Recreational fluke MSE economic modeling overview

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1 Overview

This document describes the data and behavioral model used to evaluate angler preferences and behavior. Results from this model will parameterize a fishery simulation algorithm that can predict the impacts of regulatory changes on angler participation, angler welfare, and recreational fishing mortality. The behavioral model and its results are discussed, followed by a description of the simulation algorithm. The intent is to integrate output from the simulation algorithm, i.e., fishing mortality-at-age, with a population dynamics model such that impacts of regulatory changes on future stock conditions can also be assessed.

Note that discussion of the behavioral model and its results in Sections 6 and 7 apply to summer flounder and black sea bass, as well as other species included in a 2010 choice experiment survey. However, in section 8, I describe how the behavioral model results are incorporated into a fishery simulation algorithm that is tailored to the recreational summer flounder fishery.

2 Non-market valuation methods

Understanding the full range of costs and benefits associated with alternative regulations for managing recreational summer flounder in the northeast United States requires evaluating the economic and behavioral impacts to the recreational fishing community. For fisheries managers, these impacts typically include shifts in fishing effort and the monetary value of changes in angler well-being. However, some features of a recreational fishing experience that may be affected by changes in regulations, such as harvesting and releasing fish, are not traded explicitly and therefore lack explicit prices to signal values. To quantify the value of these non-market attributes and illuminate the economic and behavioral tradeoffs posed by alternative regulations, a revealed preference (RP) or stated preference (SP) approach to non-market valuation is needed.

RP methods use data on observed behavior, while SP methods use data from carefully constructed surveys that ask people about their preferences and values. The key advantage of using revealed versus stated preference data is that the former does not suffer from hypothetical bias that may arise when people's stated preferences or behaviors diverge from their actual behavior in a real-world setting. In contrast, stated preference survey data can be collected in such a way that allows for estimation of virtually any non-market good or attribute. Such data is particularly important when observational data is missing, inadequate, or nonexistent, which is the case in a recreational fisheries settings where managers are interested in the effect of regulations that have yet to be implemented.

We take a stated preference approach to estimating the non-market value that recreational anglers place on harvesting and releasing popular species found along the coast from Maine to North Carolina. In particular, we collected and analyzed data from a choice experiment (CE) survey. In a CE question, survey respondents are presented with two or more multi-attribute options that vary in attribute levels. CE questions typically include as an attribute a payment, such as a cost or tax, which would be incurred upon selection; this allows for monetary valuation of attributes. Respondents are then asked to compare the options presented and choose their preferred option. Framed in this way, a CE mimics a real-world purchasing decision whereby consumers compare multiple alternatives of a good and are assumed to choose the one that maximizes utility. Data collected from a CE survey can be used to measure the marginal value of changes in attributes as well as the likelihood of purchase contingent on a set of attributes characterizing the good in question.

3 Choice experiment survey

Our stated preference choice experiment data come from a survey administered during 2010 as a follow-up to the Access Point Angler Intercept Survey (APAIS), an in-person survey that collects information from anglers at publicly accessible fishing sites as they complete their fishing trips. The APAIS is one of several surveys used by the Marine Recreational Information Program (MRIP) to produce catch and effort estimates for recreational marine species across the United States. Anglers who participated in the APAIS in coastal states from Maine to North Carolina during 2010 were asked to participate in the voluntary follow-up CE survey. Those willing to participate were sent CE survey contact materials via mail or email shortly after the intercept interview. A total of 10,244 choice experiment surveys were distributed, of which 3,234 were returned for an overall response rate of 31.5%.

The survey instrument contained three sections. Section (A) collected information about respondents' fishing experiences in the past year and species preferences, as well as the factors that influence respondents' decision to go fishing. Section (B) contained a set of choice experiment questions (Figure 1). In each of these questions, anglers were presented with three hypothetical fishing trips composed of different attributes. Trip A and Trip B contained different species-specific regulations, catch, harvest, as well as trip costs. Trip C was an option to go fishing for species other than those listed in Trip A and Trip B, and was added as an attempt to capture target species substitution. Respondents were asked to compare and choose their favorite among the three trip options, or choose to not going saltwater fishing given the trip options displayed. Lastly, section (C) gathered demographic information including gender, birth year, education, ethnicity, and income. Given regional differences in species availability, survey versions were developed for four sub-regions: (i) coastal states from Maine through New York, (ii) New Jersey, (iii) Delaware and Maryland, and (iv) Virginia and North Carolina. The four survey versions differed in the species other than summer flounder and black sea bass included in Sections A and B.[1]

4 Experimental design

For each regional version of the survey, multiple sub-versions that differed in levels of the trip attributes shown within and across choice questions were administered. Trip attribute levels were chosen based on historical catch and trip expenditure data and corroborated with focus group feedback. They were then randomized across choice questions using an experimental design that sought to maximize the statistical efficiency of the ensuing model parameters. Each experimental design was specified to produce a total 128 choice questions. Because 128 is too many questions for a single respondent to answer, questions were randomly allocated into 16 subsets such that each respondent was presented with eight choice questions.

[1] In terms of the CE attributes in Section B, the Maine to New York version included fluke, black sea bass, and scup; the New Jersey version included fluke, black sea bass, scup, and weakfish; the Delaware and Maryland version included fluke, black sea bass, and weakfish; and the Virginia and North Carolina version included fluke, black sea bass, weakfish, and red drum.

SECTION B: SALTWATER FISHING TRIPS

The following questions help us understand tradeoffs made by anglers when they go fishing.
Compare Trip A, Trip B, and Trip C in the table below, then **answer** questions **1A** and **1B**.
Compare only the trips on this page. Do **not** compare these trips to trips on other pages in this survey.

	Trip Features	Trip A	Trip B	Trip C
Summer Flounder (Fluke)	Regulations	1 Fluke, 16" or larger	3 Fluke, 18" or larger	Go fishing for striped bass or bluefish
	Fish Caught	3 to 13 Fluke, 22" TL	1 Fluke, 15" TL	
	Fish Kept	1 Fluke	0 Fluke	
Black Sea Bass	Regulations	20 Bl. S. Bass, 14" or larger	30 Bl. S. Bass, 9" or larger	
	Fish Caught	30 Bl. S. Bass, 12" TL	10 Bl. S. Bass, 9" TL	
	Fish Kept	0 Black Sea Bass	10 Black Sea Bass	
Scup (Porgy)	Regulations	20 Scup, 12.5" or larger	5 Scup, 13" or larger	
	Fish Caught	3 Scup, 16" TL or larger	40 Scup, 6" TL or smaller	
	Fish Kept	3 Scup	0 Scup	
Weakfish	Regulations	0 Weakfish of any size	5 Weakfish, 12" or larger	
	Fish Caught	7 Weakfish, 15" TL	1 Weakfish, 18" TL	
	Fish Kept	0 Weakfish	1 Weakfish	
Total Trip Cost		$160	$160	$45

Definitions:

- **Regulations:** The legal minimum size restriction and bag limit for this trip.
- **Fish caught:** The number of fish caught on this trip and the total length (TL) of those fish.
- **Fish kept:** The number of fish you can legally keep on this trip.
- **Total trip cost:** ***Your portion*** of the costs associated with this trip, including bait, ice, fishing equipment purchase or rental, daily license fees, boat rental fees, boat fuel, trip fees, and round trip transportation costs associated with traveling to and from the fishing location. Travel costs may include vehicle fuel, car rental, tolls, airfare, and parking.

1A Choose your favorite trip. (Please mark only **one** trip with a ☑ or a ☒.)

Trip A ☐
Trip B ☐
Trip C ☐
I would not go saltwater fishing ☐

Figure 1. Example choice experiment question from the New Jersey survey version.

5 Choice experiment sample

A total of 3,234 people completed or partially completed the mail or web version of the survey. Of these respondents, 2,941 answered at least one of the eight choice experiment questions. We removed from this sample 491 respondents who universally choose the zero-cost, "Do not go saltwater fishing" option as their favorite trip, or universally chose Trip C as their favorite trip. Johnston et al. (2017) note that such choice patterns can be interpreted as scenario rejection whereby "respondents do not interpret scenarios as intended and thus value something different from the intended item or outcome”.[2] We also excluded from analysis 38 respondents who indicated that the survey was not completed by the person to whom it was mailed. The remaining sample consisted of 2,474 anglers.

Table 1 displays some demographic characteristics of sample anglers in each region. Sample anglers were predominantly male (90-93% in each region) and Caucasian (92-94% in each region). The average age was just over 52 in each region. Between 60% and 66% of the sample in each region had household incomes ranging from $20,000 to $100,000, while between 24% and 28% had household incomes above $100,000. Lastly, the average number of days spent fishing during the previous calendar year (2009) varied from 20 to 30 across regions, with New Jersey anglers fishing considerably more frequently in the past year than anglers in other regions.

Table 1. Demographic characteristics of choice experiment sample.

Characteristic	ME-NY n=449	NJ n=359	DE/MD n=594	VA/NC n=1,072
% male	92.2	93.0	90.2	89.7
% Caucasian	94.4	94.2	92.3	93.6
Mean age	52.9	52.8	53.2	52.2
Education				
% with high school graduate or GED	23.4	32.3	31.7	22.4
% with some college but no degree or associate's degree	33.4	29.2	26.3	35.8
% with bachelor's degree or higher	31.0	25.9	27.1	33.5
Household income				
% less than $20,000	6.5	2.2	6.6	4.4
% between $20,000 and $100,000	59.7	66.3	63.3	66.0
% over $100,000	28.3	27.0	24.2	25.0
Mean # fishing trips taken during 2009	21.9	29.9	19.6	21.1

6 Behavioral model framework

Choice experiment data can be used to evaluate consumer preferences for, behavioral response to, and welfare impacts from marginal changes in non-market goods or attributes (Louiviere et al. 2000). The primary purpose of collecting our choice experiment data was to identify the non-

[2] Key parameter estimates from ensuing choice models that include these participants are similar in sign, significance, and magnitude to those presented here.

market value of keeping and releasing recreational summer flounder such that the likely economic and behavioral impacts of regulatory changes could be assessed.

We analyzed our CE data using random utility models (McFadden 1973), which decompose the overall utility angler n receives from alternative j $(j = A, B, C, or\ D)$ into two components: V_{nj}, a function that relates observed fishing trip attributes x_{nj} to utility, and ε_{nj}, a random component capturing the influence of all unobserved factors on utility. Angler utility can be expressed as

$$\begin{aligned} U_{nj} &= V_{nj} + \varepsilon_{nj} \\ &= \beta_n' x_{nj} + \varepsilon_{nj}, \end{aligned} \tag{1}$$

where β_n' is a vector of preference parameters measuring the part-worth contribution of trip attributes x to angler n's utility, and ε_{nj} is an independent and identically distributed Type I extreme value error term. Under the random utility framework, an angler will select alternative i if it provides maximum utility over all alternatives available to him or her in a given choice occasion, i.e.

$$U_{ni} > U_{nj}\ \forall\ j \neq i. \tag{2}$$

We estimated panel mixed logit models, which allow for unobserved preference heterogeneity—a recommended best-practice for stated preference analysis (Johnston et al. 2017)—through estimation of parameter distributions for the attributes specified as random. Allowing preferences to vary across individuals is the primary advantage of the mixed logit over the basic multinomial logit (MNL) model, which assumes that individuals have the same preferences. Panel mixed logit estimation also resolves some behavioral limitations of the MNL model, including the independence of irrelevant alternatives property and the assumption that unobserved factors that influence decisions are uncorrelated over repeated choice situations (Hensher and Greene 2003). The probability that angler n chooses alternative i is obtained by integrating the logit formula over the density of β (Train 2003):

$$P_{ni} = \int \frac{e^{\beta' x_{ni}}}{\sum_{j=1}^{J} e^{\beta' x_{nj}}} f(\beta)\, d\beta. \qquad (3)$$

These probabilities are approximated via simulation in which repeated draws of β are taken from $f(\beta|\theta)$, where θ refers to the mean and covariance of this distribution. For each draw, the logit formula is calculated for all choice scenarios (up to eight) faced by individual n. Then, the product of these calculations is taken, giving the joint probability of observing individual n's sequence of choices. The average of these calculations over all draws is the simulated choice probability, $\check{P}_{ni}$. The estimated parameters are the values of θ that maximize the simulated log likelihood function

$$LL = \sum_{n=1}^{N} \sum_{t=1}^{T} \sum_{j=1}^{J} d_{ntj} \ln(\check{P}_{ntj}), \qquad (4)$$

where $d_{njt} = 1$ if individual n chose alternative j in choice scenario t and zero otherwise.

We specified the utility associated with fishing trip alternatives A and B as a linear additive function of the number of fish kept and released by species and the trip cost. The utility associated with Trip 3, a fishing trip for other species, was specified as a constant term (*fish for other species*) and a trip cost. The estimated parameter on *fish for other species* measures the utility derived from fishing for alternative species relative to that derived from the other alternatives. The utility associated with the non-fishing, "I would not go saltwater fishing" alternative (alternative D), was specified as a function of a constant term (*do not fish*) that captures preferences for not fishing. To allow for diminishing marginal utility of catch (Lee et al. 2017), keep and release attributes entered the model as their square root. The estimated models assumed that all non-cost parameters were normally distributed, while the cost parameter was treated as fixed to facilitate welfare calculations (Revelt and Train 2000).

7 Behavioral model results

Estimation results from the panel mixed logit models are shown in Table 2. The mean parameters measure the relative importance of each trip attribute on overall angler utility, while the standard deviation parameters measure the extent to which preferences vary across the sampled population.

In general, the estimated mean parameters are of the expected sign. Mean parameters on *trip cost*, the marginal utilities of price, are negative and significant across the regional models and suggest that higher trip costs reduce angler utility. Across the models, parameters on the keep variables are positive, significant, and higher in magnitude than each species' respective release parameter. This means that each species is predominantly targeted for consumption rather than sport. Anglers in each region value keeping summer flounder more than they value keeping other species, as the parameters on $\sqrt{\textit{summer flounder kept}}$ are largest in magnitude relative to the other species' keep parameters. Signs and significance of the release parameters vary by species and region and are mostly insignificant. However, the parameter on $\sqrt{\textit{summer flounder released}}$ in the VA/NC model suggests that anglers in this region value catching and releasing summer flounder. Additionally, in two of the three regional models, the parameter on $\sqrt{\textit{weakfish released}}$ is positive and significant. Catching and releasing scup reduces the fishing utility of anglers in New Jersey according to the parameter on $\sqrt{\textit{scup released}}$. Anglers likely perceive catching and having to release these small fish as a nuisance when fishing for larger and more valuable target species. Baseline levels of non-fishing utilities, captured by the parameters on *do not fish*, are negative and significant, meaning that, when given the option to do so, anglers get more utility from fishing than not fishing. In contrast, the parameters on *fish for other species* suggest that anglers place a relatively high value on trips in which the target species is striped bass and bluefish (or striped bass, bluefish, cobia, and Spanish mackerel in the VA/NC model). This is not surprising given that striped bass is the most popular recreational species in this region and that Trip C was most frequently selected as the favorite trip by choice experiment respondents. Lastly, with the exception of $\sqrt{\textit{black sea bass released}}$ in the ME-NY and NJ models, the significance of standard deviations parameters confirms that preferences for fishing trip attributes vary across anglers, i.e., that marginal changes in attribute levels will affect different anglers differently.

Table 2. Estimated utility parameters from panel mixed logit models.

	ME-NY		NJ		DE/MD		VA/NC	
Mean parameters	*Estimate*	*St. Error*	*Estimate*	*St. Error*	*Estimate*	*St. Error*	*Estimate*	*St. Error*
trip cost	-0.012***	0.000	-0.009***	0.000	-0.009***	0.000	-0.008***	0.000
$\sqrt{\text{SF kept}}$	0.559***	0.063	0.762***	0.067	0.807***	0.051	0.521***	0.033
$\sqrt{\text{SF released}}$	-0.061	0.046	0.013	0.043	0.040	0.034	0.108***	0.022
$\sqrt{\text{BSB kept}}$	0.275***	0.034	0.174***	0.034	0.239***	0.027	0.192***	0.019
$\sqrt{\text{BSB released}}$	-0.021	0.024	0.015	0.025	-0.011	0.020	0.020	0.013
$\sqrt{\text{scup kept}}$	0.075***	0.021	0.097***	0.021				
$\sqrt{\text{scup released}}$	-0.010	0.015	-0.039**	0.016				
$\sqrt{\text{WF kept}}$			0.394***	0.056	0.379***	0.045	0.231***	0.032
$\sqrt{\text{WF released}}$			0.093**	0.044	0.064*	0.036	0.030	0.024
$\sqrt{\text{RD kept}}$							0.454***	0.040
$\sqrt{\text{RD released}}$							0.081***	0.025
do not fish	-2.641***	0.252	-2.095***	0.288	-2.963***	0.259	-3.908***	0.259
fish for other species	1.429***	0.181	1.139***	0.208	0.645***	0.159	0.454***	0.121
St. dev. parameters								
$\sqrt{\text{SF kept}}$	0.678***	0.081	0.677***	0.081	0.599***	0.065	0.464***	0.044
$\sqrt{\text{SF released}}$	0.336***	0.064	0.181**	0.088	0.317***	0.049	0.221***	0.036
$\sqrt{\text{BSB kept}}$	0.261***	0.043	0.334***	0.045	0.287***	0.039	0.200***	0.032
$\sqrt{\text{BSB released}}$	0.087	0.063	0.012	0.080	0.160***	0.027	0.131***	0.023
$\sqrt{\text{scup kept}}$	0.143***	0.039	0.113**	0.045				
$\sqrt{\text{scup released}}$	0.014	0.067	0.117***	0.022				
$\sqrt{\text{WF kept}}$			0.199*	0.114	0.381***	0.066	0.393***	0.048
$\sqrt{\text{WF released}}$			0.278***	0.062	0.227***	0.067	0.146**	0.057
$\sqrt{\text{RD kept}}$							0.601***	0.059
$\sqrt{\text{RD released}}$							0.356***	0.035
do not fish	2.554***	0.221	2.394***	0.214	2.448***	0.214	2.918***	0.206
fish for other species	1.920***	0.135	1.832***	0.142	1.900***	0.127	1.991***	0.096
No. choices	3460		2768		4514		8340	
No. anglers	449		359		594		1072	
Pseudo R^2	0.332		0.274		0.323		0.307	
LL	-3203.6		-2785.2		-4236.5		-8010.3	
LL(0)	-4796.6		-3837.3		-6257.7		-11561.7	
AIC	6441.1		5612.3		8506.9		16062.6	
BIC	6569.2		5765.9		8639.6		16239.4	

Notes: *, **, and *** represent significance at the 10%, 5%, and 1% level of significance, respectively. SF = summer flounder, BSB = black sea bass, WF = weakfish, RD = red drum.

8 Simulating aggregate effects of management actions

8.1 Economic sub-model

To assess the effect of management actions on angler behavior, welfare, and fishing mortality, we integrate the utility parameters in Table 2 with historical catch and effort data in a predictive model of angler participation (Lee et al. 2017; Holzer and McConnell 2017). The model simulates individual choice occasions and uses estimated utility parameters to predict the probability of these choice occasions occurring. With a vector of utility parameters β' measuring the relative importance of fishing attributes x on angler utility, Train (2003) shows that the probability of a choice occasion occurring can be calculated as:

$$P = \frac{e^{\beta' x}}{1 + e^{\beta' x}}. \tag{5}$$

A multipart simulation algorithm (Appendix figure A1) is used to arrive at realized values of x that resemble actual fishery conditions.

A choice occasion begins by drawing a target number of summer flounder from a catch-per-trip distribution fitted to historical MRIP catch data (Figure 3). Given that summer flounder and black sea bass are commonly caught together, we account for correlation in catch between the two species through the use of copulas. Copulas are functions that describe the dependency among random variables and allow us to create the correlated multivariate data used in the simulation model. We specify negative binomial marginal distributions for each catch series derived from historical MRIP catch data, and choose a t-Copula to provide a correlation structure that approximates the observed correlation in the two series. Catch of other species included in the simulation is assumed independent, and these distribution are fitted (negative binomial) to historical MRIP catch data.[3]

The length of each summer flounder caught is then drawn at random from a catch-at-length distribution. We link the size distribution of summer flounder in the ocean with the size distribution of summer flounder anglers catch by creating catch-at-length distributions that are a

[3] Catch-per-trip data for all species included in the simulation are based on recreational fishing trips that caught or primarily targeted summer flounder.

function of the stock structure, following Lee et al (2017). Rearranging the Shaeffer (1954) catch equation, we solve for recreational selectivity (q_l) of length-l fish in a baseline year,

$$q_l = \frac{C_l}{N_l E}, \tag{6}$$

where C_l is catch of length-l fish, N_l is population numbers of length-l fish, and E is fishing effort. Recreational selectivity is the fraction of population fished by a unit of effort and will increase when the population decreases holding catch constant, or when catch increases holding the population constant. [insert graphs of rec. selectivity]. We use age-length indices to convert median projected population abundance from ages to lengths and MRIP data to construct C_l and E at the year level. Having constructed q_l for a baseline year, C_l can then be computed for any stock structure, $\widetilde{N_l}$. Rearranging equation 6 and dividing C_l by total catch gives the probability of catching a length-l conditional on the stock structure:

$$Prob[length = l] = \frac{\tilde{C}_l}{\sum_l^L \tilde{C}_l} = \frac{q_l \widetilde{N_l}}{\sum_l^L q_l \widetilde{N_l}}. \tag{7}$$

Once numbers and sizes of fish caught are assigned to each simulated choice occasion, the length of each fish is checked against the minimum size limit and the fish is allocated to that choice occasion's keep or release bin. All summer flounder caught subsequent to the possession limit being reached are released. After summer flounder catch is apportioned appropriately as either kept or released, the same process is used to determine numbers of other target species kept and released. The entire process up to this point is repeated 20 times for each choice occasion, with each repetition drawing a new target number of summer flounder and other species' catch. After each choice occasion completes 20 repetitions of catch, it is assigned a trip cost that is randomly drawn from a distribution of trip costs derived from 2017 angler expenditure survey data (Lovell et al. 2020).

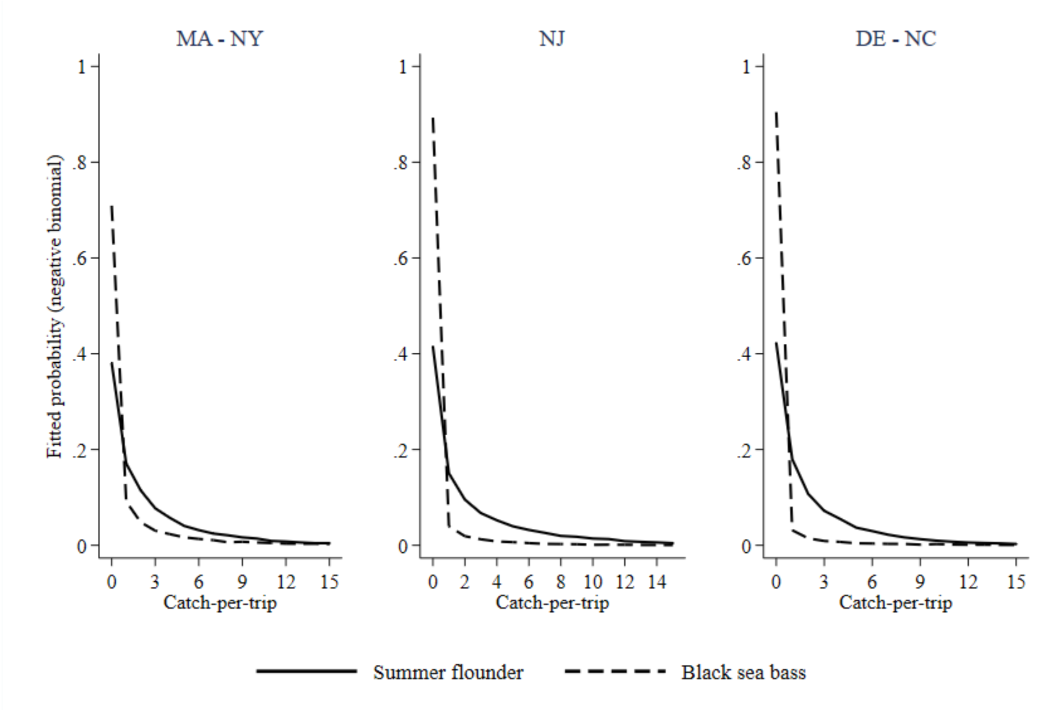

Figure 3. Detail of lower tail of 2019 catch-per-trip probability distributions. Distributions for scup, weakfish, and red drum not shown.

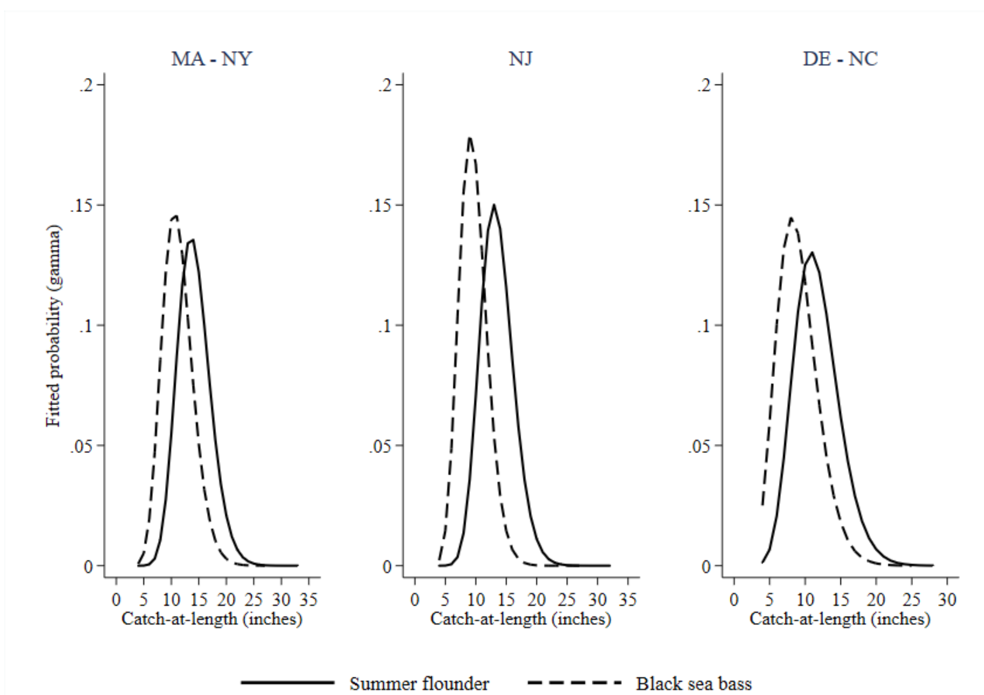

Figure 4. 2019 catch-at-length probability distributions. Distributions for scup, weakfish, and red drum not shown.

Recreational fishing regulations, trip costs, catch, and the estimated utility parameters vary across the study region. We consider these geographical distinctions in the simulation model. To begin, choice occasions are generated separately for each of the nine coastal states encompassing the study region (Massachusetts through North Carolina), with each subject to that state's recreational summer flounder and other species regulations.[4] Trip costs are drawn from distributions that vary by mode and state; the number of choice occasions assigned charter-, head boat-, private boat-, and shore-based trip costs in each state is in proportion to the number of fishing trips that caught or primarily targeted summer flounder by mode in that state during the baseline year. The MRIP data used to generate catch-per-trip and catch-at-length distributions are aggregated to the regional level for three sub-regions: (i) coastal states from Massachusetts through New York, (ii) New Jersey, and (iii) coastal states from Delaware through North Carolina. This level of geographic aggregation accounts for regional differences in catch-per-trip and catch-at-length while limiting the loss of statistical precision that occurs from using MRIP data at lower levels. Lastly, the set of utility parameters used to calculate predicted probabilities are drawn from one of the four regional models in Table 2 in concordance with the state or region in which that choice occasion occurs.

Values of keep and release by species and trip cost along with the estimated utility parameters from Table 2 are used to compute the predicted probability of the choice occasion occurring, calculated as the average over the 20 draws of catch. The number of expected fishing trips is the sum of predicted probabilities over all choice occasions. Total harvest and releases are calculated as the sum of probability-weighted harvest and release over all choice occasions. To account for the fact that the estimated utility parameters are uncertain estimates of true angler preferences, we calculate predicted probabilities, harvest, and release 20 times based on random draws from a multivariate normal distribution with a mean and variance-covariance matrix set to the model estimates in Table 2.

We calibrate the simulation model by generating a number of choice occasions such that the sum of probabilities in a given state equals the MRIP-based estimate of total fishing trips that caught or targeted summer flounder in that state during the baseline year. [enter calibration statistics].

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[4] The simulation model accounts for regulations that vary within and across species over the course of the season in any given state.

To assess the potential impact of regulatory changes on fishery outcomes, we re-run the simulation model, drawing from a new catch-at-length distribution for summer flounder based on equation 7 and imposing alternative bag and size limits across the states. Choice occasion probabilities are calculated from equation 5 using the altered vector of trip attributes x. Again, we use these probabilities to determine total fishing effort (number of trips), harvest, and releases across states.

We also calculate the expected change in consumer surplus (CS) associated with each choice occasion n. Expected change in consumer surplus is the difference in expected utility in dollar terms between the original state (0; baseline regulations) and altered state (1; alternative regulations). The mean expected change in consumer surplus across choice occasions is

$$\Delta E\left(CS_{nj}\right) = \frac{1}{D}\sum_{d=1}^{D}\left(\frac{\ln\left(\sum_{j=1}^{J} e^{V_{nj}^{1}}\right) - \ln\left(\sum_{j=1}^{J} e^{V_{nj}^{0}}\right)}{-\beta_{TC}}\right) \tag{8}$$

where D is the total number of draws from the distribution of utility parameters, V_{nj}^{1} and V_{nj}^{o} are expected utility under alternative and baseline regulations, and β_{TC} is the marginal utility of price.

References

Hensher, David A., and William H. Greene. 2003. "The Mixed Logit Model: The State of Practice." *Transportation* 30 (2): 133–76.

Holzer, J., and K. McConnell. 2017. "Risk Preferences and Compliance in Recreational Fisheries." *Journal of the Association of Environmental and Resource Economists* 4 (S1): S1–43.

Johnston, Robert J., Kevin J. Boyle, Wiktor Vic Adamowicz, Jeff Bennett, Roy Brouwer, Trudy Ann Cameron, W. Michael Hanemann, et al. 2017. "Contemporary Guidance for Stated Preference Studies." *Journal of the Association of Environmental and Resource Economists* 4 (2): 319–405.

Lee, M., S. Steinback, and K. Wallmo. 2017. "Applying a Bioeconomic Model to Recreational Fisheries Management: Groundfish in the Northeast United States." *Marine Resource Economics* 32 (2): 191–216.

Louiviere, J., D. Hensher, and J. Swait. 2000. *Stated Choice Methods: Analysis and Applications*. Cambridge University Press.

Lovell, Sabrina J, James Hilger, Emily Rollins, Noelle A Olsen, and Scott Steinback. 2020. "The Economic Contribution of Marine Angler Expenditures on Fishing Trips in the United States, 2017." *NOAA Technical Memorandum*. Vol. NMFS-F/SPO. U.S. Dep. Commerce.

McFadden, D. 1973. "Conditional Logit Analysis of Qualitative Choice Behavior." In *Frontiers in Econometrics*, 105–142. New York.

Revelt, David, and Kenneth Train. 2000. "Customer-Specific Taste Parameters and Mixed Logit: Households' Choice of Electricity Supplier." *Working Paper, University of California, Berkeley*, 1–32.

Train, K. 2003. *Discrete Choice Methods with Simulation*. New York: Cambridge University Press.

Appendix

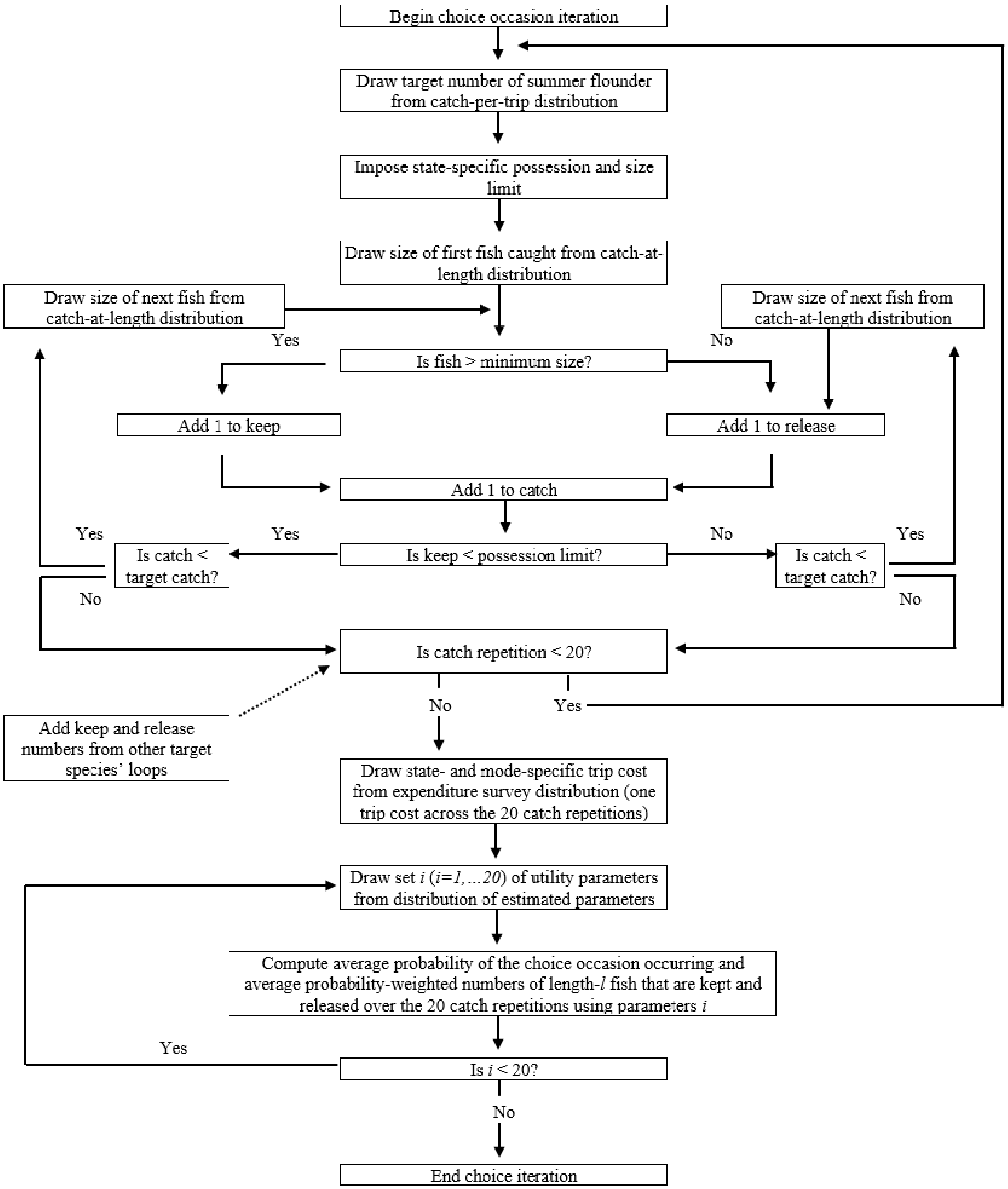

Figure A1. Choice occasion simulation algorithm.