Methods for Recreational Decision Tools

Modeling the Combined Effects of Snapper-Grouper Amendment 37 Proposed Management Measures for Recreationally-Caught Hogfish

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Introduction

The Florida Fish and Wildlife Conservation Commission (FWC) completed a benchmark stock assessment for hogfish in 2014 (SEDAR-37 2014). The South Atlantic Fishery Management Council (Council)'s Scientific and Statistical Committee (SSC) reviewed the assessment and provided fishing level recommendations in October 2014. The Council received the SSC's recommendations at their December 2014 meeting. Based on genetic evidence, the SSC supported treating hogfish in the South Atlantic as two stocks: Georgia-North Carolina (GA-NC) and Florida Keys/East Florida (FLK/EFL). Each stock was then evaluated with regard to fishing level recommendations. The SSC developed catch level recommendations for the GA-NC stock using the Only Reliable Catch Stocks (ORCS) approach, as outlined in Level 4 of the Council's acceptable biological catch (ABC) control rule. For the FLK/EFL stock, the SSC considered the benchmark assessment to represent the best available science and recommended it for use in management. The Southeast Fisheries Science Center (SEFSC) concurred with this determination. The assessment results indicated the FLK/EFL stock is undergoing overfishing, is overfished and, therefore, is in need of a rebuilding plan.

In response to the outcome of the SEDAR-37 (2014) assessment, the Council began development of Amendment 37 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region (SG-37). SG-37 proposes different ABCs, annual catch limits (ACLs), annual catch targets, seasonal closures, minimum size limits (MSL), and bag limits for the FLK/EFL and GA-NC hogfish stocks. This report presents the development of recreational decision tools (RDTs) to simulate the impacts of various combinations of proposed management measures to support SG-37 (Figure 1).

Current Management Regulations

The following regulations currently apply to South Atlantic hogfish recreational fishing:

1) 12-inch fork length MSL (South Atlantic Federal waters, State waters off Florida and South Carolina)
2) 5-fish per harvester daily bag limit (South Atlantic Federal waters, State waters off Florida)

SNAPPER-GROUPER AMENDMENT 37: RECREATIONAL HOGFISH

RECREATIONAL DECISION TOOL for EAST FLORIDA / FLORIDA KEYS STOCK

Baseline landings based on average of 2012-2015

MODEL INPUTS:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1. Select seasonal closure:	31	29	31	30	31	30	31	31	30	31	30	31	<- max days to close
Select number of days each month will be closed:	31	29	31	30	31	30	0	0	0	31	30	31	<- days closed
Percent of month closed:	100%	100%	100%	100%	100%	100%	0%	0%	0%	100%	100%	100%	<- pct of month closed

2. Select effort shift scalar: 0% effort shift — *How much will catch rates increase in months surrounding seasonal closure, reflecting possible effort shifting?*

3. Select minimum size limit: 16" FL (inches) — *Current recreational minimum size limit is 12" Fork Length (FL)*

4. Select bag limit or vessel limit: 1 fish / angler on the vessel — *Current recreational bag limit is 5 fish per angler on the vessel.*

ACL ALTERNATIVE 2a:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Projected Recreational Landings (N):	0	0	0	0	0	0	4,008	4,007	970	0	0	0	
Projected Recreational Dead Discards (N @ ρ=10%):	762	712	968	966	563	545	408	408	140	172	251	260	
Projected Recreational Removals (N):	762	712	968	966	563	545	4,416	4,415	1,110	172	251	260	Assumes 10% release mortality rate for hook and line, perfect compliance for spear trips (73% of all landings).

ACL ALTERNATIVE 2b:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Projected Recreational Landings (N):	0	0	0	0	0	0	4,008	4,007	970	0	0	0	
Projected Recreational Dead Discards (N @ ρ=10%):	762	712	968	966	563	545	408	408	140	172	251	260	
Projected Recreational Removals (N):	762	712	968	966	563	545	4,416	4,415	1,110	172	251	260	Assumes 10% release mortality rate for hook and line, perfect compliance for spear trips (73% of all landings).

ACL ALTERNATIVE 2c:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Projected Recreational Landings (N):	0	0	0	0	0	0	4,008	4,007	970	0	0	0	
Projected Recreational Dead Discards (N @ ρ=10%):	762	712	968	966	563	545	408	408	140	172	251	260	
Projected Recreational Removals (N):	762	712	968	966	563	545	4,416	4,415	1,110	172	251	260	Assumes 10% release mortality rate for hook and line, perfect compliance for spear trips (73% of all landings).

PROJECTION RESULTS:

LANDINGS

	Alt 2a	Alt 2b	Alt 2c	
Recreational ACL (LBS):	34,672	32,939	31,205	FIXED ACL, DOES NOT ADJUST TO DIFFERENT SIZE LIMITS, BASED ON SAFMC STAFF
Recreational ACL (N):	16,514	15,688	14,863	PROPOSED OFL, ABC, AND ACL IN NUMBERS APPROACH FROM SAFMC STAFF PRESENTATION 3/4/2016 TO SAFMC-SSC
Total Projected Recreational Landings (N):	8,985	8,985	8,985	
%ACL Landed:	54%	57%	60%	
	0%	0%		<--Select ACT buffer [feature disabled]

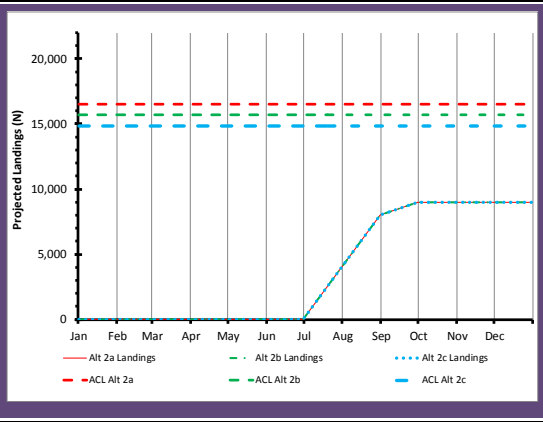
REMOVALS

	Alt 2a	Alt 2b	Alt 2c
Total Projected Recreational Removals (N):	15,141	15,141	15,141

QUOTA CLOSURE

	Alt 2a	Alt 2b	Alt 2c
Projected Closure Date:	N/A	N/A	N/A
Open Days in Season:	92	92	92

Note: This model does not account for effort shifting that may take place during a seasonal closure, nor does it consider any changes in the average size of hogfish during rebuilding. Thus, management reductions presented in these tables may be overestimates, and caution should be taken in their interpretation and use.



ECONOMIC EFFECTS PROJECTIONS:

ACL Alt 2a

CHANGE FROM STATUS QUO CONSUMER SURPLUS (2014 $) - Full Recreational Fishery

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
-$159,771	-$149,430	-$357,406	-$309,745	-$67,404	-$65,239	-$132,421	-$132,433	-$20,015	-$33,077	-$18,691	-$19,310	-$1,464,942

ACL Alt 2b

CHANGE FROM STATUS QUO CONSUMER SURPLUS (2014 $) - Full Recreational Fishery

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
-$159,771	-$149,430	-$357,406	-$309,745	-$67,404	-$65,239	-$132,421	-$132,433	-$20,015	-$33,077	-$18,691	-$19,310	-$1,464,942

ACL Alt 2c

CHANGE FROM STATUS QUO CONSUMER SURPLUS (2014 $) - Full Recreational Fishery

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
-$159,771	-$149,430	-$357,406	-$309,745	-$67,404	-$65,239	-$132,421	-$132,433	-$20,015	-$33,077	-$18,691	-$19,310	-$1,464,942

Note 1: This model implicitly assumes that hogfish will be landed in addition to other species on a trip and that the proposed action will have no effect on the number of recreational trips that would be expected to occur under the status quo.
Note 2: Estimated landings are rounded to the nearest whole fish and all landed fish are assigned the same value regardless of size.
Note 3: For a breakdown by mode, see Economics tab (link below).

ADDITIONAL DETAILS AVAILABLE ON THE ECONOMICS TAB

Figure 1A. Screenshot of FLK/EFL hogfish recreational decision tool, showing dropdown menus for user-specified management measures.

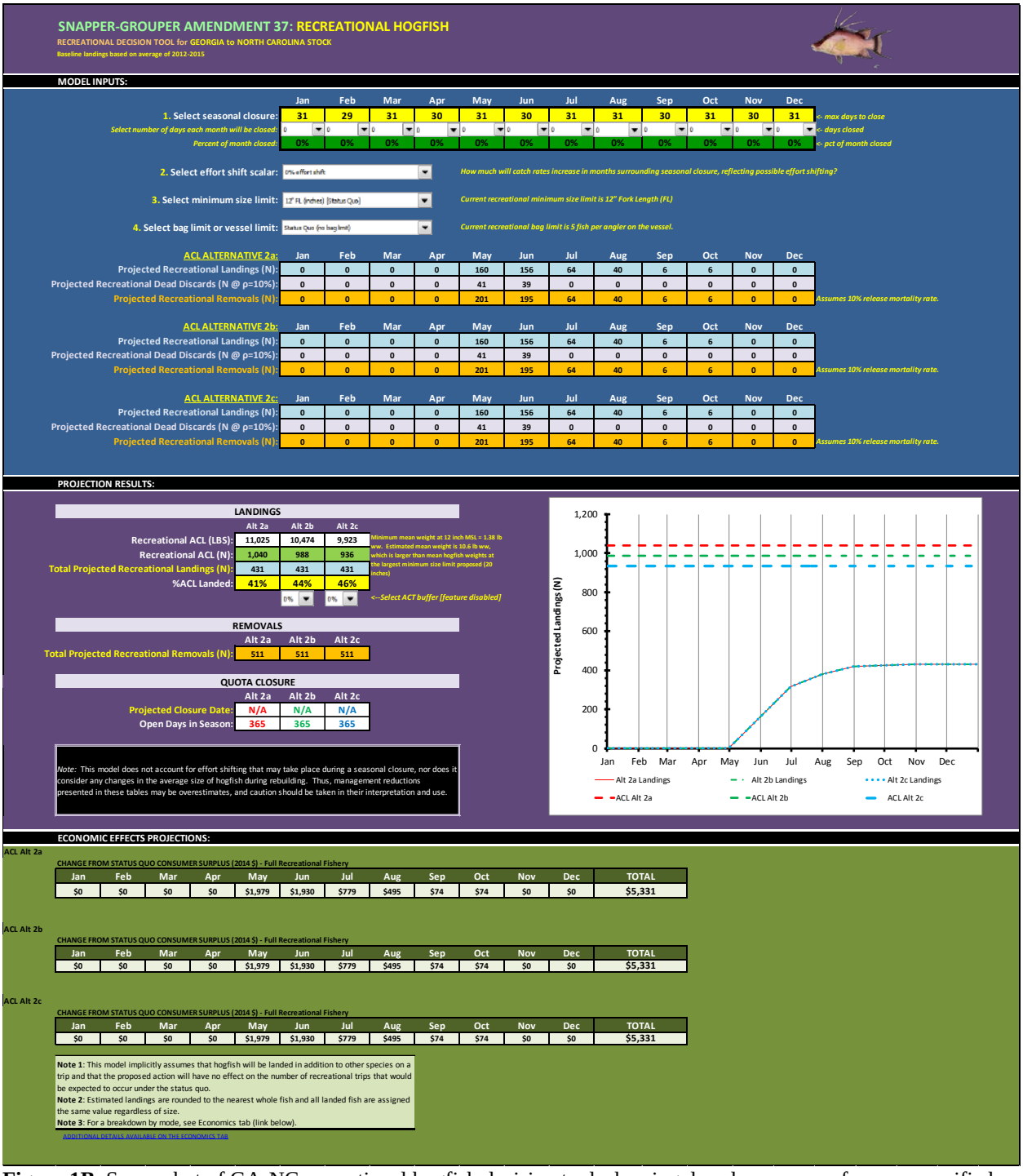


Figure 1B. Screenshot of GA-NC recreational hogfish decision tool, showing dropdown menus for user-specified management measures.

Methods

The RDTs for FLK/EFL (Figure 1A) and GA-NC (Figure 1B) hogfish were implemented in Microsoft Excel using drop-down menus to obtain user inputs regarding desired management measures. Excel was chosen because it is widely available for constituent use. Impacts of management measures were simulated using programs written in SAS (SAS Institute, Cary, NC). The RDTs evaluated seasonal closures, size limits, and bag limits.

Data Sources

Recreational landings data for hogfish are typically obtained from the SEFSC's ACL Dataset, which provides aggregated landings data from the Marine Recreational Information Program (MRIP) and the SEFSC's Southeast Region Headboat Survey (SRHS). The ACL dataset provides improved quality assurance and quality control on the raw data generated by the MRIP and SRHS. The ACL dataset uses MRIP weight estimates when available. In some cases, MRIP provides an estimate of numbers landed but no weight estimate, due to missing weights in the intercept data. In these cases, the SEFSC uses weight substitutions based on a minimum of 30 samples to provide a weight estimate in the ACL data. MRIP intercepts collect data on port agent observed landings ('A' catch) and angler reported landings ('B1' catch) and discards ('B2' catch) in numbers by species, two-month 'wave' (e.g., Wave 1 = Jan/Feb, …, Wave 6 = Nov/Dec), area fished (inland, state, and federal waters), mode of fishing (charter, private/rental, shore), and state (Florida, North Carolina, South Carolina, and Georgia). SRHS landings are generated after the end of each calendar year, at which time they are included in the ACL dataset. SRHS landings in weight are calculated using a combination of logbook reports and dockside sampling, and adjustments to landings are made based on underreporting and misreporting determined through dockside validation by port agents. SRHS records contain trip-level information on number of anglers, trip duration, date, area fished, landings (number of fish) and releases (number fish) by species.

Because SEDAR-37 (2014) identified three hogfish stocks (FLK/EFL, GA-NC, and Gulf of Mexico), and SG-37 includes separate actions for managing the FLK/EFL GA-NC stock in the Council's jurisdiction, the underlying data required a modified ACL dataset. Working with SEFSC, an approach was developed that was mostly consistent with how the SEFSC assigns weights for ACL monitoring but with minor modifications for hogfish due to the stock definitions emerging from SEDAR-37 (2014). The SEFSC typically assigns average weights to headboat and MRIP data based on a minimum sample size of 30 using the following hierarchy:

sub-region, year, state, mode of fishing, wave, area of fishing (i.e., inshore vs. offshore)

The SESFC code was used for weight estimation coupled with the raw MRIP data; however, GA-NC was considered to be a separate sub-region. The Monroe County area was assigned to the FLK/EFL sub-region prior to running weight estimation so that regional average weight draws for Florida would not pull from the Gulf of Mexico sub-region for the Monroe County sub-region. Numbers of fish were expanded appropriately using MRIP-developed site weights.

Because low sample sizes often led to aggregation at the species-region level, eliminating all temporal variability, another level of hierarchy (*decade*) was added:

sub-region, decade, year, state, mode of fishing, wave, area of fishing (i.e., inshore vs. offshore)

The program was recoded to specify minimum sample size thresholds of n=10 for GA-NC and n=30 for FLK/EFL. Due to low sub-region sample sizes, the minimum sample size for GA-NC was set at the highest value that would still capture decadal trends in average weight. An output file of hogfish landings and discards in numbers and pounds was generated, by mode and wave, and included headboat data from the SEFSC Recreational ACL Database (accessed Nov 2015). This file included information from Wave 1, 1986 to Wave 3, 2015.

Due to a lack of clear interannual trends and high interannual variability, mean landings from the most recent four fishing years (2012-2015) were used to project 2017 landings; however, there is high uncertainty in projected landings, especially for Waves 1-2 off FLK/EFL and Wave 3 off GA-NC (note error bars in Figure 2). Dead discards were assumed to be 10 percent of the total discards under the release mortality rate for hook-and-line used in SEDAR-37 (2014). Data from 2015 were included, when available, because high landings in early 2015 resulted in an early recreational closure and led the Council to request revised projections from FWC.

The SEFSC reviewed the code and associated output, and agreed with the approach to assigning average weights to hogfish for SG-37. The possible misidentification of some hogfish as 'pigfish' in North Carolina was discussed. The SEFSC recommended not making any changes to the MRIP size file to handle this potential issue; they indicated National Marine Fisheries Service (NMFS) Office of Science and Technology (OS&T) would need to recommend these modifications. NMFS OS&T subsequently evaluated these issues and sent a letter to the Council indicating they did not feel any changes were conclusively supported. Additionally, the SEDAR-37 (2014) assessment did not make any modifications for this potential misidentification.

Landings, biological data (size of catch), and catch-effort information from the MRIP and SRHS surveys were used to evaluate reductions in landings and discards (when available) associated with various proposed hogfish closed seasons, bag limits, and size limits. Following approaches used in the most recent stock assessment, MRIP data from Monroe County were post-stratified and removed from west Florida landing and discard estimates. Due to a lack of more temporally-resolved landings data, landings were assumed uniformly distributed across days within waves for MRIP and days within months for headboat.

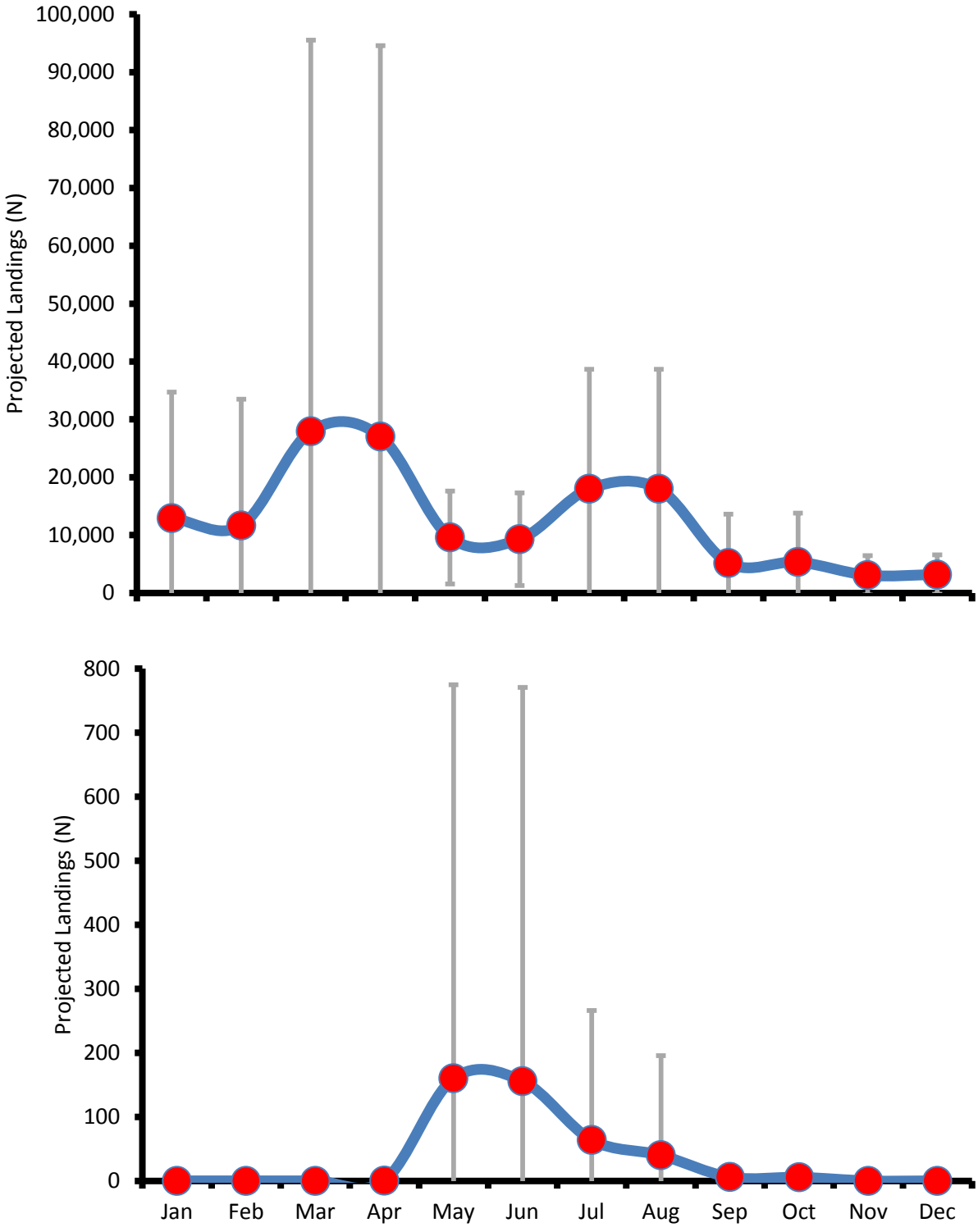


Figure 2. South Atlantic recreational hogfish mean landings 2012-2015 for FLK/EFL (top) and GA-NC (bottom), with error bars denoting 95% confidence intervals.

Table 1. Projected 2017 baseline monthly recreational landings and discards in numbers of fish for A) FLK/EFL and B) GA-NC hogfish under status quo management measures with no seasonal or quota closures. Assumes MRIP landings uniformly distributed within waves. Projection based on mean 2012-2015 observed landings.

A) FLK/EFL

LANDINGS	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
SRHS	29	23	25	16	13	16	10	7	5	6	9	19
MRIP CHARTER	283	256	108	104	354	343	16	16	174	180	324	335
MRIP PRIVATE	12,604	11,384	27,813	26,916	9,228	8,930	17,961	17,961	4,994	5,161	2,743	2,835
	12,915	**11,663**	**27,946**	**27,036**	**9,595**	**9,289**	**17,988**	**17,984**	**5,173**	**5,346**	**3,077**	**3,188**

DISCARDS	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
SRHS	21	17	54	34	5	6	0	0	2	3	6	12
MRIP CHARTER	211	191	234	227	134	130	0	0	84	87	206	213
MRIP PRIVATE	3,846	3,473	2,056	1,989	2,861	2,769	249	249	164	169	1,458	1,506
	4,078	**3,682**	**2,344**	**2,250**	**3,001**	**2,905**	**249**	**249**	**250**	**259**	**1,670**	**1,731**

B) GA-NC

LANDINGS	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
SRHS	0	0	0	0	1	2	24	1	2	2	0	0
MRIP CHARTER	0	0	0	0	7	7	7	7	4	4	0	0
MRIP PRIVATE	0	0	0	0	152	147	32	32	0	0	0	0
	0	**0**	**0**	**0**	**160**	**156**	**64**	**40**	**6**	**6**	**0**	**0**

DISCARDS	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
SRHS	21	17	54	34	5	6	0	0	2	3	6	12
MRIP CHARTER	0	0	0	0	0	0	0	0	0	0	0	0
MRIP PRIVATE	0	0	0	0	406	393	0	0	0	0	0	0
	0	**0**	**0**	**0**	**406**	**393**	**0**	**0**	**0**	**0**	**0**	**0**

Seasonal Closures

Landings of hogfish are highly seasonal; thus, reductions associated with seasonal closures differ greatly depending upon the time period selected for closure (Figure 2). To model the effects of a seasonal closure, users of the RDT models can specify the number of days closed for each month. These choices were converted to a percentage of days closed for a given month. The projected landings during that month under the other user-specified management measures were then reduced by the percentage of the month that was closed. Landings were assumed uniformly distributed within months. Because seasonal closures might result in effort shifting, the effects of increased catch rates in open months were evaluated with a user-defined effort shift scalar ranging from 0 percent to 100 percent. Because catch rates were expressed as daily catch rates rather than catch per unit effort, the effort shift scalars were designed to redistribute days as a proxy for increased effort before and after closures. This approach allowed the model to compensate for lost fishing days due to seasonal closures while preserving differences in daily catch rates between months. When effort shifting was selected by the user, projected catch rates and discards during open months under the user-selected management measures were scaled to compensate for lost fishing days:

$$L_{mode,m} = \left(BL_{mode,m} * O_m\right) * \left(1 + \sigma_m * \begin{cases} if < 100\%\ closed: \left[\left(\frac{\sum_{d=Jan\ 1}^{Dec\ 31}[d=closed]}{\sum_{d=Jan\ 1}^{Dec\ 31}[d]}\right) * \left(1 + \frac{\sum_{m=Jan}^{Dec}[O_m=0\%]}{\sum_{m=Jan}^{Dec}[O_m>0\%]}\right)\right] \\ if\ 100\%\ closed: 0 \end{cases}\right) \quad (1)$$

where $L_{mode,m}$: projected landings after accounting for change in open season, $BL_{mode,m:}$ projected landings by mode and month, d: day of the month, O_m: percent of month open to fishing, and σ_m: effort shift scalar for open month m.

Size Limits

Length measurements collected during biological sampling associated with SRHS and MRIP were converted to inches fork length using standard conversion factors and equations summarized in SEDAR-37 (2014). Data from the three most recent available years were used from SRHS catch-effort files (2011-2013) and SEFSC-prepared MRIP catch-effort files (2012-2014). The mean and standard deviation for reductions in harvest under simulated size limits across the three most recent years were computed by simulating the removal of undersized fish at different size limits, recomputing landings, and comparing those recomputed landings to the baseline.

The impacts of proposed MSL were simulated by multiplying projected landings by the simulated scalar reduction in harvest under different proposed MSL. Because the ACL for hogfish will be specified in numbers of fish, scalar multipliers were calculated in numbers of fish for each mode of fishing (charter, headboat, and private/rental) for MSL at 1-inch intervals between 12-20 inches as follows:

$$\varsigma_{mode,m} = (G + B)/C, \quad (2)$$

where $\varsigma_{mode,m}$: MSL impact scalar, *C*: catch in number of fish at the current MSL, *G*: number of fish that are greater than or equal to the proposed MSL, and *B*: number of fish smaller than the current MSL (non-compliance or measurement error).

$$L_{mode,m} = BL_{mode,m} * \varsigma_{mode,m}, \quad (3)$$

where $L_{mode,m}$: projected landings after accounting for change in bag limit, $BL_{mode,m:}$ projected landings by mode and month, and $\varsigma_{mode,m}$: size limit scalar impact.

Under equation (3) above, the scalar for the recreational status quo of 12 inches would be 100 percent. Data were pooled across waves when necessary to avoid sample sizes lower than 30 fish. Figure 3 presents available information, by sub-region, regarding fork lengths of sampled fish. Figure 3 helps clarify why the size limit impacts in Table 3 are greater for the FLK/EFL sub-region. The size limit approach assumes a level of illegal harvest consistent with historical observations.

Bag Limits

The impacts of proposed bag limits were simulated by multiplying projected landings by the simulated scalar reduction in harvest under different proposed bag limits. Data from the three most recent available years were used from SRHS catch-effort files (2011-2013) and SEFSC-prepared MRIP catch-effort files (2012-2014). The mean and standard deviation for reductions in harvest under simulated bag limits across the three most recent years were computed by simulating the removal of undersized fish at different bag limits, recomputing landings, and comparing those recomputed landings to the baseline.

Because the ACL for hogfish will be specified in numbers of fish, scalar multipliers were calculated in numbers of fish for each mode of fishing (charter, headboat, and private/rental) for bag limits ranging from 1 fish per vessel to 5 fish per angler (status quo). Bag limit impacts were modeled by modifying trip records when catch-per-angler on the trip exceeded a given bag limit. For example, if catch per angler on a trip was 3 fish/angler and the bag limit being simulated was 1 fish/angler, the catch per trip was adjusted to reflect a 1 fish/angler catch rate. The total landings in numbers of fish were summarized by bag limit alternative, year, and mode of fishing:

$$\beta_{mode,m} = (C - E - I)/C, \quad (4)$$

where $\beta_{mode,m}$: bag limit impact by mode and month, *C*: catch in number of fish at the current bag limit, *E*: number of fish on trip that exceed the proposed bag limit, *I*: number of fish above the current bag limit (non-compliance or measurement error)

$$L_{mode,m} = BL_{mode,m} * \beta_{mode,m}, \quad (5)$$

where $L_{mode,m}$: projected landings after accounting for change in bag limit, $BL_{mode,m}$: projected landings by mode and month, $\beta_{mode,m}$: bag limit scalar impact.

The average ratio of bag limit modified landings to reported landings across the most recent three years was used as the bag limit scalar ($\beta_{mode,m}$), by mode. Data were pooled across waves when necessary to avoid sample sizes lower than 30 fish. Table 4 shows projected bag limit reductions for hogfish, by region and mode of fishing. The size limit approach assumes a level of illegal harvest consistent with historical observations.

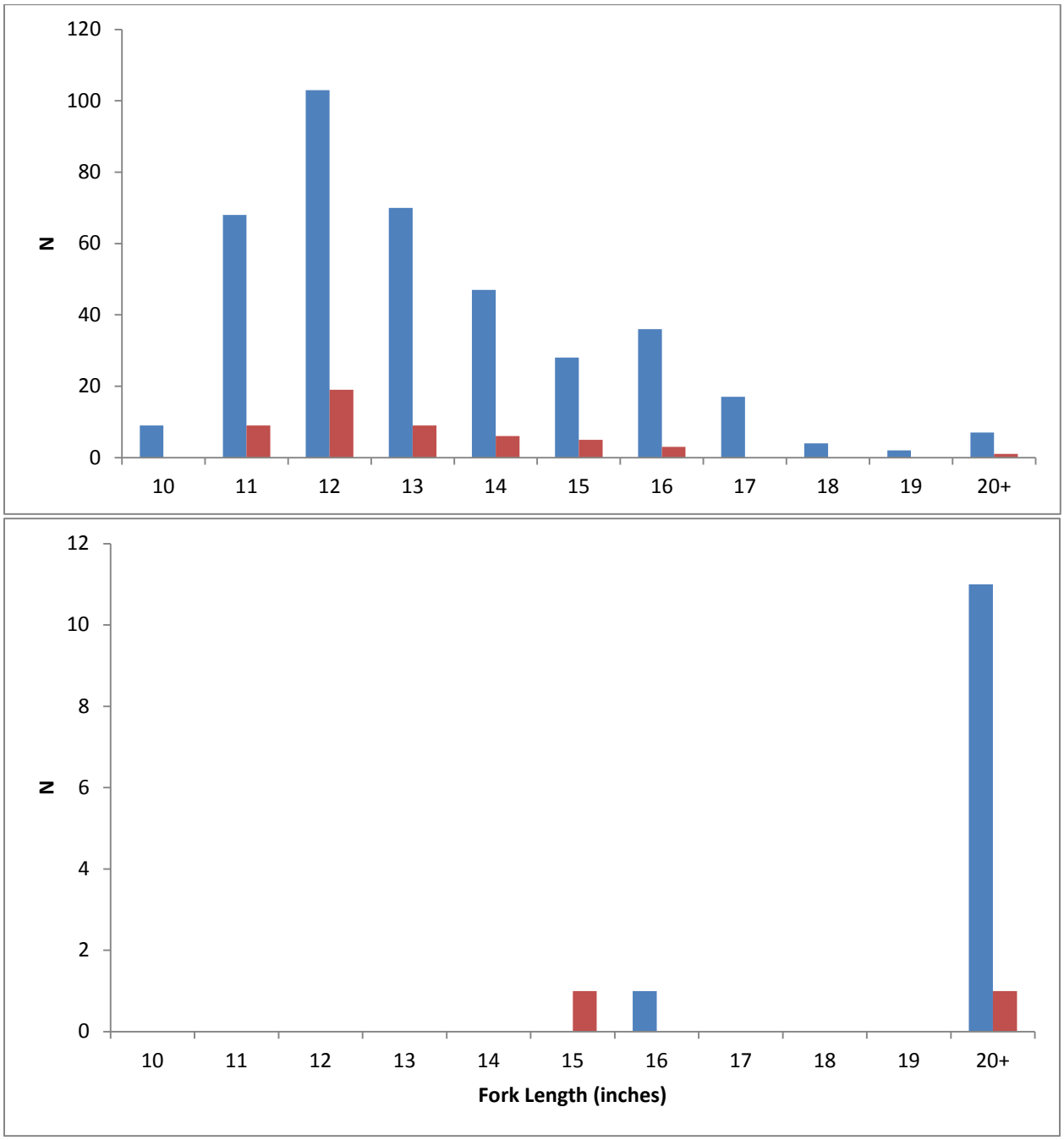


Figure 3. Fork lengths of landed hogfish reported by SRHS (2011-2013; red) and MRIP (2012-2014; blue) for FLK/EFL (top) and GA-NC (bottom) stocks of hogfish.

Combined Effects of User-Defined Management Measures

For both RDT models, if month (*m*) was 100 percent closed, landings were set to zero fish for all modes. If a month was partially or fully open, the projected landings (L) were computed as follows:

$$L_{mode,m} = \left(BL_{mode,m} * O_m * \varsigma_{mode,m} * \beta_{mode,m}\right) * \left(1 + \sigma_m * \begin{cases} if < 100\%\ closed: \left[\left(\frac{\sum_{d=Jan\ 1}^{Dec\ 31}[d = closed]}{\sum_{d=Jan\ 1}^{Dec\ 31}[d]}\right) * \left(1 + \frac{\sum_{m=Jan}^{Dec}[O_m = 0\%]}{\sum_{m=Jan}^{Dec}[O_m > 0\%]}\right)\right] \\ if\ 100\%\ closed: 0 \end{cases}\right)$$

Projected discards were computed as baseline discards plus the difference between projected landings (L) and baseline landings (BL). Projected increased landings and discards due to effort shifting also accounted for changes in management measures. The new management discards resulting from new management measures were assumed to be distributed across spear and hook-and-line gear types based on observations from SEDAR-37 (2014). In the FLK/EFL sub-region, recreational landings were 73 percent spear from 2010-2012 (SEDAR-37 2014, Tables 7.2.2.1, 7.2.3.5, and 7.2.3.6). Spear trips were assumed to only select legal fish; thus, only 27 percent of new management discards (i.e., those originating from hook-and-line trips) were added to baseline discards to compute total discards. Per SEDAR-37 (2014), approximately 4 percent of total discards are attributable to spear gear, despite this gear comprising a much larger proportion of the overall landings. Although anecdotal information suggests a high proportion of the GA-NC sub-region landings come from spear trips, they are infrequently sampled by MRIP (SEDAR-37 2014, Table 7.2.3.1). From 2010-2012, no spear trips from the GA-NC sub-region were intercepted; thus, 100 percent of new management discards from the GA-NC sub-region were added to baseline discards to compute projected discards. For both sub-regions, projected discards from hook-and-line were multiplied by a 10 percent release mortality rate to convert to dead discards, consistent with the SEDAR-37 (2014) release mortality rate for hook-and-line gear. Projected dead discards were added to projected landings to determine total removals.

For both decision tools, the projected monthly landings were summed across the year for a variety of user-defined management scenarios and compared to the SG-37 ACL alternatives. In instances where the management measures were insufficient to constrain harvest below the ACL, the projected quota closure date was computed along with the total landings at the time of closure. Uncertainty in mean projected closure dates and projected landings were determined across 1000 bootstrapped runs of each user-selected model configuration. Bootstrapping runs accounted for uncertainty in projections data by averaging across 2012-2015 landings generated from random draws from a normal distribution fit to mean and standard deviation from landings survey data from the modified hogfish landings dataset discussed previously. Bootstrapping also accounted for uncertainty in size limit and bag limit reductions using random draws for these reductions drawn from normal distributions fit to the mean and standard deviation of the most recent three years of simulated size and bag limit reductions.

For the FLK/EFL sub-region, ABC recommendations in numbers of fish and pounds were provided by the SEDAR-37 (2014) stock assessment under status quo management measures at $P_{rebuild}$=72.5 percent over 10 years. Under different size limits, bag limits, and season openings, selectivity and retention functions in the stock assessment might change, leading to different ABC recommendations. The most appropriate method to address the feedback between selected

management measures and ABC recommendations would be to run updated stock assessment projections using the new management measures; however, this would require modifications to the SEDAR-37 (2014) stock assessment program that will not be completed in time. In response to a concern by SERO staff that an ABC in pounds might be exceeded under increasing MSLs without corresponding reductions in the ACL in numbers, Council staff proposed a method to set the ABC and total ACL in numbers of fish. Council staff also developed a modified yield per recruit (YPR) model to investigate the effects of changes in the MSL on fishing mortality rate (*F*). The modified YPR analysis indicated that the fishery could continue to harvest the same number of fish up to the 20-inch proposed MSL alternative with little to no effect on the overall value of *F*. After substantial discussion and a review of yield-per-recruit analyses performed by SAFMC staff, the SAFMC's Scientific and Statistical Committee recommended use of the Council staff's proposed ACL time series that would not change under different MSLs (SAFMC 2016). In this time series, the ACL at 100 percent of the ABC for 2017 is 16,514 fish. The RDT manages towards SG-37 ACL Alternatives 2a-2c (i.e., 100 percent, 95 percent, and 90 percent of the ABC).

For the GA-NC sub-region, the ABC recommendation in pounds is based on the SSC's ORCS approach, with a catch statistic of 40,818 pounds whole weight from 2006 (maximum catch 1999-2007), a risk of overexploitation of 1.25, and a risk tolerance of 0.7. The resultant ABC recommendation of 35,716 pounds whole weight is allocated 30.9 percent to the recreational sector. The recreational ABC allocation of 11,025 pounds whole weight is converted to 1,040 fish, based on the 2012-2015 mean weight of 10.60 pounds whole weight. Because the observed mean weight of landed fish off GA-NC is much larger than the mean weight of a fish at a 20-inch size (5.61 lb), no adjustments to the GA-NC recreational ACL were explored; the ACL for the sub-region was fixed at 1,040 fish.

Economic Effects

Dynamic short-term economic effects projections are built into the RDT. Estimates are displayed in 2014 dollars. Baseline economic values for recreational hogfish in each sub-region, FLK/EFL and GA-NC, were simulated using projected daily catch rates for each sub-region, absent any changes to existing hogfish management measures. Prior to the implementation of SG-37, hogfish was managed as a single stock from east Florida to North Carolina, excluding MRIP landings from Monroe County, with an ACL of 85,355 pounds whole weight in MRIP-based units. To determine what the baseline landings would be if no actions were taken in SG-37, landings were projected in pounds whole weight from east Florida to North Carolina based on mean 2012-2015 landings from the SEFSC Recreational ACL Database (accessed September 2015). The projected overage date in the Council jurisdiction was determined as April 26. The baseline for economic comparisons in the FLK/EFL model included projected landings (in numbers) from east Florida from January 1 – April 26. Landings from Monroe County for the entire year were also included in the economic comparison baseline; in the absence of SG-37, fishers in Monroe County would not be anticipated to hit a quota closure if Monroe County hogfish remained as part of the western Gulf of Mexico quota. For the GA-NC RDT, the baseline for economic comparisons included landings from GA-NC (in numbers) from January 1 – April 26.

For the recreational sector, short-term economic effects are estimated as changes in consumer surplus (CS); an estimate of the value received by recreational anglers from catching and keeping hogfish. To calculate CS, the projected landings (number of fish) for each month were multiplied by the willingness to pay for an additional 'snapper' ($12.37) from Haab et al. (2012), the best proxy for willingness to pay for hogfish[1]. The RDT displays the total change in CS relative to the status quo under any combination of ACL, MSL, bag limit, and season closure alternatives. The RDT does not assign any value to hogfish that are caught and released, so although changes in discard rates may have long-term positive or negative economic effects in terms of future yields, these are not captured in the CS estimates provided by the RDT. Such long-term economic effects should, however, be considered in the regulatory analysis for SG-37.

Results

Seasonal Closures

Closures during time periods of highest landings will provide the most efficient reductions in harvest. Table 1 shows hogfish landings by month. For the FLK/EFL region, the highest landings occur in Mar-Apr followed by July-Aug. For the GA-NC region, the highest landings occur in May-June with very few landings outside those months.

Minimum Size Limits

MSLs, especially at 15 inches fork length and above, appear to be an effective means of constraining harvest off FLK/EFL (Table 2a). MSLs in the FLK/EFL region appear to be effective across all modes. MSLs off GA-NC appear to be ineffective, especially for private mode; however, their impacts are somewhat uncertain due to limited data (Table 2b). Figure 2 indicates most fish off the GA-NC sub-region are greater than 20 inches fork length. An MSL of 17 inches fork length or greater off the GA-NC sub-region would provide some reductions in for-hire harvest.

Bag Limits

In both sub-regions, a 1-fish per-vessel per-day bag limit is anticipated to result in extreme cuts to harvest across all modes (Table 3). Due to their high passenger capacity, bag limits that constrain catch per angler are relatively ineffective for headboats (Table 3). Off FLK/EFL, bag limits of 2 fish and 1 fish per angler appear relatively effective for constraining harvest (Table 3a). Off GA-NC, bag limits had no impact on harvest with the exception of 1-fish per-vessel limits (Table 3b).

[1] All kept hogfish are assigned the same value, regardless of their size. In reality, anglers may receive higher value from larger fish, though this cannot be estimated with available data.

Combined Effects

Table 4a presents estimates of closure date, season length, landings, removals, and change in consumer surplus for a variety of proposed combinations of management measures for the FLK/EFL stock. Not surprisingly, uncertainty in closure date and landings was higher under scenarios with long recreational fishing seasons, allowing more days with uncertain catch rates to accumulate. Substantial economic losses are anticipated relative to the baseline under all scenarios because the proposed ACL alternatives in this sub-region are much lower than projected baseline landings in this sub-region, and charter and private anglers in the Monroe County area would no longer be aggregated into the Gulf of Mexico, which has a stock ACL and no history of quota closures. Under the Council's preferred ACL, Alternative 2b, and preferred MSL alternative of 16 inches fork length, with a 1-fish per-person per-day bag limit, and a July 1 – Sept 30 fishing season, the season would be 92 days, with no quota closure predicted. With a May 1 opening, a 16-inch MSL and a 1-fish-per-person bag limit, a quota closure is anticipated after 245 open days, on December 5, with a standard deviation of around 20 days (i.e., 95 percent confidence limit range: October 27 – No Closure). Effort shifting would result in increased landings and discards within the open season and associated economic gains. Figure 4 shows the impacts of effort shifting on landings, discards, and change in consumer surplus for the Council's current preferred alternatives. Effort shifting can lead to substantial increases in catch during the open season and may result in early quota closures and lost potential revenue. Increasing the size limit or reducing the bag limit are anticipated to greatly reduce total removals in the FLK/EFL region due to the ability of spearfishers to select legal fish and avoid discards.

Table 4b presents estimates of closure date, season length, landings, removals, and change in consumer surplus for a variety of proposed combinations of management measures for the GA-NC stock. No closures to prevent an ACL overage are anticipated for any combination of management alternatives for the GA-NC component of the stock. Due to the lack of closures, uncertainty in projected landings and reductions from various management measures did not impact estimates of season length or landings.

Table 2. Projected reductions of headboat and MRIP hogfish landings off (A) FLK/EFL and (B) GA-NC, in numbers, by month, for various minimum size limits. Note: data have been pooled to achieve a minimum sample size of 30 fish per estimate.

A) FLK/EFL

	HB (NUMBERS; 2011-2013)											
FORK LENGTH	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	43%	43%	43%	43%	43%	43%	43%	43%	43%	43%	43%	43%
14	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%	59%
15	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%
16	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
17	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%
18	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%
19	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%
20	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%
	CHARTER (NUMBERS; 2012-2014)											
FORK LENGTH	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	18%	18%	18%	18%	18%	18%	18%	18%	18%	18%	9%	9%
14	39%	39%	39%	39%	39%	39%	39%	39%	39%	39%	33%	33%
15	79%	79%	79%	79%	79%	79%	79%	79%	79%	79%	70%	70%
16	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	76%	76%
17	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
18	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
19	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
20	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%

	PRIVATE (NUMBERS; 2012-2014)											
FORK LENGTH	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	34%	34%	35%	35%	15%	15%	31%	31%	43%	43%	35%	35%
14	54%	54%	50%	50%	30%	30%	53%	53%	54%	54%	56%	56%
15	63%	63%	61%	61%	71%	71%	54%	54%	60%	60%	63%	63%
16	75%	75%	70%	70%	73%	73%	59%	59%	63%	63%	71%	71%
17	82%	82%	81%	81%	84%	84%	69%	69%	77%	77%	80%	80%
18	86%	86%	84%	84%	90%	90%	87%	87%	79%	79%	84%	84%
19	89%	89%	86%	86%	90%	90%	90%	90%	81%	81%	85%	85%
20	89%	89%	88%	88%	90%	90%	90%	90%	83%	83%	85%	85%

B) GA-NC

	HB (NUMBERS; 2011-2013)											
FORK LENGTH	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
15	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
16	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%
17	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%
18	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%
19	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%
20	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%
	CHARTER (NUMBERS; 2012-2014)											
FORK LENGTH	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
15	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
16	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
17	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
18	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
19	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
20	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%

	PRIVATE (NUMBERS; 2012-2014)											
FORK LENGTH	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
15	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
16	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
17	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
18	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 3. Projected reductions of headboat and MRIP hogfish landings off (A) FLK/EFL and (B) GA-NC, in numbers, by month, for various bag limits. Note data have been pooled to achieve a minimum sample size of 30 fish per estimate.

A) FLK/EFL

Headboat (2012-2014), Numbers												
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1 Fish/Vessel	32%	21%	18%	17%	22%	35%	64%	68%	27%	27%	26%	29%

MRIP Charter (2012-2014) Numbers												
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3 Fish/Angler	5%	5%	5%	5%	4%	4%	5%	5%	0%	0%	0%	0%
2 Fish/Angler	16%	16%	15%	15%	11%	11%	10%	10%	4%	4%	5%	5%
1 Fish/Angler	24%	24%	32%	32%	23%	23%	23%	23%	17%	17%	11%	11%
1 Fish/Vessel	91%	91%	95%	95%	94%	94%	92%	92%	93%	93%	91%	91%

MRIP Private (2012-2014) Numbers												
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4 Fish/Angler	5%	5%	3%	3%	6%	6%	3%	3%	6%	6%	5%	5%
3 Fish/Angler	10%	10%	12%	12%	14%	14%	11%	11%	14%	14%	11%	11%
2 Fish/Angler	22%	22%	24%	24%	26%	26%	21%	21%	29%	29%	23%	23%
1 Fish/Angler	42%	42%	43%	43%	49%	49%	45%	45%	49%	49%	43%	43%
1 Fish/Vessel	99%	99%	99%	99%	99%	99%	100%	100%	99%	99%	93%	93%

B) GA-NC

Headboat (2012-2014), Numbers												
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1 Fish/Vessel	41%	41%	41%	41%	41%	41%	41%	41%	41%	41%	41%	41%

MRIP Charter (2012-2014) Numbers												
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1 Fish/Vessel	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%

MRIP Private (2012-2014) Numbers												
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1 Fish/Angler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1 Fish/Vessel	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%

Table 4. Mean and standard deviation from 1000 bootstrapped estimates of closure date, season length (days), landings (number of fish), removals (number of fish), and change in CS from status quo (SQ) in 2014 USD for a variety of proposed combinations of SG-37 management measures. Council preferred in bold. All runs assume no effort shifting.

A) FLK/EFL

ACL Alternative	Season	Size Limit	Bag Limit	Closure Date	Open Days	Landings (N)	Removals (N)	Change from SQ CS ($)
Alt 2a	Jan 1-Dec 31	12	5 Fish/Angler	02/09	39 ± 0.76	16,311 ± 119	22,204	$ (1,375,086.31)
Alt 2b				02/07	37 ± 0.75	15,486 ± 121	21,394	$ (1,385,402.89)
Alt 2c				02/05	35 ± 0.74	14,659 ± 122	20,584	$ (1,395,707.10)
Alt 2a	Jan 1-Dec 31	15	1 Fish/Angler	04/25	39 ± 0.76	16,380 ± 105	22,204	$ (1,375,086.31)
Alt 2b				04/20	37 ± 0.73	15,558 ± 98	21,394	$ (1,385,402.89)
Alt 2c				04/16	107 ± 4.31	14,728 ± 100	20,584	$ (1,395,707.10)
Alt 2a	July 1-Dec 31	15	2 Fish/Angler	11/01	137 ± 26.36	16,454 ± 146	22,448	$ (1,371,993.81)
Alt 2b				10/16	114 ± 24.59	15,641 ± 79	21,633	$ (1,382,372.24)
Alt 2c				09/30	97 ± 21.09	14,804 ± 72	20,835	$ (1,392,528.01)
Alt 2a	July 1-Dec 31	16	2 Fish/Angler	11/21	184 ± 26.21	16,065 ± 678	21,610	$ (1,382,681.49)
Alt 2b				11/09	184 ± 27.49	15,508 ± 408	21,610	$ (1,382,681.49)
Alt 2c				10/25	150 ± 26.95	14,782 ± 211	20,854	$ (1,392,292.98)
Alt 2a	July 1-Dec 31	16	1 Fish/Angler	11/21	184 ± 25.79	16,052 ± 669	21,610	$ (1,382,681.49)
Alt 2b				11/08	184 ± 26.92	15,504 ± 384	21,610	$ (1,382,681.49)
Alt 2c				10/26	150 ± 27.50	14,788 ± 176	20,854	$ (1,392,292.98)
Alt 2a	May 1-Dec 31	17	2 Fish/Angler	11/20	245 ± 26.37	15,493 ± 927	19,759	$ (1,406,209.23)
Alt 2b				11/12	245 ± 28.32	15,192 ± 670	19,759	$ (1,406,209.23)
Alt 2c				10/31	245 ± 28.36	14,669 ± 389	19,759	$ (1,406,209.23)
Alt 2a	May 1-Dec 31	16	1 Fish/Angler	12/13	245 ± 17.80	14,424 ± 887	19,711	$ (1,406,802.99)
Alt 2b				12/05	245 ± 19.57	14,391 ± 826	19,711	$ (1,406,802.99)
Alt 2c				11/29	245 ± 23.39	14,239 ± 648	19,711	$ (1,406,802.99)
Alt 2a	**July 1-Sept 30**	**16**	**1 Fish/Angler**	No Closure	92 ± 0	9,497 ± 890	15,141	$ (1,464,941.99)
Alt 2b				**No Closure**	**92 ± 0**	**9,497 ± 890**	**15,141**	**$ (1,464,941.99)**
Alt 2c				No Closure	92 ± 0	9,497 ± 890	15,141	$ (1,464,941.99)

B) GA-NC

ACL Alternative	Season	Size Limit	Bag Limit	Closure Date	Open Days	Landings (N)	Removals (N)	Change from SQ CS ($)
Alt 2a	Jan 1-Dec 31	12	None	No Closure	365 ± 0	470 ± 33	493	5,059.33
Alt 2b				No Closure	365 ± 0	470 ± 33	493	5,059.33
Alt 2c				No Closure	365 ± 0	470 ± 33	493	5,059.33
Alt 2a	**Jan 1-Dec 31**	**17**	**2 Fish/Angler**	No Closure	365 ± 0	412 ± 30	493	5,059.33
Alt 2b				**No Closure**	**365 ± 0**	**412 ± 30**	**493**	**5,059.33**
Alt 2c				No Closure	365 ± 0	412 ± 30	493	5,059.33
Alt 2a	Jan 1-Dec 31	16	2 Fish/Angler	No Closure	365 ± 0	445 ± 32	493	5,059.33
Alt 2b				No Closure	365 ± 0	445 ± 32	493	5,059.33
Alt 2c				No Closure	365 ± 0	445 ± 32	493	5,059.33
Alt 2a	Jan 1-Dec 31	20	4 Fish/Angler	No Closure	365 ± 0	445 ± 32	498	5,133.55
Alt 2b				No Closure	365 ± 0	445 ± 32	498	5,133.55
Alt 2c				No Closure	365 ± 0	445 ± 32	498	5,133.55

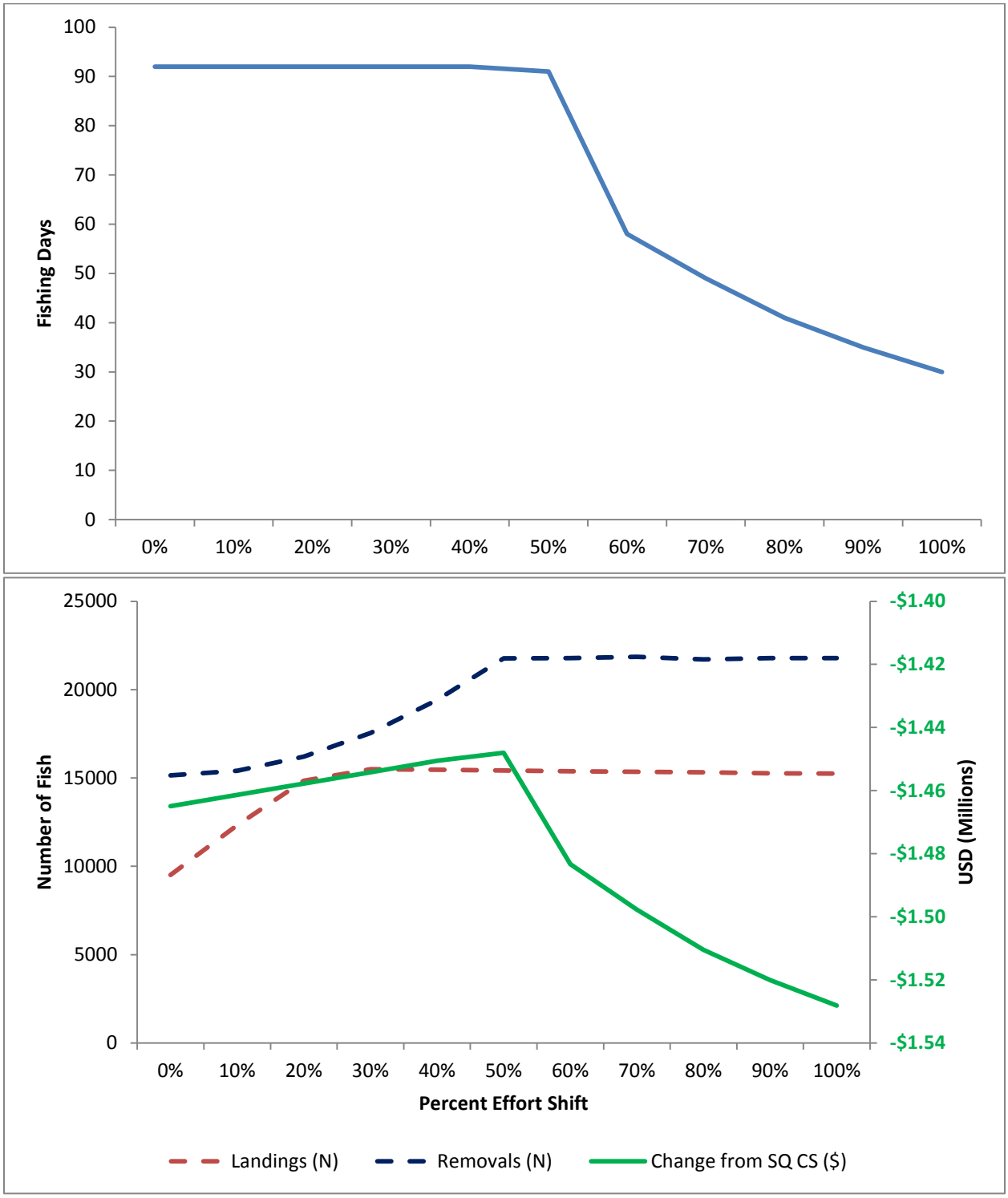


Figure 4. Impacts of effort shifting on estimates of fishing days (top; blue), landings (bottom; red), removals (bottom; dark blue), and change in CS from status quo (SQ) in 2014 USD (bottom; green - right axis) for Council's preferred SG-37 management measures for FLE/FLK (assumes ACL=95 percent ABC, July 1-Sept 30 season, 16-inch MSL, 1-fish/angler bag limit).

Discussion

As with most projection models, the reliability of the RDTs is dependent upon the accuracy of the underlying data and input assumptions. Although the RDTs attempt to address uncertainties in catch rates and the impacts of various management measures, the bounds of this uncertainty are not fully captured by the models as currently configured; as such, they should be used with caution for management decision-making. As a foundation for comparisons, it is assumed that the 2012-2015 mean catch rate is representative of future trends in catch rates. As evidenced by the error bars in Figure 2, substantial uncertainty exists in this projected baseline, especially for the GA-NC sub-region, where hogfish catches may be viewed as a somewhat rare event. Baseline discards (see Table 1) are also highly uncertain, especially for the GA-NC sub-region. Economic conditions, weather events, changes in catch-per-unit effort, fisher response to management regulations, variation in survey estimates due to rarity of intercepts, and a variety of other factors may cause departures from this assumption.

A total hogfish harvest prohibition during a given month may reduce angler incentive to deliberately target hogfish, which may, in turn, reduce encounter rates with the stock during that month. The MRIP intercept records where anglers reported targeting hogfish were identified as 'target' trips. Trip elimination was not considered in the RDT because preliminary analyses indicated trip elimination was an unrealistic assumption for hogfish. This model implicitly assumes that hogfish would be landed in addition to other species on a trip and that the proposed action would have no effect on the number of recreational trips that would be expected to occur under the status quo. This is supported by analysis of the MRIP intercept files (2010 through 2014), which shows hogfish are typically landed in conjunction with other species. If the hogfish season were shortened, it is assumed that anglers would still fish for these other species, and if it were lengthened, it is assumed that anglers would harvest hogfish that would have otherwise been discarded or avoided (in the case of spearfishing). Because there is no expected change in angler trips, for-hire businesses (charter and headboat vessels) are not expected to be negatively affected in terms of producer surplus. The expectation is that for-hire anglers would still book the same number/type of trips at the same price point.

In addition to the aforementioned sources of uncertainty, the modeled reductions associated with management measures assume that past performance is a good predictor of future dynamics. The range of data considered has been constrained to recent years to reduce the unreliability of this assumption; however, due to recent quota closures, substantial variability in recent catches, and the substantial changes in management being proposed (i.e., shifting stock boundary, large cuts to ACL, changes in MSLs, bag limits, and closed seasons), these estimates should be viewed as reliable for relative comparisons but less useful for predicting exact closure dates or precise economic impacts. Bootstrapping runs accounting for uncertainty in monthly catch rate estimates and reductions associated with various proposed management measures indicate that quota closure estimates could deviate by over a month, and that uncertainty is highest when the season is long, because uncertainty in daily catch rates accumulates through time. Uncertainty was also higher for when moderately effective management measures were selected rather than draconian measures.

The relative impacts of various proposed management options explored in the RDT are anticipated to be robust to uncertainty in future catch rates; however, the exact season lengths projected are subject to high uncertainty. The RDT models account for size and bag limit impacts separately. Harvest eliminated by a size limit might be also computed as eliminated by a bag limit or vice versa. Effort shifting may lead to increased removal rates before and after a closure that partially offset the reductions expected from the closure. Little information exists to inform management decision-making regarding the extent of effort shifting possible. A recreational closure was implemented from June 1-July 31 for Gulf of Mexico greater amberjack in June 2011. In 2009 and 2010, Wave 3 (May-June) landings for greater amberjack were averaged 44 percent of the annual harvest; from 2011-2015, Wave 3 landings have only averaged 19 percent of the annual harvest, indicating a cut in harvest nearly proportional with the reduction in open days (i.e., 0 percent effort shifting). However, Wave 4 (July-Aug) landings have been far more variable with no clear indication of a reduction in harvest associated with the seasonal closure, suggesting up to a 100 percent post-closure effort shift may have occurred. Due to substantial uncertainty in the amount of effort shifting that might occur, it was configured as a user-defined feature in the RDT. Increased effort shifting leads to increased landings; under some scenarios this might also lead to an earlier quota closure (Figure 4).

The RDTs do not consider non-compliance with various proposed regulations, which would similarly offset the projected reductions. Violations of any of these assumptions would cause the models to overestimate the impacts of proposed management measures. The models do not consider differences in the impacts of management measures by gear. In the FLK/EFL RDT, based on observations from SEDAR-37 (2014), only 27 percent of fish that would have been landed under status quo management measures are converted to discards because knife-edged selectivity is assumed for spearfishing gear, so only hook-and-line gears create discards. Data were not available on the catch effort files to evaluate management measures by gear; if management measures are less effective for hook-and-line gear, the RDT model for FLK/EFL would underestimate total removals by underestimating landed catch and overestimating dead discards. Because management reductions presented in this report may be overestimates, caution should be taken in their interpretation and use. By contrast, changes in economic conditions and/or fuel prices may influence fishing effort. Reduced effort due to external forces such as high fuel prices could lead to harvest less than that predicted by the RDT models.

The FLK/EFL RDT indicates that additional management regulations are necessary to rebuild FLK/EFL hogfish and constrain harvest to the ACL. Increasing the MSL is one effective means of constraining harvest and may also provide additional benefits due to the unique life history of hogfish. Hogfish are monandric, protogynous hermaphrodites, where fish mature as females first, and are expected to eventually become male if they live long enough. Research conducted on hogfish that would belong to the FLK/EFL stock indicate that a single male maintains harems of 5 to 15 females (Colin 1982, Muñoz et al. 2010) during extended spawning seasons that last for months. Hogfish are pair spawners (Davis 1976, Colin 1982), and spawning occurs daily during spawning season (McBride and Johnson 2007, Collins and McBride 2008, Muñoz et al. 2010). The size (7.8-28.6 inches fork length) and age (1-11 years) range at which sexual transition occurs indicates that transition is socially mediated (Collins and McBride 2011). Life history studies on hogfish that would belong to the FLK/EFL stock have estimated female size and age at 50 percent maturity to occur between 6.0 and 7.6 inches FL and 0.9 to 1.6 years

(McBride et al. 2008, Collins and McBride 2011). Males may occur as small as 7.8 inches FL, but size at 50 percent male maturity has been estimated as 16.4 inches fork length and 7 years in the Florida Keys (McBride et al. 2008). Sex change in hogfish can take several months (McBride and Johnson 2007), so removal of the dominant male has the potential to significantly affect harem stability and decrease reproductive potential (Munoz et al. 2010). MSLs above 16 inches fork length (Sub-alternatives a-e) may provide hogfish the opportunity to form harems and transition to males. McBride et al. (2008) state: "…the size of 50 percent male maturation, approximately 415 to 425 mm (16.3-16.7 inches) FL, is well above the current MSL. Evidently, to reduce disruption to spawning harems and avoid recruitment overfishing, the MSL should be increased."

For hogfish in the GA-NC stock, the size at transition was calculated based on macroscopic investigation of gonad samples collected in 2013 through 2015 from vessels fishing off North Carolina (Scott Van Sant, SEFSC, unpublished data). The size at which 50 percent of females transition to males was estimated to be 24 inches fork length using binary logistic regression implemented in SAS 9.1. The smallest male observed was 15 inches FL. No female hogfish were observed greater than 30 inches FL. These data are preliminary and will likely change when a complete historical analysis is completed; however, they provide a general estimate of the transition size for hogfish off North Carolina that can be considered in the management of the GA-NC stock.

Hogfish release mortality rate is estimated to be around 10 percent for hook-and-line and 100 percent for spearfishing (SEDAR-37 2014). Spearfishing is assumed to generate few discards as fishers can visually assess the size of the fish prior to shooting. Hook-and-line is assumed to be the predominant gear producing discards. Spearfishing should produce little to no bycatch during a closure, as hogfish are easily distinguished from other species. Considering these factors, a high percentage of hogfish released due to an increased size limit, bag limit, or closed season may survive to spawn and promote recovery of the stock. This is explicitly modeled in the FLK/EFL RDT because available data suggested 73 percent of landings originate from spearfishing trips; however, it is not modeled for GA-NC because no spearfishing trips were intercepted 2010-2012. Substantial anecdotal information suggests spearfishing trips are common in the GA-NC sub-region; thus, the available data may only be applicable as an estimate for the impacts of proposed management regulations on hook-and-line trips in the GA-NC sub-region. It is likely that increasing the MSL or reducing the bag limit in the GA-NC sub-region would have similar positive biological effects for hogfish as seen in the FLK/EFL RDT, by reducing total removals.

References

Colin, P. L. 1982. Spawning and larval development of the hogfish, *Lachnolaimus maximus* (Pisces: Labridae). Fishery Bulletin, U. S. 80 (4): 853-862.

Collins A, R McBride. 2008. Final report for integrating life history, mating system, fishing effects, and habitat of hogfish, *Lachnolaimus maximus*, a harem spawning fish in the southeast U.S. FWRI File Code F2541-05-07-F.

Collins, A.B. & McBride, R.S. 2011. Demographics by depth: Spatially explicit life-history dynamics of a protogynous reef fish. Fishery Bulletin, U. S., 109, 232–242.

Davis, J. C. 1976. Biology of the hogfish, *Lachnolaimus maximus* (Walbaum), in the Florida Keys. M. S. Thesis. University of Miami. Coral Gables, FL. pp: 86.

Haab, T., Hicks, R. L., Schnier, K., Whitehead, J. C. 2012. Angler heterogeneity and the species-specific demand for marine recreational fishing. Working Paper No. 10-02. Appalachian State University, Department of Economics. Available: http://econ.appstate.edu/marfin/. (September 2014).

McBride, R. S., P. E. Thurman, and L. H. Bullock. 2008. Regional variations of hogfish (*Lachnolaimus maximus*) life history: Consequences for spawning biomass and egg production models. J. Northw. Atl. Fish. Sci. 41:1–12.

McBride, R.S. and Johnson, M. R. 2007. Sexual development and reproductive seasonality of hogfish (Labridae: *Lachnolaimus maximus*), an hermaphroditic reef fish. Journal of Fish Biology 71:1270-1292.

Muñoz, R. C., M. L. Burton, K. J. Brennan, and R. O. Parker. 2010. Reproduction, habitat utilization, and movements of hogfish (*Lachnolaimus maximus*) in the Florida Keys, U.S.A.: comparisons from fished versus unfished habitats. Bull. Mar. Sci. 86:93–116.

South Atlantic Fishery Management Council (SAFMC). 2016. Scientific and Statistical Committee (SSC) Meeting Report. Charleston, SC, March 9, 2016. 13 pp.

Southeast Data Assessment and Review (SEDAR)-37. 2014. The 2013 stock assessment report for hogfish in the South Atlantic and Gulf of Mexico. Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida. 573 pp. Available at: http://sedarweb.org/docs/sar/SEDAR37_Hogfish_SAR.pdf