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Quantifying the behavioral and economic effects of regulatory change in a recreational cobia fishery

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ABSTRACT

Fisheries economists typically assume recreational anglers make decisions that maximize individual angler utility, which may depend on fishery and regulatory conditions. Under this framework, changes in regulations can lead to target species substitution by anglers in response to shifts in expectations of trip utility. A stated preference survey was developed and distributed to recreational cobia (*Rachycentron canadum*) anglers in Virginia to explore the effects of regulatory change on angler decision-making, species targeting, and resulting economic outcomes. The survey included a series of hypothetical choice scenarios, where respondents were asked to select their most preferred alternative after being presented with different fishing trips targeting cobia, red drum (*Sciaenops ocellatus*), or summer flounder (*Paralichthys dentatus*). Seven regulatory treatments of the survey were distributed, providing anglers a variety of species targeting tradeoffs. A mixed logit model was used to estimate angler preferences associated with hypothetical trip attributes and regulatory environment. Changes in angler welfare resulting from changes in cobia regulations were then assessed. Anglers were found to prefer targeting cobia to red drum or summer flounder under status quo management. Increases in catch, average weight of catch, and legal harvest of cobia were also found to provide anglers greater improvements in trip utility compared to increases in these attributes for trips targeting red drum or summer flounder. The economic effects of regulatory change were asymmetric because restrictive regulations were found to reduce angler welfare whereas liberalizing regulations had no significant effects. Increased availability of alternative target species was found to dampen the negative welfare effects of restrictive cobia regulations due to predicted target species substitution by anglers.

1. Introduction

Cobia (*Rachycentron canadum*) are a widely distributed coastal pelagic fish species found throughout tropical and subtropical Atlantic, Indian, and western Pacific oceans (Shaffer and Nakamura, 1989). They are a large, long-bodied fish, growing to over five feet in length and having a maximum weight of well over 100 pounds. The species is a popular recreational target throughout the U.S. South Atlantic and Gulf of Mexico. Commercial exploitation remains limited however, as cobia are typically solitary other than during spawning aggregations.

In U.S. waters, cobia are managed as two separate stocks, distinguishing between Atlantic and Gulf migratory groups, with a boundary set at the Florida-Georgia state line. A stock assessment completed in 2013 indicated that the Atlantic migratory group was not overfished and that overfishing was not occurring, though a decline in spawning stock biomass since the early 2000s was noted (SEDAR, 2013). In 2015 and 2016, recreational harvests far exceeded annual catch limits for the Atlantic group, triggering accountability measures that closed the fishery early in federal waters (81 FR 12601, March 10 2016; 82 FR 8363, January 25 2017). The majority of Atlantic cobia are caught in state waters however, limiting the effectiveness of federal regulations. In 2017, the Atlantic States Marine Fisheries Commission (ASMFC) approved an interstate fishery management plan (FMP) for the Atlantic migratory group. In addition to setting state-specific annual soft targets for harvests in Virginia, North Carolina, South Carolina, and Georgia, the FMP established a one fish per person bag limit and a 36″ fork length minimum size (ASMFC, 2017). States were allowed to implement alternative management measures provided they were deemed to have equivalent conservation value. In March of 2019, cobia was removed from the federal Coastal Migratory Pelagic Resources FMP and management authority for the Atlantic migratory group transitioned from the South Atlantic Fishery Management Council to the ASMFC (84 FR 4733, February 19 2019).

From 2013–2017, recreational anglers in Virginia took on average

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225,600 trips per year targeting cobia (NMFS Fisheries Statistics Division, personal communication). Harvest associated with these recreational trips accounted for 39 % of all landings of the Atlantic migratory group during this period. Cobia are a popular recreational target during the summer months when they congregate in the Chesapeake Bay to spawn (Richards, 1967; Shaffer and Nakamura, 1989). They are caught by anglers using a variety of methods, though bottom fishing and sight casting are thought to be the most common (Kirkley and Kerstetter, 1997). The Virginia Marine Resources Commission (VMRC) restricted cobia harvests through a one fish per person bag limit and a 40″ total length minimum size limit during the 2017 Virginia cobia season, which ran from June 1st through September 15th. It is recognized that current recreational regulations implemented in both state and federal waters are subject to change as managers seek to balance conservation and use of the resource (ASMFC, 2017).

While cobia is a popular target species throughout its domestic range, there has been little research investigating the motivations, preferences, and values associated with recreational cobia angling. Multiple studies have considered cobia as part of gamefish species aggregates during comprehensive investigations of recreational value (e.g., McConnell and Strand, 1994; Kirkley et al., 1999; Haab et al., 2000) or when focusing on a particular species of management relevance (e.g., red drum *Sciaenops ocellatus*, Schuhmann, 1998). Results from these studies are of only limited use in management and regulation of cobia however, because value estimates or behavioral predictions unique to cobia angling cannot be identified. Still, prior research has indicated that gamefish species aggregates generate larger net benefits when compared to other species groups (Kirkley et al., 1999; Haab et al., 2000), suggesting that estimates of value and preferences with respect to individual species within the broad group may be important to fishery managers and recreational stakeholders. Indeed, several economically important species targeted in the South Atlantic and Gulf of Mexico have been the focus of studies quantifying angler preferences and value, such as dolphinfish *Coryphaena hippurus* and king mackerel *Scomberomorus cavalla* (Carter and Liese, 2012), red snapper *Lutjanus campechanus* (Gillig et al., 2000; Carter and Liese, 2012), and Atlantic bluefin tuna *Thunnus thynnus* (Goldsmith et al., 2018). A better understanding of the preferences and decision-making by anglers in the recreational cobia fishery would help facilitate consideration of angler benefits and satisfaction in resource management decisions, while also enhancing the ability to predict behavioral responses to potential changes in fishery or regulatory conditions (Fedler and Ditton, 1994; Fenichel et al., 2013; Hunt et al., 2013; Beardmore et al., 2014).

Regulatory changes can elicit behavioral responses by anglers that are difficult to forecast, modifying trip expectations and outcomes that affect the desirability or utility associated with recreational fishing and, by extension, angler well-being (Fenichel et al., 2013; Abbott et al., 2018). Several revealed and stated preference approaches can be used to estimate angler preferences and analyze behavioral response in the context of regulatory change. Challenges in defining anglers' choice sets, as well as the ability to evaluate preferences across a broad suite of attributes and attribute levels—including novel regulatory combinations—have led many researchers to utilize stated preference methods in investigations of anglers' regulatory preferences. Discrete choice experiments (DCEs), where respondents are presented multiple hypothetical choice alternatives and asked to select those they most (or least) prefer, are a common approach (e.g., Aas et al., 2000; Oh et al., 2005; Oh and Ditton, 2006; Carter and Liese, 2012; Lew and Larson, 2012; Goldsmith et al., 2018). In these applications, regulations are typically included as attributes of hypothetical alternatives along with catch-related aspects of a fishing trip. Respondents thus make decisions by comparing regulatory (e.g., size and bag limits) and non-regulatory (e.g., catch, size of catch, cost) aspects of each potential trip. This approach may present anglers with unfamiliar or confusing choice scenarios as preferences for regulations are most likely tied to their resulting impacts on allowable harvest and may, or may not, be independent of this harvest impact. Indeed, researchers have occasionally noted counterintuitive results with respect to regulatory preferences, possibly arising from respondent misinterpretation (e.g., Carter and Liese, 2012). Including regulations directly in choice scenarios as trip attributes may therefore confound estimation of angler preferences, suggesting that a more nuanced approach is necessary to understand regulatory response.

Changes in regulations and fishery conditions may lead to shifts in trip-taking, directed trip-level fishing effort, as well as species targeted. Target species substitution in response to fisheries management decisions can undermine policy objectives as anglers reallocate effort across an array of available target species, possibly resulting in unintended and unforeseen outcomes with broad ecosystem effects (Sutton and Ditton, 2005; Gentner and Sutton, 2008). This behavior also influences the resulting economic effects of a policy change realized by individual anglers and local businesses that depend on the recreational sector. Anglers target a wide variety of seasonally-available recreational species in the Chesapeake Bay (Kirkley and Kerstetter, 1997). It is not known whether anglers currently targeting cobia would switch to target another species were regulatory or fishery conditions to change, though such behavior is plausible and could be consequential in terms of both the management of alternative target species as well as its effects on anglers and fishing communities.

This study sought to improve our understanding of angler preferences, values, and behavior in the recreational fishery for Atlantic cobia within the context of regulatory change. Changes in cobia regulations were hypothesized to affect trip-level utility, possibly leading to changes in fishing behavior and angler net benefits. To investigate angler response to changes in trip attributes and regulatory context, a survey instrument was developed that included a series of hypothetical choice scenarios. Rather than incorporating regulations directly into choice alternatives, the survey included a variety of regulatory treatments that modified species targeting tradeoffs across individuals in the sample. Following estimation of angler preferences using a mixed logit model, changes in angler welfare resulting from changes in regulations were explored under a variety of available target species scenarios. In what follows, we first describe survey development and implementation before discussing our modeling approach and main findings of the research.

2. Methods

2.1. Survey development

An online survey containing questions related to recreational fishing behavior, expenditures, and preferences, with a focus on cobia, was developed in collaboration with Virginia recreational anglers and managers at the VMRC during the spring and summer 2017. Two focus groups were held during survey development. The first focus group took place in May 2017 and was used to review an initial paper draft of the survey and discuss question wording, structure, layout, and also assess angler comprehension of questions and survey material. Once the online survey instrument was developed, a second focus group was held in August 2017 to evaluate survey performance across multiple platforms (laptops, cellphones) and further review material. In total, eight anglers participated during survey development focus groups. Following the second focus group, the online survey instrument was further refined before being finalized in October of 2017. The final survey included 18–28 questions, depending on within-survey responses, in addition to four choice scenarios, where hypothetical fishing trips were described and respondents were asked to select the alternative they most preferred. The survey was approved by William & Mary's Protection of Human Subjects Committee (Protocol # PHSC-2017-09-07-12327-amscheld; see Supplementary Material for an example survey).

Table 1
Trip attributes and attribute levels included in choice scenarios.

Attribute	Number of levels (values)
Target species	3 (Cobia, Red Drum, Summer Flounder)
Catch (numbers)	3 (Cobia: 1, 2, 3; Red Drum, Summer Flounder: 3, 6, 9)
Average weight of catch (lb)	3 (Cobia: 12, 20, 45; Red Drum: 3, 6, 45; Summer Flounder: 1.5, 3, 4.5)
Individual trip cost	3 ($50, $100, $150)

2.2. Experimental design

Choice scenarios for the survey were developed and organized primarily to enable estimation of preferences associated with cobia angling and target species substitution. Each hypothetical choice occasion included two fishing trips, with each trip targeting one of three species: cobia, red drum, or summer flounder (*Paralichthys dentatus*); the latter two species being common targets of recreational anglers in the lower Chesapeake Bay during the summer. Four trip-related attributes—target species, catch (numbers), average weight of catch, and cost, each with three levels—were included when generating trip alternatives (Table 1). Values of catch and average weight of catch represented species-specific low, medium, and high estimates that were determined through conversations with recreational anglers and by evaluation of recreational catch data. For red drum, the largest average weight corresponded to an adult red drum while low and medium values were sizes typical of juveniles.

An efficient experimental design was developed using macros in SAS software (SAS 9.3; SAS Institute, Inc., Cary, NC USA) that combined candidate trip alternatives into choice scenarios, maximizing design balance and orthogonality subject to user-specified constraints (Kuhfeld, 2010). Restrictions were added when generating choice scenarios such that trip alternatives that either both targeted red drum or both targeted summer flounder were not compared to one other, nor were cobia trip alternatives for which one trip clearly dominated the other (e.g., caught more and bigger fish while having a lower trip cost). Twenty choice scenarios were generated from the full factorial design and grouped into one of five blocks containing four choice scenarios each, a number suggested to not be cognitively burdensome in previous surveys of recreational anglers (Aas et al., 2000; Hicks, 2002; Goldsmith et al., 2018).

Each of the five DCE blocks was combined with each of seven cobia regulatory scenarios, developed in conjunction with VMRC to reflect a realistic range of regulations (Table 2), for a total of 35 different survey versions. Individual respondents thus only saw one set of potential cobia regulations within and across all four choice scenarios contained in a single survey. Summer flounder regulations (17″ minimum size, 4 fish per person) and red drum regulations (18″-26″ slot limit, 3 fish per person) were held constant within and across all choice scenarios and survey versions to reflect regulations used in Virginia in 2017. Regulations for all three species were included as text presented above each choice scenario, compelling the respondent to consider trip outcomes as opposed to regulatory environment.

Legal harvest (number of fish) was included as a fifth derived attribute. Trip alternatives presented the average weight of catch in pounds while regulations specified minimum and maximum lengths in inches. This was done to disassociate trip attributes from regulatory context, though it necessitated the conversion of weights to lengths to determine legal harvest. Species-specific length-weight relationships from the literature were used for conversions (Lux and Porter, 1966; SEDAR, 2013, 2015). To reflect variation in the length-weight relationship, as well as in the size of individual fish caught on a particular trip, it was assumed that catch lengths followed a normal distribution with a standard deviation equal to 15 % of the average length of catch. Legal harvest was calculated by assessing the distribution of catch lengths for a particular trip, given average weight, and determining the percent within legal size limits. This percentage was then multiplied by catch and rounded to the nearest whole number. Legal harvest was equal to the number of fish within legal size limits that was less than or equal to the bag limit (note that for the catch and release cobia regulatory scenario, all cobia trips had zero legal harvest).

Table 2
Cobia regulatory scenarios included in the experimental design. In all scenarios except “Catch and Release Only” (no permitted harvest), no more than one fish harvested could be larger than 50″. Medium Minimum Size, Low Bag Limit corresponded to 2017 Virginia regulations.

Cobia regulatory scenario	Minimum size	Bag limit
Low minimum size, low bag limit	37″	1
Medium minimum size, low bag limit	40″	1
High minimum size, low bag limit	43″	1
Low minimum size, high bag limit	37″	2
Medium minimum size, high bag limit	40″	2
High minimum size, high bag limit	43″	2
Catch and release only	–	–

2.3. Survey implementation

The survey frame included all individuals who held a 2017 Virginia cobia permit and had provided email and valid mailing addresses (n = 5947 of the 6577 cobia permits issued to recreational anglers). Managers acknowledged that there were likely some anglers who fished for cobia in 2017 without obtaining the required permit, given that the program was in its first year (Jiorle, 2017). It is also possible that there were anglers who had previously targeted cobia, when regulations were more liberal, but did not fish for the species or obtain a cobia permit in 2017. As our study aimed to accurately capture the preferences and behavior of anglers who had targeted cobia, it was decided to also include a stratified random sample of individuals with email and valid mailing addresses who held a Virginia saltwater recreational fishing license but not a cobia permit, stratified by state of residency (Virginia or non-Virginia resident; n = 4053 drawn from 102,676 recreational license holders with email and valid mailing address who had not obtained a 2017 cobia permit). The final survey frame included residents of 43 states, the District of Columbia, and the US Virgin Islands; however, the majority of individuals were residents of Virginia (82 %) and most non-residents were from close neighboring states. Email and mailing addresses for cobia permit and saltwater recreational fishing license holders were obtained from the VMRC (in 2017 there were 242,763 Virginia saltwater recreational fishing license holders).

The survey was implemented online using the survey platform Qualtrics (Qualtrics, Provo, UT). An initial email invitation containing a link to the online survey was sent on October 27, 2017. This was followed by a postcard approximately two weeks later that contained the survey web address and a Quick Response (QR) code that could be scanned to access the online survey. A final email reminder was sent on December 11, 2017. Due to the relatively large survey frame and mixed-mode invitation (email and postcard), it was determined that providing a unique survey link or code for each individual would not be practical (e.g., use of private codes could lead to a large volume of calls and emails regarding survey access that would not be able to be addressed in a timely manner). A restriction was created such that each unique Internet Protocol (IP) address could only respond to the survey once, reducing the possibility that one individual could respond multiple times. The survey closed on December 20, 2017; individuals who had begun the survey before this time were allowed up to one additional month to finish. The approved research protocol did not allow collection of individually identifiable information as questions regarding an individual's fishing behavior could be viewed as sensitive if linked to their recreational permit holdings (i.e., individuals targeting cobia without the cobia permit). Respondents were asked how they learned of the survey however, and those who indicated channels other than the invitation email or postcard were removed from subsequent analyses.

Several steps were taken to ensure the survey collected data from a representative sample of cobia anglers. Average responses to questions on angler trip-taking and demographics were compared with data collected through a recent large national survey (Brinson and Wallmo, 2013) as well as data collected from cobia anglers by state managers (Jiorle, 2017). Additionally, previous research has noted that more avid anglers may be more likely to respond to recreational fishing surveys, which can affect estimation of angler preferences and willingness-to-pay (Johnston et al., 2006). We analyzed responses to questions on trip-taking and cobia trip expenditures in relation to survey response date, hypothesizing that more avid anglers would be more likely to respond earlier (more avid anglers might be expected to have an increased interest in survey material and thus respond more promptly). Specifications of the preference model were estimated including response day and state of residence (binary variable equaling one for individuals living outside Virginia) as interaction terms with hypothetical trip costs and cobia targeting to evaluate whether early responding individuals or those living outside Virginia held different preferences. Finally, responses to several questions were tested for significant differences across versions of the survey containing different hypothetical cobia regulations. Categorical responses (state of residence, income, target species, factors indicated as influencing species targeting) were evaluated using chi-squared tests while continuous responses (age, number of recreational saltwater trips over previous year, number of cobia trips in 2017, and cobia trip expenditures) were tested for differences across survey regulatory treatments using one-way analysis of variance tests.

2.4. Choice modeling

In each choice scenario, respondents were asked to select their most preferred option from the following four alternatives: “TRIP A”, “TRIP B”, “Target a different saltwater species”, or “Do not go saltwater fishing” (Fig. 1). Trips A and B potentially differed across five dimensions: species targeted, catch, average weight of catch, legal harvest, and trip cost. No specific attributes were associated with the options “Target a different saltwater species” and “Do not go saltwater fishing”.

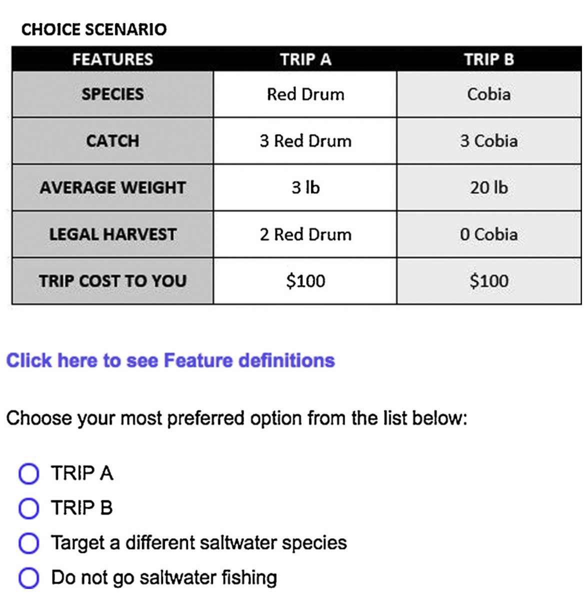

Fig. 1. Example choice scenario presented to respondents. Regulations for all three potential target species are not shown here but were presented to respondents above fishing trip choice alternatives. In this example, cobia regulations allowed no legal harvest (catch and release only).

Species-specific regulations were provided above presented choice scenarios and remained constant across the four scenarios shown to an individual.

Respondent decision-making was assessed using a random utility framework. Random utility models (RUMs) assume that individuals act so as to maximize their well-being, or utility, when making decisions over a discrete number of alternatives. Additionally, it is assumed that decisions are influenced by both observable and unobservable factors (McFadden, 1974). The utility of respondent n associated with choice alternative i can be specified as:

$$U_{ni} = \beta_n^{'} x_{ni} + \varepsilon_{ni} \ . \tag{1}$$

In (1), utility depends on a vector of attributes associated with choice alternative i for individual n (x_{ni}), a vector of individual preferences associated with alternative attributes ($ß_n$), and a random scalar (ε_{ni}) that is assumed to be independently and identically Gumbel distributed. When presented with a finite set of alternatives, an individual chooses the option with the highest associated level of utility, such that alternative i is chosen when:

$$U_{ni} > U_{nj} \, for \, all \, j \neq i \ . \tag{2}$$

A variety of RUMs have been developed to empirically explore discrete choice decision-making as described in (1) and (2) (Train, 2009). We utilized a random parameters mixed logit specification:

$$P_{ni} = \int \left(\frac{e^{\beta^{'} x_{ni}}}{\sum_j e^{\beta^{'} x_{nj}}}\right) f(\beta) d\beta \ . \tag{3}$$

In (3), the probability that individual n chooses alternative i (P_{ni}) is a function of observable attributes of alternative i (x_{ni}), attributes of all alternatives included in j (x_{nj}), and preference parameters ($ß$). The mixed logit is a flexible functional form that enables modeling of heterogeneous individual preferences through selection of a mixing distribution $f(ß)$, which is used to characterize the distribution of preferences across a population. Choice probabilities integrate over this preference distribution.

Respondents' choices in hypothetical choice scenarios were modeled using a mixed logit panel model. This allowed for correlated choice behavior by respondents across choice occasions via their individual preference parameters, which were fixed across decisions for an individual respondent but varied across respondents. Error terms associated with each choice occasion were assumed to be independent (a multinomial probit model, which relaxes this restriction, was also estimated). The joint probability for a sequence of choices was therefore equal to the product of individual choice probabilities (Morey et al., 1993; Lew and Larson, 2012). Preference parameters were estimated by maximizing the following log-likelihood:

$$LL = \sum_{n=1}^{N} \sum_{t=1}^{T} \sum_{j=1}^{J} d_{ntj} ln(P_{ntj}) \ . \tag{4}$$

The log-likelihood in (4) sums the natural logarithm of choice probabilities over N individuals, T choice occasions for each individual, and J alternatives for each choice occasion. The binary variable d_{ntj} was equal to one when individual n on choice occasion t chose alternative j, and zero otherwise.

The utility associated with choice alternatives was thought to depend on trip characteristics and the regulatory environment. Four dummy variables were constructed to evaluate species targeting preferences: cobia, juvenile red drum (3 lb and 6 lb), adult red drum (45 lb), and summer flounder, each of which equaled one for choice alternatives targeting these species and zero otherwise. Adult red drum was considered separately as it is a catch-and-release only fishery that is frequently targeted in geographically distinct areas. The alternative “Target a different saltwater species” was treated as the reference level and an alternative specific constant (ASC) was therefore included for the option "Do not go saltwater fishing". The impacts of changes in cobia regulations were evaluated through a series of regulatory dummy variables interacted with the cobia dummy variable. These interaction terms equaled one for cobia choice alternatives in survey versions under a particular regulatory change compared to status quo management (bag limit increase, minimum size limit decrease, minimum size limit increase, and catch and release) and zero otherwise. This model structure allowed for shifts in average cobia targeting preferences in response to regulatory change.

Preferences associated with catch, average weight of catch, and legal harvest were estimated separately for trips targeting cobia and non-cobia species by interacting cobia and non-cobia trip dummy variables with these trip attributes. Red drum and summer flounder trip attributes were considered jointly as attributes characterizing non-cobia trips given our research focus on cobia as well as an experimental design that did not present anglers with choice scenarios where both trips targeted the same non-cobia species (i.e., choice scenarios where both trips targeted red drum or summer flounder were not included and thus respondents did not evaluate trip attribute tradeoffs across trips targeting these species). Before constructing cobia and non-cobia trip attribute interaction terms, catch, average weight of catch, and legal harvest variables were standardized by species using z-score transformations. This was done to control for differences in scale across attributes and target species. Coefficients for species dummy variables therefore captured the utility associated with an average trip (average within survey), while coefficients for catch, average weight of catch, and legal harvest attribute interaction terms measured the utility associated with a one standard deviation increase in these variables. An additional dummy variable was added to capture potential non-linear (threshold) effects associated with legal harvest of cobia. This term was equal to one when a trip targeting cobia had zero legal harvest and zero otherwise (45.45 % of cobia trips in experimental design, including 36.36 % of trips having non-zero bag limits). Note that choice alternatives for trips targeting juvenile red drum or summer flounder had non-zero legal harvest in all instances. An additional model was also estimated for comparison, removing catch, average weight of catch, and legal harvest covariates and instead including total weight of catch (number of caught fish times average weight of catch) and total weight of legal harvest (approximated as number of legally harvestable fish times average weight of catch).

Species targeting dummy variables, the no-trip ASC, and attribute interaction terms were included in the mixed logit model as normally distributed random parameters. Trip cost was included as a non-random variable, which served to increase model stability and facilitate straightforward calculations of willingness-to-pay (WTP) (Revelt and Train, 1998; Sillano et al., 2005). An additional ASC for "TRIP A" was included to control for factors related to the presentation of choice alternatives but unrelated to attributes of the alternative itself ("TRIP A" was presented on the left-hand-side of choice scenarios and was the first listed option, which could have impacted choice behavior).

Due to its construction as a derived attribute, legal harvest was correlated with catch, average weight of catch, and, for cobia, cobia regulations. The mixed logit model returns parameter estimates identifying independent (orthogonal) effects that measure changes in trip utility corresponding to changes in an individual trip attribute, holding all other attributes fixed. This means that angler preferences estimated for catch, average weight of catch, and regulatory terms should be interpreted as being independent of changes in legal harvest, as well as vice versa. For example, the coefficient on cobia catch measures the utility associated with a one standard deviation increase in trip catch of cobia, holding legal harvest constant. Conversely, the coefficient on cobia legal harvest measures the utility associated with a one standard deviation increase in legal harvest of cobia, holding catch constant. In this context, cobia and non-cobia catch parameters measure preferences for additional catch that cannot be legally retained (i.e., catch that has to be released), while legal harvest parameters measure preferences associated with relaxation of binding regulations (i.e., additional harvest independent of additional catch). Similarly, preference parameter estimates for cobia regulations measure the shift in average cobia targeting preferences under a particular regulatory change, independent of the effect of that regulation on legal harvest (i.e., regulatory preferences as distinct from their impact on legal harvest). Two additional models, one excluding legal harvest and another excluding cobia regulatory interaction terms, were estimated to better understand the effects of this correlation on preference parameters. Results from these models are included in the Supplementary Material.

2.5. Economic analysis

Two sets of random draws of model parameters were constructed subsequent to estimation of the mixed logit model. First, 10,000 random draws were taken from a multivariate normal distribution with a mean and variance-covariance matrix set to model estimates, following the procedure originally proposed by Krinsky and Robb (1986). Each of the 10,000 draws was then used to make an additional 1000 draws from a multivariate normal distribution with a mean set to model coefficients of fixed parameters together with the means of random parameters and a variance-covariance matrix that captured the estimated preference heterogeneity (Hensher and Greene, 2003). This resulted in a sample of 10,000,000 preference parameters incorporating both statistical, or sample, uncertainty as well as preference heterogeneity. Expected mean values and 95 % confidence intervals associated with WTPs and changes in angler welfare resulting from changes in cobia regulations were calculated using the 10,000 Krinsky-Robb draws. The set of 10,000,000 parameter vector draws, which captured the full extent of variation in angler preferences, was used in characterizing WTP heterogeneity.

WTP for a recreational fishing trip targeting cobia, juvenile red drum, or summer flounder was calculated as:

$$WTP_j = -\frac{\sum_a \beta_a x_a - \beta_{NoTrip}}{\beta_{TC}}. \tag{5}$$

WTP in (5) was calculated by summing the partial utilities associated with trip attributes a (excluding trip cost), subtracting the ASC for the no trip alternative, and dividing the resulting value by the negative marginal utility associated with trip cost (β_{TC}). This measure corresponded to the maximum amount that would be paid for fishing trip j.

WTP values were calculated for average 2017 trips targeting each species as well as for cobia trips under hypothetical regulatory changes. The Marine Recreational Information Program (MRIP) collects data on angler effort, catch, and harvest by species. These data were used to calculate average values for catch, harvest, and average weight of harvest associated with private boat trips in Virginia during 2017, where cobia, red drum, or summer flounder were the primary species targeted. As weight information is only collected for landed fish, average weight of harvest was used as a proxy for average weight of catch. Cobia legal harvest attribute values were adjusted for hypothetical regulatory scenarios assuming changes in legal harvest within our experimental design, arising due to changes in regulations, would be proportionately similar to expected changes in legal harvest for hypothetical average 2017 trips. Under status quo regulations, average legal harvest was 0.59 cobia/trip within choice scenarios presented in the survey. This value increased to 0.77 cobia/trip and 0.82 cobia/trip when bag limits were increased or the minimum size limit was decreased, respectively. Average legal harvest decreased to 0.50 cobia/trip when the minimum size limit was increased, and to zero cobia/trip under catch and release regulations, however. Hypothetical cobia regulatory scenarios were therefore assumed to increase legal harvest per trip by 31 % for a bag limit increase and 38 % for a minimum size limit decrease, but decrease legal harvest by 15 % for a minimum size limit increase and 100 % in a catch and release only fishery (see Supplementary Table S1 for attribute values used in constructing WTPs as well as survey averages and standard deviations). Since average legal harvest values indicated many cobia trips with zero harvest, the zero legal harvest dummy variable was adjusted to reflect the assumed proportion of zero harvest trips (e.g., average legal harvest of 0.1 cobia/trip would correspond to 90 % of trips having zero legal harvest, or a value of 0.9 for the zero legal harvest dummy variable).

Mean WTPs for marginal increases in cobia catch, average weight of catch, and legal harvest were also calculated. These values were constructed by dividing preference parameters for these attributes by the negative coefficient on trip cost. Trip attribute WTPs, which measured WTP for a one standard deviation increase in each attribute, were then re-scaled to their respective units by dividing by attribute standard deviations. WTP for legal harvest of cobia with respect to the first fish was calculated by adding to the marginal value, the WTP associated with non-zero legal harvest (i.e., the coefficient on the zero legal harvest dummy variable divided by the marginal utility associated with trip cost).

Changes in angler wellbeing in response to regulatory changes might occur if regulations affect trip preferences and fishing behavior. Compensating surplus (CS) associated with a regulatory change was calculated to assess possible regulatory impacts on angler welfare (Hanemann, 1984; Hoyos, 2010):

$$CS = -\frac{1}{\beta_{TC}}\left[ln\left(\sum_j e^{\beta x_j^1}\right) - ln\left(\sum_j e^{\beta x_j^0}\right)\right] . \tag{6}$$

In (6), CS measures the amount of money necessary to compensate an angler for a change in utility resulting from a change in cobia regulations, where x_j^0 and x_j^1 correspond to vectors of trip attributes (including cost) for each trip alternative j before and after the regulatory change, respectively.

Changes in angler welfare in response to changes in cobia regulations were assessed under four available target species scenarios: 1) cobia, red drum, summer flounder; 2) cobia, summer flounder; 3) cobia, red drum; and 4) cobia only. This was done to evaluate regulatory impacts across a broad suite of recreational fishery conditions that may affect substitution behavior. To simplify analyses, target species scenarios including red drum considered targeting of juvenile red drum only. In all scenarios, the set of available choice alternatives was restricted to taking an average (2017) quality trip targeting one of the available species or doing something other than saltwater fishing (see Supplementary Table S1 for choice alternative attribute values, including cobia under hypothetical regulatory changes). The survey included questions asking respondents about average trip expenditures when targeting cobia as well as how these costs compared to those when targeting other species (see Supplementary Material for survey questions). Responses to these questions were used to derive reasonable approximations of average trip costs used in (6).

All statistical modeling and data analyses were performed in the statistical software R (R Core Team, 2018). The mixed logit model was estimated using the "mlogit" package (Croissant, 2018). The function "mvrnorm" contained in the "MASS" package was used in constructing multivariate normal random draws of parameter vectors (Venables and Ripley, 2002).

3. Results

3.1. Survey response

Email and postcard invitations were distributed to 10,000 individuals. During the eight-week survey window, 2698 individuals visited the survey site and 2535 answered at least one question. From this sample, 1646 individuals indicated they had targeted cobia within the last five years and had been invited to participate in the survey through the invitation email or postcard. Responses from individuals who did not indicate targeting cobia or learning of the survey through the invitation email or postcard were removed from all subsequent analyses (note that individuals who did not respond to these questions were also removed). Of these respondents, 90 % were residents of Virginia. The majority of non-resident respondents were from the neighboring states of Maryland and North Carolina.

The average birth year of respondents was 1966 (51 years old) and approximately 60 % of individuals had completed an associate's, bachelor's, advanced, or professional degree. There was considerable variation in reported personal annual pre-tax income, however 60 % of respondents indicated incomes of $75,000 or greater. Survey respondents reported taking 26 recreational fishing trips on average during the previous year and three (median; mean of five) recreational cobia trips during the 2017 season. Respondent demographics reported here were similar to those reported by Brinson and Wallmo (2013), who note that respondents in their national saltwater angler survey on average fished for 25 days over the last year, were 53 years old, had completed an associate's degree or higher, and had household annual incomes greater than $60,000. Additionally, Jiorle (2017) reported that in 2017 1882 anglers indicated taking 4,969 cobia trips (2.64 reported trips/angler on average). There were no significant differences across survey versions (regulatory treatments) in any of the considered demographic (age, income, state of residence) or fishing-related variables (target species, factors influencing species targeting, the number of annual fishing or cobia trips, and cobia trip expenditures).

3.2. Responses to cobia angling questions

Respondents reported variable cobia avidity, with 15 % indicating they took zero cobia trips in 2017 while 10 % responded they took 10 or more. When asked how many cobia trips per month respondents would take under ideal weather conditions and 2017 regulations, 55 % selected 0–2 trips/month, 31 % chose 3–5 trips/month, and 13 % indicated they would take six or more cobia trips per month. The primary reason for recreationally targeting cobia selected by respondents was that cobia "provide a good fight/are fun to fish for" (90 %). A majority of respondents also stated that they target cobia because they enjoy eating them (67 %). The primary mode indicated when targeting cobia recreationally during the 2017 season was private boat (93 %). A small number of individuals had targeted cobia from shore (8 %) or aboard a for-hire vessel (9 %) at least once during the 2017 season however. The primary fishing method reported when targeting cobia was chumming or bottom fishing (57 %). Sight fishing was also common (27 %) and a small group of respondents indicated no primary method or switching between methods depending on conditions (11 %). No significant correlation existed between survey response day and the number of cobia trips taken in 2017 (P-value = 0.37) or average cobia trip expenditures (P-value = 0.89), indicating early responding individuals did not appear to be more avid anglers.

The median level of average trip expenditures for individuals on recreational trips targeting cobia was $140, with 80 % of respondents indicating average trip costs between $40 and $420. Boat fuel made up the largest share of trip costs (33 % of costs on average), followed by fuel for a car or truck (14 % of costs), food and drink from convenience stores (14 % of costs), chum (11 % of costs), and live bait (11 % of costs). Average trip expenditures differed across individuals depending on their stated primary fishing method, with individuals primarily sight fishing spending more on average (median $160/trip), compared to those who primarily chum or bottom fish ($140/trip), fish from a pier or beach ($81/trip), or have no primary cobia fishing method ($145/trip). Individuals who were not residents of Virginia were found to spend more on cobia trips (median cost of $190/trip) due to increased expenditures on lodging (9 % of costs on average compared to 2 % for residents), fuel for a car or truck (18 % of costs compared to 13 % for residents), and food and drink from restaurants (7 % of costs compared to 3 % for residents). Most individuals who had targeted cobia owned a boat they had used for this purpose (80 %; no significant difference between residents and non-residents). Though of those anglers with private vessels targeting cobia, many fewer had fishing towers installed on their boats (17 %; no significant difference between residents and non-residents).

Approximately half of respondents (49 %) indicated that fishing for cobia was about the same cost or less expensive when compared to other inshore or nearshore species they target. An equal percentage indicated that targeting cobia was more expensive. In the subsequent analyses calculating changes in angler welfare arising from changes in cobia regulations, we considered two potential cost scenarios: 1) fishing trip expenditures are equivalent across target species and set to the median reported cobia trip costs of $140; and 2) targeting cobia is 25 % more expensive than targeting red drum or summer flounder, and thus costs of $140 (cobia) and $112 (red drum, summer flounder) were applied. Results from the former cost scenario are presented below while those of the latter are included in the Supplementary Material. Given differences in expenditures between resident and non-resident anglers, angler welfare estimates are best interpreted as representative of Virginia residents.

3.3. Choice modeling

Cobia trips were presented to respondents in choice scenarios at approximately twice the frequency of either summer flounder or red drum trips (the experimental design was balanced in terms of trips targeting cobia and non-cobia species). Conditional on the number of times an option was presented and a choice made, trips targeting cobia were selected most frequently (46.48 %), followed by summer flounder (43.44 %), red drum (36.68 %), and targeting a saltwater species not described in either trip option (10.44 %). The no saltwater fishing trip alternative was selected least frequently (2.41 %). In total, 6214 choice scenario responses were analyzed using the mixed logit discrete choice model. Several variables included in the model were found to be important factors affecting decision-making, and comparison of the full model with an intercept-only model using a likelihood ratio test indicated inclusion of covariates significantly improved model fit (Table 3).

Table 3
Parameter estimates for the mixed logit discrete choice model. Coefficients and standard errors are presented. Statistical significance denoted as ".", "*", "**", and "***" corresponding to significance at the 10, 5, 1, and 0.1 % levels, respectively.

Variable	Coefficient (mean)		SE	Coefficient (sd)		SE
Cobia	4.642	***	0.236	2.462	***	0.137
Red Drum	2.162	***	0.162	1.861	***	0.216
Adult Red Drum	2.490	***	0.219	3.110	***	0.496
Summer Flounder	3.072	***	0.157	2.438	***	0.184
No Trip	−3.513	***	0.339	2.774	***	0.250
Cobia x Catch	0.232	***	0.048	0.379	***	0.094
Cobia x Weight	0.653	***	0.070	0.389	***	0.097
Cobia x Legal Harvest	0.264	*	0.121	0.224	*	0.111
Non Cobia x Catch	0.148	.	0.078	0.255	*	0.128
Non Cobia x Weight	0.293	***	0.061	0.108		0.124
Non Cobia x Legal Harvest	0.189	*	0.092	0.046		0.132
Cobia x Zero Legal Harvest	−1.404	***	0.256			
Cost	−0.011	***	0.001			
Cobia x Bag Limit Increase	0.100		0.148			
Cobia x Minimum Size Decrease	−0.355	*	0.176			
Cobia x Minimum Size Increase	−0.628	***	0.169			
Cobia x Catch and Release	−1.683	***	0.247			
Trip A	0.267	***	0.067			
N Observations	6214					
NLL	5209.7					
Likelihood Ratio Test ($\chi 2$)	2567.1	***				

The average respondent preferred trips targeting cobia to those targeting summer flounder or red drum (adult and juvenile). All standard deviations associated with random parameters for species' dummy variables were statistically significant, indicating heterogenous targeting preferences. Species targeting preferences were also found to be influenced by cobia regulations. Aside from a bag limit increase, which had no significant effect on cobia targeting preferences, all regulatory changes decreased the utility associated with targeting cobia (thus increasing relative preferences for targeting other species). It is worth reiterating that these effects were independent of regulatory impacts on legal harvest. For example, the probability that an angler would select a trip targeting cobia, over one targeting red drum or summer flounder, under average catch conditions, a trip cost of $140, and zero legal harvest, ranged from 0.20 (catch and release) to 0.56 (status quo regulations, bag limit increase).

Several other variables in the model were also found to be statistically significant. For the average respondent, increases in cobia or non-cobia catch, average weight of catch, and legal harvest were positively related to trip utility. In general, anglers derived more utility from increases in cobia trip attributes as compared to attributes for trips targeting non-cobia species. Significant heterogeneity was found with respect to preferences for all cobia trip attributes. Preferences for cobia and non-cobia catch were especially variable (cv > 1), suggesting substantial heterogeneity within the sampled population for increases in trip catch that could not be legally retained. Comparison across trip attribute coefficients, which were estimated using standardized covariates, indicated that changes in average weight of catch elicited that largest changes in trip utility (i.e., the size of fish caught tended to be more important than the number). Preferences for legal harvest of cobia were found to be non-linear, with the first fish harvested producing substantially more trip utility as compared to the second. As expected, trip cost was negative and highly significant. The positive and significant parameter on "TRIP A" indicated that individuals tended to choose this option more frequently, irrespective of trip attributes. Including this parameter in the model ensures that estimates of other parameters are not confounded by factors related to the presentation of choice alternatives.

Several additional specifications of the choice model were explored to better understand angler preferences. Models allowing for shifts in trip cost preferences for non-resident respondents and individuals responding early to the survey (potentially more avid, high-interest anglers) indicated angler WTP did not depend on these factors. Additionally, non-resident and early responding anglers were not found to have stronger cobia targeting preferences compared to residents or those responding to the survey later on. Removing legal harvest from the mixed logit model led to increases in magnitude and significance of cobia and non-cobia catch parameters, as these variables now captured the marginal value of increases in trip catch irrespective of changes in legal harvest (Supplementary Table S2). Under this specification, restrictive regulations were also found to cause greater disutility due to corresponding reductions in legal harvest. Models removing cobia regulatory terms (Supplementary Table S3) and including total weight of catch and harvest produced results consistent with findings presented in Table 3, but had slightly weaker fits to the data. Predicted choice probabilities estimated using a multinomial probit model, which relaxed the restriction of error independence, were found to be strongly correlated with predictions from the mixed logit model (Pearson correlation coefficient of 0.97). Across all model specifications evaluated, preference parameters appeared robust in sign, significance, and relative magnitude.

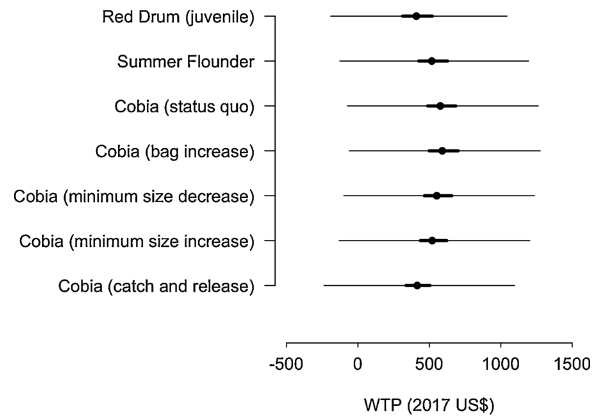

Fig. 2. Willingness-to-pay for recreational fishing trips of average quality targeting juvenile red drum, summer flounder, and cobia under status quo 2017 Virginia regulations, a bag limit increase, a minimum size limit decrease, a minimum size limit increase, and catch and release only. Means (points) and associated 95 % confidence regions (thick horizontal lines) were estimated using 10,000 random draws of mean preference parameters. Thin horizontal lines correspond to 95 % confidence regions of the full WTP distribution estimated using 10,000,000 random draws of preference parameters incorporating individual preference heterogeneity.

3.4. Economic analysis

Mean WTPs under status quo 2017 regulations for average trips targeting juvenile red drum, summer flounder, and cobia were $408.94 (95 % CI: [$312.48, $521.02]), $517.08 (95 % CI: [$425.59, $627.88]), and $576.85 (95 % CI: [$488.11, $685.14]), respectively (Fig. 2). Considering the full possible range of targeting preferences within the sampled population led to wide distributions of WTP values (Fig. 2, thin horizontal lines).

Changes in cobia trip attributes and regulations were found to significantly affect trip WTP. Mean WTPs for an additional cobia caught and a one-pound increase in average weight of catch were $24.89 (95 % CI: [$14.38, $36.78]) and $4.16 (95 % CI: [$3.23, $5.22]), respectively. WTP for the first cobia harvested was $158.84 (95 % CI: [$117.62, $207.76]), whereas subsequent legal harvest was valued at $34.89/fish (95 % CI: [$3.00, $67.80]). Mean WTP for an average trip targeting cobia increased under a bag limit increase to $590.31 (95 % CI: [$499.13, $701.35]) but decreased under a minimum size limit decrease to $551.63 (95 % CI: [$465.60, $657.09]). Restrictive regulatory changes further reduced cobia trip WTP to $519.68 (95 % CI: [$437.89, $621.47]) under a minimum size limit increase and $414.78 (95 % CI: [$335.97, $504.67]) under a catch and release only recreational cobia fishery. The large decrease in trip WTP under the catch and release only regulatory scenario (28 % decline from status quo) was due to the direct influence of regulatory environment on trip utility as well as the reduction in legal harvest. Under a catch and release only recreational cobia fishery, 11.08 % of the full WTP distribution, which incorporates both sample uncertainty and preference heterogeneity, was less than zero. This suggests that the hypothetical regulatory change could make some portion of the population averse to targeting cobia at even nominal cost.

Restrictive regulations (minimum size limit increase and catch and release only) were found to lead to statistically significant decreases in angler welfare (Table 4). Across four available target species scenarios, reductions in angler welfare ranged from losses of $29.77 to $56.58 per trip for a minimum size limit increase and losses of $62.20 to $158.68 per trip for catch and release only regulations. Losses in angler welfare were found to increase as fewer or less desirable alternative target species options were available due to reduced target species substitution possibilities. In scenarios where summer flounder or red drum were available, target species substitution was found to be the dominant behavioral response to changes in cobia regulations (Table 4). When cobia was considered a more expensive targeting option, the welfare effects of regulatory changes were slightly reduced as (cheaper) trips targeting alternative species now produced slightly higher net benefits (Supplementary Table S4).

Table 4
Changes in angler welfare and species targeting resulting from changes in cobia regulations, assuming equal targeting costs across species. Compensating surplus (CS) at the fishing trip level was estimated for four potential regulatory changes and four alternative available target species scenarios. Available target species scenarios include: “All” (cobia, summer flounder, red drum); “No RD” (cobia, summer flounder); “No SF” (cobia, red drum); and “No RD, SF” (cobia only). All scenarios use status quo 2017 Virginia regulations as the base case. Compensating surplus standard errors are presented beneath mean estimates. Changes in the probability of targeting cobia (Δ P(C)) and non-cobia species (Δ P(NC)) are also shown. Statistical significance denoted as “.”, “*”, “**”, and “***” corresponding to significance at the 10, 5, 1, and 0.1 % levels, respectively.

		All	No RD	No SF	No RD, SF
Bag Limit Increase	CS	$8.32	$9.10	$11.68	$13.36
		8.21	8.94	11.47	13.09
	Δ P(C)	0.04	0.03	0.02	0.00
	Δ P(NC)	−0.04	−0.03	−0.02	—
Minimum Size Decrease	CS	-$14.20	-$15.75	-$21.17	-$25.01
		9.03	9.93	13.31	15.67
	Δ P(C)	−0.07	−0.07	−0.04	0.00
	Δ P(NC)	0.07	0.07	0.04	—
Minimum Size Increase	CS	-$29.77***	-$33.34***	-$46.56***	-$56.58***
		8.91	9.60	13.12	15.45
	Δ P(C)	−0.16	−0.15	−0.10	−0.01
	Δ P(NC)	0.16	0.15	0.09	—
Catch and Release	CS	-$62.20***	-$71.54***	-$113.78***	-$158.68***
		12.63	13.06	20.23	23.02
	Δ P(C)	−0.40	−0.42	−0.36	−0.04
	Δ P(NC)	0.40	0.42	0.34	—

4. Discussion

We developed and implemented a survey of recreational cobia anglers to evaluate preferences and decision-making under a variety of regulatory conditions. Responses to recreational fishing trip choice scenarios were modeled using a mixed logit specification, estimating heterogeneous angler preferences associated with targeting red drum, summer flounder, and cobia, as well as cobia and non-cobia trip attributes. Model findings indicated that, of the three species, cobia was most preferred under status quo regulations, followed by summer flounder, and red drum. Additionally, cobia trip attributes were found to be more important to anglers when compared with trip attributes for non-cobia species. Finally, angler behavior and resulting welfare impacts were shown to depend on both cobia regulations and alternative target fishery conditions.

In this analysis, WTP was estimated for recreational trips targeting juvenile red drum, summer flounder, and cobia under a variety of regulatory conditions. Our trip WTPs were calculated using average 2017 values for catch, harvest, and average weight of harvest as reported by MRIP (note that MRIP averages included zero-catch trips). Lew and Larson (2012) estimated WTP for resident and nonresident saltwater sportfishing trips in Alaska targeting Pacific halibut *Hippoglossus stenolepis*, Chinook salmon *Oncorhynchus tshawytscha*, and coho salmon *O. kisutch*. The authors found that for Alaska residents fishing from private boats, trip WTP ranged from $246 to $444 for single species trips and up to $718 for multispecies trips. Despite obvious differences in target species and the angling population surveyed, trip WTP estimates provided here are generally similar to those presented in Lew and Larson (2012). Lew and Larson (2012) did however observe significant differences in trip WTP for resident and non-resident anglers. Non-resident anglers in our sample were found to have higher travel expenses associated with cobia trips but did not appear to exhibit different WTP or cobia targeting preferences. The majority of non-resident anglers responding to this survey were from close neighboring states, owned boats used to target cobia, and were similar to resident anglers in terms of primary fishing mode, motivations, and commonly targeted species. Nevertheless, future research should carefully consider differences in trip expenditures, opportunity costs of time, and fishing preferences in relation to travel distance and site access opportunities, which generally differ between resident and non-resident anglers.

Cobia trip attribute WTPs were also estimated in this study. Johnston et al. (2006) performed a meta-analysis of 48 studies reporting WTP estimates for increased recreational catch of both fresh- and salt-water species. Our WTP estimate for an additional cobia caught is close to the mean reported in Johnston et al. (2006) ($16.82/fish, 2003 dollars) and is well within a conservative estimate of their range ($0.05 - $327.29, 2003 dollars). Note, however, that the coefficient on catch from the model presented in Table 3 corresponds to an increase in catch without an increase in legal harvest (i.e., catch and release). Anglers were found to have a higher WTP for unconditional increases in catch (~$37/cobia; results from a model removing legal harvest covariates are presented in Supplementary Table S2). This study found that WTP for an additional cobia caught was ~16 % of the WTP estimated for the first cobia harvested, yet ~71 % of the WTP estimated for subsequent harvest. Goldsmith et al. (2018) report WTP for increases in catch of Atlantic bluefin tuna to be worth 35–74 % of WTP for increases in harvest, speculating that this may be because the species is both a highly desirable food fish as well as a valuable gamefish. In this study, 90 % of cobia anglers indicated targeting cobia because they “provide a good fight/are fun to fish for”. A large WTP for the first cobia harvested suggests that consumptive aspects of cobia fishing may be the primary source of derived value. However, a sharp decline in WTP for subsequent harvest indicates diminishing marginal returns, as has been found in other studies (e.g., Carter and Liese, 2012), and further suggests non-consumptive aspects may be relatively more important past this first-fish threshold.

Several prior studies have examined angler preferences and values with respect to fisheries management and recreational regulations using stated preference approaches similar to those applied here. In these studies, regulations typically have been included as attributes in choice alternatives (Aas et al., 2000; Oh et al., 2005; Oh and Ditton, 2006; Carter and Liese, 2012; Lew and Larson, 2012; Goldsmith et al., 2018) or anglers have been asked to rank or vote on management options directly (Gillis and Ditton, 2002; Stoll and Ditton, 2006). The experimental design used here varied regulations across but not within surveys, leading to species targeting preferences that were conditional on regulatory environment. Preferences for cobia regulatory options were estimated by evaluating shifts in the distribution of cobia targeting preferences under different regulatory treatments. This approach was used because it presents individuals choice scenarios that closely resemble decision-making occasions most anglers have some degree of familiarity with. It was also useful in disentangling preferences for regulations from their resulting impacts on legal harvest. However, it should be noted that respondent heterogeneity across regulatory treatments may confound estimates of regulatory preferences, and it is not recommended that this strategy be applied in surveys distributed to small and/or highly heterogenous populations. We found no significant differences in average responses across different regulatory treatments for several demographic and fishing-related variables, suggesting observed shifts in cobia targeting preferences were most likely the result of changes in cobia regulations.

While other studies including regulatory attributes within choice experiments have generally found anglers prefer less restrictive regulations (e.g., Aas et al., 2000; Lew and Larson, 2012; Goldsmith et al., 2018), here we found that anglers primarily preferred status quo management. As our model identified regulatory preferences as distinct from changes in legal harvest, these findings indicate that anglers value both consumptive aspects of a recreational trip as well as the regulatory context of that consumption (i.e., preferences for legal harvest and regulatory environment are, or may be, distinct). This was apparent when evaluating cobia targeting probabilities associated with identical zero-harvest trips occurring under different regulatory regimes, where changes in the minimum size limit or the introduction of catch and release only regulations reduced the probability of targeting cobia (without impacting legal harvest). Regulatory preferences found here may be related to concerns regarding future harvest opportunities or stock conservation. It is also possible, and perhaps more likely, that these preferences are the result of aversion towards change from a status quo baseline (referred to as status quo bias; Samuelson and Zeckhauser, 1988). Preference for the status quo is in part due to loss aversion, a behavior originally acknowledged in prospect theory (Kahneman and Tversky, 1979; Kahneman et al., 1991). Loss aversion could further explain the asymmetric welfare effects found for restrictive versus liberalizing regulations, where the former were seen to significantly reduce angler welfare while the latter had no significant effects.

Changes in fishing or regulatory conditions that affect the utility derived from recreational angling may cause individuals to substitute between different recreational activities (Ditton and Sutton, 2004) or among alternative target species (Fisher and Ditton, 1993; Hunt et al., 2002; Sutton and Ditton, 2005; Gentner and Sutton, 2008). Researchers investigating recreation substitution have frequently sought to identify alternatives yielding similar levels of benefits when compared to those derived from recreational fishing or targeting a particular species (Ditton and Sutton, 2004; Sutton and Ditton, 2005). The utility framework used here, conversely, considered substitution a behavior resulting from shifts in expected benefits among recreational alternatives due to changes in fishery or regulatory conditions. Analysis of the welfare effects resulting from changes in cobia regulations revealed that anglers were predicted to substitute alternative target species in response to shifts in cobia regulations. This behavior impacted potential losses resulting from restrictive regulations, which were larger when fewer or less desirable alternative targets were available. Substitution behavior might therefore be considered a loss mitigation strategy, and increased quality or availability of substitution possibilities would thus reduce the welfare effects associated with changes in an individual fishery.

As a result of substitution behavior between alternative target species in response to regulatory change, cobia management decisions have the potential to undermine management of other species. Similarly, targeting pressure on cobia might also be expected to be influenced by conditions in other, substitute fisheries. The popularity of cobia as a recreational target in Virginia has increased substantially over the last two decades, with average annual directed private or rental boat trips from 2009 through 2018 nearly double the average level from a decade earlier. Concurrent with this increase has been a 47 % reduction in recreational catch of summer flounder and a decline in directed effort of over 50 % during the last five years (NMFS Fisheries Statistics Division, personal communication). While it is unknown whether or not recent increases in cobia targeting are related to effort reductions in summer flounder, possibly due to decreases in summer flounder size and abundance and increasingly restrictive regulations (i.e., recreational substitution), the analysis presented here suggests this explanation is at least plausible. Additional research is needed to identify both historical and predicted target species substitution patterns, which could ultimately inform ecosystem-based fisheries management policies (Marshall et al., 2018).

Anglers were found to strongly prefer recreational fishing to non-fishing alternatives, selecting “Do not go saltwater fishing” on only 2.41 % of choice scenarios. Though anglers responded to marginal changes in trip costs as expected—strongly preferring lower cost trips—the range of trip costs considered in choice alternatives was relatively low in comparison to trip costs reported by anglers, and could have been seen as unrealistic to anglers who typically spend several hundred dollars per cobia trip (e.g., if lodging is required). A higher or broader range of trip costs used in hypothetical fishing trip choice scenarios would likely have resulted in more frequent selection of the no fishing alternative. The reference alternative, “Target a different saltwater species”, was meanwhile chosen 10.44 % of the time. “Target a different saltwater species” included no associated trip attributes and was therefore open to respondent interpretation. It is possible that respondents viewed this alternative as a trip targeting cobia, red drum, or summer flounder when a particular choice scenario presented trips that did not include these species. This would introduce correlation into unobserved components of alternative specific utility, and is thus a potential limitation of our survey design. Choice probabilities estimated using a multinomial probit model, which relaxes the restriction or error independence, were found to generally agree with estimates from the multinomial logit model however.

Estimates of changes in angler welfare were provided at the fishing trip level for hypothetical trips of average quality. Determining aggregate, fishery-wide changes in welfare would require consideration of anglers’ recreational demand at the seasonal or annual level (e.g., Morey et al., 1993; Phaneuf et al., 2000; Criddle et al., 2003). Counterfactual cobia trips under hypothetical regulations were constructed assuming catch and average weight of catch would not change, and also that changes in legal harvest would be proportionately similar to those included in the experimental design of our survey. Detailed modeling of counterfactual fishery outcomes was beyond the scope of work considered here, but is perhaps a place for future research.

CRediT authorship contribution statement

Andrew M. Scheld: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing - original draft, Writing - review & editing. **William M. Goldsmith:** Conceptualization, Investigation, Writing - original draft, Writing - review & editing. **Shelby White:** Investigation, Writing - review & editing. **Hamish J. Small:** Conceptualization, Investigation, Writing - review & editing, Funding acquisition. **Susanna Musick:** Funding acquisition, Investigation, Writing - review & editing.

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