Modeling the Combined Effects of Gulf Reef Fish Amendment 37 Proposed Management Measures for Gray Triggerfish

LAPP/DM Branch
NOAA Fisheries Service
Southeast Regional Office

Introduction

Gray triggerfish (*Balistes capriscus*) is one of 31 reef fish species in the Fishery Management Plan (FMP) for the Reef Fish Resources of the Gulf of Mexico. The FMP provides management for reef fish species in federal waters of the Gulf of Mexico.

A benchmark stock assessment was conducted in 2006 for the Gulf of Mexico gray triggerfish stock (SEDAR 9 2006). The assessment results indicated the stock was both overfished and experiencing overfishing (SEDAR 9 2006). Following the assessment results, in 2008 Amendment 30A was implemented and established commercial and recreational annual catch targets (ACTs), annual catch limits (ACLs), accountability measures, and a stock rebuilding plan. This amendment was expected to end overfishing and rebuild the gray triggerfish stock within 10 years of the 2008 implementation, or by the end of 2017.

In 2011, an update stock assessment was conducted for Gulf of Mexico gray triggerfish (SEDAR 9 Update 2011). Results from the update stock assessment indicated the gray triggerfish stock is experiencing overfishing, and the stock is overfished. Amendment 37 is currently being drafted to establish management measures that will end overfishing of gray triggerfish and rebuild the stock by 2017. Current management measures include a 14 inch FL minimum size limit for both the commercial and recreational sector, and a 20 fish aggregate recreational bag limit. Species other than gray triggerfish included in the recreational aggregate bag limit are vermilion snapper, lane snapper, almaco jack, tilefish, goldface tilefish, and blueline tilefish. Amendment 37 proposes an increase to the minimum size limit (16 or 18 inches FL), closed seasons for both sectors, trip limits (25, 50, and 75 pounds) for the commercial sector, and modification to the bag limit (1, 2, or 4 gray triggerfish per angler) for the recreational sector. Commercial and recreational decision tools were created to evaluate the efficacy of the different management measures.

Data Sources

Commercial landings data for Gulf of Mexico gray triggerfish were obtained from the Southeast Fisheries Science Center's (SEFSC) Trip Interview Program (TIP) (accessed March 2012), and the SEFSC's coastal fisheries logbook program (CFLP) (accessed February 2012). TIP data were collected by port samplers that interviewed fishermen and collected information on the length and numbers of gray triggerfish landed, gear used, and information on the fishing trip (e.g., date, location). CFLP provided information on landings (in lbs), gear used, area, and depth of capture for each trip.

Recreational landings data for Gulf of Mexico gray triggerfish were obtained from the Marine Recreational Fisheries Statistics Survey (MRFSS), the Texas Parks and Wildlife Department (TPWD) Creel Survey, and the Southeast Headboat Survey (HBS). MRFSS and TPWD conduct

dockside intercepts to collect information on the size and number of gray triggerfish caught by mode (charter, private/rental, shore). HBS collects size and number of gray triggerfish caught through dockside sampling and logbooks completed by headboat operators.

Methods

Reductions in landings are necessary to achieve the proposed ACLs and ACTs. Various trip limits, minimum size limits, closed seasons, and bag limits were explored as tools to reduce harvest, prevent overfishing, and avoid an early closure of gray triggerfish in-season. Percent reduction of landings for each management measure were determined using 2009 to 2011 data. All calculations were done using SAS (SAS Institute, Cary, NC).

Commercial Trip Limits

Trip limits from 25 to 200 pounds whole weight (ww) per trip were examined using CFLP data. To model trip limits, if total catch per logbook-reported trip was greater than the trip limit being analyzed, the value was re-set to the new trip limit, otherwise no changes to landed catch were made. Estimated reductions were calculated on a monthly basis based on the difference in landings with no trip limit compared to landings when a trip limit was imposed. Commercial fishermen were assumed to release or stop targeting gray triggerfish once their trip limit was met. Given the small weights in the trip limits being considered, it was also assumed that additional trips (compared to historical levels) targeting gray triggerfish would not occur.

The majority of gray triggerfish trips reported relatively small landings per trip (Figure 1). Over 55% of the trips caught 25 pounds or less and over 70% of the trips caught 50 pounds or less. These relatively small landings were reflected in trip limit reduction estimates with the largest reductions occurring at trip limits of 25 and 50 pounds (Table 1).

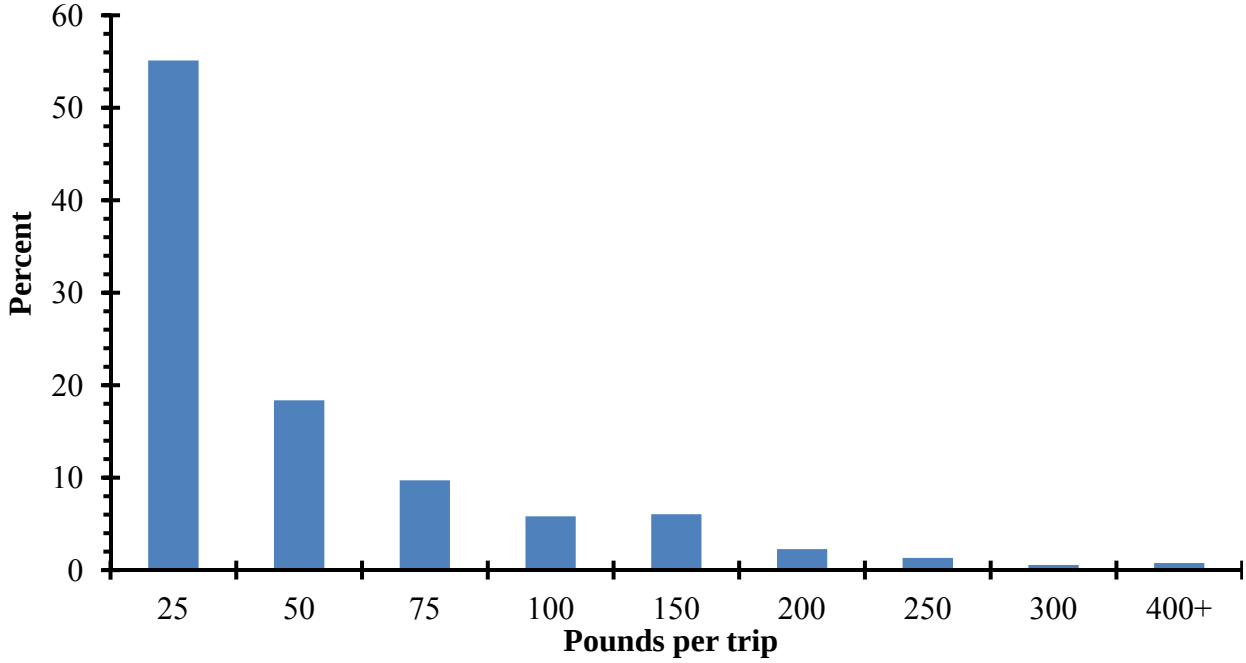


Figure 1. Percent of commercial trips landing different amounts of gray triggerfish in the Gulf of Mexico from 2009-2011 (n = 4,692 trips). Pounds are in whole weight.

Table 1. Projected reductions of commercial gray triggerfish landings by month for various trip limits. Results are based on 4,692 trips during 2009-2011. Warmer colors denote higher reductions in landings.

Trip Limit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
25	58%	67%	61%	63%	63%	62%	53%	57%	63%	64%	66%	64%
50	40%	52%	42%	44%	43%	42%	33%	36%	43%	43%	48%	43%
75	30%	44%	31%	32%	30%	30%	21%	23%	29%	29%	35%	30%
100	25%	39%	24%	23%	21%	23%	14%	15%	20%	22%	26%	21%
150	20%	32%	16%	13%	11%	14%	6%	7%	10%	11%	16%	11%
200	18%	28%	11%	7%	7%	10%	4%	3%	6%	5%	11%	7%

Commercial Minimum Size Limit Analyses

Length measurements were collected through the TIP. All of the length measurements were in mm. The majority (99%) of the gray triggerfish samples in the TIP dataset were in FL, but some data were in total length. All lengths were converted to inches fork length using standard conversion factors and equations summarized in Table 2. The size limit analysis estimated the percent reduction in weight so the weight of each fish was required. No weight information was available in the TIP dataset so weight was estimated from length using the equations summarized in Table 2.

Table 2. Meristic conversions for Gulf of Mexico gray triggerfish. The conversions came from SEDAR 9 update 2011.

Conversion	Model
Total Length (mm) to Fork Length (mm)	TL = 1.1889*(FL) – 10.5017
Whole Weight (lbs) to Fork Length (mm)	WW = (0.00000002039*(FL*3.0203))*2.2046

Figure 2 provides the length distribution for the commercial landings in 1 inch increments from 2009-2011. There was a high level of non-compliance to size limits with 26% of the fish harvested below the current minimum size limit (14 inches FL).

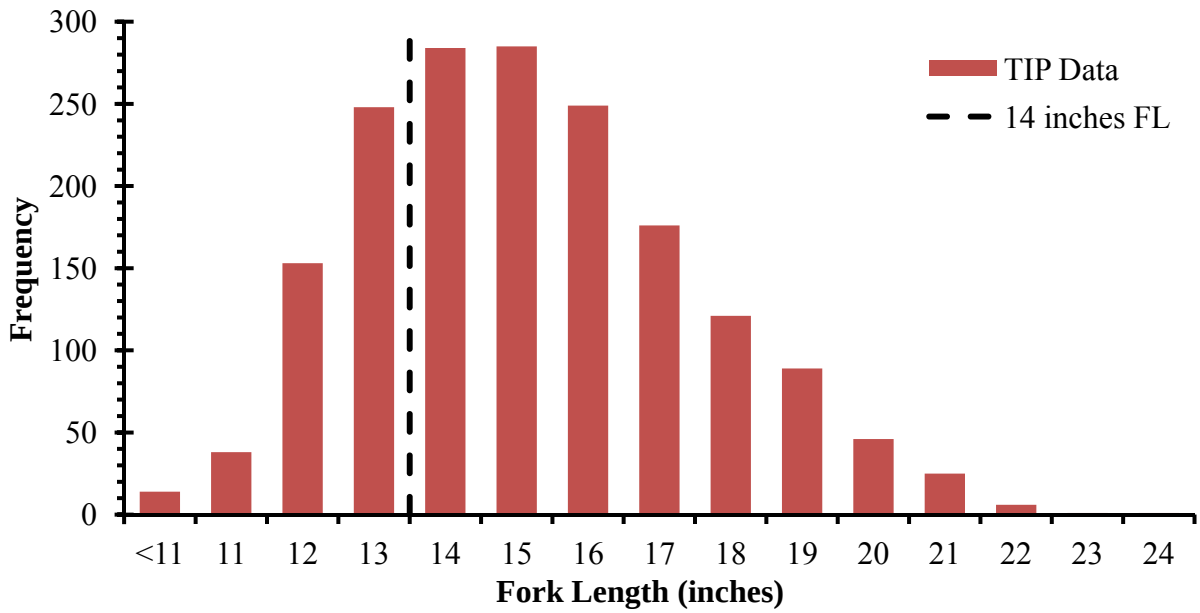


Figure 2. Gulf of Mexico fork length distribution for commercially landed gray triggerfish from TIP for 2009 to 2011 (n=1,736 gray triggerfish). The dashed black line denotes current commercial minimum size limit of 14 inches FL.

Monthly reductions in harvest in weight were calculated for minimum size limits (MSL) at 1 inch intervals between 15-20 inches as follows:

Percent reduction = *((C – G) - B)/C*, where:
C = catch in pounds ww of TIP samples
G = weight of TIP fish that are greater than or equal to the MSL
B = weight of fish smaller than the 14-inch FL MSL (non-compliance or measurement error)

Percent reductions associated with MSL were normalized to a 0% reduction at the commercial status quo of 14 inches FL. Due to concerns about low sample sizes, output was pooled for 2009-2011 data which produced greater than 150 gray triggerfish samples for each month. Projected MSL impacts were calculated for each month (Table 3).

Table 3. Projected reduction of commercial gray triggerfish landings by month for various minimum size limits. Warmer colors denote higher reductions.

Size Limit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15	14%	11%	11%	16%	14%	8%	17%	10%	13%	8%	14%	12%
16	24%	29%	24%	28%	25%	24%	27%	29%	33%	23%	32%	27%
17	39%	48%	40%	39%	40%	26%	36%	50%	46%	41%	50%	44%
18	59%	63%	52%	43%	51%	37%	43%	72%	52%	55%	62%	56%
19	68%	71%	62%	57%	68%	44%	46%	83%	62%	68%	73%	71%
20	77%	80%	73%	70%	77%	48%	55%	89%	69%	80%	78%	81%

Recreational Bag Limits

The number of gray triggerfish caught per angler on a given trip was collected by MRFSS, TPWD, and HBS. The MRFSS system classifies recreational catch into three categories:

- Type A - Fish that were caught, landed whole, and available for identification and enumeration by the interviewers.
- Type B - Fish that were caught but were either not kept or kept but not available for identification.
    - Type B1 - Fish that were caught and filleted, released dead, given away, or disposed of in some way other than Types A or B2.
    - Type B2 - Fish that were caught and released alive.

Type A and B1 catches were used for bag limit analyses. Type A catch represents the total catch of all anglers on a fishing trip. However, some or all of the anglers contributing to the A catch are also interviewed to report type B1 catch, and those may be recorded on an individual basis. If the number of people contributing to the A catch was greater than the number of people interviewed to report B1 catch, the following formula, following Brooks (2004), was used to account for possible under reporting of the B1 catch:

$$B1 = B1_{interviewed} \times (\#\ people\ in\ fishing\ party / \#\ people\ interviewed\ to\ report\ B1\ catch).$$

The total catch per angler was then determined by summing the total Type A and Type B1 catch (AB1) for each trip and then dividing it by the number of anglers in the fishing party. Percent reductions in harvest were estimated for bag limits ranging from 1 to 10 gray triggerfish per person. If AB1 catch per angler was greater than the bag limit being analyzed, the value was re-set to the new bag limit ($AB1_{bag\ limit}$), otherwise no changes to the catch were made.

The following formulas were used to estimate reductions in harvest resulting from bag limits:

$$If\ AB1\ catch <= bag\ limit,\ then\ harvest = A + B1$$

$$If\ AB1\ catch > bag\ limit,\ then\ harvest = AB1_{bag\ limit}$$

Reductions for TPWD and HBS bag limits were calculated in a similar manner as described above, except no B1 catch data were available. If the catch per angler was greater than the bag limit being analyzed, the value was re-set to the bag limit, as described above. If the catch per angler was less than the bag limit being analyzed, then no change to the catch was made. Percent reductions associated with bag limits were estimated relative to the status quo of the 20 fish aggregate bag limit, by mode of fishing. Table 4 provides the monthly percent reductions for bag limits from 1 to 10 gray triggerfish. MRFSS and TPWD output were pooled by mode. Due to small bag limit sample sizes at the beginning of the year (January to March) and at the end of the year (October to December) the samples in these months were pooled to accomplish a minimum sample size of 30 gray triggerfish. The impact of bag limits varied by mode: the largest reductions were observed in the private mode while the smallest reductions were observed in the headboat mode.

Table 4. Projected reduction of gray triggerfish landings by month for various bag limits for A) MRFSS and TPWD charter, B) MRFSS and TPWD private, and C) Headboat. Warmer colors denote higher reductions.

A) MRFSS & TPWD Charter

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	5%	0%	0%	0%	1%	1%	1%
8	0%	0%	0%	0%	0%	7%	0%	0%	0%	1%	1%	1%
7	0%	0%	0%	0%	0%	9%	0%	0%	0%	2%	2%	2%
6	0%	0%	0%	0%	0%	12%	0%	0%	0%	2%	2%	2%
5	0%	0%	0%	1%	0%	14%	2%	0%	1%	3%	3%	3%
4	0%	0%	0%	3%	0%	17%	4%	0%	1%	3%	3%	3%
3	4%	4%	4%	5%	0%	19%	9%	0%	1%	6%	6%	6%
2	16%	16%	16%	9%	7%	23%	14%	2%	4%	9%	9%	9%
1	41%	41%	41%	24%	22%	30%	30%	20%	21%	21%	21%	21%

B) MRFSS & TWPD Private

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10	4%	4%	4%	2%	0%	21%	2%	0%	0%	0%	0%	0%
9	7%	7%	7%	4%	0%	23%	3%	0%	0%	0%	0%	0%
8	9%	9%	9%	5%	0%	25%	5%	0%	0%	0%	0%	0%
7	11%	11%	11%	6%	0%	27%	6%	0%	0%	0%	0%	0%
6	13%	13%	13%	7%	0%	29%	8%	2%	0%	0%	0%	0%
5	15%	15%	15%	14%	8%	31%	9%	7%	0%	0%	0%	0%
4	17%	17%	17%	23%	19%	34%	11%	11%	1%	1%	1%	1%
3	20%	20%	20%	31%	29%	36%	12%	15%	3%	3%	3%	3%
2	30%	30%	30%	40%	39%	38%	15%	20%	13%	13%	13%	13%
1	52%	52%	52%	52%	49%	48%	29%	30%	25%	25%	25%	25%

C) Headboat

Bag Limit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
2	0%	0%	0%	1%	1%	1%	0%	2%	1%	1%	1%	1%

1	4%	4%	4%	5%	5%	3%	2%	4%	7%	4%	4%	4%

Recreational Minimum Size Limit

Length measurements were collected during biological sampling associated with MRFSS, HBS, and TPWD. The length measurement unit recorded was mm. MRFSS and HBS recorded length in FL and TPWD recorded total length. All lengths were converted to inches FL using standard conversion factors and equations summarized in Table 2. The size limit analysis estimated the percent reduction in weight landed. Thus the weight of each fish was required. MRFSS and HBS recorded weights. No weight information was available for TPWD intercepts and some of the MRFSS and HBS samples did not have weight data. When weight data were unavailable it was estimated from length using the equations summarized in Table 2.

Figure 3 provides the length distribution of recreationally caught gray triggerfish by mode (MRFSS, HBS, and TPWD) in 1 inch increments from 2009-2011. Approximately 35% of the fish harvested were below the current minimum size limit of 14 inches FL.

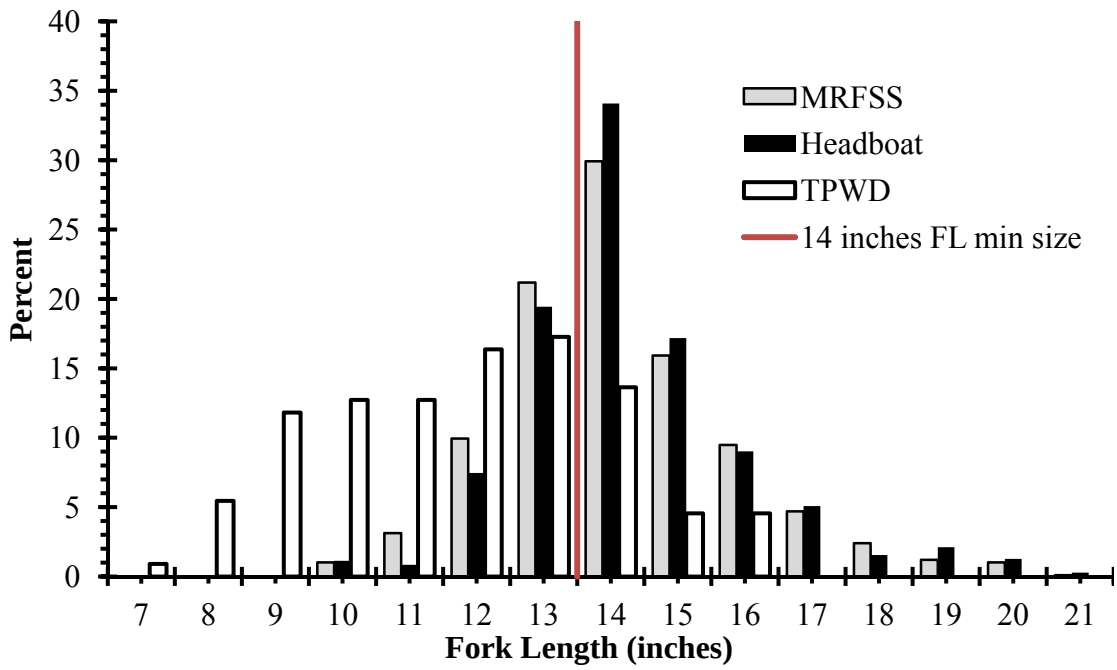


Figure 3. Gulf of Mexico fork length distribution of recreationally landed gray triggerfish from MRFSS, HBS, and TPWD for 2009 to 2011 (n=1,906). The red line denotes the current recreational minimum size limit of 14 inches FL.

Monthly reductions in harvest in weight were calculated for each mode of fishing (charter, headboat, and private/rental) for minimum size limits (MSL) at 1 inch intervals between 15-20 inches as follows:

Percent reduction = $((C - G) - B)/C$, where:

C = catch in pounds ww
G = weight of fish that are greater than or equal to the MSL
B = weight of fish smaller than the 14-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 size limit of 14 inches FL. Due to concerns about low sample sizes, output was pooled for 2009-2011 data. MRFSS and TPWD output were pooled by mode. If a sample size of 30 gray triggerfish was not achieved then the samples were pooled with the nearest months until a sample size of 30 was achieved. HBS had an adequate sample size (>30 gray triggerfish) in each month so pooling was not conducted. Projected MSL impacts varied by month and mode (Table 5).

Table 5A. Projected reductions of gray triggerfish landings by month for various minimum size limits for A) HBS, B) MRFSS and TPWD charter, and C) MRFSS and TPWD private. Warmer colors denote higher reductions.

A) HBS

Size Limit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15	34%	34%	34%	32%	41%	22%	10%	27%	31%	35%	35%	35%
16	54%	54%	54%	43%	63%	41%	33%	39%	48%	56%	56%	56%
17	64%	64%	64%	54%	74%	55%	52%	52%	57%	63%	63%	63%
18	68%	68%	68%	63%	80%	64%	63%	63%	65%	69%	69%	69%
19	72%	72%	72%	63%	82%	73%	65%	63%	67%	71%	71%	71%
20	76%	76%	76%	75%	82%	79%	74%	63%	69%	74%	74%	74%

B) MRFSS & TPWD Charter

Size Limit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15	27%	27%	27%	36%	29%	20%	25%	27%	25%	29%	29%	29%
16	38%	38%	38%	51%	52%	30%	42%	43%	45%	46%	46%	46%
17	50%	50%	50%	63%	66%	55%	53%	57%	56%	58%	58%	58%
18	56%	56%	56%	66%	69%	64%	63%	65%	65%	67%	67%	67%
19	56%	56%	56%	71%	72%	71%	69%	68%	69%	72%	72%	72%
20	56%	56%	56%	72%	74%	82%	73%	71%	72%	76%	76%	76%

C) MRFSS & TPWD Private

Size Limit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15	29%	29%	29%	26%	23%	7%	14%	18%	16%	24%	24%	24%
16	40%	40%	40%	49%	52%	18%	16%	26%	29%	40%	40%	40%
17	40%	40%	40%	63%	71%	27%	16%	30%	47%	44%	44%	44%
18	40%	40%	40%	72%	85%	39%	22%	30%	51%	58%	58%	58%
19	40%	40%	40%	72%	85%	52%	27%	30%	51%	58%	58%	58%
20	40%	40%	40%	72%	85%	52%	27%	30%	51%	63%	63%	63%

2013 Predicted Landings

Amendment 37 is being drafted in 2012 and the resultant management measures will be imposed on the 2013 fishing year. An estimate of monthly commercial and recreational 2013 landings are needed to apply the percent reductions from the various management measures, and determine the predicted landings relative to ACLs and ACTs. Predicted 2013 landings for both commercial and recreational sectors came from Seasonal Auto-Regressive Integrated Moving Average (SARIMA) models. Forecasting future gray triggerfish catches is particularly well-suited to SARIMA models since their landings have a long-term time-series trend and a seasonal trend (Box and Jenkins 1976). The models used past, present, and future exploitable abundance from the latest assessment (SEDAR 9 Update 2011) and a linear combination of historical catch data (accounting for seasonal trends). The incorporation of historical data and exploitable biomass into the model will likely produce future landings that more closely reflect actual future landings than if only historical landings were used as a proxy. Additional details of the SARIMA model projections can be found in the 2012 Recreational Red Snapper Quota Closure Analysis (SERO-LAPP-2012-01).

The historical commercial catch data input into the SARIMA model was the SEFSC's Commercial ACL dataset which was broken into monthly landings. Table 6A provides the SARIMA predicted 2013 commercial landings by month, and Figure 4A displays the annual commercial 2009, 2010, 2011, and predicted 2013 landings by month. The different landings distribution in 2010 could be due to fisheries closures that were in place as a result of the Deepwater Horizon MC 252 oil spill.

The historical recreational catch data input into the SARIMA model were the three recreational datasets (i.e. MRFSS, HBS, and TPWD). The HBS landings were on a monthly scale but the MRFSS and TPWD predictions came from uniformly distributing the landings for each two-month wave to create monthly landings. Predicted 2013 recreational landings by month and mode are presented in Table 6B, and Figure 4B displays the annual recreational 2009, 2010, 2011, and predicted 2013 landings by month. The different landings distribution in 2010 could be due to fisheries closures that were in place as a result of the Deepwater Horizon MC 252 oil spill.

Table 6. Projected monthly 2013 A) commercial landings and B) recreational landings in pounds whole weight for Gulf of Mexico gray triggerfish under status quo management measures with no seasonal closures.

A. Commercial Landings	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Landings (lbs ww)	12,173	11,074	14,241	15,273	16,130	13,572	13,483	16,620	15,577	15,999	16,141	18,410	178,693

B. Recreational Landings	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
HBS	0	0	1,272	2,645	4,196	9,541	5,528	2,313	265	949	0	0	26,709
TPWD CHARTER	23	24	25	26	63	62	118	118	61	63	26	26	635
TPWD PRIVATE	0	0	0	0	0	0	0	0	0	0	0	0	0
MRFSS CHARTER	1,646	1,357	13,358	12,849	33,518	32,385	19,370	19,353	11,826	12,234	3,104	3,226	164,226
MRFSS PRIVATE	7,151	6,456	7,029	6,800	71,207	68,888	18,175	18,180	5,746	5,974	2,666	2,790	221,062
TOTAL	**8,821**	**7,836**	**21,685**	**22,320**	**108,984**	**110,876**	**43,191**	**39,964**	**17,898**	**19,220**	**5,795**	**6,041**	**412,631**

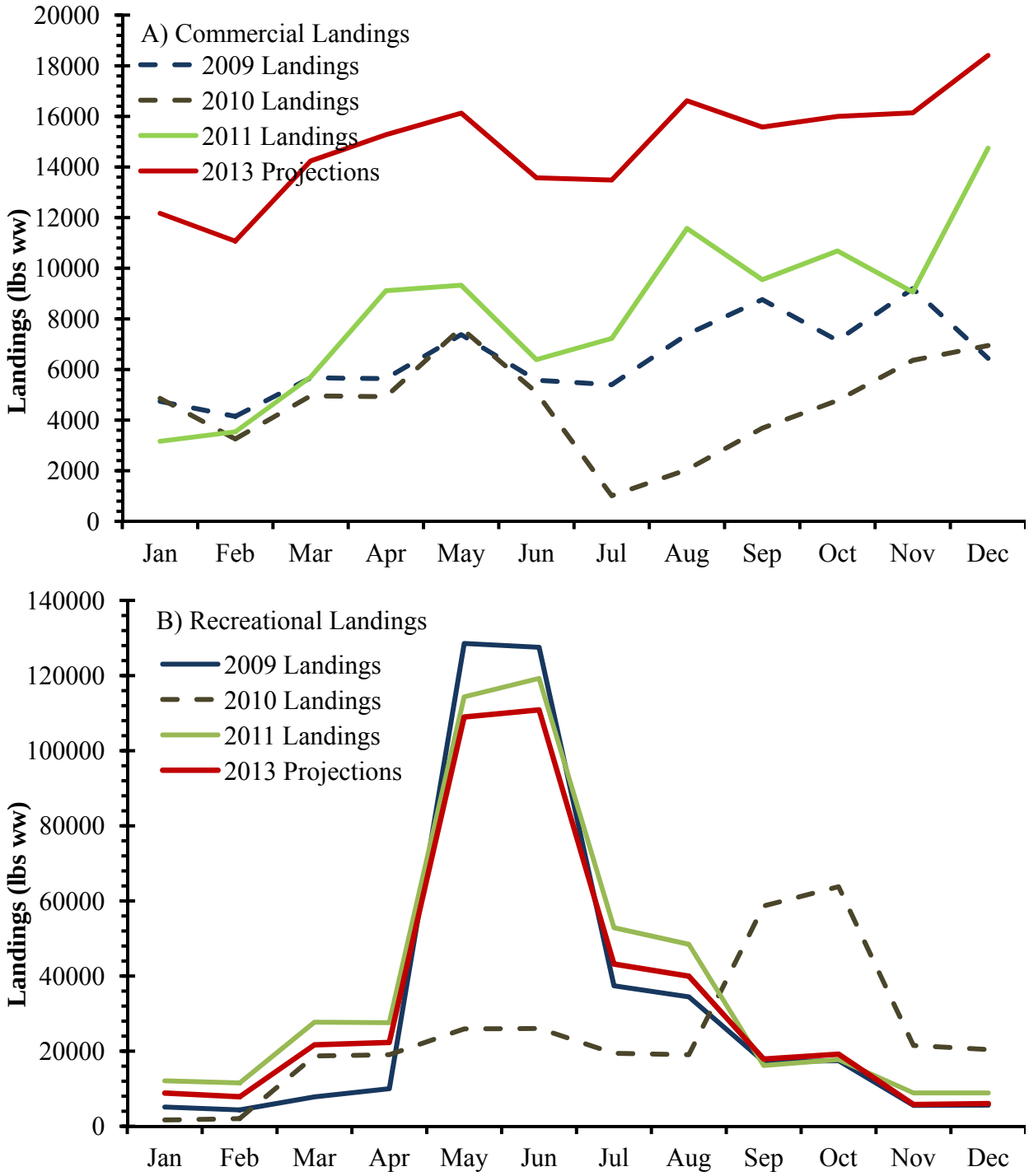


Figure 4. Monthly Gulf of Mexico gray triggerfish landings distributions. Figure A displays the 2009, 2010, 2011, and projected 2013 commercial landings, and Figure B displays the 2009, 2010, 2011, and projected 2013 recreational landings of gray triggerfish in the Gulf of Mexico by month. The recreational landings include MRFSS, HBS, and TPWD landings.

Seasonal Closure Analyses

Landings of gray triggerfish are highly seasonal in the Gulf of Mexico; thus, reductions associated with seasonal closures differ greatly depending upon the time period selected for closure (Figure 4). The impact of a seasonal closure was modeled by converting the number of days closed into a percentage of days closed for a given month. The projected landings during that month were then reduced by the percentage of the month that was closed.

Decision Tools

Percent reductions calculated from changes in management measures were applied to 2013 monthly projected landings to determine how much harvest would be reduced. These results were incorporated into commercial and recreational decision tools. For both models, if month (*m*) was 100% closed, landings were set to zero pounds for all sectors. For the commercial decision tool (CDT), if a month was partially or fully open, the projected monthly commercial landings (CL) were computed as:

$$CL_m = PCL_m * T_m * O_m * \varsigma_m$$

where PCL: projected 2013 commercial landings, T: projected trip limit reduction, O: percent of month open to fishing, and ς: projected size limit reduction.

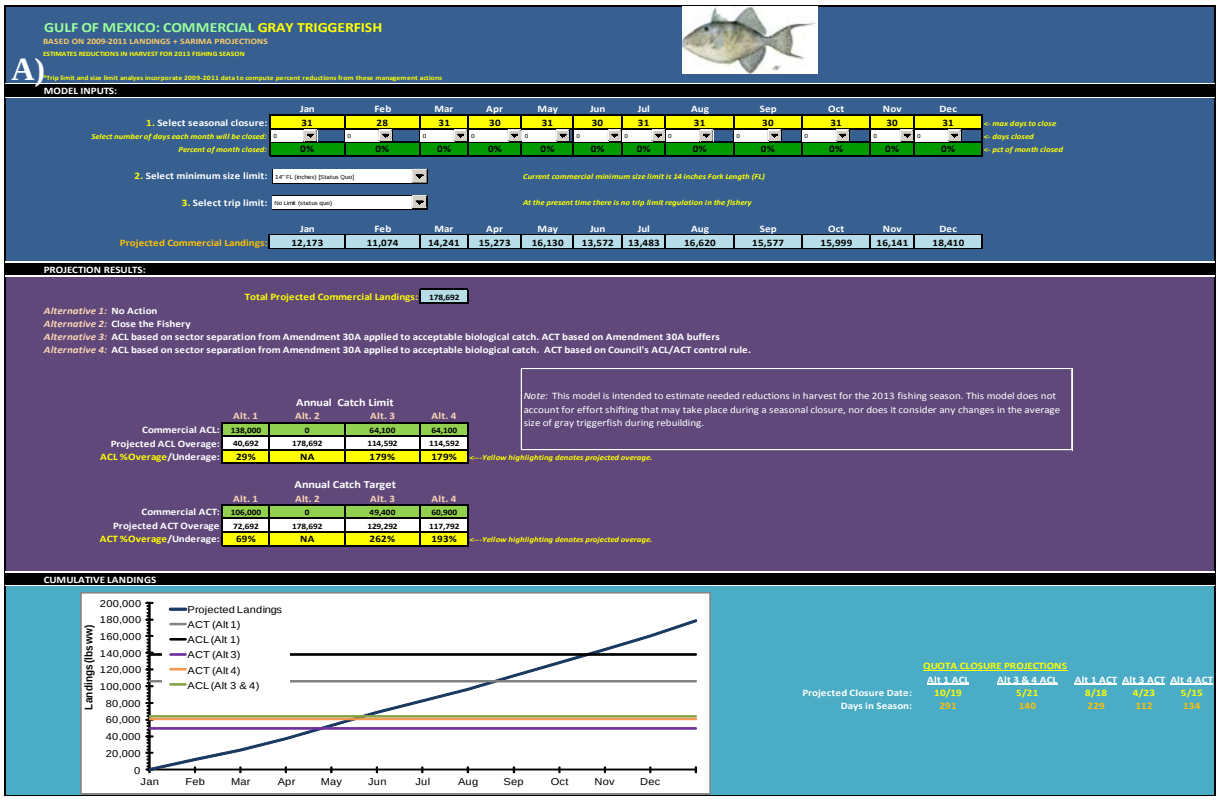
For the recreational decision tool (RDT), if a month was partially or fully open, the projected monthly recreational landings (RL) were computed as follows:

$$RL_{sector,m} = PRL_{sector,m} * O_m * \varsigma_{sector,m} * \beta_{sector,m}$$

where PRL: projected 2013 recreational landings, O: percent of month open to fishing, ς: projected size limit reduction, and β: projected bag limit reduction.

The projected monthly recreational landings were calculated for each sector (headboat, private, and charter) based on various management measures imposed. The sector landings (RL_{sector}) were combined to predict the total recreational landings.

The commercial decision tool (CDT) and recreational decision tool (RDT) were implemented in Microsoft Excel using drop-down menus for inputting desired management measures (Figure 5). Excel was chosen because it is widely available for constituent use.



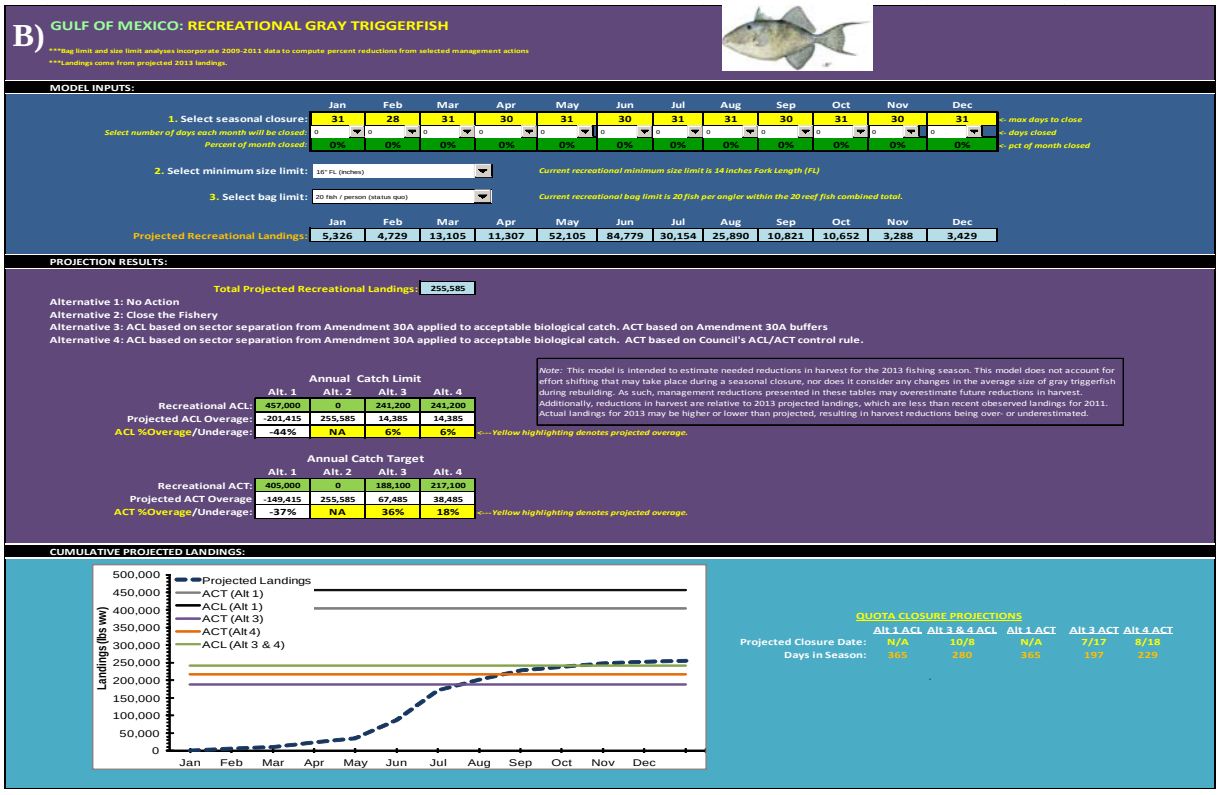


Figure 5. Screenshots for A) commercial and B) recreational gray triggerfish decision tools.

For both decision tools, the projected landings were summed across the year for a variety of user-defined management scenarios and compared to the Amendment 37 ACL and ACT alternatives. For purposes of this analysis, results are only summarized based on the Council's preferred ACL/ACT alternatives. The Council's preferred alternative sets an ACL of 64,100 lbs ww and an ACT of 60,900 lbs ww. In instances where management measures were insufficient to constrain harvest below the ACT, the projected quota closure date was computed.

Results

Commercial

The 25 pound trip limit was predicted to reduce landings significantly whereas the 200 pound trip limit was predicted to have a relatively small influence on reducing the landings (Table 1). However, the reduction from the 25 pound trip limit alone is not enough to reduce the landings below the preferred ACL and ACT alternatives. Therefore, a size limit or seasonal closure needs to be combined with the 25 pound trip limit to accomplish the necessary reduction in landings.

The size limit management measures are not predicted to have significant reduction in landings (>30%) over the course of the year unless it's increased to at least 17 inches FL (Table 3). A factor reducing the effectiveness of the size limits reducing the landings is the high level of non-compliance to commercial size limits. The length distribution of gray triggerfish in the commercial catch had 26% of the fish harvested below the current minimum size limit (14 inches FL) (Figure 2).

The predicted 2013 commercial landings by month had the lowest landings in the early months (January and February) and the highest landings in the later months (August to December) (Figure 4A). Therefore, the largest reductions in landings from seasonal closures would occur in the later months.

Table 7 presents projected commercial landings and days open in the season under a variety of management measures that meet the preferred alternative 4 ACL (64,100 lbs ww) and ACT (60,900 lbs ww). If no management measures are implemented the model predicts the ACT will be exceeded on May 15th. Other than a closed season of 2 months or greater, or a large increase in minimum size (>19 inches FL), a combination of more than one management measure is needed to reduce the landings below the preferred ACT.

Table 7. Projected commercial harvest (lbs ww) of Gulf of Mexico gray triggerfish under a variety of proposed management measures that predict landings below the preferred alternative 4 ACL (64,100 lbs ww) and ACT (60,900 lbs ww).

Closed Season	Days Open	Minimum Size Limit (inches FL)	Trip Limit (lbs ww)	Total Projected Landings (lbs ww)
None	134	14	none	Closed on May 15
Apr-May	304	14	25	56,596

Jun-Jul	304	14	25	56,682
Jun -Jul	304	17	50	48,635
None	365	18	75	57,807
None	365	17	50	60,266
Jun 26-Dec	176	16	none	59,510
Aug-Dec	212	14 (status quo)	50	55,652
Jul-Dec	181	14 (status quo)	75	55,905

Recreational

Despite the exploration of a large range of bag limits there is predicted to be very little reduction in landings achieved until the aggregate bag limit is reduced to 4 gray triggerfish per angler per trip or less. This is a reflection of the fact that the number of gray triggerfish harvested per angler is low.

The size limit management measures have potential to produce significant reduction in landings (>30%) over the course of the year with increases in the size limit to 15 inches or larger. A factor reducing the effectiveness of the size limits reducing the landings is the high level of non-compliance to recreational size limits. The length distribution of gray triggerfish in the recreational catch had about 35% of the fish harvested below the current minimum size limit (14 inches FL) (Figure 3).

The predicted 2013 recreational landings by month peaked in May and June. Therefore, the largest reductions from seasonal closures would occur in the May and June and only moderate reductions in the other months.

Table 8 presents projected recreational landings and days open in the season for a variety of management alternatives for the preferred alternative 4 (ACL = 241,200 and ACT = 217,100 pounds ww). If no management measures are implemented the model predicts the ACT will be exceeded on June 12th. Additionally, a mix of management measures can reduce the landings to prevent the ACT from being exceeded.

Table 8. Projected recreational landings (lbs ww) of Gulf of Mexico gray triggerfish under a variety of proposed management measures that predict landings below the preferred alternative 4 ACL (241,200 lbs ww) and ACT (217,100 lbs ww).

Closed Season	Days Open	Minimum Size Limit (inches FL)	Bag limit (fish/person)	Total Projected Landings (lbs ww)
None	162	14	20	Closed on June 12
May - Jun	304	14 (status quo)	20 (status quo)	192,771

Jun – Jul	304	14 (status quo)	2	206,965
Jan – Apr & Jul - Dec	61	14 (status quo)	18	216,970
Jun – Jul	304	15	20 (status quo)	191,421
Jan – Mar & Oct - Dec	183	16	20 (status quo)	215,056
Jun	335	15	5	215,803
None (status quo)	365	16	3	211,109
Mar - May	273	14 (status quo)	2	207,096
None (status quo)	365	15	1	210,634

Discussion

As with most projection models, the reliability of the CDT and RDT results are dependent upon the accuracy of their underlying data and assumptions. We have attempted to create a realistic baseline as a foundation for comparisons, under the assumption that projected 2013 landings will accurately reflect actual 2013 landings. Uncertainty exists in this projection, as economic conditions, weather events, changes in catch-per-unit effort (CPUE), fisher response to management regulations, and a variety of other factors may cause departures from this assumption. The bounds of this uncertainty are not captured by the model as currently configured; as such, landing rates may be higher or lower than projected. In addition to the aforementioned sources of uncertainty, the modeled reductions associated with management measures assume that past performance in the fishery is a good predictor of future dynamics. We have attempted to constrain the range of data considered to recent years to reduce the unreliability of this assumption.

Any increase to the minimum size limit will increase dead discards, but the effective reduction rate is based upon the assumption of 0% release mortality. The assumption of 0% discard mortality was determined in the Gulf of Mexico gray triggerfish assessments (SEDAR 9 2006, SEDAR 9 Update 2011).

The Deepwater Horizon MC 252 oil spill did cause gray triggerfish landings to decline because of fishing closures in 2010 (Figure 4); however, the length, weight, and numbers of gray triggerfish per trip from 2010 had similar distributions to 2009 and 2011. Therefore, 2010 data was included in the analysis.

Both the commercial and recreational sectors exhibited high levels of non-compliance to size limits (Figures 2 and 3). All of the predicted reductions for the size limit alternatives are based on current fishing practices. It's possible that compliance could be improved through education

and outreach projects that incorporate gray triggerfish size limit regulations. This compliance could achieve additional reductions in landings beyond those considered by this analysis.

Neither model accounts 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 input of historical catch data into the SARIMA predicted 2013 recreational landings came from datasets that had the landings applied on different scales. HBS landings were on a monthly scale, but the MRFSS and TPWD predictions created monthly landings from uniformly distributing the landings for each wave. Therefore, any monthly differences within a wave for the MRFSS and TPWD datasets were not incorporated into the model for seasonal closure analyses. However, the reductions for recreational size limits and bag limits came from intercept data which was available for each month which allowed these two recreational management measures to incorporate monthly differences.

The predicted 2013 commercial landings are higher than landings from the recent years (2009 to 2011) (Figure 4A). However, the predicted 2013 commercial landings incorporation of historical data and exploitable biomass into the model which makes the prediction more likely to reflect future landings than using just historical landings as a proxy.

The predicted 2013 landings generated from the SARIMA model does take into account changes in exploitable abundance as the stock is rebuilding. However, this prediction is only for 2013 and the management measures will likely be applied for more than one year. Therefore, additional changes in the average size of gray triggerfish during rebuilding will not be considered. An increased average size would lead to fishermen capturing their quota more rapidly relative to previous years under similar effort levels. All of these factors would result in more pessimistic projections. As such, management reductions presented in this report may be overestimates, and caution should be taken in their interpretation and use. By contrast, continued adverse economic conditions and rising fuel prices may reduce effort, which would counter these other trends.

In general, the models suggest additional management regulations are necessary to rebuild gray triggerfish within the allowable time frame and constrain harvest. Tables 7 and 8 provide a combination of management regulations to reduce the landings to the preferred alternative ACL and ACT levels. A combination of management alternatives may lessen the hardship on the fishermen since it reduces the need for lengthy closed seasons or large size limits.

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