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Title: Preferences for derelict gear mitigation strategies by commercial fishers

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Abstract

Local, national, and international efforts to address the issue of derelict fishing gear are often limited by resources and costs. Managers and policymakers have implemented various preventative, impact reducing, and curative measures to decrease derelict fishing gear abundance and impacts, but stakeholder support is essential for success. To identify stakeholder preferences and the most efficient measures to address the issue of derelict blue crab pots in Chesapeake Bay, we distributed a stated preference survey with a discrete choice experiment to 1,032 licensed commercial fishers in Virginia and received a 42% response rate. The DCE consisted of hypothetical scenarios with two alternatives that included a combination of derelict pot mitigation activities paired with incentives or none, and a third alternative for maintaining the status quo. The probability of participation in derelict pot mitigation activities for the average respondent ranged from 0.46 (SE = 0.07) for "Recycle at facility on land," to 0.03 (SE = 0.02) for "Pot modification." Management incentives (e.g., bushel limit increase, pot limit increase, or season extension) were generally not found to induce participation in mitigation activities; however, heterogeneity observed in preferences of fishers could be used to target different segments of the population to participate in specific actions. For example, individuals that perceived derelict pots to cause negative impacts only were much more willing to participate in mitigation activities. Addressing the complex problems caused by marine debris, especially derelict fishing gear, is costly, and understanding stakeholder preferences and decision-making can help managers and policymakers reduce costs.

Keywords: Derelict fishing gear, Commercial pot fishery, Random utility model, Discrete choice experiment, Blue crab, Marine debris

Highlights:

- Assessed commercial fishers' preferences and perceptions of derelict fishing gear.
- Most mitigation activities were considered too burdensome by fishers.
- Fishers preferred monetary incentives over regulatory benefits.
- Strong negative perceptions of derelict pots increased willingness to participate.

1 Introduction

Marine debris persists around the globe, contributing to a complex problem in fisheries worldwide (Galgani et al. 2015, Richardson et al. 2019). Calls for action to combat marine debris have resounded throughout international (United Nations General Assembly 2004), national (Marine Debris Act 2006), and state (Register 2014) governing bodies. Each call has explicitly identified the need to reduce derelict fishing gear, a type of marine debris that consists of any fishing gear abandoned, lost, or otherwise discarded (Macfadyen et al. 2009). Richardson et al. (2019) estimated that 6% of all fishing nets, 19% of all traps and pots, and 29% of all fishing lines are lost around the world each year. Derelict fishing gear, in particular pots and traps, is responsible for significant ecological and economic impacts through increased entanglements and bycatch mortality, as well as damaging habitats that support marine fish and shellfish, reducing stocks of target and non-target species, and decreasing fishery profits (Guillory 1993, Wood 2010, Arthur et al. 2014, Bilkovic et al. 2016, Scheld et al. 2016, Wilcox et al. 2016, DelBene et al. 2019). Pots may become derelict when a vessel's propeller strikes the buoy line, storms or strong currents move a pot or submerge the buoy making it difficult to locate, equipment fails, or pots are intentionally abandoned (Bilkovic et al. 2016). Numerous strategies have been developed to address the issue of derelict pots, but their effectiveness can be hindered by various factors, such as acceptability by commercial fishers and enforcement (Macfadyen et al. 2009, Brodbeck 2016). Technological solutions also exist, but they are often too costly for commercial fishers to implement (e.g., using acoustic technology to mark pot locations for retrieval; He and Suuronen 2018, Lebon and Kelly 2019). Strategies that engage stakeholders (e.g., surveys, task-forces, workshops) can improve the quality of management decisions (Reed 2008) and may help increase acceptability and enforceability of efforts to address derelict fishing gear.

In the U.S., governments, academic institutions, non-governmental organizations, commercial fishers, and the public have worked together to combat the issue of derelict pots (Bilkovic et al. 2016, Bowling 2016, Lebon and Kelly 2019). Pot and trap fisheries in the U.S. target a variety of valuable commercial species, such as American lobster *Homarus americanus*, blue crab *Callinectes sapidus*, Caribbean spiny lobster *Panulirus argus*, and Dungeness crab *Metacarcinus magister*. Most pot fisheries operate within the territorial waters of a state, and the majority of state laws only permit the pot's owner or an authorized individual to remove pots, including derelict pots, complicating mitigation efforts. Managers and policymakers have implemented requirements in many areas that could reduce the abundance or impacts of derelict pots, for example, installation of bycatch reduction devices and escape panels, implementation of derelict pot removal programs, as well as limits on fishing effort and temporal and spatial gear use restrictions (Bowling 2016, DelBene 2020). In several fisheries, stakeholder engagement has been seen as important to successful implementation of these actions and other initiatives. For instance, commercial fishers have volunteered or been paid to assist in derelict pot location and removal programs, experiment with new gear modifications, recycle their old pots at facilities on land, and participate in gear buyback programs (Havens et al. 2011, Bowling 2016, Lebon and Kelly 2019).

Chesapeake Bay is the largest estuary in the U.S., located within Maryland and Virginia state borders. The waterbody supports diverse user groups, including recreational boaters and fishers, academic researchers and educators, the maritime shipping and transportation industry, U.S. military, shellfish aquaculture operations, and commercial fishers targeting finfish and shellfish. Its commercial blue crab fishery supports over a thousand active fishers and is responsible for 30-40% of U.S. commercial harvests, with ex-vessel revenues valued at over US

$100 million in 2016 (NMFS 2018). Historically, the Chesapeake Bay commercial blue crab fishery has harvested the greatest abundance of blue crabs in the U.S., significantly contributing to the culture and economy of the region (Kennedy et al. 2007). The present-day fishery generally begins in March and closes in November, and, according to the most recent assessment released in 2021, overfishing is not occurring and the blue crab population is not depleted (Chesapeake Bay Stock Assessment Committee 2020). Commercial blue crab fishers often hold licenses to participate in multiple fisheries, such as oyster *Crassostrea virginica*, conch *Busycotypus canaliculatus*, or striped bass *Morone saxatilis*, rotating their operations based on the season and markets (White and Scheld 2021). Pots are the primary gear used, representing 95% of the harvest in the commercial blue crab fishery (VMRC 2017), and are constructed from two types of material: galvanized wire and vinyl coated wire. Recent estimates suggest that 12-20% of all licensed pots become derelict each year and approximately 145,000 derelict pots are thought to be present at any given time (Bilkovic et al. 2016). These derelict pots can reduce harvests of blue crab, continue to capture valuable recreational and commercial species, and create a navigational hazard for vessels (Bilkovic et al. 2016, DelBene et al. 2019). Analysis evaluating an extensive marine debris location and removal program in Virginia waters (2008-2014) found that removal of 34,408 derelict pots increased harvest by 13,504 MT over six years due to reduced competition between active and derelict gear (Scheld et al. 2016).

In Virginia, the Virginia Marine Resources Commission (VMRC) manages the commercial blue crab fishery and enforces regulations on size, season, time of day, and daily harvest limits, as well as the number of pots permitted to be fished (licenses range from 85 to 425 pot limits), area closures, and installation of cull rings in pots to create openings for undersized crabs to escape. Since 2008, the VMRC and state policymakers have engaged with fishers to address the issue of derelict pots, but historical tensions and limited resources have produced obstacles to implementing successful, long-term mitigation activities. These obstacles were evident in January 2018, when fishers organized to lobby the Virginia legislature and defeated a proposed bill that would have required crab pots to incorporate an escape panel that degraded if the pot became derelict (SB 552 2018). This bill would have increased costs for commercial fishers but lacked any incentive measures. Improved stakeholder engagement is therefore needed to understand and incorporate commercial fishers' preferences into management decisions that address the problems produced by derelict pots.

Stated preference survey methods are frequently employed to identify the preferences of stakeholders in environmental policy settings, providing valuable information for managers and policymakers (Hanley and Czajkowski 2019). In particular, discrete choice experiments (DCEs) measure preferences by analyzing the tradeoffs that one makes when presented with different options defined by hypothetical attributes. DCEs have been used to evaluate fishers' preferences and decision-making for policy or management options (e.g., size limits, harvest regulations, and quota allocations) in commercial (Wattage et al. 2005, Fitzpatrick et al. 2017) and recreational fisheries (Aas et al. 2000, Lew and Larson 2015, Goldsmith et al. 2018). More recently, DCEs have been used to assess public perceptions of marine debris on beaches and willingness to participate in beach clean-ups (Brouwer et al. 2017, Lucrezi and Digun-Aweto 2020), but we are unaware of any study that has quantified commercial fishers' perceptions and preferences on activities that address derelict fishing gear. Furthermore, decision-making may be influenced by the type of incentive, whether monetary or non-monetary, depending on the context and specific behavior (Maki et al. 2016, Grilli and Curtis 2021). For instance, fishers have been presented with various monetary (e.g., cost to fish) and non-monetary (e.g., biological outlook for the fish stock, size of fish, catch probability, and number of fish hooked and lost before landing) incentives in DCEs (Aas et al. 2000, Lew and Larson 2015, Fitzpatrick et al. 2017, Goldsmith et al. 2018), which may have different effects on decision-making when it comes to contributing to a public good (Lefebvre and Stenger 2020).

Working collaboratively with commercial fishers, we gathered information on crabbing activity and derelict crab pots, while also evaluating management preferences related to mitigation alternatives in an effort to develop sustainable, stakeholder-driven solutions. The objectives of this study were to (1) identify commercial fishers' perceptions of derelict crab pots, (2) measure their willingness to accept (WTA) and participate in activities to mitigate the negative effects of derelict crab pots, and (3) examine the effectiveness of monetary and non-monetary incentives to influence willingness to participate.

2 Methods

The study surveyed commercial crab fishers that were licensed to operate in Virginia waters in 2017 (Figure 1). Stated preference surveys were used and consisted of two parts: (1) attitudinal and behavioral questions on fishing activity and derelict crab pots, in addition to demographic questions, and (2) a DCE where questions presented hypothetical mitigation activities or policy measures paired with incentives to address the issue of derelict pots. The DCE was then used to quantify participants' decision-making and preferences.

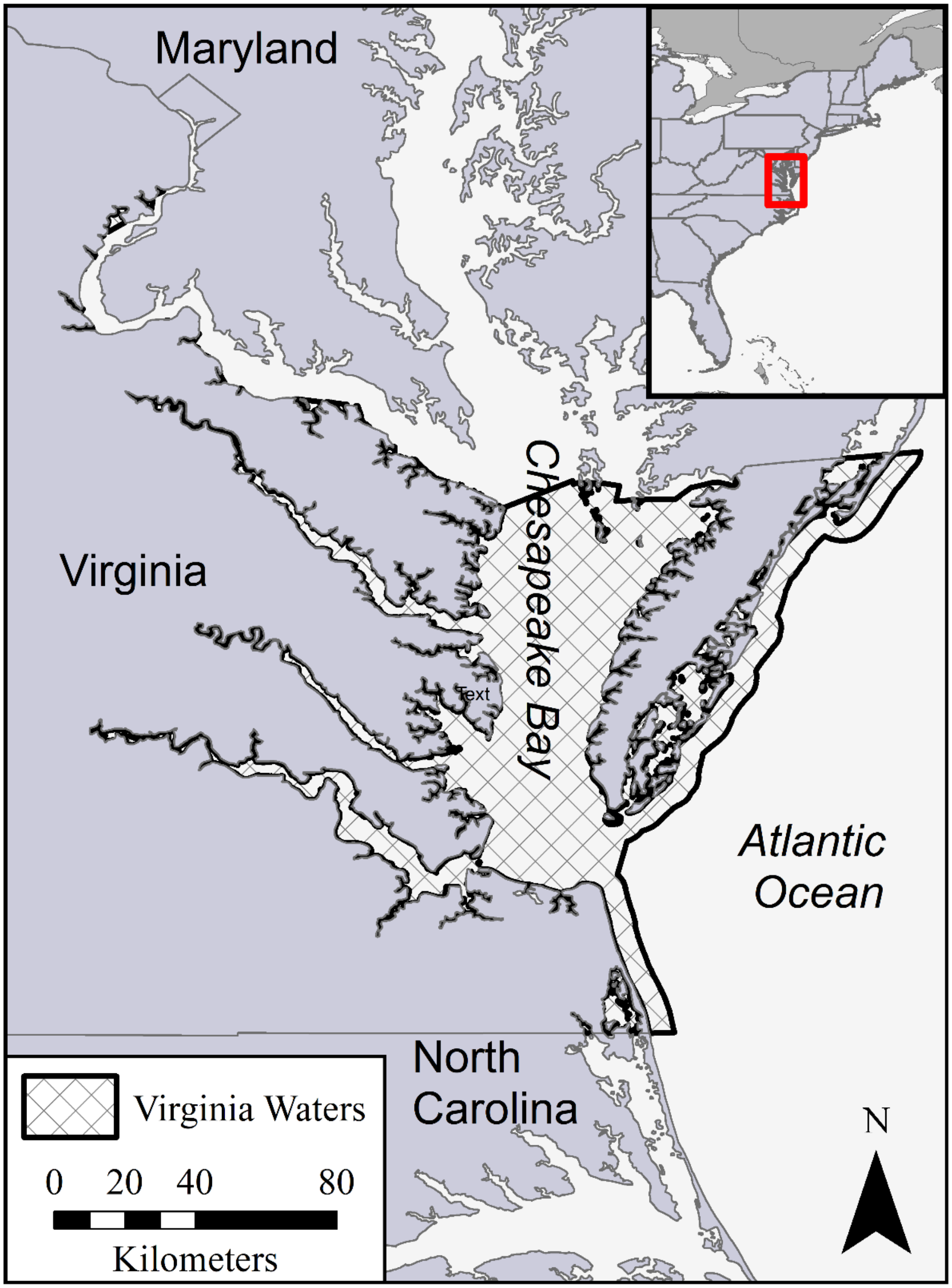

Figure 1 Map of the study area in the Chesapeake Bay region.

2.1 *Survey development*

Because blue crab fisheries occur in state waters, we reviewed existing regulations and derelict pot mitigation activities in U.S. states with a commercial blue crab fishery (see DelBene 2020 for a summary of the review). We solicited input from fishery managers at VMRC on hypothetical mitigation activities and incentives that were practical for the Virginia commercial blue crab fishery. For example, we considered spatial restrictions to reduce vessel or gear interactions that could cause a pot to become derelict; requirements to install owner identification tags on pots to strengthen enforcement on fishing effort limits, thus reducing the number of pots that could become derelict; and programs to locate and remove derelict pots. Possible incentives consisted of monetary payments, as well as management incentives such as increasing daily harvest limits (also known as bushel limits), increasing pot limits, allowing access to deploy pots in areas restricted to commercial crabbing, increasing the duration of the commercial blue crab season, or reducing license fees. Draft survey materials and questions were formulated based on the information gathered from this review, input from fishery managers, questions from a previous survey that targeted Virginia crab fishers (Rhodes and Shabman 1994), and suggested wordings and question formats from Dillman et al. (2009).

Two focus groups of commercial fishers were hosted to develop and refine survey materials. The first focus group occurred in Gloucester, Virginia, with four commercial fishers in November 2018. Each participant reviewed draft survey materials and answered survey questions. We then discussed the wording of questions, layout, and purpose for including specific questions to ensure the survey was clear, concise, and well received. Survey materials were revised after the first focus group. Following the same procedure for review and discussion, these materials were shared at a second focus group with five commercial fishers in

Wachapreague, Virginia, in December 2018. Different locations were used for the two focus groups to engage fishers from unique segments of the fishery on the eastern and western shores of Chesapeake Bay, since crabbing environments (e.g., salinity, water depth, user conflicts) vary across Virginia's tributaries, the Chesapeake Bay mainstem, and coastal bays. Feedback from the focus groups was incorporated in a revised version of survey materials that was shared with state resource managers and the president of an industry group of Virginia commercial fishers for a final review.

The final survey instrument contained 25 questions composed of multiple-choice, yes-no, and fill in the blank responses in Part 1; three choice scenarios that presented hypothetical activities and incentives to reduce the number of derelict pots and their impacts in Part 2 (see Table 1 for definitions); and a blank page for any additional thoughts or comments.

	Definition
Activity/Policy measure:	
Educate recreational boaters	Recreational boaters will be educated on best practices to avoid crab pot buoys and lines, this activity will not require any fisher participation
Galvanized pots only	Only use galvanized wire crab pots (no vinyl-coated)
Pot modification	Modify each blue crab pot to prevent continuing capture of animals if it becomes derelict
Pot tags	Attach a tag to each blue crab pot to identify ownership if buoy is lost
Recycle at facility on land	Recycle all old crab pots at a facility on land
Soak time limit	Check blue crab pots every 72 hours
Three-day removal program	Participate in a three-day derelict pot location and removal program
Non-monetary incentive:	
Bushel limit increase	Daily bushel limit increases by 5-10% of current license limit
Pot limit increase	Daily pot limit increases by 5-10% of current license limit
Season extension	Additional two weeks of commercial crabbing before or after the originally permitted season

Table 1 Definitions for hypothetical activities and non-monetary management incentives included as different attribute values in choice scenarios (Figure S.1 includes definitions used in the survey).

2.2 *Experimental design*

Each choice scenario within the DCE asked participants to select their most preferred option from two multi-attribute alternatives and a third alternative that represented the status quo (i.e., no mitigation activity nor incentives). Three attributes defined each hypothetical multi-attribute alternative: the mitigation activity, with seven levels; a non-monetary management incentive, with four levels; and a monetary incentive of a cash payment, with four levels (Table 2). All levels for each attribute were defined during survey development (Table 1), and these definitions, with exception to cash payment, appeared beneath each choice scenario (Figure 2). The definition for cash payment was included in the DCE introduction (the hypothetical amount of money received as a one-time payment for participating in the corresponding activity; see Figure S.1).

Attribute	Number of levels	Values
Activity/Policy measure	7	Educate recreational boaters, Galvanized pots only, Pot modification, Pot tags, Recycle at facility on land, Soak time limit, Three-day removal program
Non-monetary incentive	4	None, Bushel limit increase, Pot limit increase, Season extension
Cash payment	4	None, \$100, \$300, \$500

Table 2 Generic attributes and attribute levels included in the DCE.

Question 2. Which of the following options would you most prefer to reduce the number of derelict blue crab pots and their impacts?

	OPTION A	OPTION B	OPTION C
ACTIVITY	Pot tags	Soak time limit	No activity
INCENTIVE	Pot limit increase	Bushel limit increase	None
CASH PAYMENT	$300	None	None

Choose your **most preferred** option from the list below. Select **ONE**.

- ◯ Option A
- ◯ Option B
- ◯ Option C

Definitions Box

ACTIVITY

Pot tags: Attach a tag to each blue crab pot to identify your ownership if the buoy is lost.

Soak time limit: Check your blue crab pots every 72 hours.

INCENTIVE

Pot limit increase: Your daily pot limit increases by 5-10% of your current license limit (for example, if you have a 255 pot license, then a pot limit increase of 10% will allow you to deploy up to 281 pots per day).

Bushel limit increase: Your daily bushel limit increases by 5-10% of your current license limit (for example, if you have a 255 pot license and are permitted to harvest 29 bushels per day, then a bushel limit increase of 10% will allow you to harvest about 32 bushels per day).

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Figure 2 An example of a choice scenario included in the survey. Definitions for each attribute presented were provided beneath the choice scenario.

The harmful effects of derelict pots have been documented extensively in the scientific literature (Guillory 1993, Wood 2010, Arthur et al. 2014, Bilkovic et al. 2016, Scheld et al. 2016, Wilcox et al. 2016, DelBene et al. 2019), but little is known about how these findings may influence fishers' decision-making or preferences related to mitigation activities. Our DCE included a treatment group that presented a brief summary of information from derelict crab pot studies conducted in Chesapeake Bay (Giordano et al. 2010, Bilkovic et al. 2014, 2016, Scheld et al. 2016, DelBene et al. 2019) and other locations around the U.S. (Guillory 1993, North Carolina Division of Marine Fisheries 2013) to test the effect of providing scientific information on decision-making and preferences. Half of the sample received surveys that included the following underlined informational sentence in the DCE introduction: "Scientific studies conducted in Virginia and elsewhere have shown that each derelict crab pot may kill 16-26 blue crabs per year and that derelict crab pots can reduce fishery harvest by as much as 30% by competing with actively fished gear."

The experimental design was determined using macros in SAS software (SAS 9.4; SAS Institute, Inc., Cary, NC USA) to maximize design balance and orthogonality (Kuhfeld 2010). Restrictions were included to ensure the activities and non-monetary incentives of multi-attribute alternatives were never identical in a choice scenario. Additionally, we restricted the activity "Educate recreational boaters" from being paired with any non-monetary incentive or cash payment (as this would not require any action from fishers), while all other activities appeared with a non-monetary incentive, cash payment, or both. The final design identified 15 choice sets that were split into five blocks, resulting in three choice scenarios for each survey participant. The five blocks were duplicated to create the treatment group that included the informational sentence; thus, there were 10 unique versions (blocks) of the survey.

2.3 Survey distribution and data collection

Mailing addresses for all commercial fishers that possessed a Virginia hard crab pot license in 2017 were obtained from the VMRC (N = 1,054). This included 58 Maryland, 8 North Carolina, and 988 Virginia residents. Although survey questions focused on the most recent 2018 crabbing season, we relied on 2017 license data because license sales for 2018 were incomplete at the time of our data request. The commercial blue crab fishery in Virginia is limited entry and license lists are similar from one year to the next. The original list of mailing addresses was reduced to remove undeliverable addresses, as well as focus group participants that helped develop the survey. We randomly assigned individuals to one of the 10 survey versions such that each version of the survey was represented approximately equally across the population. To track survey responses and maintain participant confidentiality, individuals were randomly assigned unique identification numbers that were printed on the survey cover page.

Implementation procedures described by Dillman et al. (2009) were followed and consisted of four mailings: a prenotice letter (sent on February 11, 2019), a survey packet (February 15), a postcard reminder/thank you (February 25), and a replacement survey packet sent to non-respondents (March 21). The survey packet contained a cover letter, postage-paid return envelope, and the six-page survey. Mailing dates were selected to limit overlap with the 2019 Virginia commercial blue crab season, which opened on March 17, 2019. Survey participation was incentivized by randomly selecting four respondents to receive US $100 grocery gift cards. To inform fishers about the survey, we disseminated a press release to local news outlets in late January 2019. All survey materials, implementation and data collection procedures were approved by William & Mary's Protection of Human Subjects Committee (Protocol ID: PHSC-2018-11-28-13146-amscheld).

2.4 Choice modeling

Responses to the choice scenarios were analyzed using random utility models (RUMs), which assume individuals select the choice alternative that maximizes their utility or well-being. RUMs allow for observed and unobserved factors to influence the decision to select a particular option, and thus determine utility (McFadden 1974). Observed factors, in our application, were obtained from survey responses and license information and were associated with the choice alternative and individual decision-maker; whereas unobserved factors consisted of any unknowns that could influence decision-making and were not captured by the survey.

Discrete choice probabilities can be derived from utility-maximizing behavior. The mixed logit model specifies choice probabilities as,

$$P_{ni} = \int \left(\frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \right) f(\beta) d\beta. \tag{1}$$

In (1), the probability that individual n selects option i is dependent on the observed factors of option i for individual n, x_{ni}; x_{nj}, which includes attributes of all options available, j; and all preference parameters, β'. Additionally, the density $f(\beta)$ is a mixing distribution that allows the distribution of preferences to be defined across the population. This provides flexibility within the model to account for a variety of behavioral expectations and unobservable factors across a heterogeneous population.

The mixed logit model was specified to accommodate survey response data where individuals were presented three choice scenarios within each survey. We allowed for differences in tastes among individuals by treating preference parameters as fixed across all three choice scenarios answered by an individual, but potentially variable across individuals. Random error terms were assumed to be independent. We estimated preference parameters by maximizing the following log-likelihood:

$$LL = \sum_{n=1}^{N} \sum_{t=1}^{T} \sum_{j=1}^{J} d_{ntj} ln(P_{ntj}), \quad (2)$$

where the natural logarithm of the mixed logit choice probabilities in (2) is summed over N individuals, T choice scenarios answered by an individual, and J options within each choice scenario. A binary variable, d_{ntj}, identified when an option was selected (equal to one) or not selected (equal to zero).

The mixed logit model estimated preference parameters for generic attributes and individual-specific interaction terms. Dummy variables were constructed for seven levels of derelict pot mitigation activities and three levels of non-monetary management incentives (see Table 1 for definitions of levels). Each dummy variable was assigned a value of one when a particular mitigation activity or non-monetary incentive was present in an alternative and zero when absent. Coefficients for activities and non-monetary incentives were estimated as random parameters with normal distributions. Normal distributions were assumed because the population of fishers is operationally and geographically heterogeneous, thus participation in an activity will not always result in a cost (negatively affect utility) and receiving a non-monetary incentive will not always benefit individuals (positively affect utility). For instance, participation in mitigation activities could positively affect the utility (or have no effect) for individuals that already performed a proposed activity (e.g., only used galvanized wire pots) or perceived derelict pots to be a problem that they wanted to help address. Furthermore, receiving a non-monetary incentive could negatively affect the utility of individuals that oppose any change in management practices and wanted to maintain the status quo. Cash payment was included as a continuous and nonrandom generic attribute to allow for straightforward calculations of WTA for mitigation activities. Two interaction terms were included to test the effects of perceptions and information on participation in derelict pot mitigation activities. The first interaction term was constructed by assigning a one to individuals that perceived derelict pots to cause only negative impacts and all other individuals a zero (i.e., individuals that did not respond to the question or perceived derelict pots to cause only positive, both positive and negative, or no impacts). This term was interacted with a dummy variable equal to one for alternatives including mitigation activities (Options A, B; Figure 2) and zero for the no activity alternative (Option C). We examined the effect of perceiving derelict pots to cause only negative impacts, because negative impacts are most reported in the scientific literature (Guillory 1993, Giordano et al. 2010, Wood 2010, Arthur et al. 2014, Bilkovic et al. 2016, Scheld et al. 2016, DelBene et al. 2019). A second interaction term was included to test for the effect of including the informational sentence on participation decisions. This term was equal to one for alternatives including mitigation activities in surveys where the sentence was present and zero otherwise.

The final version of the model included all generic attributes and two interaction terms. A likelihood ratio test was used to compare the final model to a null model with no covariates.

2.5 Economic analysis

Following the Krinsky and Robb (1986) resampling methodology, 10,000 random draws were taken from a multivariate normal distribution constructed from the mean and covariance matrix of model parameter estimates. The resampled parameter estimates were then used to calculate means, standard errors, and 95% confidence intervals for WTAs. Mean WTAs (i.e., the amount of money an individual would need to receive to participate in an activity and experience no change in utility) were calculated for activities by taking the mean of the ratio of resampled parameter estimates for an activity a, β_a, divided by the negative of the resampled parameter for cash payment, β_C:

$$WTA_a = -\frac{\beta_a}{\beta_C}. \tag{3}$$

Mean WTA was not calculated for "Educate recreational boaters" because we restricted cash payments from being paired with this activity in the experimental design. Equation (3) was modified to calculate the monetary value associated with non-monetary incentives, by replacing β_a with β_q. Thus, the mean monetary value for non-monetary incentive q (i.e., change in WTA due to incentive q) was equal to the mean of the ratio of resampled parameter estimates for incentive q, β_q, divided by the negative of the parameter for cash payment, β_C. To determine mean WTAs for mitigation activities and the effect of incentives for participants that perceived derelict pots to cause only negative impacts, we added the resampled parameter for the interaction term, "Any activity x Negative impact perceived," to the numerator of (3). The marginal effect of the interaction term "Any activity x Negative impact perceived" on the probability of participation was evaluated at the means of all other covariates.

All statistical analyses and modeling were performed in R (R Core Team 2018). The mixed logit model was estimated with the mlogit function in the mlogit package (Croissant 2018). The mvrnorm function in the MASS package was used to conduct random parameter draws from a multivariate normal distribution (Venables and Ripley 2002).

3 Results

3.1 Survey response rate and non-DCE questions

There was a 42% response rate for the survey with 430 out of a potential 1,032 fishers returning the survey packet (Figure S.1). Survey responses were received through July 2019 and were representative of the license categories and states of residency observed in the population, as well as the 10 various survey versions (Pearson's chi-squared tests, $p > 0.05$).

Participants reported having 34 years (SE = 0.8; n = 414) of commercial crabbing experience on average, and 56% (n = 416) of participants indicated relying on commercial crabbing for the majority of their income. The average fisher reported losing 10% (SE = 0.7%; n = 348) of all crab pots fished in 2018, and "Commercial/recreational vessel traffic" (76%) and "Storms/severe weather" (75%) were reported as the main reasons pots become derelict (n = 416). Perceptions of derelict pot impacts were heterogeneous (n = 416): 10% positive, 29% negative, 31% both positive and negative, and 30% no impact. The primary negative impacts noted in a follow-up question were the costs required to replace the lost gear (34%) and that derelict pots capture and kill fishes and crabs (30%), whereas 20% answered negligible/no impact (n = 409). Positive impacts written in a comment box and elsewhere throughout the survey noted beneficial habitat impacts (n = 19): "oysters strike on them," "supply a place for small crabs and fish to hide from predators," and "ghost pot is actually an artificial reef."

Respondents were asked yes-no questions to identify their willingness to participate in specific mitigation activities and a multiple-choice question concerning preferred incentives to encourage participation in a mitigation activity (Table 3). Respondents were most willing to participate in "Drop off old/derelict pots at recycling facilities on land" (86%; n = 342) and "Locate and remove derelict pots" (80%; n = 320). "Cash payment" (38%) and "None" (26%) were the most preferred incentives (n = 399). These activities and incentives were included in the choice scenarios to better understand tradeoffs in decision-making and preference heterogeneity. A summary of additional responses pertaining to attitudinal and behavioral questions on fishing activity and derelict crab pots, in addition to demographic questions, is included in Table S.1.

	% of "Yes" responses	n
Activity/Policy measure:		
Check pots every 72 hours	65	292
Drop off old/derelict pots at recycling facilities on land	86	342
Install pot identification tags on each pot	27	269
Locate and remove derelict pots	80	320
Modify each pot to reduce derelict pot bycatch	17	254
Only use galvanized wire crab pots (no vinyl-coated pots)	50	324
Incentive†:		399
Bushel limit increase	8	-
Cash payment	38	-
Pot limit increase	12	-
Season extension	7	-
None	26	-
Other (please explain)	9	-

†Responses were obtained from a single multiple-choice question; thus, n equals 399 across all responses.

Table 3 Non-DCE responses to yes-no questions that asked about willingness to participate in activities and a multiple-choice question on the incentive that would most encourage participation.

3.2 Choice modeling

The mixed logit model was used to analyze responses by 409 individuals to 1,192 choice scenarios. Choice scenarios that were unanswered or had multiple options selected were excluded from the analysis. The status quo alternative (Option C) was selected in 35% of the choice scenarios, and 82 respondents selected the status quo alternative for all three choice scenarios. Multiple factors included in the model had a significant effect on fishers' decision-making (Table 4). For instance, cash payments had a significant positive effect on participation in mitigation activities ($p < 0.001$). Inclusion of an informational sentence in the DCE introduction did not have a significant effect ($p > 0.05$). However, participants that perceived derelict pots to cause only negative impacts were significantly more likely to select options with a mitigation activity ($p < 0.001$).

Variable	Coefficient (Mean)		SE	Coefficient (SD)		SE
Activity: Educate recreational boaters	1.225	*	0.560	3.780	*	1.773
Activity: Galvanized pots only	-1.570	***	0.378	2.661	***	0.667
Activity: Pot modification	-3.526	***	0.527	1.336	*	0.556
Activity: Pot tags	-3.387	***	0.642	4.082	***	0.945
Activity: Recycle at facility on land	-0.164		0.301	0.964	.	0.531
Activity: Three-day removal program	-1.762	***	0.455	2.892	***	0.837
Activity: Soak time limit	-2.342	***	0.470	1.890	**	0.645
Non-monetary incentive: Bushel limit increase	0.370		0.292	2.527	***	0.573
Non-monetary incentive: Pot limit increase	0.948	**	0.300	1.824	***	0.440
Non-monetary incentive: Season extension	0.133		0.284	2.675	***	0.578
Cash payment	0.003	***	0.001			
Any activity x Informational sentence included	-0.127		0.224			
Any activity x Negative impact perceived	1.579	***	0.298			

Table 4 Results for the mixed logit discrete choice model, with mean coefficients and the absolute value of standard deviation coefficients included for random variables (number of choice scenario responses = 1,192; Log-Likelihood = -1127.8; Likelihood Ratio Test ($\chi 2$) = 359.15, $p < 0.001$; Significance: $.p < 0.1$, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$).

Unless otherwise indicated, model results presented or discussed pertain to participants that did not perceive derelict pots to cause only negative impacts (71% of DCE respondents). Decision-making for the average participant was significantly affected by all activities except "Recycle at a facility on land." "Educate recreational boaters" did not require any action from fishers and was the only activity that positively affected utility. On average, "Pot limit increase" was the only non-monetary incentive that significantly affected decision-making. The standard deviation for each random factor was significant or marginally significant, identifying heterogeneity in preferences. The greatest heterogeneity was observed for "Pot tags" and "Educate recreational boaters," but the coefficients of variation for most random factors were greater than one, suggesting substantial variability in fishers' decision-making and preferences. Similar significance, as well as direction and magnitude of effect, were observed for activity and incentive parameters when the model was run without interaction terms.

3.3 Economic analysis

Mean WTAs were positive for all derelict pot mitigation activities, but the mean WTA for "Recycle at facility on land" was not significantly different from zero ($p > 0.05$). Mean WTAs were: US $1,449 (SE = 359) to participate in "Pot modification," US $1,384 (SE = 360) for "Pot tags," US $954 (SE = 238) for "Soak time limit," US $712 (SE = 194) for "Three-day removal program," US $638 (SE = 185) for "Galvanized pots only," and US $61 (SE = 129) for "Recycle at facility on land" (Figure 3). The probability of participation for the average respondent, also referred to as willingness to participate, with no incentive was: 0.46 (SE = 0.07) for "Recycle at facility on land," 0.18 (SE = 0.06) for "Galvanized pots only", 0.16 (SE = 0.06) for "Three-day removal program," 0.10 (SE = 0.04) for "Soak time limit," 0.04 (SE = 0.03) for "Pot tags," and 0.03 (SE = 0.02) for "Pot modification." If individuals were provided an incentive of a “Pot limit increase,” mean WTAs (for all mitigation activities) would decrease by an average of US $389 (SE = 149). However, this incentive was not enough to encourage participation in any activity for which WTA was significantly greater than zero for the average respondent. If resource managers wanted to package a US $300 cash payment with a “Pot limit increase,” the probability of participation for the average respondent would be: 0.82 (SE = 0.05) for “Recycle at facility on land,” 0.54 (SE = 0.08) for “Galvanized pots only”, 0.49 (SE = 0.10) for “Three-day removal program,” 0.35 (SE = 0.08) for “Soak time limit,” 0.17 (SE = 0.08) for “Pot tags,” and 0.15 (SE = 0.06) for “Pot modification.” When compared to non-DCE responses for willingness to participate in mitigation activities, the equivalent to “Recycling at facility on land” was still the most preferred and “Pot modification” and “Pot tags” were the least preferred activities (Table 3).

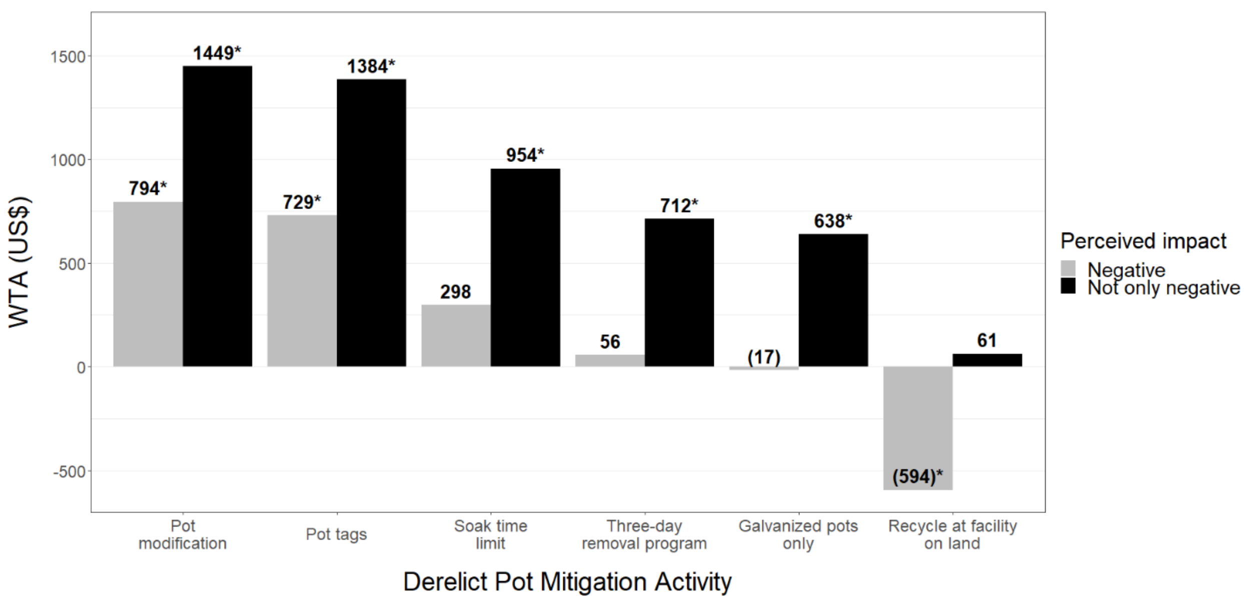

Figure 3 Mean WTA to participate in each hypothetical derelict pot mitigation activity differentiated by perceptions of derelict pot impacts. A single asterisk (*) denotes WTA significantly different from 0 at a 95% confidence level determined from 10,000 multivariate normal random draws of the parameter vector.

On average, fishers who perceived derelict pots to cause only negative impacts had participation probabilities that were 0.37 (SE = 0.06) higher compared to those who did not. Mean WTAs were significantly lower and closer to zero for these fishers as well, ranging from US $794 (SE = 224) to participate in “Pot modification,” to individuals actually willing to forgo US $594 (SE = 257) in cash payments to participate in “Recycle at facility on land.” Additionally, if managers offered a package of US $300 cash payment and a “Pot limit increase,” then mean willingness to participate in mitigation activities would increase to: 0.95 (SE = 0.02) for “Recycle at facility on land,” 0.84 (SE = 0.06) for “Galvanized pots only,” 0.81 (SE = 0.07) for “Three-day removal program,” 0.71 (SE = 0.08) for “Soak time limit,” 0.48 (SE = 0.13) for “Pot tags,” and 0.44 (SE = 0.10) for “Pot modification.”

4 Discussion

Willingness to participate in most derelict pot mitigation activities was low and non-monetary management incentives were generally ineffective in offsetting perceived costs for the average respondent. Thus, a combination of incentives, preferably a cash payment and “Pot limit increase,” would be necessary to encourage participation. Other than a cash payment, “Pot limit increase” was the most preferred incentive, even though fishers surveyed in the past supported enforcement of pot limits (Rhodes et al. 2001). Furthermore, in this previous study more than 70% felt pot limits could not be adequately enforced, suggesting pot limits were a non-binding constraint. Since 2008, VMRC has enforced a 15% reduction on hard pot limits (Chapter 4 VAC 20-880-10 *et seq*. 2008). The recent history of this management decision likely influenced fishers’ preferences for a “Pot limit increase” to recover 5-10% of that 15% reduction, despite the difficulties in enforcing pot limits. It is important to note that no incentives were required for the average fisher to willingly participate in “Recycle at facility on land” or support “Educate recreational boaters," suggesting these activities would be the easiest to implement. Overall, there was substantial preference heterogeneity across responses from fishers, suggesting some segments of the population would be more willing to participate in mitigation activities and more receptive to incentives than others. Even though most activities would be difficult to implement due to high WTAs, model results allow for calculation of participation probabilities for various combinations of activities and incentives.

Although we cannot rule out protest responses or hypothetical bias, survey development and collected responses suggest these were likely not significant factors in this study. Commercial fishers were familiar with the issue of derelict pots and a variety of potential solutions as these topics have been frequently debated during public management meetings and among industry members. Furthermore, blue crab fishers in Virginia have received monetary compensation from managers through license buybacks, when hired to participate in derelict pot removal efforts (Havens et al. 2011) or trial pot modifications to reduce derelict pot bycatch, and several other programs. We are unaware of Virginia fishers receiving compensation in the form of non-monetary management incentives in the past, which could explain the limited effect of non-monetary incentives on decision-making. Extensive consultation with fishers and fishery managers during survey development indicated that the included mitigation activities and incentives would be perceived as credible, and there was no clear indication in survey responses that choice scenarios were not believable. The motivation of the 82 respondents that selected the status quo alternative for all three choice scenarios was not measured. However, a degree of aversion to management intervention should be expected given the long history of disagreements and conflict between Chesapeake Bay blue crab fishers and fishery managers (Paolisso 2002, Kennedy et al. 2007, Tobias 2009). Finally, though hypothetical bias remains a continual concern in stated preference research, minimal evidence has been found in empirical WTA estimates (Penn and Hu 2021).

4.1 Drivers of preference variability in decision-making

Heterogeneity observed in fishers' preferences could be further explained by incorporating non-DCE responses in the models, recognizing inherent variability in fishing practices across geographic locations. For instance, WTAs decreased by US $656 for fishers that perceived derelict pots to cause only a negative impact, indicating that implementation of any mitigation activity would be much easier within this segment of the population. Additional analysis found that the type of negative impact perceived could also influence decision-making, such that fishers were more willing to participate in an activity if they thought capturing and killing fishes and crabs was the primary negative impact (as opposed to the costs required to replace their lost gear). This agrees with past studies that have found strong connections between attitudes, values, and willingness to participate in pro-environmental behavior (Stern et al. 1995, Takahashi and Selfa 2014).

Inclusion of the informational sentence did not influence fishers' decision-making. Initially, we anticipated that inclusion of this informational sentence would increase awareness of derelict pot impacts and fishers' willingness to participate in mitigation activities. However, it is possible that fishers did not read the informational sentence because it was included on a survey page with no questions and the statement itself was relatively brief. There was also evidence that some fishers disagreed with the scientific information in the sentence. Fisher comments (n = 3) written next to the informational sentence included: "show data on this not true," "Questionable data!," "wrong," and "Fake truth," which would imply fishers may have read the sentence but disagreed with it. The rejection of statements that compete with an individual's own beliefs is not uncommon in fisheries, and often arises between groups that share conflicting stances on an issue (Johnson and Griffith 2010). Accounting for the beliefs of fishers may increase the effectiveness of mitigation activities for derelict fishing gear, for example by targeting fishers who agree with the management action or taking necessary steps to overcome differences in beliefs.

Supplemental analyses determined that fishers who had previously participated in a derelict pot removal program were less willing to participate in a "Three-day removal program." This contradicted non-DCE responses, where 91% (n = 35) of fishers that previously participated in a removal program were willing to "Locate and remove derelict pots." This difference between choice scenario and non-DCE responses was likely due to differences in the description of a removal program and a lack of sufficient incentives included in the DCE. A previous state-wide removal effort, Virginia's Marine Debris Location and Removal Program, occurred during the off-season months in the winter and provided monetary incentives of US $300/day and US $50/week for incidentals plus fuel costs (Havens et al. 2011) and, in subsequent years, modified to US $330/day. The maximum cash payment available in the DCE was US $500/three days, whereas the previous removal program paid over US $900/three days. The higher payments distributed to fishers during the past removal program may have instilled expectations that were not met by the attributes included in our choice scenarios.

4.2 Application to management and policy decisions

In the U.S., state resource managers and policymakers are responsible for addressing the issue of derelict blue crab pots. Integration of local information and scientific knowledge can strengthen the decision-making process (Mackinson and Nottestad 1998). Results from our survey provide preferences and opinions from fishers that can be integrated with existing scientific knowledge to efficiently address the issue of derelict pots. Managers and policymakers are often resource limited, so it is important that their decisions are effective and efficient. Our mixed logit model allows managers to quantify the monetary cost of achieving fisher buy-in and can be used as a management tool to estimate commercial fishers' willingness to participate in proposed mitigation activities. In practice, managers could select one of the hypothetical mitigation activities with a package of incentives and use model estimates to determine fishers' willingness to participate. For example, we could predict the strong pushback from fishers that led to the defeat of SB 552 (2018) in the Virginia legislature by including "Pot modification" as the hypothetical activity with no incentives in the model. Under this management scenario, the probability that an average fisher would willingly participate was just 0.03 (SE = 0.02) and increased to 0.13 (SE = 0.06) for individuals that perceived derelict pots to cause only negative impacts. Because only 11% (n = 419; Table S.1) of fishers reported voluntarily attending a fisheries management agency meeting in 2018 and 84% previously felt they had little impact on the regulatory process (Rhodes et al. 2001), our survey results provide managers and policymakers with valuable information on fisher preferences to inform decision-making related to management and mitigation of derelict fishing gear.

Our survey provides a framework for U.S. states and other regions to use when considering actions that address the issue of derelict fishing gear. Actions to reduce derelict gear abundance and impacts have been implemented in various fisheries around the world (Macfadyen et al. 2009, Bowling 2016, He and Suuronen 2018, Lebon and Kelly 2019), but we are not aware of any evaluation at this scale that identified fishers' preferences for those actions. Although mitigation activities and incentives included in the survey were selected for applicability to Virginia's commercial blue crab fishery, mitigation actions implemented in other

U.S. states informed development of our survey. For instance, the states of Florida, Louisiana, and Texas implement derelict pot removal programs that rely on volunteers to locate and remove derelict pots (Bowling 2016, DelBene 2020). Members of the public, including fishers, volunteer their time and vessels to work with resource managers to recover derelict pots from designated areas. These programs are resource intensive and alternative preventative measures, several of which were preferred by fishers in our survey (e.g., "Recycle at facility on land" and "Educate recreational boaters"), should be considered to help reduce costs. Unfortunately, many preventative measures like gear tracking or reducing fishing effort are not well-received by commercial fishers and can be too costly for them to willingly participate (Macfadyen et al. 2009, Brodbeck 2016, He and Suuronen 2018). Multiple costs and benefits must be examined to attain optimal management of the resource (Scheld et al. 2021). Additional costs, such as logistical and equipment, will need to be considered by managers and policymakers when assessing mitigation alternatives, as will the desired outcomes for a particular action, which may vary for activities that prevent, reduce, or cure deleterious effects. For instance, modifying a pot would only reduce bycatch mortality, whereas removal of a derelict pot eliminates continued ecological and economic impacts. Furthermore, low probabilities of participation may be enough to achieve desired management outcomes that target "hotspots" (sensitive areas of concern or areas with high fishing effort; Bilkovic et al. 2016, Scheld et al. 2016). Research similar to that presented here, including willingness to pay surveys of the public, could be used to inform these decisions and help better understand the magnitude of tradeoffs among policy alternatives.

When determining the best actions to take against marine debris, managers and policymakers need to consider the costs imposed on stakeholders. Stated preference surveys that utilize DCEs are a valuable tool to identify stakeholder preferences and decision-making to ensure actions will be effective at decreasing marine debris abundance and impacts. There is no universal solution for marine debris; however, common tools and techniques can be used to identify the unique local solutions needed to tackle this pressing issue in an efficient manner.

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References

Aas, Ø., W. Haider, and L. Hunt. 2000. Angler responses to potential harvest regulations in a Norwegian sport fishery: a conjoint-based choice modeling approach. *North American Journal of Fisheries Management* 20(4): 940-950. https://doi.org/10.1577/1548-8675(2000)020<0940:ARTPHR>2.0.CO;2.

Arthur, C., A. Sutton-Grier, P. Murphy, and H. Bamford. 2014. Out of sight but not out of mind: harmful effects of derelict traps in selected U.S. coastal waters. *Marine Pollution Bulletin* 86: 19-28. https://doi.org/10.1016/j.marpolbul.2014.06.050.

Bilkovic, D.M., K. Havens, D. Stanhope, and K. Angstadt. 2014. Derelict fishing gear in Chesapeake Bay, Virginia: Spatial patterns and implications for marine fauna. *Marine Pollution Bulletin*, 80: 114-123. https://doi.org/10.1016/j.marpolbul.2014.01.034.

Bilkovic, D.M., H.W. Slacum Jr, K.J. Havens, D. Zaveta, C.F. Jeffrey, A.M. Scheld, D. Stanhope, K. Angstadt, and J.D. Evans. 2016. Ecological and Economic Effects of Derelict Fishing Gear in the Chesapeake Bay: 2015/2016 Final Assessment Report. Prepared for Marine Debris Program, Office of Response and Restoration, National Oceanic and Atmospheric Administration. Available: https://marinedebris.noaa.gov/reports/effects-derelict-fishing-gear-chesapeake-bay-assessment-report. (December 2019).

Bowling, T. 2016. State Derelict Fishing Gear Laws and Regulations. NSGLC-16-05-01. National Sea Grant Law Center, University, Mississippi. Available: http://nsglc.olemiss.edu/projects/dfg/index.html. (December 2019).

Brodbeck, L. 2016. Mechanisms to support the recycling/reuse of fishing gear and the prevention of gear becoming lost/abandoned at sea - Barrier assessment. Prepared for the Circular Ocean project. Available: http://www.circularocean.eu/research/. (December 2019).

Brouwer, R., D. Hadzhiyska, C. Ioakeimidis, and H. Ouderdorp. 2017. The social costs of marine litter along European coasts *Ocean & Coastal Management* 138: 38-49. https://doi.org/10.1016/j.ocecoaman.2017.01.011.

Chapter 4 VAC 20-880-10 *et seq.* 2008. "Pertaining to Hard Crab Pot Limits." Virginia Marine Resources Commission. Available: https://mrc.virginia.gov/Notices/pn_multi0509.shtm. (December 2019).

Chesapeake Bay Stock Assessment Committee 2020. 2020 Chesapeake Bay Blue Crab Advisory Report. (Chesapeake Bay Program, 2020). Available: https://www.chesapeakebay.net/who/group/chesapeake_bay_stock_assessment_committee. (May 2021).

Croissant, Y. 2018. mlogit: Multinomial Logit Models. R package version 0.3-0.

https://CRAN.R-project.org/package=mlogit.

DelBene, J.A., D.M. Bilkovic, and A.M. Scheld. 2019. Examining derelict pot impacts on harvest in a commercial blue crab Callinectes sapidus fishery. *Marine Pollution Bulletin* 139: 150-156. https://doi.org/10.1016/j.marpolbul.2018.12.014.

DelBene, J.A. 2020. Investigating economic costs of derelict blue crab *Callinectes sapidus* pots and preferred mitigation solutions in the Chesapeake Bay (Master's thesis). The Virginia Institute of Marine Science at College of William & Mary, Gloucester Point, Virginia, 101p.

Dillman, D.A., J.D. Smyth, and L.M. Christian. 2009. *Internet, Mail, and Mixed-mode Surveys: The Tailored Design Method. (3rd ed.)* John Wiley & Sons, Inc., Hoboken, New Jersey.

Fitzpatrick, M., C.D. Maravelias, O.R. Eigaard, S. Hynes, and D. Reid. 2017. Fisher's Preferences and trade-offs between management options. *Fish and fisheries* 18(5): 795-807. https://doi.org/10.1111/faf.12204.

Galgani, F., G. Hanke, and T. Maes. 2015. Global distribution, composition and abundance of marine litter, in: Marine anthropogenic litter (pp. 29-56). Springer, Cham. https://doi.org/10.1007/978-3-319-16510-3_2.

Giordano, S., J. Lazar, D. Bruce, C. Little, D. Levin, H.W. Slacum Jr., J. Dew-Baxter, L. Methratta, D. Wong, and R. Corbin. 2010. Quantifying the effects of derelict fishing gear in the Maryland portion of Chesapeake Bay. In: Final Report to the NOAA Marine Debris Program. National Oceanic and Atmospheric Administration, Silver Spring, Maryland. Available: https://marinedebris.noaa.gov/research/regional-impact-assessment-derelict-fishing-gear-chesapeake-bay. (December 2019).

Goldsmith, W.M., A.M. Scheld, and J.E. Graves. 2018. Characterizing the Preferences and Values of U.S. Recreational Atlantic Bluefin Tuna Anglers. *North American Journal of Fisheries Management* 38(3): 680-697. https://doi.org/10.1002/nafm.10064.

Grilli, G. and J. Curtis. 2021. Encouraging pro-environmental behaviours: A review of methods and approaches. *Renewable and Sustainable Energy Reviews* 135: 110039. https://doi.org/10.1016/j.rser.2020.110039.

Guillory, V., 1993. Ghost fishing by blue crab traps. *North American Journal of Fisheries Management* 13(3): 459–466. https://doi.org/10.1577/1548-8675(1993)013<0459:GFBBCT>2.3.CO;2.

Hanley, N. and M. Czajkowski. 2019. The role of stated preference valuation methods in understanding choices and informing policy. *Review of Environmental Economics and Policy* 13(2): 248-266. https://doi.org/10.1093/reep/rez005.

Havens, K.J., D.M. Bilkovic, D. Stanhope, and K. Angstadt. 2011. Fishery failure, unemployed commercial fishers, and lost blue crab pots: an unexpected success story. *Environmental Science & Policy* 14(4): 445–450. https://doi.org/10.1016/j.envsci.2011.01.002.

He, P. and P. Suuronen. 2018. Technologies for the marking of fishing gear to identify gear components entangled on marine animals and to reduce abandoned, lost or otherwise discarded fishing gear. *Marine Pollution Bulletin* 129(1): 253-261. https://doi.org/10.1016/j.marpolbul.2018.02.033.

Johnson, J.C. and D.C. Griffith. 2010. Finding common ground in the commons: intracultural variation in users' conceptions of coastal fisheries issues. *Society & Natural Resources* 23(9): 837-855. https://doi.org/10.1080/08941920802409585.

Kennedy, V.S., M. Oesterling, and W.A. Van Engel. 2007. History of blue crab fisheries on the U.S. Atlantic and Gulf coasts. Pages 655–709 in V. Kennedy and L. Cronin (eds) The Blue crab: *Callinectes sapidus*. Maryland Sea Grant College, College Park.

Krinsky, I. and A.L. Robb. 1986. On approximating the statistical properties of elasticities. *The Review of Economics and Statistics* 715-719. https://doi.org/10.2307/1924536.

Kuhfeld, W.F. 2010. Marketing research methods in SAS: experimental design, choice, conjoint, and graphical techniques. SAS Institute, Inc., Cary, North Carolina.

Lebon, K.M. and R.P. Kelly. 2019. Evaluating alternatives to reduce whale entanglements in commercial Dungeness Crab fishing gear. *Global Ecology and Conservation* 18: e00608. https://doi.org/10.1016/j.gecco.2019.e00608.

Lefebvre, M. and A. Stenger. 2020. Short- & long-term effects of monetary and non-monetary incentives to cooperate in public good games: An experiment. *PLoS ONE* 15(1): e0227360. https://doi.org/10.1371/journal.pone.0227360.

Lew, D.K. and D.M. Larson. 2015. Stated preferences for size and bag limits of Alaska charter boat anglers. *Marine Policy* 61: 66-76. https://doi.org/10.1016/j.marpol.2015.07.007.

Lucrezi, S. and O. Digun-Aweto. 2020. “Who wants to join?” Visitors’ willingness to participate in beach litter clean-ups in Nigeria. *Marine Pollution Bulletin* 155 https://doi.org/10.1016/j.marpolbul.2020.111167.

Macfadyen, G., T. Huntington, and R. Cappell. 2009. Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO). Rome, Italy. Available: http://www.fao.org/3/i0620e/i0620e00.htm. (December 2019).

Mackinson, S. and L. Nottestad. 1998. Points of view: combining local and scientific knowledge. *Reviews in Fish Biology and Fisheries* 8(4): 481-490. https://doi.org/10.1023/A:1008847106984.

Maki A., R.J. Burns, L. Ha, and A.J. Rothman. 2016. Paying people to protect the environment: A meta-analysis of financial incentive interventions to promote proenvironmental behaviors. *Journal of Environmental Psychology* 47: 242-255. https://doi.org/10.1016/j.jenvp.2016.07.006.

Marine Debris Act (Marine Debris Research, Prevention, and Reduction Act), 33 U.S.C. § 1951 *et seq.* 2006. Available: https://uscode.house.gov/view.xhtml?path=/prelim@title33/chapter33A&edition=prelim. (December 2019).

McFadden, D. 1974. Conditional logit analysis of qualitative choice behavior, in: Zarembka, P. (Ed.) Frontiers in Econometrics (pp. 105-142). Academic Press, New York, New York.

National Marine Fisheries Service (NMFS). 2018. Fisheries economics of the United States, 2016. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-F/SPO-187a, 243p. Available: https://www.fisheries.noaa.gov/content/fisheries-economics-united-states-2016. (December 2019).

North Carolina Division of Marine Fisheries. 2013. North Carolina Blue Crab (*Callinectes sapidus*) Fishery Management Plan: Amendment 2. North Carolina Department of Environmental and Natural Resources. North Carolina Division of Marine Fisheries. Morehead City, North Carolina. Available: http://portal.ncdenr.org/web/mf/fmps-under-development. (December 2019).

Paolisso, M. 2002. Blue crabs and controversy on the Chesapeake Bay: A cultural model for understanding watermen's reasoning about blue crab management. *Human Organization* 61(3): 226-239.

Penn, J.M. and W. Hu. 2021. The extent of hypothetical bias in willingness to accept. *American Journal of Agricultural Economics* 103(1): 126-141. https://doi:10.1111/ajae.12121.

Reed, M.S. 2008. Stakeholder participation for environmental management: a literature review. *Biological Conservation* 141(10): 2417-2431. https://doi.org/10.1016/j.biocon.2008.07.014.

Register, K. 2014. Developing a Marine Debris Reduction Plan for Virginia. Prepared for the Virginia Coastal Zone Management Program. Available: https://www.deq.virginia.gov/Programs/CoastalZoneManagement/CZMIssuesInitiatives/MarineDebris.aspx. (December 2019).

Rhodes, A. and L.A. Shabman. 1994. Virginia's Blue Crab Pot Fishery: The Issues and the Concerns. VSG-94-09. Virginia Sea Grant, Blacksburg, Virginia.

Rhodes, A., D.W. Lipton, and L.A. Shabman. 2001. A socio-economic profile of the Chesapeake Bay commercial blue crab fishery. Chesapeake Bay Commission.

Richardson, K., B.D. Hardesty, and C. Wilcox. 2019. Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis. *Fish and Fisheries*. https://doi.org/10.1111/faf.12407.

SB 552, Crab pots and peeler pots; marine-biodegradable escape panels, penalty. 2018 Session (Virginia 2018). Available: https://lis.virginia.gov/cgi-bin/legp604.exe?181+sum+SB552. (December 2019).

Scheld, A.M., D.M. Bilkovic, and K.J. Havens. 2016. The dilemma of derelict gear. *Scientific Reports* 6: 19671. https://doi.org/10.1038/srep19671.

Scheld, A.M., D.M. Bilkovic, and K.J. Havens. 2021. Evaluating optimal removal of derelict blue crab pots in Virginia, US. In Review.

Stern, P.C., L. Kalof, T. Dietz, and G.A. Guagnano. 1995. Values, beliefs, and proenvironmental action: Attitude formation toward emergent attitude objects. *Journal of Applied Social Psychology* 25(18): 1611-1636. https://doi.org/10.1111/j.1559-1816.1995.tb02636.x.

Takahashi, B. and T. Selfa. 2015. Predictors of pro-environmental behavior in rural American communities. *Environment and Behavior* 47(8): 856-876. https://doi.org/10.1177/0013916514521208.

Tobias, C. 2009. The tragedy of the commons: The case of the blue crab. *Southern California Interdisciplinary Law Journal* 19: 73.

United Nations General Assembly (UNGA). 2004. A/RES/59/25. Resolution adopted by the General Assembly [without reference to a Main Committee (A/59/L.23 and Add.1)]. 59/25. Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments. Available: https://undocs.org/en/A/RES/59/25. (December 2019).

Venables, W.N. and B.D. Ripley. 2002. Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0.

Virginia Marine Resources Commission (VMRC). 2017. Memorandum: Blue Crab Fishery Management Plan. https://rga.lis.virginia.gov/Published/2017/RD519. (May 2021).

Wattage, P., S. Mardle, and S. Pascoe. 2005. Evaluation of the importance of fisheries management objectives using choice-experiments. *Ecological Economics* 55(1): 85-95. https://doi.org/10.1016/j.ecolecon.2004.10.016.

White, S. and A.M. Scheld. 2021. Characterizing changes in participation and diversification in small-scale fisheries of Virginia, USA. In Review.

Wilcox, C., N.J. Mallos, G.H. Leonard, A. Rodriguez, and B.D. Hardesty. 2016. Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. *Marine Policy* 65: 107-114. https://doi.org/10.1016/j.marpol.2015.10.014.

Wood, A. 2010. Impacts of derelict crab pots on diamond-back terrapins and other estuarine species in coastal North Carolina, Final Report to the NOAA Marine Debris Program. National Oceanic and Atmospheric Administration, Silver Spring, MD, p. 27.