Methods for Recreational Decision Tools

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

LAPP/DM and Social Science Branches
National Marine Fisheries Service, Southeast Regional Office

Introduction

The Florida Fish and Wildlife Conservation Commission completed a 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 and is overfished and, therefore, 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, minimum size limits (MSL), and bag limits for the FLK/EFL and GA-NC hogfish stocks. This report presents the development of a recreational decision tool (RDT) to simulate the impacts of various combinations of proposed management measures to support SG-37.

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)

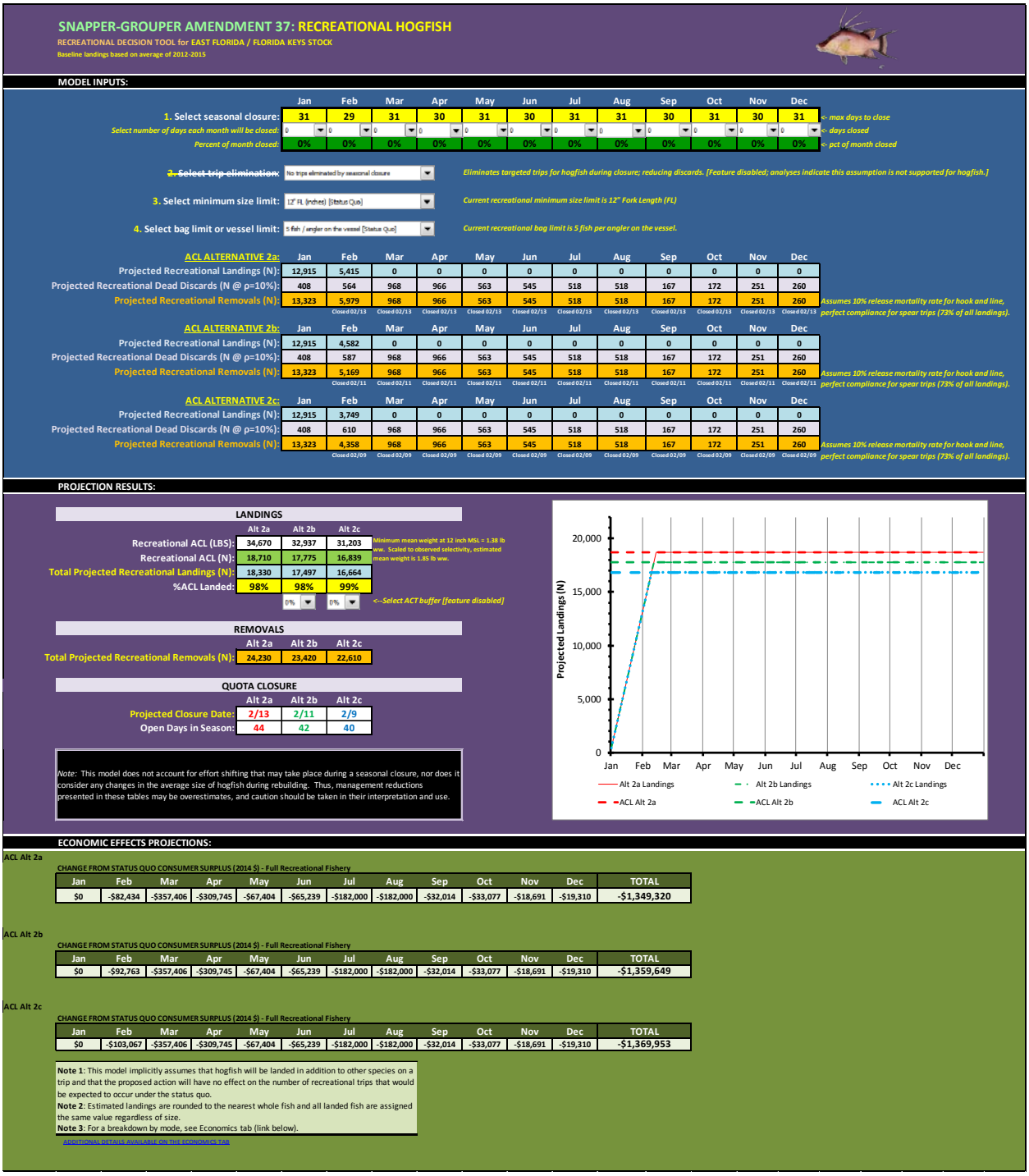

Figure 1A. Screenshot of FLK/EFL hogfish recreational decision tool, showing dropdown menus for user-specified management measures.

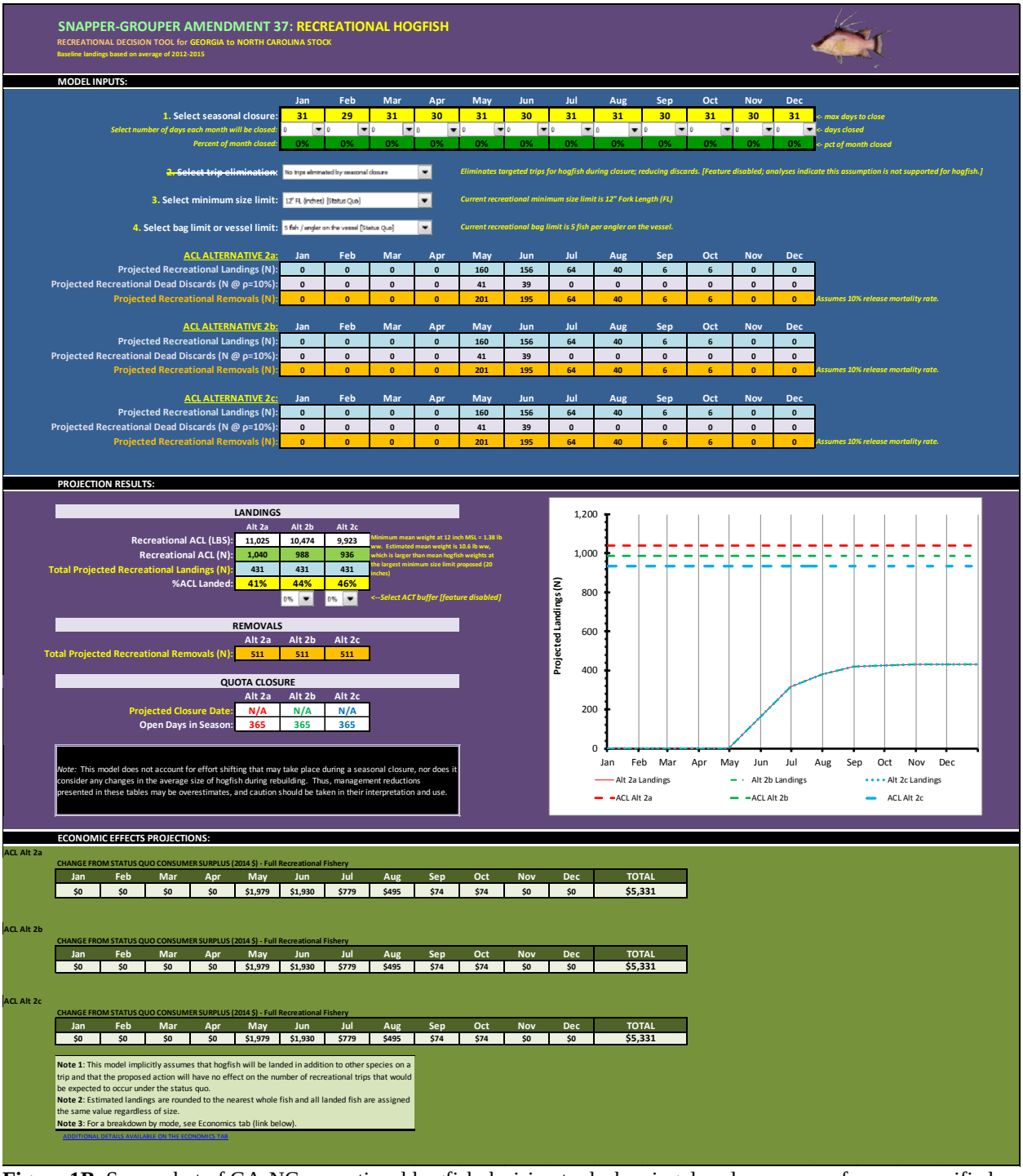

Figure 1B. Screenshot of GA-NC recreational hogfish decision tool, showing dropdown menus for user-specified management measures.

Methods

The RDTs for FLK/EFL and GA-NC hogfish were implemented in Microsoft Excel using drop-down menus to obtain user inputs regarding desired management measures (Figures 1A and 1B). 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 RDT 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 different treatment. Working with SEFSC, an approach was developed that is consistent with how the SEFSC assigns weights for ACL monitoring but with some modifications for hogfish. The SEFSC assigns average weights to headboat and MRIP data based on a minimum sample size of 30 with the following hierarchy:

sub_reg year new_sta new_moden wave new_arean

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 jurisdiction prior to running weight estimation so that regional average weight draws for Florida would not pull from the Gulf of Mexico 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_reg decade year new_sta new_moden wave new_arean

The program was recoded to specify minimum sample size thresholds of n=10 for GA-NC and n=30 for FLK/EFL. 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 1986 to Wave 3, 2015. 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 landings in early 2015 resulted in a recreational closure and led the Council to request revised projections.

The SEFSC reviewed the code and associated output, and agreed with this 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 each of these 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. Landings were assumed uniformly distributed across days.

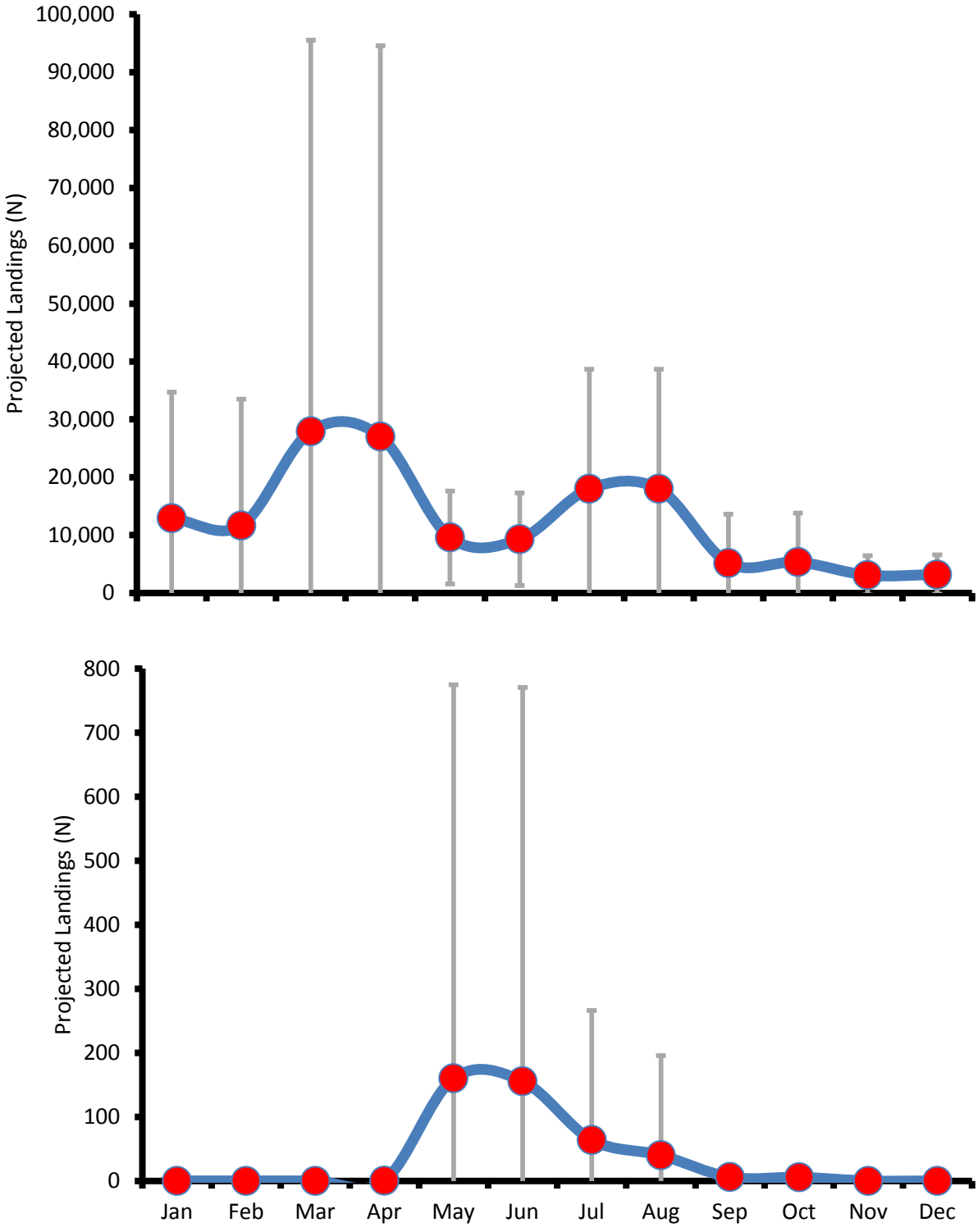

Figure 2. South Atlantic recreational hogfish mean landings 2012-2015 for FLK/EFL (top) and GA-NC (bottom), with error bars denoting 95% confidence intervals.

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; no effort shifting or effort compression was modeled.

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).

Reductions in harvest (both numbers and weight of fish) were calculated for each mode of fishing (charter, headboat, and private/rental) for MSL at 1-inch intervals between 12-20 inches as follows:

Percent reduction = $((C - G) - B)/C$, where:
C = *catch in either number of fish or pounds WW*
G = *number or weight of fish that are greater than or equal to the MSL*
B = *number or weight of fish smaller than the 12-inch FL MSL (non-compliance or measurement error)*

Percent reductions associated with MSL were estimated by mode of fishing normalized to a 0% reduction at the recreational status quo of 12 inches. 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 4 are greater for the FLK/EFL sub-region. The size limit approach assumes a level of illegal harvest consistent with historical observations.

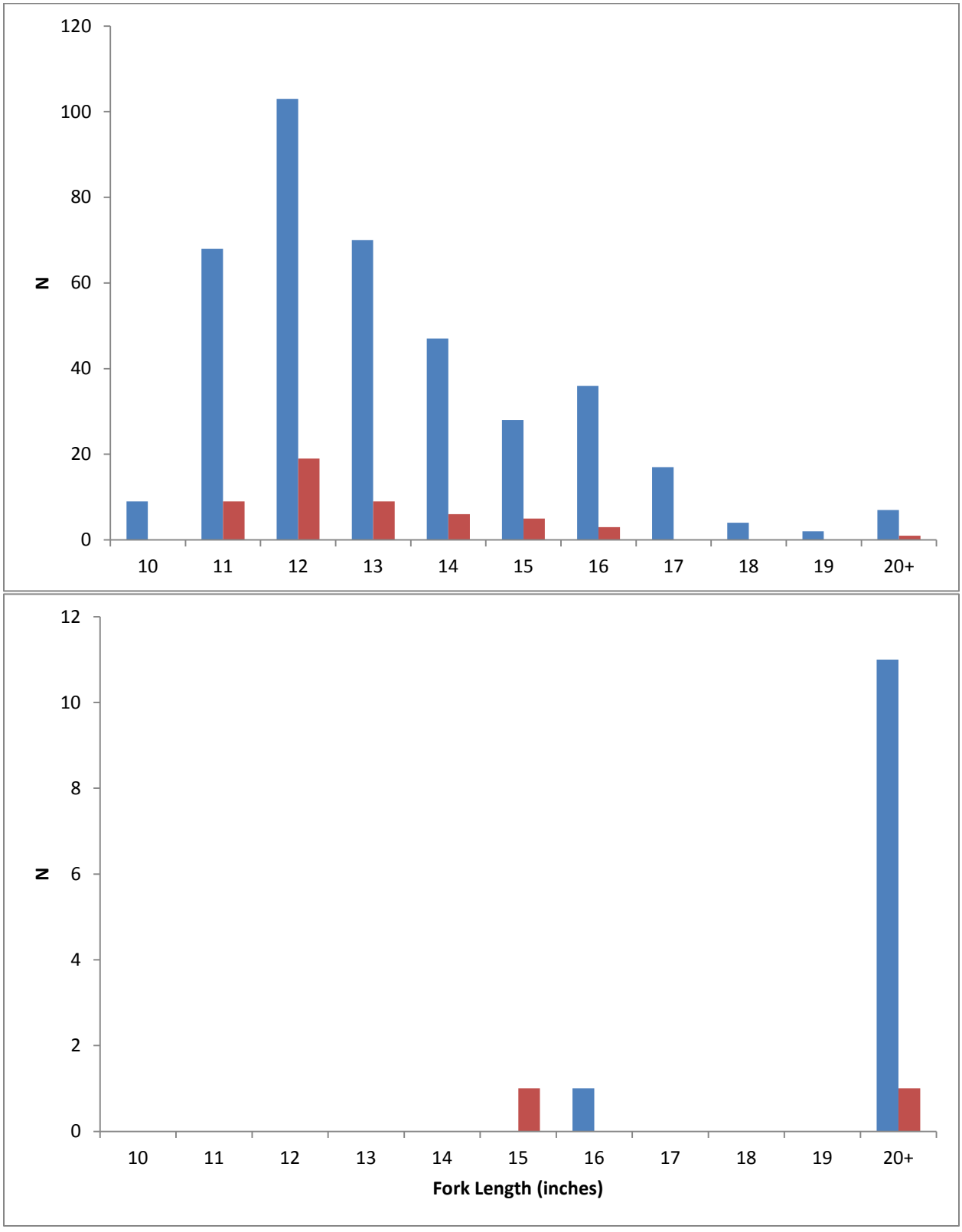

Figure 3. Fork lengths of landed hogfish reported by SRHS (2011-2013; red) and MRIP (2012-2014; blue) for FLK/EFL (top) and GA-NC (bottom) stocks of hogfish.

Combined Effects of User-Defined Management Measures

For both RDT models, if month (*m*) was 100% 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:

$$L_{mode,m} = BL_{mode,m} * O_m * \varsigma_{mode,m} * \beta_{mode,m}$$

where BL: baseline landings, O: percent of month open to fishing, ς: percent landed catch remaining following size limit implementation, β: percent landed catch remaining following bag limit implementation.

Projected discards (D) were computed as baseline discards plus the difference between projected landings (L) and baseline landings (BL). The new management discards (BL-L) resulting from new management measures were assumed to be uniformly distributed across spear and hook-and-line gear types. 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% of new management discards were added to baseline discards to compute D. 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 aggregate landings at the time of closure.

For the FLK/EFL sub-region, an ABC recommendation in pounds was provided by the SEDAR-37 (2014) stock assessment. The RDT is configured to manage towards the SG-37 ACL alternatives based on the projected 2017 ABC of 38,367 pounds whole weight from projections at $P_{rebuild}$=72.5% over 10 years. The recreational allocation of this ABC is 34,670 pounds whole weight. Because the SEDAR-37 (2014) assessment's terminal year was 2012, which was prior to the changes to the MRIP Access Point Intercept Survey enacted in 2013, the years 2012-2015 were selected for computation of a baseline mean weight. The 2012-2015 period incorporates the terminal year in the SEDAR-37 (2014) assessment and is consistent with the time period used for projecting landings. The mean weight for 2012-2015 in the FLK/EFL sub-region was

1.85 pounds whole weight. 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.

Table 2 provides hogfish mean weights from the von Bertalanffy growth curve in SEDAR-37 (2014). Because SG-37 proposes to manage hogfish to an ACL in numbers of fish, but also contains alternatives to increase the MSL, if the ACL is not adjusted to account for changes in mean weight anticipated under different MSLs, the allocation of the ABC could be exceeded. For example, off FLK/EFL, 20,576 fish at a 20-inch MSL would weigh at least 115,431 pounds whole weight, or 3.3 times higher than the recreational allocation of the ABC. Thus, if the ACL in numbers is not adjusted to reflect the change in mean weight of landed fish at different minimum size limits, the RDT would allow overfishing of the stock in pounds.

We explored different options for how to adjust the ACL in numbers at different minimum size limits for both sub-regions. For FLK/EFL, six approaches were explored for how to divide the recreational allocation in pounds by a mean weight to derive a recreational ACL in numbers that would prevent overfishing and reflect the projected mean size at different minimum size limits:

1. Divide by mean weight of fish at minimum size,
2. Divide by mean weight of fish at minimum size scaled up by 1.85/1.38 [ratio of observed landed mean weight at 12 inches limit relative to mean von Bertalanffy estimated size at 12 inches],
3. Divide by mean weight of fish at minimum size scaled up by observed 139 percent inter-growth bin ratio [mean weight at 12 inches is 1.38, mean weight at 13 inches is 1.72, observed mean weight is 1.85, approximately 139 percent of the way between 12-13 inches],
4. Divide by weighted mean of weights of intercepted fish in the remaining size bins at or above the specified minimum size,
5. Divide by weighted mean of weights of intercepted fish in the size bins two steps below to above the specified minimum size [accounting for observed undersized fish retention]
6. Divide by weighted mean of weights of intercepted fish in the remaining size bins at or above the specified minimum size scaled to the observed mean weight of 1.85 pounds whole weight per fish at a 12-inch MSL.

Of these approaches, (3) was selected for the FLK/EFL RDT. The selected option (3) accounts for some retention of fish above the minimum size limit and is based on a ratio between observed and modeled data. It results in weight estimates that are slightly above the minimum sizes for all sizes except 20 inches, because no intercepted fish were >20 inches. The first approach fails to consider that fish larger than the MSL will be retained. It also implicitly assumes a normal distribution around the minimum size, which would be illegal as undersized fish should not be

retained. The second approach fails to account for reduced ability to encounter larger fish as the size limit is increased. The fourth approach cannot be reconciled with observed data due to a lack of site weighting. The fifth approach assumes non-compliance and also cannot be reconciled with observed data at the current MSL due to lack of site weighting. The sixth approach computationally results in average weights below the mean weight at the minimum size limit when the MSL is above 14 inches.

For GA-NC, seven approaches were explored for how to divide the recreational allocation in pounds by a mean weight to derive a recreational ACL in numbers that would prevent overfishing and reflect the projected mean size at different MSL:

1. Divide by mean weight of fish at minimum size,
2. Divide by mean weight of fish at minimum size scaled up by ratio of observed landed mean weight at a 12-inch limit to von Bertalanffy estimated mean size at 12 inches,
3. Divide by mean weight of fish at minimum size scaled up by observed inter-growth bin ratio [mean von Bertalanffy estimated weight at 12 inches is 1.38, mean von Bertalanffy estimated weight at 13 inches is 1.72, observed mean landed weight is 10.60],
4. Divide by weighted mean of weights of intercepted fish in the remaining size bins at or above the specified minimum size,
5. Divide by weighted mean of weights of intercepted fish in the size bins two steps below to above the specified minimum size [accounting for observed undersized fish retention]
6. Divide by weighted mean of weights of intercepted fish in the remaining size bins at or above the specified minimum size scaled to the observed mean weight of 10.60 pounds whole weight/fish at a 12-inch minimum size.
7. Keep mean weight constant given that 10.60 pounds whole weight is above the mean size for the largest minimum size under consideration.

Of these approaches, (7) was selected for the GA-NC RDT, as all other approaches resulted in unrealistic average weights, fish less than 20 inches are rarely encountered (Figure 3), and the mean size of current landings at 10.60 pounds whole weight /fish is much larger than the mean weight of a 20-inch fish, which is the largest minimum size under consideration. Table 2 shows the ACLs in numbers for each minimum size limit alternative.

Table 2. Hogfish mean weights (Wt, pounds whole weight) at different fork lengths (FL) from the von Bertalanffy growth curve in SEDAR-37 (2014), with modeled mean weights for each sub-region at different size limits accounting for selectivity. Recreational allocation of the ABC in pounds would remain fixed, but recreational sector ACL would change depending on minimum size limit, reflecting anticipated new mean weight of landed fish. Council preferred alternative in bold.

FL (cm)	FL (in)	Wt (g)	Wt (lbs)	FLK /EFL Mean Wt (lbs)	FLK /EFL Rec ABC Allocation (lbs)	FLK /EFL Rec ACL @ 100% ABC (N)	FLK /EFL Rec ACL @ 95% ABC (N)	GA-NC Mean Wt (lbs)	GA-NC Rec ABC Allocation (lbs)	GA-NC Rec ACL @ 100% ABC (N)	GA-NC Rec ACL @ 95% ABC (N)
25.4	10	380	0.84	1.19	34,670	29,189	**27,730**	10.60	11,025	1,040	**988**
27.94	11	493	1.09	1.49	34,670	23,215	**22,054**	10.60	11,025	1,040	**988**
30.48	12	626	1.38	1.85	34,670	18,710	**17,775**	10.60	11,025	1,040	**988**
33.02	13	780	1.72	2.26	34,670	15,324	**14,558**	10.60	11,025	1,040	**988**
35.56	14	956	2.11	2.72	34,670	12,737	**12,100**	10.60	11,025	1,040	**988**
38.1	15	1,156	2.55	3.23	34,670	10,728	**10,192**	10.60	11,025	1,040	**988**
40.64	16	1,380	3.04	3.81	34,670	9,111	**8,655**	10.60	11,025	1,040	**988**
43.18	17	1,630	3.59	4.44	34,670	7,811	**7,420**	10.60	11,025	1,040	**988**
45.72	18	1,907	4.2	5.15	34,670	6,737	**6,400**	10.60	11,025	1,040	**988**
48.26	19	2,212	4.88	5.90	34,670	5,881	**5,587**	10.60	11,025	1,040	**988**
50.8	20	2,546	5.61	5.61	34,670	6,180	**5,871**	10.60	11,025	1,040	**988**

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, minimum size limit, bag limit, and season closure alternatives.

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. If the trip elimination option was selected by the RDT user, in the event of a management or quota closure, target trips were assumed to no longer occur. This feature was disabled in the current version of 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

[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.

effort, 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. 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

Minimum Size Limits

MSL, especially at 15 inches fork length and above, appear to be an effective means of constraining harvest off FLK/EFL (Table 3a). MSL 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 3b). 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 4). Due to their high passenger capacity, bag limits that constrain catch per angler are relatively ineffective for headboats (Table 4). Off FLK/EFL, bag limits of 2 fish and 1 fish per angler appear relatively effective for constraining harvest (Table 4a). Off GA-NC, bag limits had no impact on harvest with the exception of 1-fish per-vessel limits (Table 4b).

Combined Effects

Table 5a 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. 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 15 inches fork length, with a 1-fish per-person per-day bag limit, the season would be 84 days, with a closure on the 25th of March. With a 2-fish per-person per-day bag limit, the season would decrease to 71 days, with a closure the 12th of March. If the season started in May, it would last 111 days under a 1-fish bag limit and 90 days under a 2-fish bag limit. Longer seasons could be achieved with a July start date and a 1-fish bag limit. 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 spearfishermen to select legal fish and avoid discards.

Table 5b 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.

Table 3. 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 4. 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 5. 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.

A) FLK/EFL

ACL Alternative	Season	Size Limit	Bag Limit	Closure Date	Open Days	Landings (N)	Removals (N)	Change from SQ CS ($)
Alt 2a		12	5 Fish/Angler	13-Feb	44	18,330	24,230	$(1,349,319.60)
Alt 2b				11-Feb	42	17,497	23,420	$(1,359,648.55)
Alt 2c				9-Feb	40	16,664	22,610	$(1,369,952.76)
Alt 2a		15	1 Fish/Angler	28-Mar	87	10,683	16,792	$(1,443,950.10)
Alt 2b				25-Mar	84	10,086	16,211	$(1,451,334.99)
Alt 2c				22-Mar	81	9,488	15,630	$(1,458,719.88)
Alt 2a		15	2 Fish/Angler	14-Mar	73	10,561	16,673	$(1,445,446.87)
Alt 2b				12-Mar	71	10,030	16,157	$(1,452,015.34)
Alt 2c				10-Mar	69	9,499	15,641	$(1,458,583.81)
Alt 2a	May 1 – Dec 31	15	1 Fish/Angler	22-Aug	114	10,592	16,704	$(1,445,051.03)
Alt 2b				19-Aug	111	10,149	16,273	$(1,450,530.94)
Alt 2c				15-Aug	107	9,559	15,699	$(1,457,841.61)
Alt 2a	May 1 – Dec 31	15	2 Fish/Angler	31-Jul	92	10,550	16,663	$(1,445,558.20)
Alt 2b				29-Jul	90	10,126	16,250	$(1,450,803.08)
Alt 2c				26-Jul	87	9,489	15,631	$(1,458,682.77)
Alt 2a	June 1 – Dec 31	15	1 Fish/Angler	6-Sep	98	10,726	16,835	$(1,443,381.08)
Alt 2b				28-Aug	89	10,074	16,200	$(1,451,458.69)
Alt 2c				25-Aug	86	9,631	15,769	$(1,456,926.23)
Alt 2a	**July 1 – Sept 30**	**15**	**1 Fish/Angler**	**N/A**	**92**	**10,203**	**16,325**	**$ (1,449,850.59)**
Alt 2b				**29-Sep**	**91**	**10,168**	**16,292**	**$ (1,450,283.54)**
Alt 2c				**14-Sep**	**76**	**9,645**	**15,783**	**$ (1,456,753.05)**
Alt 2a	July 1 – Dec 31	17	1 Fish/Angler	7-Dec	160	7,807	13,995	$(1,479,513.85)
Alt 2b				3-Nov	126	7,414	13,613	$(1,484,387.63)
Alt 2c				13-Oct	105	7,022	13,232	$(1,489,249.04)

B) GA-NC

ACL Alternative	Closed Days	Size Limit	Bag Limit	Closure Date	Open Days	Landings (N)	Removals (N)	Change from SQ CS ($)
Alt 2a		12	5 Fish/Angler	N/A	365	431	511	$5,331.47
Alt 2b				N/A	365	431	511	$5,331.47
Alt 2c				N/A	365	431	511	$5,331.47
Alt 2a		**17**	**2 Fish/Angler**	**N/A**	**365**	**411**	**493**	**$5,059.33**
Alt 2b				**N/A**	**365**	**411**	**493**	**$5,059.33**
Alt 2c				**N/A**	**365**	**411**	**493**	**$5,059.33**
Alt 2a		18	2 Fish/Angler	N/A	365	411	493	$5,059.33
Alt 2b				N/A	365	411	493	$5,059.33
Alt 2c				N/A	365	411	493	$5,059.33
Alt 2a		20	5 Fish/Angler	N/A	365	411	493	$5,059.33
Alt 2b				N/A	365	411	493	$5,059.33
Alt 2c				N/A	365	411	493	$5,059.33
Alt 2a	Jan 1 – Apr 30, Aug 1 – Dec 31	17	1 Fish/Angler	N/A	273	47	166	$569.02
Alt 2b				N/A	273	47	166	$569.02
Alt 2c				N/A	273	47	166	$569.02
Alt 2a	Jan 1 – Apr 30, Aug 1 – Dec 31	17	2 Fish/Angler	N/A	273	47	166	$569.02
Alt 2b				N/A	273	47	166	$569.02
Alt 2c				N/A	273	47	166	$569.02
Alt 2a	Jan 1 – May 31, Aug 1 – Dec 31	17	2 Fish/Angler	N/A	304	206	308	$2,523.48
Alt 2b				N/A	304	206	308	$2,523.48
Alt 2c				N/A	304	206	308	$2,523.48
Alt 2a	Jan 1 – June 30, Aug 1 – Dec 31	17	2 Fish/Angler	N/A	334	360	447	$4,428.46
Alt 2b				N/A	334	360	447	$4,428.46
Alt 2c				N/A	334	360	447	$4,428.46

Discussion

As with most projection models, the reliability of the RDT models is dependent upon the accuracy of the underlying data and input assumptions. 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. The bounds of this uncertainty are not captured by the models as currently configured; as such, they should be used with caution for management decision-making. 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 minimum size limits, 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.

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. Additionally, the RDT models do not account for effort shifting that may take place during a seasonal closure. Effort shifting may lead to increased removal rates before and after a closure that partially offset the reductions expected from the closure. The models also 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 RDT models to overestimate the impacts of proposed management measures. 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.

In general, the models suggest additional management regulations are necessary to rebuild hogfish in the FLK/EFL within the allowable time frame and constrain harvest to the ACL. Increasing the minimum size limit 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% 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). Minimum size limits 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 minimum size limit. Evidently, to reduce disruption to spawning harems and avoid recruitment overfishing, the minimum size limit 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% 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 minimum size limit 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.

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