limit increases (**Appendix Table 1**). This is due to the lower population abundance available to the fishery when harvest begins. The exploited F rates must go up since the same numbers of fish are assumed to be taken from a smaller portion of the population. In this hypothetical population, the exploited F more than doubled when the minimum size went from 12 inches to 20 inches.

However the population F (F for all ages selected for by the fishery above the current 12-inch minimum size) remains constant and the total F (including discard mortality) barely changes as the minimum size increases (**Appendix Table 1**). The population F remains constant because the same numbers of fish are being landed, regardless of what size they are. For hogfish, the dead discards are relatively low since the bulk of the fishery is prosecuted via diving where the fisherman can avoid interacting with an undersized fish. Although including the dead discards increases the total kills (additional 310 dead fish at a 20 inch size limit), it only increases by a relatively small amount, which does not significantly increase the total F. Including discards had minimal impact for this simulated population, but it is likely that discards from other fisheries that are dominated by hook and line harvest will have a greater effect on the total F.

When a size limit is changed, the expected yield in pounds will differ even though the ACL in numbers was not changed. In the simulated example, the expected yield for an ACL of 10,000 fish increased from 70,298 lbs. for a 12-inch size limit to 107,863 lbs. for a 20-inch size limit. As the size limit increases, the harvest shifts to larger, heavier fish and the yield from these fish naturally increases.

This shift in harvest can have an overall impact on the population differently than modelled by a simple YPR approach. Larger fish often spawn more and have greater fecundity than smaller individuals. When these larger fish are removed from the population, the reproductive capacity of the population could be reduced. These complex interactions need to be modelled through a projection analysis using the stock assessment results.

Appendix Table 1. Results of the YPR simulation showing pounds harvested and F rates at different minimum sizes. Size Lim (in) is the proposed size limit in inches, Num Harvested is the number of fish harvested, Lbs. Harvested is the pounds harvested associated with the numbers of fish harvested at a given size limit, Exploited F is the F rate on the portion of the population that can be harvested under the given size limit, Population F is the overall F rate felt by the population greater than the current 12 inch minimum size under each proposed size limit, and Total F is the F rate that includes the dead discards.

Size Lim (in)	Num Harvested	Lbs Harvested	Exploited F	Population F	Total F
12	10,000	70,298	0.08	0.08	0.08
14	10,000	80,457	0.10	0.08	0.08
16	10,000	90,133	0.13	0.08	0.08
18	10,000	99,293	0.16	0.08	0.08
20	10,000	107,863	0.21	0.08	0.09