A Model to Evaluate Recreational Management Measures
using MRIP Data - Final Report

I. Purpose and Need

Once overfishing in a fishery has been eliminated and the overfished stock has been
rebuilt, fishery management regulations can be liberalized. However, there is
considerable uncertainty associated with the outcome of the more liberal fishery
management regulations in an upcoming year. Fortunately, the application of risk
and uncertainty analytical techniques can be used to assess this situation and assist
in formulating an effective fishery management strategy (Dixit and Pindyck, 1994).
While the outcome of a particular regulatory change on the next fish caught is
unknown, this methodology allows the prediction of the probability associated with
the outcome that a particular landed fish will be in a certain size class.

Marine fisheries management for summer flounder includes a system of output
controls that regulate the retention of fish by commercial fishermen and
recreational anglers. The rebuilding program from 2000-2010 included more
restrictive management measure such as minimum fish sizes, per person possession
limits, and closed seasons for the recreational fishery.

This analysis allows for the evaluation of recreational management measures (i.e.,
minimum size, possession limit, and open season) for an upcoming fishing year by
predicting the landings that are likely to occur across all length categories using a
logistic regression analysis. A second analysis estimates the potential total number
of fish landed and caught for a set of fishery management regulations and known
conditions in a specific fishery. These results can then be compared to the
recreational harvest limit for the upcoming fishing year to determine if the
measures will allow for the harvest limit to be achieved.

II. Data, Methods, and Analysis

Sources for the data used in this analysis are listed in subsection IIA. The SAS data
sets provided by the National Marine Fisheries Service (NMFS) have been formatted
and labels for these formatted variables are available from NMFS. The staff of the
Mid-Atlantic Fisheries Management Council (MAFMC) provided the regulatory
history and estimates of stock abundance for the summer flounder fishery. Sources
for other data used in this assessment are available to the public and listed below.

The second subsection (IIB) is a description of the estimation methods and their
derivation used to determine the probabilities that a landed fish falls in a specific
size category. A simple theoretical explanation is provided for the logistic
regression estimation model from which these probabilities are estimated.

The third subsection (IIC) provides an example of how the probability distribution related to the landing of an individual fish by an angler is dependent on the economic, biological, and regulatory environment that exists at a point in time. Since the regulatory objective is to increase the size of the fish stock, the associated risk given the uncertainty of achieving this goal is the value of the fish given up in a previous time period to increase the likelihood of landing a larger fish in some future time period when a larger biomass level exists. Similarly, relaxing these size constraints will reduce the future probability of landing a larger fish in return for the opportunity to harvest a smaller size fish today. The effect of these regulatory changes on the probabilities of catching or landing a fish is presented for a specific regulatory change.

II. A. Data

The Marine Recreational and Fisheries Statistics Survey (MRFSS) and the Marine Recreational Information Program (MRIP) are the primary sources of data for this assessment.   The MRIP and MRFSS data, which has been formatted in SAS, is available for download at:

Http://www.st.nmfs.noaa.gov/st1/recreational/sasdata/

Individual years of intercept data are available under the subdirectory:

Intercept Data/ag/

This data set presently covers the years 1981 to 2011 for the Atlantic and Gulf coastal states. This SAS data set is fully described in the accompanying SAS programs, with labels taken from the descriptions provided by NMFS at:

http://www.st.nmfs.noaa.gov/recreational-fisheries/access-data/data-downloads/index

in the excel spreadsheet file:

MRIP_Survey_Variables.xls

that is available from this site.

Additional information added to this data set was collected from a variety of websites and sources. The regulatory histories for summer flounder as well as its abundance index (SSB) were provided by the staff of the MAFMC from stock assessment reports prepared by the NMFS.[1] Commercial ex-vessel price information is available at:

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[1] Jessica Coakley (Mid-Atlantic Fisheries Management Council) provided the historical time series of summer flounder stock abundance estimates derived by the

http://www.st.nmfs.noaa.gov/commercial-fisheries/index

Formatted, annual and monthly data by species and state for landings and value for commercial fishing operations is readily available and easily downloaded from this website. Specific species can be identified by name on this site and downloaded for use in updating this summer flounder assessment. This data is inflated by the producer price index for fish to a base year of 2011.[2] Their website at:

http://www.bls.gov/news.release/pdf/ppi.pdf

provides detailed instructions for accessing this information and provides updated information concerning its availability and any problems that may have developed over time with the time series. This is also the source for the fuel cost data included in the summer flounder size class assessment.[3] National population size is found at the Bureau of the Census at:

http://www.census.gov/services/sas/historic_data.html

The prime rate, which is used as a proxy for capital costs, is taken from the Wall Street Journal website:

http://www.bankrate.com/rates/interest-rates/wall-street-prime-rate.aspx

All other variables and data used in this summer flounder assessment are calculated as part of the analysis using the accompanying SAS programs. For example, the two variables representing the total landed fish caught or landed by state is calculated as an output from the SAS program "MAFMC3" and the season length in days variable is simply a count of the number of days between the regulated opening and closing of the fishing season which the analyst enters in the SAS program "MAFMC5."

II. B. Method

Uncertainty theory is used to determine the impact on the probability of landing or catching a fish in a certain size class from a change in the existing fishery management infrastructure in the presence of insufficient information. This section provides an explanation of the theory and the methods utilized to operationalize the concepts of risk and uncertainty (Figure 1) for this particular type of fisheries management problem. Uncertainty theory is applied to determine the impact on the probability of landing or catching a fish in a certain size class from a change in the

National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA.

[2] Bureau of Labor Statistics; commodity code 0223.

[3] The producer price index for fuel (commodity code 057303) was used as a proxy for fuel cost.

existing fishery management regulations in the presence of imperfect information. Once this probability is estimated, it can be applied to the total number of fish landed or caught in each state to determine the distribution of catch by size category for a given set of proposed regulations.

The summer flounder fishery consists of both commercial fishermen and recreational anglers who respectively maximize profits and satisfaction from fishing. These two consumptive user groups are linked through the fish stock populations that act as a constraint on the maximum achievable by either group; i.e.,

$$\text{Max } H = \int e^{-rt} \pi \; dt + \int e^{-\partial t} \mu \; dt$$

$$\text{s.t. } dB/dt = B[G(B) - M - F_c - F_r]$$

where
    π is profits,
    μ is satisfaction,
    e^{-rt} is the commercial discount factor,
    $e^{-\partial t}$ is the recreational discount factor,
    B is biomass,
    $G(B)$ is the growth rate of biomass,
    M is natural mortality, and
    F is fishing mortality from commercial (c) and recreational (r) fishing.

The effect of this nonseparability in production assumption is that changes in demand for the in situ living marine resource by the commercial fishermen has an indirect impact on the supply of fish available to the recreational angler via the stock constraint and vice versa. For example, an increase in the ex-vessel price of fish in the commercial market would reduce the number of fish available to the recreational sector, which would result in a negative coefficient on price in an analysis of the recreational sector. Solving for the derived demand for fish in the recreational sector reveals that the solution is a function of the variables representing both the maximization of profit and satisfaction as well as abundance:

$$y = Y(\pi, \mu, B)$$

The outcome is that for each size class of fish, a separate functional form can be derived that is a function of the variables representing the maximization objective of each user group as it is influenced by the regulatory environment;

$$X_i = f_i \, (\pi, \mu, B) \qquad i = 1, \ldots, k \text{ size classes.}$$

While these theoretical relationships are well understood (Clark, 1976), data collection programs for both the recreational and commercial sectors have primarily focused on the stock population dynamics. This has resulted in imperfect information about the structural equations that actually drive these different markets and determine the size class of each fish landed.

Imperfect information is, of course, the core element of uncertainty (Dixit and Pindyck, 1994). The uncertainty in this analysis is that which is associated with the size class of the next fish landed. Fortunately, in the recreational fishery, interviewers sample the landed fish (type A) and record the size, species, and weight of each individual. This information recorded in the MRIP and MRFSS database provides a set of data that ranges from 1980 to 2011. Information from additional data sets, such as ex-vessel summer flounder prices, national population, fuel prices, and discount rates that are theoretically relevant can be added to this data set as well as regulatory measures that have been adopted over time and biomass abundance levels.

While data has been collected on the size and weight of recreationally caught fish, the subsequent population dynamics estimates of numbers and pounds of fish caught by state does not include their distribution by size class; i.e., cohort. This shortcoming is addressed using historic recreational landings interview data to determine the probability that a landed, caught, or discarded fish falls within a given size category. This probability distribution is then used to redistribute the state level estimates of numbers of landed, caught, or discarded fish into each size class. An additional step in the analysis provides estimates of the number of fish landed and the numbers reported caught for each state based on the known or predicted spawning stock biomass level and the proposed fishery management regulations which can then be decomposed into numbers of fish in each size class.

Logistic regression analysis has been discussed in Agresti (2002), Allison (1999), Collett (2003), Cox and Snell (1989), Green (2007), Hosmer and Lemeshow (2000), Stokes, Davis, and Koch (2000), and others cited in the references section is the methodology of choice when the relationship that is being investigated is between a discrete response, such as the size class of a landed fish, and a set of explanatory variables that include the regulatory environment, the biological conditions existing in the marine environment, and the economic conditions existing in the commercial and recreational fishing marketplace. The logit model where multiple possible outcomes exist can be extended to a multinomial model referred to as a generalized or baseline-category logit model of the form (McFadden, 1974):

$$\text{Log}(\Pr(Y=i|x)/\Pr(Y=k+1|x)) = \alpha_i + \beta'_i x \qquad i = 1, \ldots, k$$

Where α_i are the intercept parameters, and
β_i is the vector of the slope parameters.

II. C. Analysis

In this analysis the backward elimination option was used in the estimation of the theoretical model parameters to ensure that the best predicted value of the estimated probabilities by size category was achieved. The accompanying SAS programs include a full set of diagnostics to ensure the researcher that the best fit is

being achieved.[4] In the next subsection (II.C.2), these results are used in a policy analysis of a proposed recreational fishery management regulatory change. The final subsection of this analysis section is a discussion of the assessment methodology that provides state level landing and catch predictions when a biological stock assessment is not available or is considered obsolete.

II. C. 1. Statistical Estimation Results

Table 1 provides statistical results for a subsample of estimated parameters from the summer flounder logistic regression procedure. The first four parameters reflect information about the recreational fishing experience. The second set of four parameters represents the impacts of fishery management regulations designed to conserve recreationally harvested summer flounder.[5] The last set of parameters reflects extra-fishery effects that were expected to influence recreational angler behaviors indirectly.

As expected, the estimated parameter representing the Weight of an individual fish landed is highly significant and negatively related to the probability that a fish will be landed in a size category. That is, fewer large fish are landed than smaller fish by weight. Variables that approximate landings limit levels such as total summer flounder landed (TotSFL) have a small positive impact, while actual abundance levels (SSB) have a small negative, significant effect on the probability of a summer flounder being in a specific size category. Similarly, the effect of the number of people in a fishing party (PARTY) is small but significant for the probability of a fish landed being in a particular size class.

As the history of summer flounder fishery management has been aimed at achieving stock conservation objectives, it is not surprising to see that the negative impact of minimum size limits offshore (minsLm) in the EEZ and state allocation recreational target (ARecTrgt) parameter estimates are generally negative and statistically significant. However, the inshore minimum size limit (minslmi) in state territorial seas and the possession limits (PosLmt) both acted to increase the probability that a

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[4] Updating the data set for summer flounder when new information becomes available or applying these general programs to a new species of interest to the MAFMC would require the estimation of a new set of parameters that minimize the value of the likelihood function used in this logistic regression procedure.
[5]The fishery management history is included as specific changes in area, possession, and size limits as well as the dates when specific amendments to the management plan were adopted. These FMP and amendment qualitative variables were dropped from the model statement since they were not statistically significant once the specific size and possession limits were incorporated in the analysis. They remain as part of the program in the event that conditions in the fishery change at some point in the future.

Table 1: Analysis of Maximum Likelihood Estimates for the Probability that a Fish will be Landed in a Given Size Category.

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
---------------------------Recreational Fishing Experience Variables------------------					
Weight	1	-12.2533	0.0418	86011.0892	<.0001
TotSFL	1	0.000036	6.19E-06	33.7463	<.0001
SSB	1	-8.86E-06	2.03E-06	19.0343	<.0001
PARTY	1	-0.00268	0.000621	18.646	<.0001
---------------------------Regulatory Variables---------------------------------------					
minsLm	1	-0.0211	0.013	2.6174	0.1057
minslmi	1	0.0287	0.00497	33.3697	<.0001
PosLmt	1	0.00231	0.00153	2.279	0.1311
ARecTrgt	1	-0.00214	0.000296	51.966	<.0001
--------------------------Extra-Fishery Variables-----------------------------------					
sfldp	1	-0.8373	0.0477	308.1836	<.0001
FPPI	1	0.0034	0.000272	156.1948	<.0001
pr	1	0.0702	0.00567	153.3822	<.0001
NP	1	7.46E-09	2.71E-09	7.545	0.006
NPd	1	-0.4741	0.0488	94.5362	<.0001
omega3	1	-0.1824	0.0397	21.0956	<.0001

landed fish would be in a given size category. This tends to suggest that decreasing the offshore size limit while increasing the possession limit would tend to increase the probability that a landed fish would be in a given size category. One possible explanation for this result is that possession of an undersized fish carries with it a risk of a fine for violating the rules, but continued fishing after reaching the possession limit does not. That is, better fish, that are caught after the possession limit has been reached, can be substituted for a lesser fish that is already in an angler's possession.

The extra-fishery variables that affect recreational angler behavior behave as expected. The commercial ex-vessel summer flounder price per pound (sfldp) reduces probabilities of recreationally landed fish in a size class since it represents increases in commercial fishing effort and reduced stock abundance. The index of diesel fuel prices (FPPI) and prime rate on capital investment (pr) parameter estimates has the opposite sign since rising commercial fishery fuel and capital asset costs reduce fishing effort by that fleet.[6] National US population (NP > 0 and NPd < 0; the latter reflects a change in the time series base after 1999) indicates that demand for seafood affects the probabilities of recreationally harvested seafood

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[6] Diesel fuel is generally the most common fuel type used by full-time, commercial fishermen and the prime rate is a proxy for the unit cost of a loan to purchase or build a commercial fishing vessel.

products. Lastly, the change in consumer attitudes because of the increased health effects of omega-3 compounds (omega3) found naturally in marine fish species has had a negative effect on recreational anglers that may be a result of increased demand for marine fish by consumers at large.

These core variable parameters tend to confirm the theoretical contention that recreational fishing for summer flounder is not separable in the production of fish from the commercial fishery. This does not mean that these results should hold for other fisheries where, for example, a commercial fishery does not exist or may only be a minor contributor to total landings. In the case of other fisheries to which this set of SAS programs may be applied, other results are possible for these core variables and for the variables not displayed here that represent different interactions between fishing season, hours fished, primary or secondary targeted species, etc. The effect of these variables can be inspected as part of the output of the SAS program MAFMC5 (Table A.1 in Appendix A).

II. C. 2. Fixed Stock Assessment Landings and Catch Estimates by State

Once estimated, the parameters are used to decompose state level recreational numbers of fish landed, caught, and discarded for a set of proposed recreational summer flounder fishery management regulations. The regulations being proposed for 2013 are inshore and offshore minimum size limit for summer flounder of 16 and 17 inches. Second, a fishing season of 153 days; lasting from May 1 to September 31. Lastly, possession limits ranging from 3 to 5 fish across all size classes of fish. These changes are being proposed as a result of an estimated increase in SSB to 60,074 from 58, 711 in 2012. Information on recreational fishing has been provided for 2012 and is utilized in this analysis.[7] This approach has the advantage of being based on variable values from the year closest to 2013 from which the change in values can be calculated.

The attached excel file:

SummerFlounder16.xlsx

provides estimates of the numbers of fish landed (type A) in Table 2. Table 2 decomposes the total number of fish landed estimated in a stock assessment for each state into numbers of fish in each of 40 size classes (nszcl1 to nszcl40) for a size limit of 16 inches and possession limits of 3 fish. Table 3 decomposes state level estimates of numbers of fish landed into 40 size classes (nszcl1 to nszcl40) for a size limit of 17 inches and a possession limit of 3 fish. Tables 2 and 3 can be expanded to include estimates of number of fish landed by size class and state for discarded as well as total catch (landed plus discarded fish). The last row of each table provides a coastal aggregation of the individual state effects. Comparing the size distribution of Tables 2 to 3 for the case of a 17-inch minimum size and a 3 fish

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[7] See file: fluke_MRIP_2011-2012.xls for the data used in this example.

possession limit provides some indication of the subtle changes that could be expected when the state and coastal totals from the stock assessment are held constant. Both state level and coast wide changes can be compared for different scenarios summarizes in these tables.

According to Table 2, the 3 fish possession limit (possession=3) and a 16-inch minimum size limit result in landed fish starting at size class 10 (nszcl10) for two states with the vast majority of landings occurring at size class 16 (nszcl16) and above. When the minimum size limit is increased to 17 inches, Table 3 indicates that landed fish also start in size class 10 (10 inch fish), but at a reduced level compared to the 16-inch size limit. Increases in landed fish by size class for the 17-inch minimum size rule do not exceed the landed fish by size class for the 16-inch rule until size class 18 (nszcl18) in Table 3.

Tables B.1 to B.9 in Appendix B (SFldrSZClEstimates.xlsx) for Type A and B1 fish indicates that increasing the possession limit from 3 to 5 summer flounder while holding the size limit constant at 16 inches in Tables B.1 to B.9 results in a decrease in the numbers of discarded fish while landed fish decline and total caught declines in size class 18. However, in size class 24, the number of landed, discarded, and total caught fish increases when the possession limit increases from 3 to 5 fish. This indicates that the distribution of landings has shifted to larger, and implicitly more valuable, summer flounder with the increase in the possession limit while size is held constant.

However, with a size limit of 17 inches in Tables B.10 to B.18, landed size class 17 inch fish decline by only two thousand fish as the possession limit increases from 3 to 5 fish, discards and total catch initially increased with the possession limit set at 4 fish and then decline with a 5 fish possession limit. Total catch at the 5 fish possession limit is still higher than at the 3 fish limit. For size class 24 fish, the landings increase as the possession limit increases from 3 to 5 fish, but the discards and total catch decline with the change to a 4 fish possession limit and then increase when the possession limit is increased to 5 fish with a net loss in total catch relative to the 3 fish possession limit.

Comparisons between 16 and 17 inch minimum size classes tend to support the case that higher size classes resulted in more or the same number of fish being landed in the minimum size class with 3, 4, or 5 fish possession limits. Of course, the determination of the success or failure of these regulations depends on the fishery management objectives these possession and bag limits were designed to achieve.

II. C. 3. Quick Assessment Methodology Results

The evaluation of proposed fishery management regulations can be accomplished using an existing stock assessment as the basis for the decomposition of the landed, discarded, or caught fish. However, a stock assessment is not always available or cannot be developed in a timely manner to address a new proposed rule.

Fortunately, sufficient information is available in the MRIP database to estimate the number of fish that would result from a proposed rule for each state. This estimated number of fish could then be used as the basis for a decomposition of landed, discarded, and caught fish into different size classes. This quick assessment methodology (QAM) is not a replacement for a standard stock assessment. Instead, it is a methodology that allows the potential of proposed fishery management regulations to be investigated to avoid the costs of a standard stock assessment for a specific fish species. If the results of the QAM and subsequent size class decomposition indicate that an improvement in recreational fishery performance is possible, then a stock assessment could be conducted to verify the results that are then used as a basis for the adoption of the new regulations. Two SAS programs are included that can be used to conduct this QAM:

MAFMC7 – estimates the parameters of fish landed and caught models

MAFMC7A - predicts the total numbers of fish landed and caught

Nearly 77 percent of the variability in the numbers of fish landed and caught is explained by the parameters estimated in the SAS program MAFMC7. The attached program (MAFMC7) output provides a list of parameter values and their statistical significance level. These estimated parameters are then used in the second SAS program (MAFMC7A) to predict the numbers of fish landed and caught for each east coast state reporting summer flounder landings.

Table 4 below provides the expected changes in numbers of fish landed (Type A + B1 fish) and numbers of fish caught (Type A + B1 + B2 fish) that results from using the MAFMC7 and MAFMC7A programs to develop a quick assessment of the proposed summer flounder fishery management regulations. The analysis indicates that increases in the minimum size limit results in an increase in the numbers of fish landed (Type A fish) while an increase in the possession limit for a given minimum size fish results in a decline in the numbers of fish landed. The numbers of fish caught (Type A + B1 + B2 fish) also decline as the possession limit increases for a given minimum size fish.

Table 4: Numbers of Coast Wide Fish Landed and Caught (000 of fish)

Minimum Size (inches)	Possession Limit (number of fish)	Numbers Landed (Type A+B1)	Numbers Caught (Type A+B1+B2)
16	3	1585	3715
16	4	1777	4032
16	5	1941	4296
17	3	1668	3750
17	4	1870	3982
17	5	2043	4530

If, for example, a decline in numbers of fish caught were desired based on this assessment of the interview data for type A+B1+B2 fish, various combinations of minimum sizes and possession limits could be analyzed to determine how to achieve this goal. Beginning with a set of regulations that establish a minimum size limit of 16 inches and a possession limit of 3 fish, increasing the possession limit from 3 to 5 fish causes a 22% increase in the numbers of fish landed (A + B1) and a 16% increase in numbers of fish caught (A+B1+B2). These results because the inshore parameters while negative are slightly less negative than the parameters on offshore possession limit and minimum size are positive; i.e., the positive offshore possession and minimum size parameters are greater than the negative value of the parameters on the inshore possession and minimum size variables.

This assessment of proposed management regulations summarized in Table 4 suggests that increasing the minimum size limit on fish landed even if it allows the retention of one or more undersized fish by each angler will result in an overall decrease in discard levels and a slight increase in landed fish for possession limits of 3 and 4 fish. However, discards increase between minimum size limits of 16 and 17 inches for the 5 fish possession limit. More importantly, when combined with the distribution of catch by size class (Tables 2 and 3), or as in the attached file "SFldrSZClEstimates.xlsx", a set of programs exist that can be used to decompose these state recreational numbers of fish landed and caught into a distribution by size class as well as predicting changes in state and coastal landing levels.

III. Conclusions

Normally, model limitations would be directly or indirectly related to a lack of important information or variables vital to the outcome of an analysis. In this case, this lack of relevant information is the raison d'etre for the application of uncertainty methodologies. For example, any recreationally harvested species could be analyzed using this set of programs by changing the species selected, from summer flounder used in this case, in MAFMC3, and by editing the commercial ex-vessel price data for a coexisting commercial fishery and the fishery management history for the species of interest. Slot limits, as another example, can be incorporated into this model by taking advantage of the variable that represents state minimum sizes in conjunction with the exclusive economic zone size limits. Alternatively, the size distribution can be estimated based on probabilities that exclude regulatory restrictions on size of fish. Then, slot limits effects can be determined from changes in yield for different minimum and maximum sizes.

Shortcomings that do exist in the data collection programs are the result of their focus being solely on the biological attributes of the fishery, and will no doubt remain an ongoing problem for fisheries management. Similarly, the continued parochial focus of the economic analyses on recreational elements of a fishery will also continue to inhibit a holistic approach to fisheries management. Fortunately, these limitations are addressed by the uncertainty methodology and substantial

expansions of this model are only limited by the theoretical derivations necessary to develop them and the capabilities of the available computer software and hardware.

This model is a simple application of time proven methods to deal with imperfect information in a marketplace or natural environment. While the concepts underlying this analysis are relatively simple, their application is more complex. This report is intended to explain the steps necessary to develop both estimates of state landed or caught fish and their distribution across fish size categories for different regulatory scenarios; a step by step user guide is provided in the attached appendix. The programs in steps I to VII are used if the existing data set are modified for another species of recreationally harvested fish. These steps will update the database needed to estimate new sets of coefficients for use in a policy analysis of any existing or proposed fishery management regulations.

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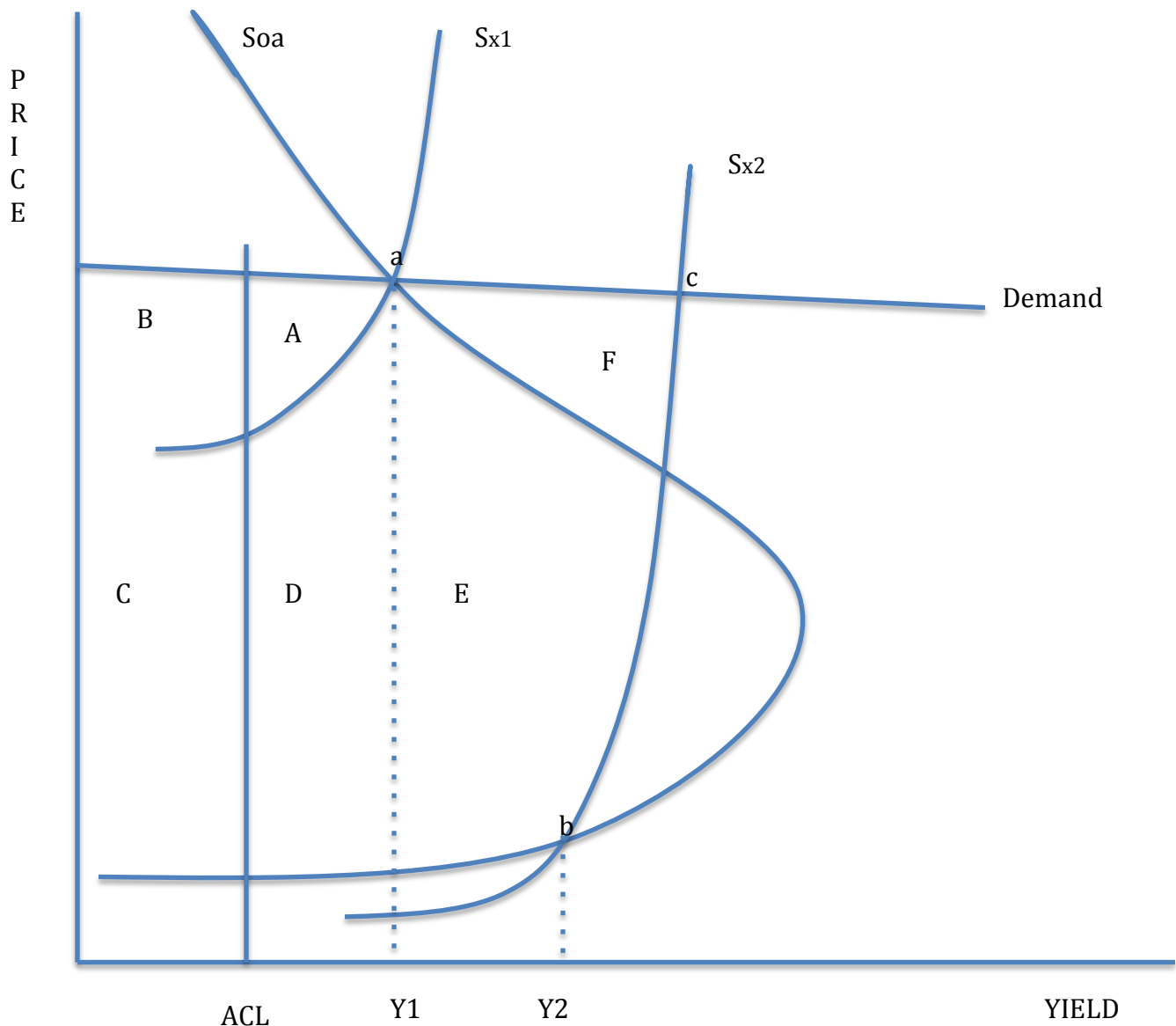
Figure 1: Risk and Uncertainty

Figure 1: The Gordon-Schaeffer-Copes model of a fishery demonstrates the level of risk associated with a potential increase in landings from a fishery after the biomass has been rebuilt to a sustainable level of yield (Anderson, 1986). The initial equilibrium (point a) has a yield of Y1 as a result of a fished stock that is overfished (X1). This represents a long-run equilibrium since the open access supply function (S_{oa}) is equal to both the demand and the stock constant supply function (S_{x1}). The net benefits corresponding to this equilibrium are equal to areas A+B. Correcting the overfished fish stock requires setting an annual catch limit (ACL) equal to ACL causing a loss in net benefits equal to area A. The ACL limit on yield allows the stock to grow to the precautionary size (X2) that results in a shift in the stock constant supply function to (S_{x2}). The S_{oa} and S_{x2} are in equilibrium at point b where yield has increased to Y2 and net benefits are equal to areas A+B+C+D+E+F. Unfortunately, supply (S_{x2}) is equal to demand at point c, which is an unsustainable point for the fishery. That is, achieving point b has an extremely low probability of success. In the context of fisheries managers evaluating proposed regulations to correct this overfished fishery problem, the risk, equal to the foregone net benefits from setting the ACL represented by area A, should be at least

equal to the expected value of the promised outcome; i.e., the probability of success of achieving point b multiplied by the increase in net benefits (the area equal to A+B+C+D+E+F).

Appendix A

Allocation of Recreational Catch by Size Category: A Users Guide

Introduction

This user guide explains the use of a series of programs written in the SAS programming language that accesses the Marine Recreational Fisheries Statistics Survey (MRFSS) and Marine Recreational Interview Program (MRIP) data files to estimate the probability that a fish landed by an angler falls within a certain size category given that it is of a particular species, which in this case is summer flounder. Uncertainty theory is applied to determine the impact on the probability of landing or catching a fish in a certain size class from a change in the existing fishery management infrastructure in the presence of insufficient information. Once this probability is estimated, it can be applied to the total estimated number of fish landed or caught in each state to determine the distribution of catch by size category for a given set of regulations.

Program Steps

The first three steps are necessary to create the permanent SAS data set for a particular species and to update that data set when additional data becomes available. Step IV creates the final database for use in the subsequent statistical analysis. Step V is necessary for the estimation of the probabilities and step VI estimates the probabilities for a given set of conditions in the fishery from which the final numbers of fish by size category are predicted. Step VII develops parameter estimates based on historical data of the number of fish landed or caught by state. These parameters are used in step VIII to estimate the number of fish landed or caught in each state for use in step VI in the event that a rapid assessment of proposed fishery management regulations needs to be conducted.

Step I

A. The MRIP and MRFSS data in SAS format is available for download at:

http://www.st.nmfs.noaa.gov/st1/recreational/sasdata/

Individual years of intercept data are under the subdirectory:

Intercept Data/ag/

which covers the years 1981 to 2011.

B. Once downloaded to your PC hard drive, the data contained in any given year can be accessed using the SAS program:

MAFMC1

Two lines need to be modified in this program. The first is the line starting with libname sasout. A libname with a path on the SAS server for which you have write access must be specified by modifying the path that is contained within the single quotes:

```
 libname sasout 'c:\Users\John Ward\My Documents\My SAS Files(32)';
```

The second modification is on the line starting with libname xptin. A libname with the xport engine and a path on the SAS server where the .xpt file resides must be specified by modifying the path that is contained within the single quotes.

```
libname xptin xport 'c:\Users\John Ward\My Documents\My SAS
Files(32)\int2011ag.xpt';
```

This program is run for each year of the MRIP and MRFSS data that is to be used in the subsequent SAS program.

Step II.

Once the data files have been expanded, the next program is:

MAFMC2

This program reads in the different wave (1-6) and record type (1-4 and 9) data to create a data file for each of the 6 waves in a given year representing type A, B1, and B2 fish categories. Some variables, used in multiple record types and years, are recorded with different types of formats (character versus numeric) that result in error messages when the data files are combined.

A. The first stage in this program is a set of macro comments that set the input and output data files. MAFMC1 creates the input data files from the downloaded data files that are stored on your computer directory. The output data files, created by MAFMC2, are temporary SAS files that are used in the next program MAFMC3. The macro commands in MAFMC2 need to be modified for each year for which data is to be compiled. As an example, the second to fourth lines of the program are:

```
 *----2011 Data-------------------------------------------------;
 *---------*Record Type 1 Year 2011 Wave 1------------------;
%let A = i12011wave1;
%let B = sasout.i1_20111;
```

The first two lines are comments that identify this program is working on 2011 Data and that it is reading in record type 1, wave 1 data for 2011. The first %let statement identifies the temporary SAS output file as i12011wave1 and the input file is identified in the second %let statement that reads the permanent SAS data file i1_20111. These file names can be easily changed using a find-replace editing

command that finds the year (in this case, 2011) and replaces it with a new year, such as 2012 when that year's recreational data becomes available. Once these data input and output file names have been changed the program can be run to create data files that are based on wave; e.g.,

```
 *--------------------Record Type 1-4 Year 2011 Wave 1------------;
 %let wave1 = i2011wave1;
```

B. The second stage in this program is to convert the record types to a standard format; e.g.,

```
non_list = input(on_list,11.);
drop on_list;
rename non_list=on_list;
```

This set of commands creates a new variable "non_list" using the input statement that creates a format of 11 characters in length. Then the SAS variable in the SAS data set is dropped and "non_list" is renamed "on_list" to replace it. This process is repeated for each variable that has this record type conflict.

C. The next stage in this program is to label each variable in the SAS data set and to identify the values of the qualitative variables.

```
label ID_CODE='Intercept Interview Identifier'
            Surtyp= 'Survey Type'

*Survey Type: 2011;
      if Surtyp = 1 then SurtypA = 'Intercept Finfish Survey';
      if Surtyp = 2 then SurtypA = 'Shrimp Survey';
      if Surtyp = 3 then SurtypA = 'Spiny Lobster Survey';
```

D. The final product of this program is a set of temporary data files for each wave within a specific year. This set of files is created by merging the files created for each record type into a single file for a wave.

Step III.

These temporary data files for each wave within a year are then combined into a permanent SAS data file using:

MAFMC3

A. The initial stage of this program identifies where the permanent SAS data file will be saved on the PC, using the libname statement. Next, are the macro commands that identify the permanent SAS output data file (%Let A = sasout.i2011;) and the temporary SAS input data files (%Let B = i2011wave1;). These wave files created in MAFMC2 are combined into a single data file for a specific year (sasout.i2011). Once this data file has been created using the set statement, the if statement limits

the data in the file to summer flounder by selecting on species code 88570301; that is, it selects summer flounder as the species that will be contained in the permanent SAS data file:

```
libname sasout 'c:\Users\John Ward\My Documents\My SAS Files(32)';
%Let A = sasout.i2011;
%Let B = i2011wave1;
%Let C = i2011wave2;
%Let D = i2011wave3;
%Let E = i2011wave4;
%Let F = i2011wave5;
%Let G = i2011wave6;
data &A;
     set &A &B &C &D &E &F &G;
           if sp_code = 8857030301;       *Summer Flounder;
              run;
```

From this point forward the data set consists exclusively of the species selected by the

```
if sp_code = 8857030301;
```

command.

B. The next stage in this program is a set of commands that determine whether the selected species is the primary target of the fishing trip (DPrim1= 1), is a secondary target of the fishing trip (DPrim2 = 1), it was an incidental catch, or is not a target of the fishing trip (NTPrim1 = 1); that is, no fish species was identified as the target of the fishing trip.

C. Beginning with the comment:

```
*---------Establishment of Size Class------------------------------;
```

is a set of commands that converts the fish length in millimeters to one inch size classes.

D. The program ends with a proc chart command that creates a series of histograms that display the distribution of number of fish by size class and state of reported landing for this specific year and fish species. A proc means command provides the total number of fish reported landed for the interview data. This total number of fish is used in the next step as a variable in the estimation of the probability of a fish being landed in a certain size class.

Step IV.

The final database is created using:

MAFMC4

which combines the annual permanent SAS data files into a final combined permanent SAS data file called sasout.SF8111. This file name indicates that data from 1981 to 2011 have been combined into one database. The first stage

```
data sasout.SF8111;
set sasout.i1981 sasout.i1982 sasout.i1983 sasout.i1984 sasout.i1985
sasout.i1986 sasout.i1987 sasout.i1988 sasout.i1989 sasout.i1990
sasout.i1991 sasout.i1992 sasout.i1993 sasout.i1994 sasout.i1995
sasout.i1996 sasout.i1997 sasout.i1998 sasout.i1999 sasout.i2000
sasout.i2001 sasout.i2002 sasout.i2003 sasout.i2004 sasout.i2005
sasout.i2006 sasout.i2007 sasout.i2008 sasout.i2009 sasout.i2010
sasout.i2011;    *MAFMC Summer Flounder Data Set 1981 to 2011;
```

can be modified to allow the database "sasout.SF8111" to be updated when 2012 data becomes available:

```
data sasout.SF8111;
  set sasout.SF8111 sasout.i2012;
run;
```

Some additional record type errors are corrected following the creation of the database. A series of if then do statements are used to add abundance in metric tons (SSB) and the total number of summer flounder landed (TotSFL) in a specific year, which was printed out by MAFMC3 program, to the sasout.SF8111 database for summer flounder.

Step V.

The probability that a fish caught in a given size class is estimated in

MAFMC5

The probability that a fish is discarded in a given size class is estimated in

MAFMCRecData5Fdiscard

Only discarded fish from the type 9 records and any fish in size classes that are below the state minimum size class regulations are included in a temporary data file titled data oned in line two of the program.

Some additional information is added to the database prior to the estimation of the probabilities since both fishers and anglers exploit summer flounder. This information reflects U.S. population size, price per pound of commercially harvested summer flounder, the prime rate on capital investment, the fuel producer price index, and the summer flounder fisheries management history. The fishery management history is included as specific changes in area, possession, seasons, state specific recreational targets, and size limits as well as the dates when specific amendments to the management plan were adopted. These FMP and amendment

qualitative variables were dropped from the model statement since they were not statistically significant once the specific size, season lengths, and possession limits were incorporated in the analysis. They remain as part of the program in the event that conditions in the fishery change at some point in the future.

The final stage of these two programs saves the estimated coefficients to a file named:

betas and betasd, respectively.

The coefficients saved in these files are used in the step VI to estimate the probability that a fish landed or caught is in a given size category for a proposed fishery management scenario. These probabilities are then used to estimate the number of fish that will be landed or caught in each size category.

Step VI

Based on the estimated coefficients (betas and betasd) from the previous two programs, the probabilities for a user specified case can be estimated using:

MAFMC6

and

MAFMCRecData6Fdiscard

These probabilities are then combined with the number of fish landed or caught provided by Jessica Coakley of the MAFMC staff (e.g., fluke_MRIP_2012.xls contains this information for 2012) to determine the number of fish landed or caught in each size class by state.

A. The fourth line from the top of the program is an if statement that sets the year and the state for which the probabilities are to be predicted. This reduces the number of observations that the SAS program will have to process and increases its speed of execution.

B. After a label statement and a series of SAS commands that provide definitions for variable values, the program derives a series of qualitative variables that are used in the estimation of the size group probabilities. This data set (data onea) is sorted by year and state (sta). This sorted data is used in the next stage in a proc means statement:

```
proc means noprint;
  by year sta;
  var wgt totsfl ssb party minslm minslmi poslmt ARecTrgt ffdays12 ffdays2 hrsf opensea
sfldp fppi pr np gear1d gear2d gear3d gear4d gear5d gear6d gear7d gear8d gear9d gear10d
gear11d gear97d gear98d gear99d gear DPrim1 DPrim2 NTPrim1 Dispo1d Dispo2d Dispo3d
Dispo4d Dispo5d Dispo6d Dispo7d areax1d areax2d areax3d areax4d areax5d Mode_FX1d
```

```
Mode_FX2d Mode_FX3d Mode_FX4d Mode_FX5d Mode_FX6d;
  output out = betam mean=wgtm totsflm ssbm partym minslmm minslmim poslmtm ARecTrgtm
        ffdays12m ffdays2m hrsfm openseam sfldpm fppim prm npm gear1d gear2d gear3d gear4d
        gear5d gear6d gear7d gear8d gear9d gear10d gear11d gear97d gear98d gear99d gear
        DPrim1d DPrim2d NTPrim1d Dispo1d Dispo2d Dispo3d Dispo4d Dispo5d Dispo6d Dispo7d
        areax1d areax2d areax3d areax4d areax5d Mode_FX1d Mode_FX2d Mode_FX3d Mode_FX4d
        Mode_FX5d Mode_FX6d;
  run;
```

to determine the average values for the variables used in the estimation equation; these values are output into a data file named betam. The mean values for the qualitative variables represent the percent of total observations that have a value for the attribute described by the variable. These percentages are used to weight the estimated parameters for those qualitative variables. This weighted value for the set of attributes described by the qualitative variable returns an average effect of that variable on the probability that a fish landed or caught falls in a particular size class. These qualitative variables are also listed in a block comment in the data betasf data step in the event that a particular attribute of one of these variables is of interest in future analyses.

C. The next data step called:

Data betamf (drop=_type_)

assigns the total number of fish landed or caught to each of the explanatory variables that are of interest in the analysis.

```
data betamf(drop=_type_);
set betam;
totsflmest = 4711;        *Total number of fish landed/caught per state;
minslmm = 16;      *Minimum size limit offshore;
*minslmim = ?;     *Minimum size limit inshore;
poslmtm = 3;           *Possession Limit offshore;
openseam = 122;    *Season Length in Days;
ssbm= 58711;           *Spawning Stock Biomass: Abundance;
fppim = 322.68;    *Fuel Price Index;
prm =3.25;             *Prime Rate;
npm=316266000;     *Population Size;
run;
```

For example, a minimum size limit offshore is set to 16 inches using the command:

```
minslmm = 16;       *Minimum size limit offshore;
```

D. The next stage is to ensure that the state variable in the data betasf data step corresponds to the set command for year and state at the beginning of the program. In this case:

```
  StaCTd = 0;
  StaDEd = 0;
  StaFLd = 0;
  StaGAd = 0;
```

```
   StaMAd = 1;
   StaMDd = 0;
   StaMEd = 0;
   StaNCd = 0;
   StaNHd = 0;
   StaNJd = 0;
   StaNYd = 0;
   StaRId = 0;
   StaSCd = 0;
```

Setting StaMAd = 1 and the other state qualitative variables to zero corresponds to the set statement in line four of the program; e.g.,

```
if year = 2011 and sta = 'MA';   *Select Year and State;
```

E. Running the program results in a final data step:

```
data Done;
     *set betasf;
     set Done betasf;
  proc print;
*     var Totprob p1 - p40;
      var sta Totnszcl nszcl1 - nszcl40;
   run;
```

The first commented set statement assigns the output to the data file Done for the first run of a series of analyses consisting of each state. The second set statement is used for all subsequent runs to add state level analyses to that data file. The proc print command lists the output in a table for each state, the total number of fish landed or caught by each state, and the breakdown of number of fish by size class.

The attached excel file

SummerFlounderSZCL.xlsx

provides estimates of the Numbers of Fish Landed (A+B1) in lines 1 to 15 and estimates of Numbers of Fish Caught (A+B1+B2) in lines 17 to 31 by size class (nszcl1 to nszcl40) for each state. Lines 33 to 42 provide the estimated probabilities (p1 to p40) for the discard fish for each state. These estimates are based on a minimum size of 16 inches per fish and a 3 fish possession limit for a season of 122 days in 2011.

Step VII

 The estimated probabilities need a total number of fish caught or landed to determine the number of fish in each size category for a particular state. These total numbers of fish can be derived from another source or can be estimated using the program:

MAFMC7

Which bases the number of total fish on the management history of the summer flounder fishery and the same variables used to estimate the probabilities of a fish being in a certain size category. This allows the estimated number of fish to reflect the same actual or potential regulations that are in effect or are being considered for the recreational fishery.

The first model (m1) predicts the number of fish landed (Type A + B1 fish) in a state that have been intercepted, identified, measured, and in some cases weighted by observers (TotSFLnmbr). The second model (m2) predicts the total number of fish (Type A+B1+B2 fish) reported to observers by anglers who did not necessarily allow them to be identified, measured, and weighted by observers (TotSFLnd). Two scatter plots at the end of the program provide a comparison of the actual and predicted values of these two dependent variables. These plots indicate that most predicted values fall within narrow bands around the actual values of the variables; this reflects the coefficient of determination of 76.7 and 76.8 percent, respectively.

These estimated parameters are stored in the file

beta2

Temporary data files w1 and w2 are also created by this program for use in Step VIII to estimate the number of fish caught (TotSFLnmbr) and landed (TotSFLnd) for each state under different fishery management strategies for use in the estimation of fish by size category in Step V.

 Step VIII.

The program:

MAFMC7A

can be used to conduct quick assessment of proposed fishery management regulations based on the existing historical data maintained in the MRFSS and MRIP data base.

A. The estimated number of fish landed (A+B1) or number of fish caught (A+B1+B2) can be predicted for different proposed regulatory changes. Additional changes of the independent variables used in conjunction with the estimated coefficients could be made to closer replicate a different year or set of underlying biological and market conditions. In the event that a quick assessment indicates a potentially desirable outcome for fisheries managers, a biological assessment could be conducted to provide a set of estimates of landings or catch by state. Once a set of estimates have been made for the states on the eastern coast of the United States, they can be decomposed into their expected size classes using Step VI.

B. The first three lines of the program create a data file (xf) by setting the output file created by the regression analysis conducted in Step VII using:

MAFMC7A

The third line identifies the state (`stVA = 1`) and year (`Year = 2011`). It also ensures that the fish weight (wgt) variable is nonzero and not missing. Proc means calculates the mean values of the independent variables that are to be combined with the estimated parameters for numbers of fish landed (the M1 model) and caught (the M2 model) from MAFMC7A. Data Numberfish corrects for

```
      data Numberfish (Keep=TotSFLnmbrhat) Landedfish
(Keep=TotSFLLndhat);
         set beta2f;
   Year = log(2011);
         if stME     = . then stME     = 0;
         if stNH     = . then stNH     = 0;
         if DPRim2   = . then DPRim2   = 0;
         if FPPI     = . then FPPI     = 0;
         if ARecTrgt = . then ARecTrgt = 0;
         if Minslmi  = . then minslmi  = 0;
         if HRSF     = . then HRSF     = 0;
         if pr       = . then pr       = 0;
         if SSB = . then SSB = 0;
      *  If SSBYear = . then SSBYear = 0;          If SSBYearvar = .
then SSBYearvar = 0;
         if Party =. then party = 0;
         if FedAlloc = . then FedAlloc = 0; if FedAllocvar = . then
FedAllocvar = 0;
         If SFldp = . then SFldp = 0;
        * if NTPrime1 = . then NTPrime1 = 0;
         Poslmtvar = log(16);
            minsLmvar = log(20.0);
            OpenSeavar = log(153);
         ssbvar = log(60074);
         ssbsfldpvar = ssbvar+sfldpvar;
         ssbFPPIvar = ssbvar+FPPIvar;
         ssbPrvar = ssbvar+Prvar;
         ssbYearvar = ssbvar+Year;
         /*------------------------------------------------;
         NPvar = 316266000;
         NPdvar = 1;
         TotSFLvar = 2168;
         Year = 2012;
         FPPIvar = 322.68;
         prvar = 3.25;
         *-----------------------------------------------------*/;
```

missing values and lists the variables that can be adjusted for different fishery management scenarios. Of special note, when the spawning stock biomass is used as part of the prediction process, interaction terms also need to be included. That is, if SSBvar is used, then ssbsfldpvar, ssbFPPIvar, ssbPrvar, ssbYearvar also need to be included in the estimation equation. Also, the value of the variables needs to be

expressed as natural logarithms; e.g., `OpenSeavar = log(153);`

C. The output of this program includes the printing of the proc means output to allow the default values to be checked, as well as, the number of fish landed and the number of fish caught are also printed in the output. An example of this policy analysis is provided in the Appendix to this user guide for the state of Virginia.

Summary

While the concepts underlying this analysis are relatively simple, their application to the actual world is complex. This 11 page user guide is intended to reduce the number of steps necessary to develop both estimates of state landed or caught fish and their distribution across fish size categories for different regulatory scenarios. In the event that a stock assessment has been conducted for landed or caught fish in each state, only the program:

MAFMC6

in step VI need be used to decompose the state totals into their expected size categories. When a standard biological stock assessment is not available, and a state level assessment is desired for a proposed recreational fishery management regulation, then the programs:

MAFMC7

And

MAFMC7A

in step VII can be employed to estimate state level fish landed and caught numbers.

Steps I to VII only need to be used when information for a new year becomes available or a different species of fish is of interest to fishery managers. These steps will update or create the database needed to estimate new sets of coefficients for use in a policy analysis of proposed fishery management regulations.