Ocean and Coastal Management 253 (2024) 107150

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Valuing shoreline habitats for recreational fishing

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ARTICLE INFO

Keywords:
Ecosystem services
Ecosystem service valuation
Natural capital
Recreational fishing
Discrete choice experiment
Coastal marshes
Living shorelines

ABSTRACT

Recreational fishing is an important ecosystem service supported by coastal habitats. Information on habitat utilization and preferences by anglers is largely unavailable, however. In this study, data was collected on habitat use and associated preferences from ~1500 licensed saltwater anglers in the Middle Peninsula region of Virginia, a rural area heavily reliant on coastal natural resources. A mixed logit model was used to estimate habitat preferences from responses to a discrete choice experiment where individuals were asked to choose preferred fishing trips to different shoreline habitat types. Coastal marshes and living shorelines (nature-based coastal protection) were found to generate considerable benefits to recreational anglers due to frequent use, low visitation costs, and high willingness-to-pay. Combining habitat-specific effort and valuation estimates suggests marshes and living shorelines in this region produce US $6.42M in annual benefits associated with recreational fishing, a value which is more than three times greater than that produced by hardened shorelines. Ecosystem service values estimated in this research can be used to increase efficiency of habitat restoration and shoreline management decisions and advance accounting of coastal natural capital assets.

1. Introduction

Ecosystems are natural capital assets that provide a variety of services vital to human livelihoods (MEA 2005). In addition to food and resource provisioning, nutrient cycling, and flood protection, recreational fishing is an important service frequently provided by coastal habitats (Barbier et al., 2011). The median ecosystem service value (2020 Int$/ha/yr) for recreational fishing in marine and coastal biomes indicated in the Ecosystem Services Valuation Database is $119/ha/yr (n = 53 value estimates) (Brander et al., 2023). This measure is highly variable with a coefficient of variation of nearly four, suggesting site features, study characteristics, and angler attributes may considerably influence estimated values. Advancing accurate accounting of natural capital assets to inform policy and coastal resource management decisions requires additional, site-specific studies that appropriately capture heterogeneity in ecosystem service provision and valuation (Guerry et al., 2015).

Recreational fishing, or fishing for sport or pleasure, is a pastime enjoyed by an estimated 220M individuals globally, including about 10% of people living in developed nations (Arlinghaus et al., 2015, 2019). In the US, recent estimates of the number of recreational saltwater anglers range from 8.5M (NMFS 2020) to 14.5M (RBFF 2023). Saltwater recreational fishing represents the dominant source of fishing mortality for several economically important US stocks (Coleman et al., 2004; NMFS 2021) and thus understanding angler behavior has significant management implications. Coastal and nearshore habitats are critically important in providing saltwater angling opportunities given their accessibility and functional role in a variety of fish life history stages (Beck et al., 2001; Seitz et al., 2014; Kritzer et al., 2016), yet little is known about angler use and preferences with respect to different coastal habitats. Widespread coastal degradation has been documented in recent decades (Waycott et al., 2009; Davidson 2014), creating resource management challenges and demonstrating a need for improved natural capital accounting to advance restoration efforts.

The drivers of angler decisions are multidimensional and complex (Fenichel et al., 2013; Hunt et al., 2013). While catch and harvest are frequently found to be key behavioral determinants (Hunt et al., 2019), it has been long recognized that a variety of non-catch related factors

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https://doi.org/10.1016/j.ocecoaman.2024.107150
Received 17 November 2023; Received in revised form 7 March 2024; Accepted 8 April 2024
Available online 18 April 2024

affect angler motivation and satisfaction (Fedler and Ditton 1994; Kirkegaard and Gartside 1998; Arlinghaus 2006). Regulations, congestion, site amenities and characteristics, travel costs, and site accessibility have all been found to affect angling decisions regarding where, what, and how much to fish (Hunt et al., 2019; Birdsong et al., 2021). Anglers also frequently note relaxation, spending time with friends and family, or being in nature as important motivations of fishing effort (Fedler and Ditton 1994). Environmental quality, including water quality, fish abundance, and aesthetics, has been shown to influence recreational fishing decisions in revealed and stated preference studies (Hunt et al., 2019). The relationship between habitat type and quality, fish availability, and catch rates has also been explored as influencing recreational angler welfare and decision making (Bell 1997; Fulford et al., 2016). There remains limited understanding of angler use, preferences, and substitution with respect to coastal habitat types, despite the importance of linking habitat to exploitation and population dynamics noted in ecosystem approaches to fisheries management (Link 2002; Pikitch et al., 2004; NOAA 2016). Understanding angler behavior is necessary in predicting responses to management actions and changes in the environment that influence trip satisfaction and recreational demand (Fenichel et al., 2013; Hunt et al., 2013) and can improve the ability of planners and resource managers to forecast recreational response to changes in the quality or availability of coastal habitats.

Shoreline armoring, or hardening, with engineered structures such as riprap revetment, bulkheads, or seawalls, is a common shoreline management practice used to reduce erosion and property loss. Armored shorelines have been found to compromise coastal habitat integrity, ecosystem service delivery, and connectivity however (e.g., Bozek and Burdick 2005; Bilkovic et al., 2006; Bilkovic and Roggero 2008; Dugan et al., 2008; Gittman et al., 2015; Dethier et al., 2016; Dugan et al., 2018). Conversely, nature-based shoreline management practices that involve the protection, restoration, or enhancement of native coastal habitats for erosion control through the placement of plants, stone, sand, and other materials, and do not disrupt natural land-water connections and processes (i.e., living shorelines), can provide multiple secondary ecosystem benefits (Bilkovic et al., 2016). For example, many living shoreline designs include the use of wetland vegetation, which can provide refuge and foraging habitat for fish and crustaceans (Davis et al., 2006; Currin et al., 2008; Scyphers et al., 2011; Gittman et al., 2016; Smith et al., 2021; Guthrie et al., 2022). While barriers to increased utilization of this shoreline management strategy remain (Morris et al., 2022), all coastal US states currently have non-regulatory or regulatory policies that encourage, endorse, or require living shorelines where suitable for erosion control (Mason et al. in prep). Understanding recreational use of coastal habitats, including different shoreline types, can inform estimates of benefits and costs associated with shoreline management policies.

The Chesapeake Bay is home to a variety of habitats that support extensive use by recreational anglers. In Maryland and Virginia, anglers record over 13M trips each year, with approximately 90% occurring in nearshore coastal and estuarine waters (Personal communication, NMFS Fisheries Statistics Division, March 31, 2023). Previous studies of recreational angling behavior in this region have investigated the impacts of improved water quality on angler welfare (Lipton and Hicks 2003), angler benefits associated with oyster reef restoration (Hicks et al., 2004), and target species substitution in response to regulatory change (Scheld et al., 2020). These studies have documented high willingness-to-pay (WTP) and surplus value for recreational fishing trips targeting key species (Scheld et al., 2020) and significant benefits associated with water quality and habitat improvement (Lipton and Hicks 2003; Hicks et al., 2004). Limited information exists on habitat use and related angler decision-making, however. For example, of the estimated 12M coastal and estuarine recreational fishing trips taken annually in Maryland and Virginia, it is not known what portion visited open water, shoreline beaches, marshes, oyster reefs, sea grass meadows, or man-made structures and habitats (e.g., artificial reefs). This study sought to improve information available on recreational angler coastal habitat use and valuation to advance restoration and conservation decision-making as well as accounting of natural capital asset values for coastal habitat in the Chesapeake Bay.

2. Methods

2.1. Conceptual framework

Ecosystem goods and services are frequently not traded in markets and therefore lack price information that might otherwise reflect the value of natural capital assets. A variety of non-market valuation approaches have been developed, however, to measure the benefits provided by ecosystem goods and services (Freeman et al., 2014). Stated preference methods typically use surveys to identify individual values associated with non-market goods and services. A discrete choice experiment (DCE) is a stated preference approach wherein individuals are presented hypothetical and mutually exclusive multi-attribute alternatives and asked to select their most preferred option (Louviere et al., 2000; Hoyos 2010). Responses to DCE questions can be assessed using random utility models, where it is assumed that individuals make choices across a discrete set of alternatives to maximize their well-being and that decisions are influenced by both observable and unobservable factors (McFadden 1974). When price or cost is included as a DCE attribute, this enables estimation of decision tradeoffs in monetary units. Several studies have used a DCE approach to evaluate recreational angler preferences and estimate WTP for recreational fishing trips or trip attributes (e.g., Carter and Liese 2012; Lew and Larson 2012; Goldsmith et al., 2018; Scheld et al., 2020), as well as to quantify coastal ecosystem service values (e.g., Kosenius and Markku 2015; Oleson et al., 2015; Pascoe et al., 2019). WTP represents the maximum amount an individual would pay for a particular good or service. When costs associated with use or procurement of that good or service are deducted from WTP, a measure of net benefits is produced. In this study, a stated preference survey including a DCE was utilized to collect information on angler decision-making and allow estimation of WTP for recreational fishing trips to different shoreline habitats using a random utility model. Information on fishing trip expenditures was also collected. Trip WTP and WTP net fishing costs, or surplus benefits, associated with recreational fishing trips to shoreline habitats are presented as measures of ecosystem service value.

2.2. Study site

The Middle Peninsula of Virginia lies between the York and Rappahannock Rivers and includes six counties: Essex, Gloucester, King and Queen, King William, Mathews, and Middlesex (Fig. 1). The region is largely rural and home to just over 90,000 individuals (U.S. Census Bureau 2023). Key industries include agriculture, forestry, commercial fisheries, aquaculture, and tourism. Natural resources are thought to be the region's core strength and tourism the main opportunity for increased economic development (MPPDC 2022). In 2022, the National Oceanic and Atmospheric Administration (NOAA) selected the Middle Peninsula of Virginia as one of ten “Habitat Focus Areas” (HFAs) across the country. HFAs are locations where habitat restoration activities and resources are targeted to have the greatest impact, increase coastal community resiliency, and advance habitat science and conservation efforts.

One outcome of the HFA designation has been the development of a local-partner driven, regionally-specific *Coastal Wetlands Conservation and Restoration Plan* where living shoreline implementation is a recommended strategy for tidal wetland restoration in the region (YRSCB Roundtable, 2023). Policy encouraging use of living shorelines for stabilizing tidal shorelines has existed in Virginia since 2011 and was recently strengthened to mandate the use of living shorelines unless the best available science indicates the approach is not suitable (Living

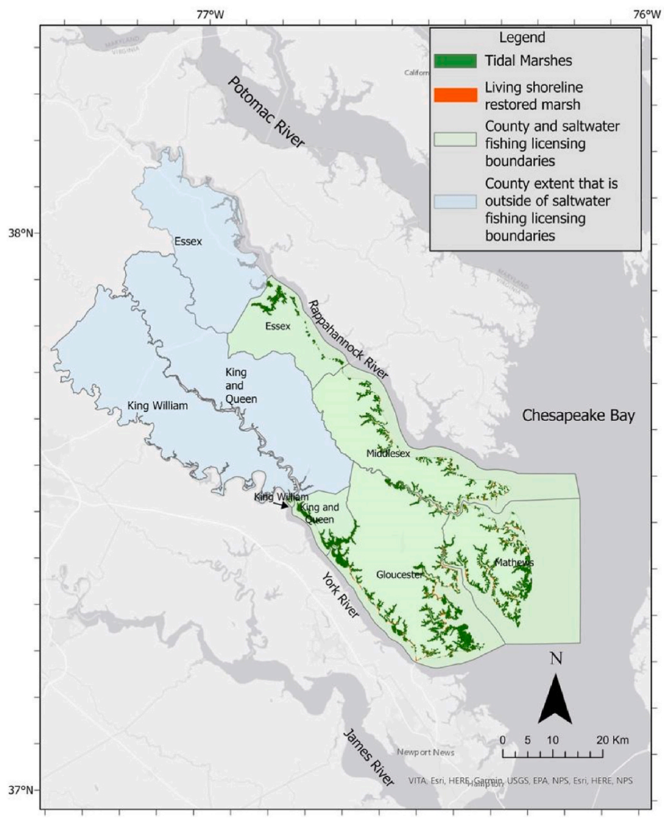

Fig. 1. Map of Middle Peninsula, Virginia with study area shown in light green within saltwater fishing licensing boundaries. There are an estimated 5898 ha of tidal marsh and 10.9 ha of restored living shoreline marsh within the study area.

Shorelines Act VA. CODE ANN. § 28.2–104.1). On average, from 2011 to 2021, about 24% of shoreline permit applicants in Virginia requested a living shoreline (CCRM 2023). Within the Middle Peninsula, more than 800 living shoreline permits have been requested to date, making up about 36% of permit requests annually (2011–2021, Gloucester, Mathews, Middlesex counties). Still, living shoreline permitting rates remain lower than those for shoreline armoring. Because the region is low-lying and experiencing the highest relative sea level rise rates along the East Coast (Boon et al., 2018), shoreline modification requests to help protect built infrastructure are expected to rise. Strategic and forward-thinking shoreline management is essential to maintain the natural resources of the region that underpin the local economies.

2.3. Survey development and implementation

An online survey was developed and distributed to recreational anglers in the Middle Peninsula region of Virginia to collect information on habitat use and preferences. The survey instrument contained 26 questions on recent fishing activity, primary fishing mode, target species and bait collection, fishing locations, habitat use, views on habitat function and importance with respect to recreational fish species, fishing motivations, and respondent demographics. Habitats considered included: beach or sandy shoreline, man-made bottom structure (artificial reef, bridge or pier pile), man-made or artificial shoreline structure (bulkhead, rock or riprap revetment, seawall), marsh or living shoreline (i.e., protected, enhanced or restored marsh that can have a stabilizing structure such as rock sill or oyster reef implemented for additional shoreline erosion control), open water, oyster reef or other natural hard bottom, and seagrass bed. Respondents could also enter in other habitat types visited if not included in the presented options. After selecting habitat types visited when fishing for target and, separately, bait species, respondents were asked follow-up questions on the number of trips, average one-way travel time on land and on water, and individual costs associated with trips to a particular habitat type randomly selected from those habitats visited (see Supplementary Materials for full survey instrument).

A DCE was also included in each survey. The DCE presented each respondent two choice scenarios including three alternatives: two hypothetical fishing trips and a no-trip option. Hypothetical fishing trips were characterized by shoreline habitat type, total travel time to reach the fishing site, and trip costs (Fig. 2). Shoreline habitat types included beach, marsh or living shoreline, and two hardened shoreline types common in the region—bulkhead and riprap revetment (Table 1). Shoreline habitats were described by name and using pictures of representative habitats from the region. The attribute levels shown for trip costs and travel time differed based on stated primary fishing mode, with individuals primarily fishing from shore or non-motorized boats being shown trip costs and travel times that were slightly lower compared to those shown to individuals primarily fishing from motorized boats. Mode-specific average trip costs were approximated based on Lovell et al., (2020) with values adjusted for inflation. Trip costs were described as including all direct expenses to the individual associated with a recreational fishing trip, such as fuel, food and drinks, ice, and bait. Travel times were based on expert opinion initially and then refined following angler feedback. Total one-way travel time was described as the amount of time in minutes it would take to reach the fishing site when traveling from their primary residence, including both travel time on land and on water. Individuals were asked to assume they would use fishing gear, methods, and site access modes they typically use, go during the season they typically fish, and target species they typically target. A prompt was also included to ask respondents not to compare options across choice scenarios. Following completion of the choice experiment, individuals were asked to indicate what factors drove trip selection to better understand angler decision-making with respect to habitat use.

Once a draft survey instrument was developed, a small focus group was held with four anglers to refine question wording, structure, and DCE attribute levels. The final DCE experimental design included 10 choice scenarios split into five blocks of two questions each. A modified Fedorov algorithm and non-informative parameter priors were used to identify a Bayesian D-efficient experimental design based on a set of candidate profiles produced using effects coding for all attributes. Experimental design was done using the package *idefix* (Traets et al., 2020) in the statistical programming language R (R Core Team 2022).

A 2021 recreational angling license list was obtained from the Virginia Marine Resources Commission and used to generate the survey sampling frame (n = 276,122 licenses). The license list included fields for licensee name, home address, email address (~17% did not provide

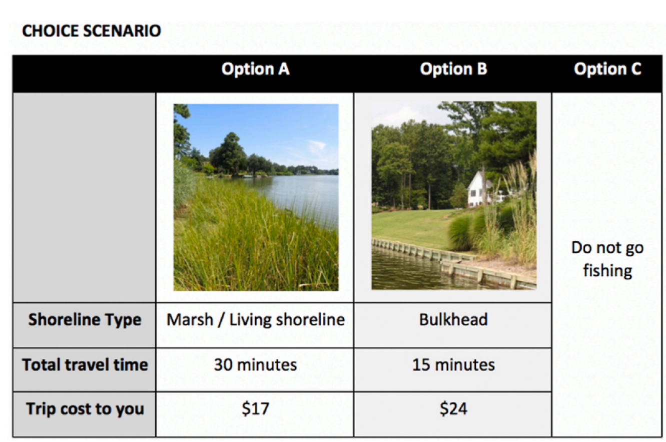

Fig. 2. Example DCE choice scenario included in the survey.

Table 1
Trip attributes and attribute levels included in DCE. For trip cost and travel time attributes, values shown to respondents were conditional on their stated primary fishing mode.

Attribute	Number of levels	Values
Shoreline habitat	4	beach, bulkhead, marsh/living shoreline, riprap revetment
Individual trip cost	3	shore/non-motorized boat: $10, $17, $24; motorized boat: $31, $52, $73
Travel time (minutes)	3	shore/non-motorized boat: 15, 30, 45; motorized boat: 30, 45, 60

an email), and license type (e.g., Virginia resident, non-resident, short duration, annual, etc.). The sample included all anglers with home addresses in one of the six Middle Peninsula counties who held an annual individual or boat license or individual registration for fishing in tidal or saltwater areas and had provided an email address (n = 5420 individuals). Additionally, the sample was expanded to include a random subset of anglers who held annual individual or boat licenses or individual registrations for fishing in tidal or saltwater, provided an email address, and lived in one of the five counties and two cities that border the Middle Peninsula region (James City County, Lancaster County, New Kent County, Richmond County, York County and the cities of Poquoson and Williamsburg) (n = 4580 individuals, 66% of license holders from included areas). These communities surrounding the Middle Peninsula are similar demographically and recreational anglers from these areas are thought to utilize habitats around the Middle Peninsula for recreational fishing.

The survey instrument was implemented online using Qualtrics (Qualtrics, Provo, UT). The full sample of 10,000 individuals were invited to participate in the survey by both email and postcard. The first invitation email was sent in April 2022. This was followed by a postcard containing a survey link and a quick response (QR) code approximately two weeks later and then a final email invitation sent in June 2022. Six individuals responded to the initial invitation email indicating they did not respond to the survey and would like to be removed from the survey sample. Invitation emails or postcards for 399 individuals were undeliverable. However, there were no instances where both email and postcard were undeliverable for the same individual, implying all 9994 individuals in the sample were contacted at least once.

2.4. Survey response analysis

Survey responses were assessed for representativeness by comparing response demographics with US Census data for counties included in the sample as well as other published studies on recreational angling that were either national in scope or sampled anglers within the region, including Brinson and Wallmo (2013), Hyman et al. (2017), Hyman and McMullin (2018), U.S. Department of the Interior et al. (2018), Valdez et al. (2018), Murphy et al. (2019), and Scheld et al. (2020). Geographic representation was considered by comparing respondent ZIP Codes with ZIP Codes of individuals included in the sample.

Standard descriptive statistics were used to assess fishing activity, fishing modes, species targeting and bait collection, fishing motivations, and respondent demographics. Habitat use and habitat-specific average trip travel time and trip expenses were assessed based on primary fishing mode: shore and nonmotorized boats (low fishing mobility, referred to as low mobility hereafter) or motorized boats and charter/party boats (high fishing mobility, referred to as high mobility hereafter). Estimates of average total trip costs were made for each of the two fishing mode groups for each habitat type considered (beach or sandy shoreline, man-made bottom structure, man-made shoreline structure, marsh or living shoreline, open water, oyster reef or other natural hard bottom, and seagrass bed). Total trip cost estimates were formulated as reported individual trip expenses plus the value of travel time. The value of travel time was set equal to round-trip travel time multiplied by one third an hourly wage rate based on the respondent's reported annual household income (Lupi et al., 2020). Trip expenses and annual household income were reported in bins: $20 bins up to $200 for trip expenses and $25,000 bins up to $200,000 for income were used, with both including options for greater than the largest bin. The mean of bins was used in calculating estimates. Trip expenses reported as greater than $200 were assessed as $201 while household incomes reported as $200,000 or more were assessed as $200,000. For individuals who did not report household income, the mean value across responses was used. Average annual angler effort for each habitat type was calculated as the fraction of respondents who indicated visiting that habitat type to fish for target species multiplied by the average reported number of trips in 2021 to that habitat type for those individuals.

A mixed logit random utility panel model was used to estimate preference parameters. This modeling approach accommodates preference heterogeneity across individuals as well as correlated behavior by an individual across multiple choice occasions by estimating preference distributional parameters (Train 2009). Utility was specified as a function of choice scenario attributes and attribute interactions with individual characteristics. A series of binary variables were included to measure preferences for trips to the shoreline habitats considered in the survey (beach, bulkhead, marsh/living shoreline, and riprap revetment). Each choice scenario included a no-trip option that served as the baseline comparison alternative for binary habitat variables. Parameters for binary habitat variables were estimated as normally distributed random parameters. A series of interaction terms were also included to allow for shifts in habitat preference parameter distributions for low mobility anglers. Trip travel time and cost were included as continuous covariates and model parameters were assumed to be log-normally distributed, such that utility responses to increases in travel time or cost were strictly negative. As trip costs and travel time both captured the "price" of a fishing trip, model specifications allowing for preference parameter correlation were estimated and tested against models without parameter correlation using likelihood-ratio tests. A follow-up question asked respondents to indicate what drove their DCE responses. Responses from individuals who selected "I do not know why I chose the trips I did" were removed prior to model estimation.

WTP for recreational fishing trips to different shoreline habitat types was evaluated using estimated preference parameters. As the utility model allowed for habitat preferences to shift according to primary fishing mode, WTP was estimated separately for high mobility (private motorized vessels, charter/party boat) and low mobility anglers (shore, non-motorized vessels). Each habitat- and mode-specific WTP was calculated by summing partial utilities associated with habitat type, by fishing mode, and travel time, and dividing by the negative marginal utility associated with trip cost. A Krinsky-Robb (1986) resampling method was used to randomly draw 10,000 parameter vectors from a multivariate normal distribution with a mean and variance-covariance structure set equal to model estimates. Each parameter draw was used to calculate a corresponding WTP value, with the full set of draws characterizing a WTP distribution. WTP was evaluated across a range of potential travel times to assess tradeoffs between trip cost and accessibility. Habitat- and mode-specific average trip expenditures reported by respondents were used to calculate threshold travel times, such that at travel times exceeding this threshold, WTP would be below reported trip expenditures (i.e., costs would exceed benefits). Information on habitat-specific expenditures and travel times was collected for trips to man-made shoreline habitats collectively and, therefore, identical values were used when assessing WTP and threshold travel times for recreational trips to bulkhead and riprap revetment shoreline habitats.

Estimated WTP was used to calculate the total and surplus benefits associated with trips to beaches, man-made shorelines, and marsh or living shoreline habitats for Middle Peninsula anglers. Total benefits were equal to WTP calculated at habitat- and mode-specific average reported one-way travel time multiplied by the total number of trips by

Middle Peninsula anglers to beaches, man-made shorelines, and marshes or living shorelines. Total trips per shoreline habitat type were calculated as the total number of Middle Peninsula recreational anglers in the sample (n = 5420 individuals) multiplied by the fraction of respondents who indicated visiting that habitat (beach, man-made shoreline, marsh/ living shoreline) to fish for target species and the average reported number of annual trips by those individuals to that habitat type. WTP and fishing effort measures were estimated separately by fishing mode and summed together for an aggregate value. Habitat-specific average trip expenditures were deducted from WTP in calculating surplus benefits. Total and surplus benefits for trips to man-made shorelines were estimated by averaging WTP values for trips to bulkhead and riprap revetment shorelines. Total marsh or living shoreline benefit estimates were divided by total area of this habitat in the Middle Peninsula to provide a measure comparable to prior studies reporting value per hectare.

Tidal marsh area within the region of the Middle Peninsula where a saltwater recreational license is required (Fig. 1) was extracted from the Virginia Tidal Marsh Inventory (TMI) (CCRM 2019). The Virginia TMI is a geospatial database of the distribution of tidal marshes for the Commonwealth of Virginia that was developed by using Virginia Base Mapping Program (VBMP) high resolution color infra-red imagery from 2009, 2011, 2013 and/or 2017 to delineate marsh boundaries at a scale of 1:1000 (VGIN, 2022). Living shoreline marsh areal extent was estimated using the best available high-resolution imagery, including VBMP (2019, 2021 and 2022) and pictometry (aerial oblique georeferenced imagery available in Gloucester County), to delineate the restored marsh boundaries associated with each living shoreline project permit location within the Middle Peninsula study area. Approved permits for living shoreline projects that either protected or restored marsh vegetation were extracted from the CCRM Tidal Shoreline Permit Database (n = 544 permits from 1974 to mid-2020, CCRM 2023). Of those, 405 living shorelines were verified as built. To avoid double counting marsh area, only the subset of living shoreline projects that involved restoring (planting) marsh vegetation were included in the living shoreline marsh area estimation (188 permit locations). In-field verification was completed between June 2022 and May 2023 at sites that could not be accurately delineated via desktop (n = 84). Field delineations of living shoreline marsh areas were completed in ArcGIS Field Maps (ESRI) using a tablet iPad Air (5th generation). When sites could be accessed by land, marsh area was delineated by walking the boundaries of the marsh with a handheld GPS (Bad Elf GNSS Surveyor BE-GPS-3300) and data recorded in ArcGIS Field Maps. Both desktop and field delineations were composited into an ArcGIS layer and total living shoreline marsh extent was extracted using ArcGIS Pro 3.1.1.

All statistical analyses were done in the R statistical programming language (R Core Team 2022). Mixed logit models were estimated using the function *mlogit* in the *mlogit* package (Croissant 2020). Models with and without random parameter correlation were estimated using 100, 200, 300, 400, and 500 Halton draws to assess stability and provide multiple comparisons of model fit. Krinsky-Robb resampling was done using the function *mvrnorm* in the MASS package (Venables and Ripley 2002).

3. Results

From the sample of 9994 individuals invited to participate in the survey, 1661 (16.62%) visited the survey website and answered at least one question, 1475 (14.76%) completed 50% or more of the survey, and 1323 (13.24%) individuals completed the entire survey. Response demographics and angler avidity were similar to previously published studies on recreational angling in the region or nationally (see Supplementary Material Table S1). In comparison to US Census data for counties included in the distribution sample, respondents were more often white, older, more educated, and more frequently male. The proportion of respondents with ZIP Codes from counties in the Middle Peninsula (54.04%) closely matched the proportion of individuals with mailing addresses in the Middle Peninsula in the full sample (54.20%).

The average number of recreational fishing trips taken by respondents in Virginia tidal waters during 2021 was 19.40 (sd = 27.45, median = 10.00, n = 1661 responses). Approximately 7% of respondents reported taking no trips. Individuals reporting no trips were not asked additional questions about fishing behavior or habitat use and did not participate in the DCE. Anglers reported their primary mode of fishing was predominately from private motorized boats (68.83% of respondents). Fishing primarily from a pier, jetty, bridge, or dock (14.70%), the shore (7.93%), a private non-motorized boat (6.90%), or a charter/party boat (0.75%) were less common. The most frequent target species were striped bass (*Morone saxatilis*) (54.34% of respondents), croaker (*Micropogonias undulatus*) and/or spot (*Leiostomus xanthurus*) (54.34%), red drum (*Sciaenops ocellatus*) (43.95%), and spotted seatrout (*Cynoscion nebulosus*) (42.11%). Additionally, 40.74% of respondents reported fishing for “Whatever bites”. Approximately one third of respondents (32.19%) reported catching their own bait, targeting primarily minnows (69.57%), crabs (51.96%), and croaker and/or spot (48.04%). Respondents reported fishing in a variety of locations, including waters around the Middle Peninsula (88.02%), the Chesapeake Bay (53.59%), rivers and small bays outside of the Middle Peninsula region (37.23%), and the Atlantic Ocean (15.26%). Anglers reported being motivated largely by non-consumptive aspects, selecting relaxation, time with friends and family, and being outdoors as the primary reasons for fishing recreationally.

When fishing for target species, respondents indicated visiting open water (62.37%), marshes or living shorelines (43.85%), man-made bottom structure (41.73%), seagrass beds (33.02%), oyster reefs or other natural hard bottom (31.84%), man-made shoreline structures (28.33%), and beaches or sandy shorelines (25.70%). Habitat use when fishing for bait included marshes or living shorelines (59.26%), open water (33.77%), beaches or sandy shorelines (32.24%), man-made shoreline structures (19.61%), man-made bottom structures (18.95%), seagrass beds (16.99%), and oyster reefs or other natural hard bottom (10.89%). A small number of respondents wrote in additional habitats visited when fishing for target species or bait, which included docks or private piers, mud flats, tidal ponds, and bathymetric features such as sandbars or ledges. When fishing for target species in 2021, 72.18% of anglers indicated visiting three or fewer habitats during the year. Among the top targeted species, individuals who targeted striped bass and croaker or spot most frequently fished open water habitats while individuals who targeted red drum and spotted seatrout most frequently fished marsh or living shoreline habitats.

Respondents ranked the importance of different habitats in supporting healthy recreational fisheries as “Extremely important” or “Very important” most frequently for marshes and living shorelines (88.56%), followed by seagrass beds (85.56%), oyster reefs or other natural hard bottom (83.13%), open water (70.94%), man-made bottom structures (67.93%), beaches or sandy shorelines (61.76%), and man-made shoreline structures (48.42%). In a follow-up question asking what beneficial functions habitats previously indicated as “Extremely important” or “Very important” provided, respondents most often selected “Access to food/forage” (90.96%), followed by “Spawning/ breeding areas” (81.48%), “Protection from predators” (80.58%), and “I do not know” (4.63%) or “Other” (2.02%). “Other” responses were primarily related to water quality benefits. When asked how living shorelines compared to natural marshes in supporting healthy recreational fisheries, a majority felt they were similar or identical (54.52%), followed by viewing living shorelines as inferior (18.74%), and individuals indicating they did not know (16.81%). A small number of respondents felt living shorelines were superior to natural marshes (8.22%).

The average number of trips in 2021 reported to specific habitats for high mobility anglers who indicated visiting those habitats ranged from 13.98 for trips to marsh and living shoreline habitats to 9.67 for trips to man-made bottom structure habitats (Table S2). For low mobility anglers, average 2021 trips ranged from 22.48 for trips to seagrass habitats to 7.47 for trips to beach habitats (Table S3). Median 2021 trip estimates displayed less variability across habitat types in general, ranging from three (beach habitats for low mobility anglers, Table S3) to eight (seagrass habitats, Tables S2 and S3). Weighting habitat-specific average effort levels by the fraction of respondents who indicated visiting that habitat to fish for target species showed fishing effort for high mobility anglers was highest for open water, marshes or living shorelines, seagrass beds, and man-made bottom structure. Weighted average effort estimates for low mobility anglers, meanwhile, were highest for seagrass beds, marshes or living shorelines, man-made shorelines, and beaches (Table 2).

Individual trip expenditures, one-way travel times, and total individual trip costs differed across habitats and angler primary fishing modes (Tables S4–S11). Across all habitats, average individual trip expenditures were greater for high mobility anglers, who reported the highest expenditures for trips to man-made bottom structure, open water, and natural hard bottom habitats (Table S4). For low mobility anglers, reported individual trip expenditures were highest for trips to open water while trips to all other habitats displayed similar reported expenditure amounts, ranging from $21.73 (marsh or living shoreline) to $31.25 (natural hard bottom) (Table S5). Less than 3% of respondents indicated average individual trip expenditures of over $200. Average one-way travel time for travel on land was generally less than 30 min. Both high and low mobility anglers reported the shortest on-land travel times for trips to marshes or living shorelines (Tables S6 and S7). Travel time on water was also generally less than 30 min, with travel time to many habitats being under 20 min. High and low mobility anglers both reported the lowest on-water average travel times for trips to marshes or living shorelines (Tables S8 and S9). Total individual trip costs, accounting for the opportunity cost of travel time, ranged from $104.31 (man-made bottom structure, Table S10) to $65.03 (marsh or living shoreline, Table S10) for high mobility anglers and from $87.21 (open water, Table S11) to $35.98 (marsh or living shoreline, Table S11) for low mobility anglers.

There were 2502 responses to DCE choice scenarios from 1256 individuals. In a follow-up question where respondents were asked what factors influenced their trip choices, the most common responses were "I chose trips where I thought I would catch species I usually target" (60.69%), "I chose trips where I thought I would catch the most fish" (54.44%), "I chose trips to habitats I can easily access" (35.95%), "I chose trips to habitats I find aesthetically pleasing" (27.70%), and "I chose trips where I thought I would catch the biggest fish" (25.14%). Travel time and trip costs were indicated as less impactful, with the options "I chose trips with the lowest travel time" (18.18%) and "I chose trips with the lowest cost" (10.41%) being selected less frequently. Additionally, 1.92% of respondents selected "I do not know why I chose the trips I did". The 48 DCE responses from these 24 individuals were removed from analysis.

Table 2
Percentage of respondents who visit a particular habitat to fish for target species and average annual effort estimates. HM = high mobility, LM = low mobility.

Habitat	% HM Respondents	HM Annual Trips	% LM Respondents	LM Annual Trips
Beach	16.80	1.71	47.01	3.51
Man-Made Bottom	44.29	4.28	35.57	3.07
Man-Made Shoreline	26.14	2.87	33.58	3.81
Marsh, Living Shoreline	42.22	5.90	47.76	4.16
Natural Hard Bottom	38.38	3.85	16.17	1.96
Open Water	73.34	7.35	36.07	3.18
Seagrass	36.72	4.65	24.13	5.42

Across choice scenarios included in the analysis, option A was selected 41.73% of the time, option B was selected 45.31% of the time, and option C, the no-trip option, was selected 12.96% of the time. Correlated random parameters models improved model fit modestly, however likelihood-ratio tests did not reject the null constrained model of uncorrelated random parameters with a high level of confidence (Table S12). Additionally, WTP estimates were found to be unstable across correlated random parameter model runs. The final model used for analysis included uncorrelated random parameters and was estimated using 300 Halton draws. Random parameter means and standard deviations were significantly different from zero for all habitat variables as well as for trip cost and travel time. Random parameter standard deviations were largest for beach and marsh or living shoreline habitats, indicating greater preference heterogeneity for recreational fishing trips to these habitats. Low mobility preference shifters were positive and moderately significant for beach and bulkhead habitats but not significant for other habitats. Model intercepts for choice scenario options A and B were not significant (Table S13).

Trips to marshes or living shorelines exhibited the highest WTP, with mean values of $219.05 and $224.74 for high and low mobility anglers, respectively (Table 3). Trips to beaches or sandy shorelines, meanwhile, were characterized by the lowest mean WTP for both angler groups. Low mobility anglers had higher WTP values for trips to beaches and bulkheads due to stronger preferences for these habitats as compared to high mobility anglers (Table S13). Slight differences in average travel times by angler mobility type (Tables S6–S9) drove differences in mean WTP values for trips to marshes or living shorelines and riprap revetment habitats, though values were not significantly different at a 95% confidence level.

Habitat- and mode-specific WTP was evaluated across a range of potential one-way trip travel times. Average reported individual trip expenditures (Tables S4 and S5) exceeded mean WTP at travel times of 36, 43, 60, and 93 min for trips to beach, bulkhead, riprap revetment, and marsh or living shoreline habitats by high mobility anglers (Fig. 3). For low mobility anglers, threshold travel times were 64, 74, 77, and 97 min for trips to beach, bulkhead, riprap revetment, and marsh or living shoreline habitats, respectively. Higher threshold travel times for trips to beach and bulkhead habitats for low mobility anglers were again due to slightly stronger preferences for these habitats as compared to high mobility anglers (Table S13).

Trips to marshes and living shoreline habitats were found to generate the highest total benefits for Middle Peninsula anglers, yielding $6.42M in annual benefits (Table 4). Trips to beaches and man-made shorelines produced considerably lower total benefits, at $0.78M and $1.78M, respectively, due both to lower fishing effort (Table 2) and WTP values (Table 3). If deducting average trip expenditures and considering surplus value, or net benefits, trips to marshes or living shorelines were estimated to yield $5.23M annually while trips to man-made shorelines produced $1.01M in annual surplus benefits (Table 5). For high-mobility anglers, trips to beach and man-made shoreline habitats yielded no surplus benefits as values were not statistically different from zero. There are an estimated 5898.06 ha of tidal marsh and 10.87 ha of

Table 3
Mean WTP for a recreational fishing trip to a particular habitat type for high mobility (HM) and low mobility (LM) anglers. WTP values were estimated at habitat- and mode-specific average one-way travel times (see Tables S6–S9 for on-land and on-water travel times). Values are 2022 USD. Standard deviations are included in parentheses. Statistical significance denoted as "*", "**", and "***" corresponding to significance at the 5, 1, and 0.1% levels, respectively.

Habitat	HM Mean WTP, $	LM Mean WTP, $
Beach	39.27* (17.18)	90.89*** (25.39)
Bulkhead	60.02** (17.81)	132.79*** (29.92)
Marsh, Living Shoreline	219.05*** (33.61)	224.74*** (43.19)
Riprap Revetment	109.66*** (19.69)	140.76*** (30.71)

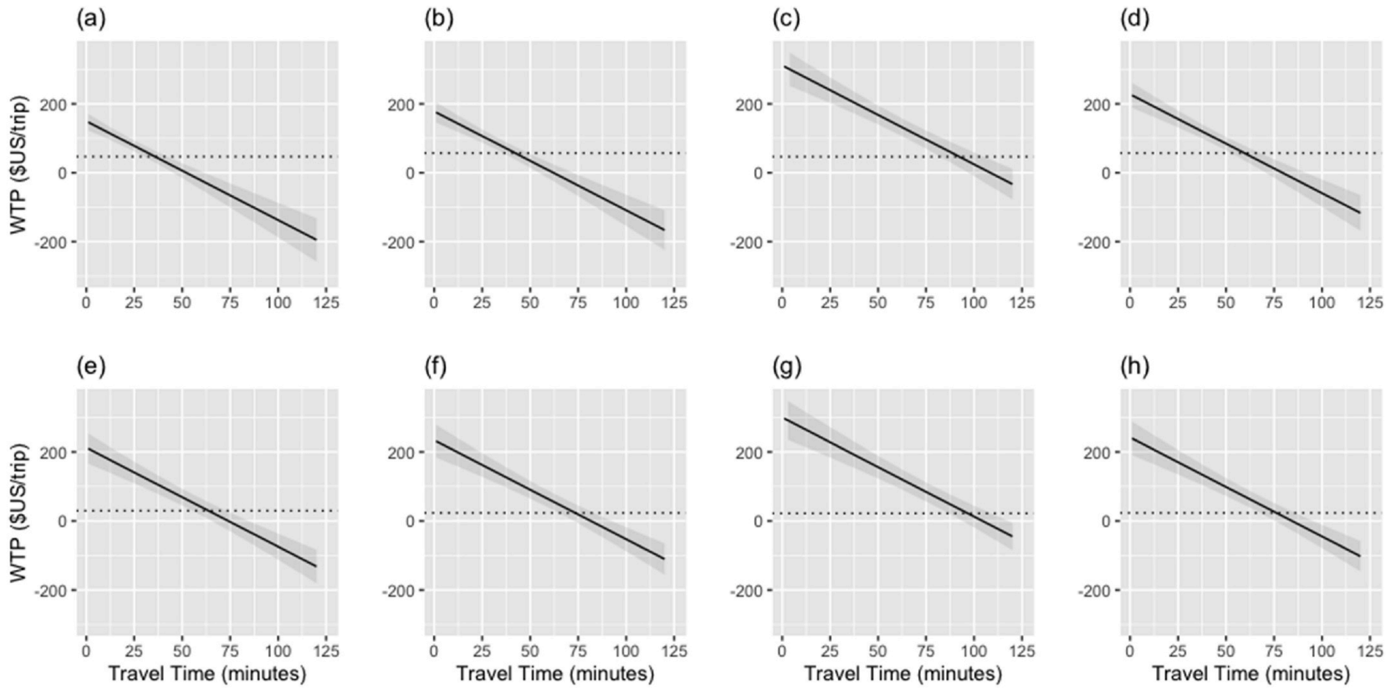

Fig. 3. WTP (2022 USD) by travel time for a recreational fishing trip to beach (high mobility anglers panel (a); low mobility anglers panel (e)); bulkhead (high mobility anglers panel (b); low mobility anglers panel (f)); marsh or living shoreline (high mobility anglers panel (c); low mobility anglers panel (g)); and riprap revetment (high mobility anglers panel (d); low mobility anglers panel (h)) habitats. Black line indicates mean and grey area indicates standard error. Dotted horizontal lines are habitat- and mode-specific average trip expenditures (see Tables S4 and S5).

Table 4
Mean total benefits (TB) associated with annual recreational fishing trips to a particular habitat type for high mobility (HM) and low mobility (LM) anglers from the Middle Peninsula, Virginia as well as combined values. Values are millions of 2022 USD. Standard deviations are included in parentheses. Statistical significance denoted as "*", "**", and "***" corresponding to significance at the 5, 1, and 0.1% levels, respectively.

Habitat	HM Mean TB, $M	LM Mean TB, $M	Total Mean TB, $M
Beach	0.25* (0.11)	0.53*** (0.15)	0.78** (0.19)
Man-Made Shoreline	0.92** (0.19)	0.86*** (0.19)	1.78*** (0.31)
Marsh, Living Shoreline	4.87*** (0.75)	1.54*** (0.30)	6.42*** (0.99)

Table 5
Mean surplus benefits (SB) associated with annual recreational fishing trips to a particular habitat type for high mobility (HM) and low mobility (LM) anglers from the Middle Peninsula, Virginia as well as combined values. Values are millions of 2022 USD. Standard deviations are included in parentheses. Statistical significance denoted as "*", "**", and "***" corresponding to significance at the 5, 1, and 0.1% levels, respectively.

Habitat	HM Mean SB, $M	LM Mean SB, $M	Total Mean SB, $M
Beach	−0.05 (0.11)	0.36** (0.15)	0.31 (0.19)
Man-Made Shoreline	0.30 (0.19)	0.71*** (0.19)	1.01** (0.31)
Marsh, Living Shoreline	3.84*** (0.75)	1.39*** (0.30)	5.23*** (0.99)

restored living shoreline marsh (188 permits) within the Middle Peninsula study area. Per hectare, marshes and living shorelines in the Middle Peninsula, Virginia were estimated to yield annually $1085.73/ha (sd = 167.88) in total benefits and $884.76/ha (sd = 167.88) in surplus benefits.

4. Discussion

In this study anglers were found to utilize a variety of habitats, with variability across primary fishing modes. Unsurprisingly, respondents who indicated fishing primarily from private motorized or charter boats exhibited higher effort at offshore habitats when compared to respondents who indicated fishing primarily from shore or non-motorized boats. Differences were also observed in habitat use when fishing for target versus bait species as well as for different target species. These findings indicate habitat use by the recreational fishing sector is complex, with potential feedbacks and interactions between fisheries and habitat management decisions. Future research should consider spatial decisions by recreational anglers in the context of habitat use to further advance ecosystem approaches to fisheries management (Link 2002; Pikitch et al., 2004; NOAA 2016).

Habitat-specific individual trip expenditures identified in this research are similar to values reported in Lovell et al. (2020) of $50.99 and $32.61 for trips by private boat and shore anglers in Virginia, respectively. Other angler groups have been found to spend considerably more on fishing trips (e.g., Lew et al., 2010; Scheld et al., 2020; Smith et al., 2022). Site accessibility is a primary driver of trip costs due to both direct expenditures and the opportunity cost of time. For example, non-resident anglers surveyed in Lew et al. (2010) typically traveled to Alaska by plane for fishing trips, spending over $900 on airfare, on average. Shrestha et al. (2002), meanwhile, report average travel time for recreational fishing trips to the remote Brazilian Pantanal of over 24 h, with average travel distance exceeding 2800 km. In this study, anglers report travel times of generally less than 30 min on land and frequently less than 20 min on water, indicating easy access to fishing opportunities at a variety of habitats. It was found that anglers would be willing to travel, at most, just over an hour and a half for an average cost fishing trip to a shoreline habitat. Interestingly, travel times did not differ markedly between the two primary fishing mode groups or across habitats. As a result, total individual trip costs incorporating opportunity costs of time largely reflected trip expenditures, with trips by private and charter boat anglers to offshore habitats being the most expensive.

This study evaluated angler preferences for trips to shoreline habitats, finding average WTP values of $39 to $225 per trip across habitat types and angler groups. Lew and Larson (2012) find average trip WTP ranging from $246 to $718 for private boat recreational saltwater fishing trips by residents in Alaska. Scheld et al. (2020) estimate average trip WTP ranging from $409 to $577 for Virginia saltwater anglers, depending on target species. Our hypothetical trips did not include catch or harvest attributes, which are frequently found to be highly valued aspects of recreational fishing trips (Hunt et al., 2019), and therefore could have led to lower WTP estimates. This study estimated preferences for recreational fishing trips to shoreline habitats among a group of anglers with easy access to a variety of target habitats and relatively low reported fishing costs. Studies evaluating angler preferences for fishing trips in remote regions (e.g., Lew and Larson 2012) or when targeting high-value trophy species (e.g., Goldsmith et al., 2018; Scheld et al., 2020) have documented higher average trip WTP, possibly due to increased angler avidity and higher trip costs limiting access to only those with strong preferences or high disposable incomes.

Angler WTP was highest for recreational fishing trips to marshes and living shorelines and lowest for fishing trips to beaches. Marshes and living shorelines were also among the most visited habitats and were generally characterized by shorter travel times and lower average trip expenditures. Frequent use, high value, and low visitation costs led to substantial benefits from this habitat for anglers in the region. In comparison to hardened shorelines, trips to marshes and living shorelines were estimated to produce 3.61 times more total benefits and 5.18 times more surplus benefits. Higher total benefits were due to higher levels of fishing effort and higher WTP while lower trip costs increased the difference in surplus benefits between these shoreline types. Recreational fishing trips to beach habitats were found to yield no surplus benefits. Recreational beach trips are frequently multi-purpose (Pascoe 2019) and thus it is possible that other beach activities are important and highly valued for this group of anglers, despite the relatively low value placed on recreational fishing. This study did not collect information on the number of habitats visited per recreational fishing trip. Anglers generally reported visiting a small number of habitats over the course of a season, though they could have visited multiple habitats during a single fishing trip. To avoid potential double counting, total and surplus benefit estimates presented here should not be aggregated across habitats. Future research exploring multi-habitat trips could be useful in refining habitat-specific effort estimates.

For marshes and living shorelines, the per hectare estimate of total annual recreational fishing benefits found here corresponds to the top quintile of values available on the Ecosystem Services Valuation Database (Brander et al., 2023). Studies documented in that database with greater per hectare estimates include Raphael and Jaworski (1979), Bell (1997), and Whitehead et al. (2006), representing both salt and freshwater wetlands as well as a mix of estimation approaches. The high value of coastal marsh habitat for recreational fishing found here likely results from a combination of angler preferences and expansive marsh coverage in the region, which affords easy and low-cost access by anglers. Per hectare value estimates assumed only Middle Peninsula anglers fished at Middle Peninsula marshes, and also that Middle Peninsula anglers fishing at marshes did so exclusively around the Middle Peninsula. The full sample included anglers from areas adjacent to the Middle Peninsula, many of whom indicated fishing in waters around the Middle Peninsula and thus suggesting value estimates may be conservative. Conversely, while rivers and bays around the Middle Peninsula were the most commonly identified fishing locations across anglers, many also reported fishing in the areas outside this region. Finally, not all marsh included in areal extent estimates is accessible for fishing and angling effort is likely concentrated in certain areas based on local fish abundances and other conditions, suggesting a heterogeneous spatial distribution of ecosystem service values. As living shorelines tend to be narrow and extend along the coastal edge, it is possible they provide a relatively high level of recreational fishing ecosystem service value, despite their small spatial footprint.

5. Conclusions

Coastal habitats provide a variety of ecosystem services though are threatened by economic development and accelerating climate change (Barbier et al., 2011). Recreational fishing is an important pastime and economic sector in many coastal communities, with fishing effort often focusing nearshore and along coastal shorelines. In this study, marshes and living shorelines were found to be critical drivers of value for recreational anglers in comparison to other shoreline types, including those with traditional hard engineering structures. A majority of recreational anglers who participated in this research indicated they felt living shorelines were similar or identical to natural marshes in supporting healthy recreational fisheries, agreeing with research finding ecological equivalence between these habitats in the region (Guthrie et al., 2022) and suggesting this nature-based shoreline modification could help mitigate ecosystem service loss due to coastal erosion and climate change (Bilkovic et al., 2016; Morris et al., 2018).

The costs associated with habitat restoration can present barriers to implementation, especially in instances where project benefits are unknown or difficult to assess. In a survey of shoreline property owners, respondents viewed living shorelines as providing greater levels of ecosystem services though a high degree of uncertainty related to provision of ecological benefits was noted (Guthrie et al., 2023). Additionally, perceptions of ecosystem services did not appear to influence shoreline modification decision making, possibly due to uncertainty in benefit provision as well as the public nature of these benefits. Marsh restoration and living shoreline projects have frequently focused on water quality benefits due to the limited availability of information on provision of other ecosystem services, such as fish habitat or recreational benefits. This study provides ecosystem service value estimates that could be used to assess benefits of future marsh restoration projects and facilitate improvements in socially efficient shoreline modification decision making.

CRediT authorship contribution statement

Andrew M. Scheld: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Donna M. Bilkovic:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Sarah Stafford:** Writing – review & editing, Methodology, Investigation. **Kathleen Powers:** Writing – review & editing, Investigation, Formal analysis. **Susanna Musick:** Writing – review & editing, Methodology, Investigation. **Amanda G. Guthrie:** Writing – review & editing, Methodology, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We thank R. Chambers, C. Gonzalez, M. Helfer, R. Isdell, M. Leu, P. Mason, M. Mitchell, and S. Knoche for helpful comments on the survey instrument and preliminary research findings; K. Angstadt, S. Gregory,

D. Stanhope, C. Tombleson, and M. Whalen for contributions to marsh and living shoreline estimates; K. Nunez for assisting in developing a Spanish translation of the survey instrument; and four recreational anglers for their guidance on survey question wording and structure. The comments from three anonymous reviewers improved this work. This research was funded by the National Oceanic and Atmospheric Administration Chesapeake Bay Office Award #NA21NMF4570524.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2024.107150.

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