Department of Economics Working Paper

Number 18-09| July 2018

Economic Values of Coastal Erosion Management: Joint Estimation of Use and Passive Use Values with Recreation Demand and Contingent Valuation Data

Craig E. Landry
University of Georgia

J. Scott Shonkwiler
University of Georgia

John C. Whitehead
Appalachian State University

Department of Economics
Appalachian State University
Boone, NC 28608
Phone: (828) 262-2148
Fax: (828) 262-6105
www.business.appstate.edu/economics

Economic Values of Coastal Erosion Management: Joint Estimation of Use and Passive Use Values with Recreation Demand and Contingent Valuation Data

Craig E. Landry
Department of Agricultural and Applied Economics
University of Georgia
Athens, GA 30602
clandry@uga.edu; 706-542-0747

J. Scott Shonkwiler
Department of Agricultural and Applied Economics
University of Georgia
Athens, GA 30602

John C. Whitehead
Department of Economics and Finance
Appalachian State University
Boone, NC 28608

Economic Values of Coastal Erosion Management:

Joint Estimation of Use and Passive Use Values

with Recreation Demand and Contingent Valuation Data

Abstract: Revealed and stated preference survey data from North Carolina households are utilized to estimate a joint structural microeconometric model of recreation demand and willingness-to-pay (WTP) for coastal erosion management among beach visitors and non-visitors. We test for and reject weak complementarity, implying existence of non-use values associated with management of North Carolina's coastal resources. We find stronger preferences for shoreline retreat (median WTP = $22.20 per household, per year) as a management strategy relative to beach nourishment (WTP = $7.45) and substantially weaker preferences for shoreline armoring (WTP = $0.09). Shoreline retreat exhibits much larger estimates of non-use values, whereas non-use values for shoreline armoring are negative. Minimizing negative environmental impacts of erosion management increases WTP over 200%. Our data permit estimates of marginal value of incremental beach width accruing to beach users and non-users (which ranges from $0.23 and $0.47 per meter).

Key words: recreation; demand; beach; erosion; management; economic; value

JEL codes: D78; H43; Q24; Q26; Q51

Economic Values of Coastal Erosion Management: Joint Estimation of Use and Passive Use Values with Recreation and Contingent Valuation Data

The coastal zone is a dynamic and recalcitrant ecological system. Management problems stemming from coastal erosion, storms, and sea level rise are exacerbated by development along the coast and, especially, at the water's edge. More than 52% of the U.S. population lives in coastal counties (Joint Ocean Commission 2012). Focusing on U.S. East Coast, approximately 86% percent of the shoreline has exhibited significant erosion in the past 100 years (Galgano et al. 2004), averaging 1.6 feet of shoreline recession per year (USGS 2010). A 2000 study by the *Federal Emergency Management Agency* (*FEMA*) and the *Heinz Center* estimates that 25% of homes within 500 feet of the US coastline could be lost by 2060, at a potential cost of $874 million per year (2017 US dollars) (Heinz Center 2000).[1] This vulnerability has serious implications for economic welfare of coastal households, viability of private and public insurance programs, recreation and tourism along the coast, regional economies adjacent to the coast, and ecological sustainability of coastal systems.

Options for management of shoreline erosion include shoreline hardening (seawalls and other structures designed to protect land and preserve property boundaries), beach replenishment (adding sand to the beach and dune system), and coastal retreat (moving buildings and infrastructure away from eroding shorelines as necessary). The effects of erosion management strategies on the configuration and value of the coastal housing units have been studied by a number of scholars (e.g., Hamilton 2007; Pompe 2008; Landry and Hindsley 2011; Gopalakrishnan, et al. 2011; Ranson 2012; Landry and Allen 2016).

[1] Figure converted from year 2000, Q1 to 2017, Q4 using US Housing Price Index for North Carolina.
[2] Until recently, North Carolina was one of only two states that prohibited shoreline hardening. In 2012, the

Management of erosion, however, also has important implications for the local tourism economy, the quality of natural coastal resources, and ecological sustainability over the long term. These aspects of management have received considerably less attention in the economic literature. In the policy world, coastal property owners have been perhaps the most vocal proponents of shoreline hardening and beach replenishment, with other voices and options receiving much less consideration.[2]

This paper employs primary survey data from North Carolina households in order to evaluate the economic welfare effects of beach erosion management alternatives on the general population. The survey gathers information on use (and non-use) of coastal beaches, perceptions of coastal resource quality, knowledge of coastal processes, and stated preference referendum votes for programs to manage coastal erosion. Following modern best-practices in stated preference analysis, we implement a consequential survey design (highlighting policy relevance and application of study findings) and measure a number of important individual perceptions, including response certainty, perceived consequences of survey responses, and efficacy of management actions at different levels of government. With a 61% response rate, our online panel data compares favorably to U.S. Census decriptive statistics for North Carolina, but with greater representation for more educated and wealthier households.

By combining information on beach users and non-users, we are able to represent diverse groups of stakeholders and conduct a comprehensive and comparative analysis of economic welfare and empirical tests on the magnitude of use and non-use values. We

[2] Until recently, North Carolina was one of only two states that prohibited shoreline hardening. In 2012, the NC legislature passed a bill (unsigned and unvetoed by the Govnernor, thus becoming law) that allows terminal groins along inlets, and there are significant pressures to allow other types of shoreline armoring.

build on the microeconomic models of Eom and Larson (2006) and Huang et al. (2015) to jointly estimate parameters of recreation demand and passive use values. Our model does not impose weak complementarity (WC - typically invoked in welfare analysis of revealed preference recreation demand), but rather can test for its existence. By combining revealed preference (RP) recreation demand and stated preference (SP) contingent valuation data, we employ a consistent behavioral model that permits analysis of co-existing use and passive use values and how these values are affected by erosion management strategy, beach width, and negative environmental impacts engendered by management interventions (all design dimensions of the stated preference survey).

Regression results indicate that demand for beach trips is decreasing in travel cost, but increasing in income, beach width, beach length, access-points, and whether the destination has ferry-only access. Consumer surplus per trip to the NC coast is $200 per household (similar to previous estimates in the literature). Further, we find statistically significant variance parameters for recreation trips and WTP for improving beach width, and a positive correlation coefficeint for trips and WTP in all models estimated. Our null model does not permit a non-use component to preferences, while two alternative models specify an exponential or linear non-use value function. Likelihood ratio tests reject the parameter restrictions implied by no non-use value, effectively rejecting the hypothesis of weak complementarity.

The exponential model appears to provide the best fit to the data, indicating mean (median) WTP for beach erosion management of $7.91 ($10.70) per household, per year. Willingness-to-pay is considerably smaller (close to $0) for beaches maintained in conjunction with shoreline armoring, but quite a bit larger for beaches maintained by shoreline retreat (each relative to beach replenishment). Minimizing negative environmental impacts associated with beach management increases WTP by over 200 percent, and most of this increase is refleted in higher non-use value. Incremental values for beach width indicate mean WTP of $0.24 per meter and median WTP of $0.47 per meter. Values for changing beach conditions that vary with policy approach could be instrumental in analysis of shoreline management and climate adaptation, wherein changes in the built environment, public infrastructure, environmental conditions, human behavior, and policy occur within a tightly coupled human-natural system with considerable spatial and temporal complexity (Slott, Smith, and Murray 2008; Smith et al. 2009; Landry 2011; McNamara, Murray and Smith 2011; Lazarus et al. 2011; McNamara and Keeler 2013; Williams et al. 2013; McNamara et al. 2015; Jin, et al. 2015; Gopalakrishnan et al. 2016, 2017; Keeler, McNamara, and Irish 2018; Mullin, Smith, and McNamara 2018).

Background

Residential and commercial development in the coastal zone facilitates access to and enjoyment of coastal amenities, such as beaches, estuaries, fisheries, and cultural resources. Dynamics of the shore have resulted in various patterns of erosion and accretion, with an overwhelming majority of shorelines along the east coast exhibiting net erosion in recent decades (Galgano, et al. 2004; USGS 2010); the North Carolina coastline, our study site, is no exception (Riggs and Ames 2003). Driven by wind, waves, storms, and sea level, erosion of beaches, bluffs, and estuarine shoreline can threaten the viability of residential and commercial development, as well as public infrastructure, by undermining foundations and exposing structures to wave attack, currents, and tidal fluctuations. Waterfront structures face the greatest risk, and owners have strong incentives to install private protective measures or lobby for public projects that protect their property. These erosion management initiatives, however, affect environmental quality and the overall appeal of beaches and estuaries for local users, tourists, and other visitors. Thus, erosion control policies influence environmental quality, sustainability, and recreation & tourism patterns for the public at large, but policy decisions can be more heavily influenced by coastal residents that face greater personal risk.

The objective of this paper is an analysis of public support and willingness to pay for coastal erosion control in order to fill a gap in the existing literature. While much has been learned about coastal residents' value of beach quality through analysis of property value data (e.g., Pompe 2008; Landry and Hindsley 2011; Gopalakrishnan, et al. 2011; Ranson 2012; Landry and Allen 2016), comparatively little is known about general public support and economic value for erosion management policies and how such policies may affect use and non-use values. Coastal erosion can result in diminished beach and dune quality, and management of erosion can create situations where the beach is transformed into a construction zone or is littered with debris and dilapidated buildings at certain points in time. Policies to manage erosion can include beach replenishment, shoreline armoring, or coastal retreat, each of which may garner different levels of support among the general public and may impact choice, experience, and value of recreational users.

Beach replenishment involves periodically replacing eroded beach and dune sand; while this can improve beach width and dune height (thus augmenting beach habitat), it may have negative impacts on other beach quality measures (texture, color, etc.) and can induce negative environmental impacts at the sand mining or placement sites. Shoreline armoring can provide protection to coastal development and affect the distribution of sand, but often has negative environmental and aesthetic impacts (including destruction of habitat, disruption of sand sharing across parts of the beach, and loss of beach width in some areas). Along sandy beaches, replenishment is usually conducted in conjunction with armoring in order to ameliorate some of these negative effects.

In contrast to *active* management of beach resources, coastal retreat is a *passive* management approach that entails moving structures and infrastructure to adapt to an evolving coastline; while this approach attempts to allow a natural barrier island system to persist, it can restrict access by limiting the extent and quality of residential and commercial development and public infrastructure that supports beach recreation and leisure activities. The process of retreat can be unsightly, as buildings and infrastructure are moved or demolished. Moreover, since it involves removal of structures and loss of land, shoreline retreat permits natural forces to impinge upon public and private property and raises legal issues related to public trust, eminent domain, and compensation.

Each of these policies induces an array of benefits and costs that may have diverse impacts on concerned parties. The interests of coastal private property owners are perhaps more obvious than the preferences and concerns of recreational users and the greater public. Since erosion control projects typically entail use of public funds and can have significant impact on the quality of natural resources (beaches, water quality, ecological habitat, etc.), the overall support for different approaches to coastal erosion management, their potential impact on recreation values, and the benefits and costs engendered by the approaches should be evaluated. Our objective in this paper is to assess economic benefits and costs of coastal erosion management policies to provide for a better understanding of tradeoffs that relate to the impact of erosion control on the recreation and tourism sectors and the public at large.

Literature

Early reviews of economic values related to beach resources and management of coastal erosion include Freeman (1995) and Bin et al. (2005). We thus focus primarily on the literature since. Of particular note is the introduction of dynamic optimization models designed to identify optimal rotation times for beach replenishment – identifying efficient sand quantities and scheduling of sediment restoration activities (Landry 2008, 2011; Smith et al. 2009), exploration of spatial externalities among communities engaging in beach replenishment (Slott, Smith, and Murray 2008; McNamara, Murray and Smith 2011; Lazarus et al. 2011; Williams et al. 2013; Gopalakrishnan et al. 2016, 2018), and political economy models of coastal development, risk mitigation, and abandonment (McNamara and Keeler 2013; Mullins, Smith, and McNamara 2018). A recent paper by McNamara et al. (2015) examines the effects of stochastic coastal storms, replenishment costs, erosion rates, and federal replenishment subsidies on optimal beach rotation and the resulting property values.

In addition to information on geomorphology and atmospheric conditions, dynamic optimization models require inputs on the economic value of beach sediments and the economic costs of manipulating the sediment budget to augment beach width and dune mass. The hedonic property price valuation method has been used to estimate marginal willingness to pay for increments in beach width (Landry, Keeler, and Kriesel 2003; Pompe

2008; Landry and Hindsley 2011; Gopalakrishnan et al. 2011; Landry and Allen 2016). Empirical estimates suggest that homeowners are willing to pay $22 to $1400 for an additional foot of beach width, though some estimates are as high as $8000 for beachfront homes.

Recreation demand models have been used to analyze preferences for beach trips and the influence of trip attributes on economic value. These measures can also play a prominent role in shoreline management and optimization models. Lew and Larson (2008) use information on individual labor market choices and trips to San Diego, CA beaches to estimate a repeated nested logit model of whether and where to go to the beach, while permitting an endogenous and jointly estimated shadow value for travel time. They find positive utility associated with beach length and estimate a compensating variation of around $22 per day. Whitehead et al. (2008, 2010) utilize the single-site demand equation approach, but combine data on revealed and stated trips in order to assess economic measures of welfare stemming from North Carolina beach visitation and how values are influenced by beach access and beach width. They estimate consumer surplus of around $90 per trip, increasing by $25 with improvements in beach access and $7 with wider beaches (2008); estimates of economic value, however, are sensitive to the choice of recreation demand model (2010). Using contingent valuation, Oh et al. (2008) estimate visitors to South Carolina beaches are willing to pay $6.60/day for additional beach access points and parking spaces.

To develop a model of individual choice of participation, activity, and beach site in California, Pendleton et al. (2012) use a nested discrete choice framework. Importantly, they find that the value of beach width varies systematically by activity, with sand-based activities exhibiting the largest value relative to water-based or pavement-based activities. Increasing beach width enhances economic value, but only up to moderate width levels. They estimate consumer surplus ranges between $13 and $74 per trip, and aggregate welfare measures for increasing beach width in the Los Angeles area by 50% are over $3 million per year. Parsons et al. (2013) combine revealed and stated preference on beach use in Delaware to assess the effects of changes in beach width on recreation. They estimate the value of Delaware beach visits at $81/ trip for those that stay overnight and $33/ trip for single-day trips. Welfare losses from narrowing of the beach width by one-quarter its current width are about $5 per day, and doubling the current beach width increases economic value by about $3 per day.

Landry (2011) outlines the components of an economic cost function for beach replenishment, but there has been little research on this topic (despite the existence of extensive archival data at Western Carolina University's *Program for the Study of Developed Shorelines* (PSDS)). An important component of beach replenishment is the potential for external costs imposed upon the surrounding environment (Speybroeck et al. 2006). These have received little attention in the literature, with a notable exception being the study of Huang, Poor, and Zhao (2007), which examines economic costs of wildlife impacts associated with beach replenishment; residents of New Hampshire and Maine are willing to pay on the order of $4 to $6 per household to prevent these impacts.[3] Likewise, there has been little research on households' willingness to pay or support for the different ways that coastal erosion can be managed – shoreline armoring, beach replenishment, and shoreline

[3] On the other hand, Shivlani, Letson, and Theis (2003) find that willingness to pay for additional beach width that provides additional habitat to sea turtle in Florida increases willingness to pay by about 25% - from $2.22 v. $2.78 per household, per visit.

retreat. These distinct responses can be viewed as a subset of adaptive measures that can be employed to manage sea-level rise – each invoking unique profiles of costs and benefits over time, accruing to different classes of property owners, public resources, beach visitors, and concerned non-users.

Our analysis provides information on household preferences for the different approaches to managing coastal erosion, while incorporating potential changes in the environment. We explore the influence of variability in beach width, environmental impacts, and individual characteristics (e.g., environmental attitudes, political ideology, education, income, etc.) on willingness-to-pay for beach replenishment, shoreline armoring, and coastal retreat for beach users and non-users. Employing a utility-theoretic valuation framework, we use revealed preference demand data and stated preference contingent valuation data to estimate total value of coastal erosion management in North Carolina, while testing for the presence of non-use value.

Data

Our data focus on visitation to and management of the North Carolina's ocean beaches. Shoreline armoring has been proscribed in the state since the 1980s, though some oceanfront properties facing high erosion risk use large sand bags to protect their homes. The North Carolina legislature, however, recently approved the use of terminal groins,[4] and some suspect that they may permit more hardening of the shoreline in the near future. Beach replenishment is conducted along many parts of the North Carolina coast; some projects are part of ongoing federal operations that were approved decades ago (e.g.

[4] Groins are shore-perpendicular structures designed to protect downdrift land and/or trap sand. Terminal groins are found at the end of the beach, often adjacent to waterways.

Wrightsville Beach), and others are funded locally (e.g. Carteret County). Like most parts of the U.S. coast, shoreline retreat is typically only employed as a measure of last resort, but there are parts of the North Carolina shore that have had to embrace retreat (e.g. South Nags Head).

The data were collected through contract with *Online Sampling Solutions, Inc.* in late fall of 2013. The data provider gave us access to their *Research Now* panel,[5] which is designed for research purposes, actively managed, and recruited using standard marketing research techniques. These sorts of large Internet panels provide for much better response rates than mail or phone surveys and have known characteristics (e.g. income, education level) that allow for analysis of sample response bias. We received a 61% response rate, and our data compares favorably to the population based on observables collected via U.S. Census (more on this below).

The survey questionnaire included a short pre-amble to describe the resource problem under study:

> *This survey is about North Carolina beaches.*
>
> *Beaches provide for storm protection and coastal recreation. Wind, waves, currents, storms, and changing sea levels have contributed to the erosion of coastal beaches. About 75% of North Carolina beaches have eroded an average of 2.7 feet per year in the past 20 years. Between 1% and 2% of the North Carolina coastline has no dry sand at high tide.*

The instrument collects information on subjects' knowledge of coastal processes (trends in seal level and damage due to coastal storms), beliefs about coastal erosion, and attitudes toward federal, state, and local governments' management of erosion. All respondents are

[5] www.researchnow.com

asked to describe their level of concern (using Likert scales) over beach width, protection of coastal properties, and the use of public money for erosion management.

We collect information on past and planned future recreation trips to the North Carolina coast. The contingent valuation part of the survey is designed to assess a cooperative state program that would pursue a concerted strategy to manage erosion on all North Carolina beaches. The proffered strategies are beach replenishment, shoreline armoring in conjunction with beach replenishment, and shoreline retreat, each relative to a status quo of no state erosion control program. For each possible strategy, a brief description of the approach was provided, as well as potential negative environmental impacts. Table 1 provides succinct summaries. (See the Appendix for additional details.) Each respondent was asked to describe their level of support for each of the coastal management strategies and the status quo (ranging from strongly oppose to strongly support).

As we are interested in both use and non-use values, we make a distinction between those respondents that visit beaches and those that do not. We classify respondents as beach users if they reported at least one trip to East Coast beaches in previous 24 months. While the distinction is somewhat arbitrary, this screening question permits us to gather detailed trip information only from those that indicate they've recently been to an east coast beach. For these subjects, we collect information on trips to North Carolina Beaches and to other East Coast beaches in previous 12 months. While 12-month recall is demanding of subjects, we provide a detailed map of the North Carolina coast to help jog memory and our data collection period (late fall) was chosen to help respondents book-end the peak summer season when most trips are taken.[6]

In addition, we include a series of contingent valuation (CV) questions to assess willingness to support beach erosion management. In assessing each specific erosion management strategy, we utilized a 'between' research design, wherein approximately one-third of sample was allocated to 'nourish', 'armor', and 'retreat'. Each respondent is asked a dichotomous choice question (Yes/No/Undecided) regarding their willingness to vote in support of their assigned erosion management plan at a randomly assigned price. Also varying 'between' are environmental effects related to erosion management. Each respondent is systematically assigned to one of the cases I – IV in Table 2 for elicitation of their initial CV response.[7] Each beach width is depicted with color photos that include a single-person for scale. (See the Appendix.)

The payment vehicle was described as an increase in beach property taxes (2 cents per $100 value) accompanied by an increase in overall state income tax. The inclusion of property taxes was incorporated to account for perceived inequity that was revealed during pre-testing. The randomly assigned bid levels developed based on a range of realistic coastal erosion management cost estimates and were $4, $28, $49, $81, and $114 per household, per year. The survey included the following text to enhance incentive compatibility (Landry and List 2006):

---

[6] In addition to revealed preference trips, we inquire about stated preferences. Each respondent is asked to state their expected future trips to North Carolina and other East Coast beaches over next 12 months under current conditions (average NC beach width of about 100 feet), and expected trips under a scenario in which North Carolina beaches are heavily eroded to an average width of 30 feet. These data are not analyzed in the current paper.

[7] Follow-up CV evaluations and SP trip information are also collected moving horizontally or vertically in Table 2 (thus adding a 'within' dimension to the trip data). These data are not utilized in the current paper.

Imagine that you have the opportunity to vote on the proposed coastal erosion management plan, ________. If more than 50% of North Carolina households vote for the plan then it would be put into practice.

Sometimes when people are asked to evaluate a proposed policy like this one, it is easy for them to say they support a policy either because they are not being asked to pay at the same time, or they don't think they will have to pay based on their response.

We want you to only respond with what you actually think you would do given the beach impacts and the estimated cost to your household.

Also consider your personal income and current payment obligations. If you vote for the policy then you would have _______ less to spend on other things each year. If you pay property taxes on a beach house you would have even less to spend on other things each year.

There is no right or wrong answer but results from this study will be shared with North Carolina coastal policy makers.

The first blank was filled with their assigned policy scenario ('nourish', 'armor', or 'retreat'), and the second blank was filled with their randomly assigned bid. Immediately following their dichotomous choice, they were asked to state their level of certainty in their response.

Lastly, respondents were asked to indicate their level of agreement with statements regarding the suitability of voting referenda to influence coastal erosion policy, the likelihood that results of the survey would be shared with North Carolina policy makers, and the likelihood that the results of the survey would influence policy makers. We also measured the self-assessed understanding in the information contained in the survey and respondents' confidence in the ability of North Carolina State Government to achieve the goals of the proffered beach erosion policy.

Descriptive statistics are presented in Table 3. Eighty-two percent of our respondents met our classification as a beach user (having visited an East Coast beach within the previous 24 months), and the average number of trips to NC beaches over the previous 12 months was 2.08. (This includes both single-day and overnight trips.) Beach site characteristics were measured using aerial photography and include average beach width, beach length, parking area (m^2/km), number of official access points per kilometer, and a dummy variable indicating ferry-access only. For those respondents making a single trip or numerous trips to a single beach, characteristics of the visited beach are utilized. For those visiting numerous beaches, we employ a weighted average of characteristics (with weights given by the relative proportion of trips to a given site). For non-visitors, characteristics at the nearest beach were utilized. Average beach width (length) was 57 meters (22,438 meters), with a minimum of 31 (6,350) and a maximum of 95 (88,700). The average parking area was 1,231 square-meters per kilometer, and the average site had 2.9 beach access points per kilometer. About 5 percent of the visited beaches were ferry-access only.

When queried about the support for the various beach erosion management strategies, similar proportions (around 46%) supported or strongly supported the three options identified – beach replenishment, shoreline armoring, and shoreline retreat - while only 16% supported the status quo (limited beach replenishment and continued erosion). The average annual tax increase associated with the erosion control policy was $54, and about a quarter of the sample responded affirmatively to the CV question. Seventy-one percent of respondents support the idea of a referendum for assessing coastal erosion policy, and two-thirds believe the results generated by our survey will be shared with NC policymakers. Over three-quarters claim to have understood all information presented in the survey. Over half of respondents perceive that survey results could have consequences regarding policy adoption, and the same proportion have confidence that policymakers can effectively adopt the management strategy.

Table 3 also includes information on household characteristics. Forty-two percent of respondents were male, with a household size of 2.3 persons. U.S. Census 2010 indicates 49% males and average household size of 2.5 persons for North Carolina. Whereas 67% of our sample has a bachelor's degree or greater educational attainment, the NC average is 26.5% (U.S. Census 2010). Median income for our sample is $62,500 (mean = $77,792), while the NC median is $46,291 (U.S. Census 2010). Eighty-seven percent of our sample reported being white (NC average is 72%). Over 7% of respondents indicated membership in an environmental organization. Seventeen percent self-identified the political view as liberal, while 39% (34%) reported moderate (conservative) political views; the remaining 10% indicated 'none of the above' for political view. Eight-six percent of respondents voted in the 2012 Presidential Election.

Methods

We build on the microeconomic models of Ebert (1998), Eom and Larson (2006), and Huang et al. (2015) to jointly estimate parameters of recreation demand and passive use values. Ebert (1998) shows how the incomplete demand system framework can be used with information on WTP for a public good to recovery the underlying preference ordering. If the Slutsky substitution matrix associated with the incomplete demand system and WTP function is symmetric and negative semi-definite, then conditions hold for weak integrability that will guarantee the existence of a pseudo-indirect utility function, which permits evaluation of exact welfare measures for goods within the incomplete system (Proposition 2' (Ebert 1998, pg. 250)).

Eom and Larson (2006) apply this method using a semi-log specification for recreation demand, which is integrated to recover a quasi-expenditure function, $E[p, Q, \theta(Q, u)]$, that depends upon travel cost, p, environmental quality, Q, and a constant-of-integration, θ. The constant term can be thought of as an index of utility, and to incorporate potential non-use value, it can be specified to depend upon Q. With appropriate data, the quasi-expenditure function can be used to assess welfare of changes related to p or Q and can test for weak complementarity (which entails no non-use value). When non-use value is present, the closed-form expression for welfare estimation permits a separation of use and non-use values. Employing recreation demand and contingent valuation data, Egan (2011) applies the Eom and Larson model to Iowa lakes data, finding support for weak complementarity (rejecting the existence of non-use value).

Huang, et al. (2015) expand the empirical framework for joint estimation, considering an array of functional froms for recreation demand and WTP. They focus primary attention on a semi-log demand specification, but their Appendix includes detailed derivations with five other common demand functional forms. We employ the following demand specification for trips, Y:

$$E(Y) = \exp(\beta p + \gamma \ln(m) + \delta \ln(Q) + \alpha' Z), \quad (1)$$

where p is the travel cost; m represents household income; Q is an environmental quality indicator, and Z includes other covariates. Following LaFrance (1990) and von Haefen (2002), we model the individual demand equation as an incomplete demand system for k + 1 beach destinations, treating the other k sites as unobserved. We normalize all prices and income by a numeriare good (county-level housing price index) to impose homogeneity, and restrict substitute site cross-price coefficients to be zero in order to impose symmetry of the Slutsky substitution matrix (LaFrance 1990; von Haefen 2002).[8] Among items in the *Z* matrix, we include site characteristics: ln(beach length), access point/km, parking spaces/km, and ferry-only access (proportion or dummy variable).

Because almost 35% of households report no beach trips for the North Carolina coast, a continuous model of trip demand is not applicable. The trip data are over-dispersed given that the mean number of trips observed is 2.08, and the variance of trips is 13.92. Thus, both a negative binomial model and a Poisson log-normal model were fit to the trip demand data. The Poisson log-normal model produced a larger log likelihood than the negative binomial specification. Although estimation is more computationally demanding for the Poisson log-normal count data demand model, we now show how it can be jointly estimated with the probit CV model to incorporate stated preference responses that would alter quality levels of the recreation site(s).

As defined by Aitchison and Ho (1989) the univariate Poisson-log normal probability mass function is obtained from a Poisson probability mass function in which the location parameter λ is assumed to follow a log-normal distribution. That is $\ln(\lambda) \sim N(\mu, \sigma^2)$, and the resulting distribution has the form:

$$P(\mathrm{Y}=\mathrm{y}) = \int_{\mathrm{R}_+} \frac{\mathrm{e}^{-\lambda}\lambda^{\mathrm{y}}}{\lambda\mathrm{y}!} \frac{\mathrm{e}^{-.5(\ln(\lambda)-\mu)^2/\sigma^2}}{\sigma\sqrt{2\pi}} d\lambda \qquad \mathrm{y} = 0, 1, 2, \ldots \tag{2}$$

---

[8] An alternative is to specify incomplete demand system for one destination and treat other sites as outside of the demand system.

Evaluation of this integral is made difficult due to the requirement that $\lambda>0$. Introducing the change of variable $\ln(\lambda) = \mu + \sigma\epsilon$, where $\epsilon \sim N(0,1)$ with the corresponding Jacobian of transformation, $\lambda\sigma$, then yields the probability mass function

$$P(Y = y) = \int_{-\infty}^{\infty} \frac{e^{-\lambda}\lambda^{y}}{y!} \frac{e^{-.5\epsilon^2}}{\sqrt{2\pi}} d\epsilon \qquad \text{where } \lambda = e^{\mu + \sigma\epsilon}. \tag{3}$$

Now consider a latent variable model for willingness to pay for beach erosion control program: $WTP^* = X\omega + \nu$ where ν is normally distributed with mean zero and variance σ_ν^2. Under the contingent valuation scenario, the respondent will vote yes when $WTP^*>tax$ which generates the probit probability: $Prob(yes) = \Phi((X\omega - tax)/\sigma_\nu)$. Here $\Phi(.)$ represents the standard normal cumulative distribution function. Next suppose that there is a normally distributed random variable w such that $w \sim N(\mu_w, \sigma_w^2)$. Then it is well known that:

$$Prob(yes|w) = \Phi([(X\omega - tax)/\sigma_\nu + \rho(w - \mu_w)/\sigma_w]/\sqrt{1-\rho^2}) \tag{4}$$

Because this conditional probability is based on Gaussian distribution theory, in general it cannot be employed with a count data variable. One exception is when w represents log λ in the Poisson-log normal distribution. The conditional probability becomes:

$$P(yes|\ln(\lambda)) = \Phi([(\omega' X - tax)/\sigma_\nu + \rho(\ln(\lambda) - \mu)/\sigma]/\sqrt{1-\rho^2}). \tag{5}$$

The joint distribution of the count and the binary response variable is given by multiplying the marginal and the conditional distributions to yield:

$$P(Y = y, WTP^* > tax) = \int_{-\infty}^{\infty} \Phi\left(\frac{(\omega' X - tax)/\sigma_\nu + \rho\epsilon}{\sqrt{1-\rho^2}}\right) \frac{e^{-\lambda}\lambda^{y}}{y!} \frac{e^{-.5\epsilon^2}}{\sqrt{2\pi}} d\epsilon \tag{6}$$

where, again, $\lambda = e^{\mu + \sigma\epsilon}$. Equation (6) represents likelihood contributions given by those respondents that answer affirmatively to the CV scenario. Likelihood of “No” responses is give by:

$$(Y = y, WTP^* \le tax) = \int_{-\infty}^{\infty} \Phi\left(\frac{(tax-\omega\prime X)/\sigma_v+\rho\epsilon}{\sqrt{1-\rho^2}}\right)\frac{e^{-\lambda}\lambda^y}{y!}\frac{e^{-.5\epsilon^2}}{\sqrt{2\pi}}d\epsilon \qquad (7)$$

To complete the joint distributions in (6) and (7), we require a form for WTP, which depends on the specification of non-use value. We consider three specifications:

1] No non-use value [constant of integration is independent of Q: $\theta = u$];

2] An exponential form [$\theta = u e^{-W\theta\varphi}$]; and

3] A linear form [$\theta = u - W\theta_\tau$].[9]

Using the results of Huang et al. (2015), WTP for coastal erosion management programs are, respectively:

1] $WTP = m - [m^{1-\gamma} + (1-\gamma)e^{Z\alpha+\beta p+\frac{\sigma_\epsilon^2}{2}}(Q_1^\delta - Q_0^\delta)/\beta]^{1/(1-\gamma)}$

2] $WTP = m - [e^{-\varphi dQ}m^{1-\gamma} + (1-\gamma)e^{Z\alpha+\beta p+\frac{\sigma_\epsilon^2}{2}}(Q_1^\delta - e^{-\varphi dQ}Q_0^\delta)/\beta]^{1/(1-\gamma)}$

3] $WTP = m - [m^{1-\gamma} + (1-\gamma)e^{Z\alpha+\beta p+\frac{\sigma_\epsilon^2}{2}}(Q_1^\delta - Q_0^\delta)/\beta - (1-\gamma)\tau dQ]^{1/(1-\gamma)}$

where $dQ=Q_1-Q_0$ and $\varphi=W\theta_\varphi$ and $\tau=W\theta_\tau$. In our application, we specify the W vector to depend upon an array of environmental characteristics — erosion control policy, beach width, and absence of negative environmental impacts — introduced in the experimental design of the CV survey. These expressions for WTP are substituted in place of Xω in equations (6) and (7), forming the basis for the log-likelihood function. This microeconomic specification permits tests of weak complementarity, a separation of use and non-use value, and testing of covariate effects on use and non-use values. WTP for a change in Q has a closed form solution, and with sufficient variation in the data we can compute incremental WTP for Q (beach width). The parameters are estimated using higher-order rectangular integration of the likelihood function in MATLAB.

[9] Similar to Huang, et al (2015), we attempted to estimate a quadratic form for (3), but had convergence problems.

Results

Parameter estimates for the joint distribution of trip demand and WTP are presented in Table 4. Column one displays results for the model with no non-use value (1] $\theta = u$), whereas column two (three) displays results for the exponential (2] $\theta = ue^{-W\theta\varphi}$) (linear (3] $\theta = u - W\theta_{\tau}$)) specification of non-use value. For the trip demand equation, we find fairly consistent results across all three specifications, with a price elasticity of -1.33 and income elasticities ranging from 0.285 to 0.300. Recreation demand is increasing in beach width (elasticities range from 0.047 to 0.077), beach length (elasticities of about 1.26), access points per kilometer (elasticities around 1.19), and ferry-only access (elasticities around 0.04). Parking area per kilometer is not statistically significant in any of the specifications. The standard deviation of the Poisson-log normal distribution ($\sigma(\epsilon)$) is around 0.7 and statistically significant in all models. Each model suggests a per-trip surplus estimate of $200 per household.

Turning to parameters for the distribution of WTP, we estimate statistically significant standard deviation ($\sigma(\nu)$ ranging from $124 to $140) for WTP for the coastal erosion plan. Note, there is some payoff to using the system estimator for recreation demand and WTP, since for all three specifications the estimate of ρ is statistically significant and positive (ranging from 0.171 to 0.184). Only the exponential specification for non-use value [2], however, finds significant covariate effects for WTP. The marginal effects are non-linear expressions derived from WTP expressions in [1] – [3], but the parameter signs indicate the direction of influence. From specification [2], we find WTP for beach erosion control is decreasing in armoring, increasing in shoreline retreat (each relative to beach replenishment), larger when negative environmental impacts are minimized, and increasing in the number of children in the household. Despite the lack of statistical significance for covariates in the linear specification [3], the weak complementary hypothesis can be soundly rejected for both specifications (χ^2_{LRT} = 58.9 for model [2] and χ^2_{LRT} = 38.52 for model [3], each p-value < -0.001). Information criteria support specification [2] over [3] (Akaike: $AIC_{[2]}$ = 3443.7; $AIC_{[3]}$ = 3452.08; Bayesian: $BIC_{[2]}$ = 3535.69; $BIC_{[3]}$ = 3538.07), but, given the similarities in ln-likelihoods, results of the Vuong Test for support of model [2] over [3] are weak (Z = 0.403).

Welfare measures for coastal erosion management depend on the specification chosen as shown in Table 5. Given skewness in our distributions of WTP for specifications [2] and [3], we use bootstrap replication with parameter transformation to estimate standard errors (as recommended by Davidson and Hinkley (1998, p.195)); the delta method is used for specification [1]. Models [1] and [2] find positive and statistically significant mean WTP of $10.03 and $7.91 per household, per year for coastal erosion management, respectively; corresponding median WTP values are $5.64 and $10.70 per household, per year. Model [3] does not exhibit a statistically significant mean, but the median WTP is, at $9.34 per household. Given the variation in initial (via RP data) and subsequent (via SP data) beach width, WTP can be expressed in incremental units. Mean WTP for beach width is $0.25 - $0.35 per meter, and median WTP for beach ranges between $0.23 and $0.47 per meter.

Tables 6a and 6b present WTP estimates for sub-samples defined by the assigned beach erosion policy treatment: beach replenishment, shoreline armoring, or shoreline retreat. For specification [2] (Table 6a), we find significantly greater mean and median

WTP for shoreline retreat: $34.35 and $22.20 (per household, per year), respectively; relative to beach replenishment: $9.24 and $7.45, respectively; and shoreline armoring: -$19.37 and $0.09, respectively. The pattern of results is similar for specification [3] (Table 6b), but with a negative mean WTP for beach replenishment (-$7.52 per household, per year) and a negative median WTP for shoreline armoring (-$7.25 per household, per year).

Tables 7a and 7b present non-use value estimates for specifications [2] and [3], respectively. For example, non-use value for specification [2] can be defined as E[Y] converges to zero, as:

$$NUV_{[2]} = m - [e^{-\varphi dQ} m^{1-\gamma}]^{1/(1-\gamma)} = m - e^{-\varphi dQ} m = m(1 - e^{-\varphi dQ}) \qquad (8)$$

with the remaining WTP being attributable to use-value:

$$UV = WTP - NUV \qquad (9)$$

Considering the median welfare measures, we derive the following breakdowns in UV and NUV: Full Sample: UV = $5.49; NUV = $5.21; Retreat Scenario: UV = $7.56; NUV = $14.64; Armor Scenario: UV = $9.31; NUV = $-9.21; Nourish Scenario: UV = $4.72; NUV = $2.73 (Table 7a—all values per household, per year). Specification [3] exhibits positive NUV for only the retreat scenario: $15.40 (Table 7b); Mean NUV for the armoring scenario is -$36.15, whereas mean NUV for the replenishment scenario is -$22.62. Given the lack of significant covariate effects and information criteria, however, we put more emphasis on specification [2].

The coefficient on Enviro is positive and statistically significant in specification [2], indicating a larger WTP for erosion management programs that produce minimal environmental impacts. Taking differences in WTP with and without the presence of negative environmental impacts indicates a median WTP of $35.10 per household, per year (standard error of $8.55). The majority of this estimate is attributable to non-use value: median of $33.82 per household. Thus, relative to the baseline full sample estimates (UV = $5.49; NUV = $5.21), minimizing environmental impacts increases total WTP by over 200% and pushes the bulk of welfare into the non-use value dimension.

Discussion

Following Ebert (1998), Eom and Larson (2006), and Huang, et al. (2015), we estimate models of beach recreation demand and total WTP for beach erosion control policies that effect beach width and coastal environmental quality. We utilize internet survey data with a response rate of 61%; our sample, however, exhibits greater levels of income and education than the general population of North Carolina. Otherwise, it appears to be fairly representative. Likert scale responses collected from all respondents indicate a slight preference for shoreline retreat (71% support or somewhat support this management approach) over beach nourishment (67% support), and also over shoreline armoring (58% support). Results of our structural econometric model exhibit a similar pattern of results, with WTP being greater for shoreline retreat, followed by nourishment and armoring. Almost ¾ of our sample believe state referendum is a good way to decide on erosion policy, with 67% believing results will be shared with policy makers, and more than half thinking it may have policy consequences. We have yet to explore the implications of these dimensions of the sample on economic value; this remains an important area of future research.

We expect that beach erosion management can affect non-use values for some portion of stakeholders, and our sampling protocol captures information from users and non-users of North Carolina beaches. As such, we adopt a research design that can account for use and non-use values. Our formulation permits correlation among recreation demand and WTP, and tests of weak complementarity (which implies zero non-use value and is often assumed in analysis of recreation demand). Our results indicate consumer surplus estimates of $200 per household, per trip ($417 per household annually). Economic benefits of a state-level erosion management program are estimated as mean WTP of $7.91 per household, per year (median WTP of $10.70). Given the current (revealed preference) and simulated (stated preference) variation in beach width (permitting identification of the δ parameter in recreation demand model [equation (1)] and WTP models [1] – [3]), we are able to estimate incremental WTP per meter of beach width, which ranges from $0.24 - $0.48 per meter, per household, per year. Estimates of marginal values of beach width have been derived from hedonic property models (Pompe 2008; Landry and Hindsley 2011; Gopalakrishnan, et al. 2011; Ranson 2012; Landry and Allen 2017), but are otherwise rare in the literature. Such estimates are instrumental in application of optimal control models to coastal management (Slott, Smith, and Murray 2008; Smith et al. 2009; Landry 2011; McNamara, Murray and Smith 2011; Lazarus et al. 2011; McNamara and Keeler 2013; Williams et al. 2013; McNamara et al. 2015; Jin, et al. 2015; Gopalakrishnan et al. 2016, 2017; Keeler, McNamara, and Irish 2018; Mullin, Smith, and McNamara 2018).

Microeconomic theory can be used to define use and non-use values stemming from a change in natural resources (Ebert 1998), and through combination of appropriate revealed and stated preference data, econometric results can provide evidence on the existence of non-use (passive use) values (Eom and Larson 2006; Huang, et al. 2015). In the context of revealed preference analysis of recreation demand, analysts often assume weak complementarity between demand for recreation trips and the quality of the recreation site. This entails an untestable assumption about preferences that permits recovery of welfare estimates, but imposes zero non-use (passive use) values. By combining revealed preferences with stated preference data, likelihood ratio tests provide evidence for rejection of the assumption of weak complementarity between beach quality and beach visitation at high levels of confidence (p-values less than 0.001). We consider two specifications for non-use value—exponential and linear; a quadratic form was attempted, but the model did not converge. Information criteria support the exponential form, and this is the only model that finds evidence of covariate effects. We first consider total WTP for coastal erosion management programs in North Carolina, then the breakdown of total WTP into use and non-use value.

Examining WTP estimates by policy approach (which are assigned to subjects via *between* experimental design), we find median WTP estimates of $22.20/hh/year for shoreline retreat, $0.10/hh/year for shoreline armoring, and $7.45/hh/year for beach nourishment for our preferred specification that accounts for non-use value with an exponential functional form. The U.S. Census estimates 3,815,392 households in North Carolina in 2015. Scaling our median WTP values produces aggregate economic welfare estimates of $84.7 million per year for shoreline retreat, approximately $381,000 per year for shoreline armoring, and $28.4 million per year for beach nourishment. Corresponding Mean WTP estimates are $34.45/hh/year for shoreline retreat, $-19.37/hh/year for shoreline armoring, and $9.24/hh/year for beach nourishment, indicating a positive skew in WTP for shoreline retreat and beach nourishment, but a negative skew for shoreline armoring.

Breaking down median WTP into use and non-use value components, we find non-use values for the full sample that are similar in magnitude to use values: UV = $5.49; NUV = $5.21 (all values in per household, per year terms), but these aggregate values mask consider heterogeneity by policy approach. For shoreline retreat, we find non-use values that exceed use value by a factor of almost two: UV = $7.56; NUV = $14.64. Whereas for beach nourishment, use values exceed non-use: UV = $4.72; NUV = $2.73. The shoreline armoring scenario produces negative estimates of non-use value (NUV = $-9.21) which are similar in absolute value to use value estimates (UV = $9.31), rendering median total WTP for shoreline armoring close to zero.

We estimate positive economic values associated with minimizing negative environmental impacts of beach erosion management. In our survey, these are described as follows: Beach Nourishment: disruption of ocean-bottom habitats, increased cloudiness in coastal waters; burial of beach organisms and alteration of sand texture on the beach (mostly short term, but can be more long-term with poor project management); Shoreline Armoring: disruption of continuous beach and loss of beach habitat; Shoreline Retreat: temporary disruption of continuous beach; temporary loss of beach habitat; temporary presence of debris on some parts of the beach (see Appendix for more details). Using a between experimental design, some subjects receive scenarios that include these negative environmental impacts, whereas others receive scenarios in which negative environmental impacts are minimized through prudent project management.

Results indicate greater WTP when these environmental impacts are minimized, and the effect on median WTP is quite large at $35.10 per household, per year. Decomposition indicates that the increase in economic value exhibits a large shift towards non-use value (estimated at $33.82 per household, with only $1.28 remaining for use values of erosion management). Despite the distinct descriptions of negative environmental impacts, our data find no significant differences in the effects on WTP for shoreline erosion management.

Future research with these data will focus on attempting to incorporate observations on SP recreation demand that permit individual projections of visitation under scenarios of widespread beach erosion (reducing average beach width from 30.5 meters to 9 meters) and erosion management scenarios that are analogous to the CV scenarios (increasing beach width using beach nourishment, shoreline armoring, and shoreline retreat with or without the presence of negative environmental impacts). Such information will allow us to estimate how recreation demand shifts with changes in resource quality and erosion management policies, but existing theory needs to be modified to incorporate changes in demand and potential biases stemming from SP responses. In addition, we have a panel of CV responses that elicit referendum response to scenarios that vary beach width and presence of environmental impacts. Future research will attempt to incorporate all of these dimensions of choice, while also accounting for respondent uncertainty, perceived consequences, and scenario plausibility. Future research should also explore the fit and robustness of functional forms, for both recreation demand and non-use values.

Conclusions

As a major front in environmental dynamics and climatic change, the coastal zone exhibits significant management problems related to coastal erosion, storms, sea level rise, and—in many area—burgeoning coastal development and increasing populations. Coastal vulnerability entails serious implications for economic welfare, human livelihoods, and environmental sustainability. Using survey data from a sample of North Carolina households, we assess economic values stemming from coastal erosion management strategies, changes in beach width, and negative environmental impacts associated with management. Our combined RP-SP approach builds on existing research (Eom and Larson 2006; Huang, et al. 2015) to estimate models of beach recreation demand and total WTP for beach erosion control policies that effect beach width and coastal environmental quality. We expect that beach erosion management can affect non-use values for some portion of stakeholders, and our sampling protocol captures information from users and non-users of North Carolina beaches. As such, we adopt a research design that can account for use and non-use values. Our formulation permits correlation among recreation demand and WTP, and tests of weak complementarity (which implies zero non-use value and is often assumed in analysis of recreation demand).

For general citizenry, we fine evidence of significant welfare gains stemming from shoreline retreat (with a large component for non-use value), modest support for beach nourishment (with significantly lower non-use value), and null values associated with shoreline armoring (consisting of negative non-use values that are of similar magnitude to use values). The results suggest that organized adaptation to shoreline change has considerable support amongst North Carolina households and deserves more study, whereas shoreline armoring has fairly low support (largely due to negative non-use values).

We find large economic values associated with minimizing negative environmental impacts of management. These impacts relate to: disturbance of benthic habitat, water turbidity, burial of beach organisms, and alteration of sand texture (beach nourishment); disruption of continuous beach and loss of habitat (shoreline armoring); temporary disruption of continuous beach, loss of habitat, and presence of debris (shoreline retreat). Minimizing these negative effects increases economic value of management over 200%, with the majority of benefit being identified as non-use value.

Existing variation in beach width embedded within the RP data combined with contingent, scenario-defined changes in beach width within the SP data permit identification of the value of changes in beach width, which enables a per-unit value for non-marginal beach width changes. Our estimates range from $0.24 - $0.48 per meter, per household, per year ($2012 US). These types of estimates, which vary with erosion control policy, are informative for policy analysis and are instrumental in application of optimal control models to coastal management and coastal adaptation to sea level rise.

(Landry 2008; Smith, et al. 2009; Landry 2011).

References

Bin O, Landry CE, Ellis C, Vogelsong H (2005) Some consumer surplus estimates for North Carolina beaches. *Marine Resource Economics* 20(2): 145-61

Carson R, Groves T (2007) Incentive and informational properties of preference questions. *Environmental and Resource Economics* 37(1): 181-210

Chang L, Krosnick JA, (2009) National surveys via RDD telephone interviewing versus the internet: Comparing sample representativeness and response quality. *Public Opinion Quarterly* 73(4): 641-78

Cummings RG, Taylor LO (1998) Does realism matter in contingent valuation surveys? *Land Economics* 74(2): 203-15

Cummings RG, Taylor LO (1999) Unbiased value estimates for environmental goods: Cheap talk design for the contingent valuation method *American Economic Review* 89(3): 649–65

Davidson AC, Hinkley DV (1998) Bootstrap methods and their application: Cambridge Univ. Press

Ebert U (1998) Evaluation of nonmarket goods: Recovering unconditional preferences. *American Journal of Agricultural Economics* 80(2): 241-54

Egan KJ (2011) Combining revealed preference and stated preference data without invoking the weak complementarity condition. Chapter 14 in Preference Data for Environmental Valuation: Combining Revealed and Stated Approaches, eds: Whitehead JC, Haab TC, Huang JC: Routledge

Eom YS, Larson DM (2006) Improving environmental valuation estimates through consistent use of multiple information. *Journal of Environmental Economics and Management* 52: 501–16

Freeman AM (1995) The benefits of water quality improvements for marine recreation: A review of the empirical evidence. *Marine Resource Economics* 10(4): 385-406.

Gopalakrishnan S, Smith MD, Slott JM, Murray AB (2011) The value of disappearing beaches: A hedonic pricing model with endogenous beach width. *Journal of Environmental Economics and Management* 61(3): 297-310

Gopalakrishnan S, McNamara D, Smith MD, Murray AB (2016) Decentralized management hinders coastal climate adaptation: The spatial-dynamics of beach nourishment," *Environmental and Resource Economics* doi:10.1007/s10640-016-0004-8: 1-27

Haab TC, McConnell KE (2002) Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation: Edward Elgar Press

Hamilton J (2007) Coastal landscape and the hedonic price of accommodation *Ecological Economics* 62: 594-602.

Huang JC, Shaw D, Chien YL, Zhao MQ (2015) Valuing environmental resources through demand for related commodities. *American Journal of Agricultural Economics* 98(1): 231-53

Jin, D, Hoagland P, Au DK, Qiu J (2015) Shoreline change, seawalls, and coastal property values. *Ocean & Coastal Management* 114: 185-193

Keeler AG, McNamara DE, Irish JL, (2018) Responding to sea level rise: Does short-term risk reduction inhibit successful long-term adaptation? *Earth's Future* 6 doi.org/10.1002/2018EF000828

Landry CE (2008) Optimal erosion management on developed barrier island beaches. *Working Paper* East Carolina University: Greenville, NC
Landry CE (2011) Coastal erosion as a natural resource management problem: An economic perspective. *Coastal Management* 39(3): 259-78
Landry CE, Hindsley P (2011) Valuing beach quality with hedonic property models. *Land Economics* 87(1): 92-108
Landry CE, List JA (2007) Using ex ante approaches to obtain credible signals for value in contingent markets: Evidence from the field. *American Journal of Agricultural Economics* 89(2): 420-29
Landry CE, Liu H (2011) Econometric models for joint estimation of revealed and stated preference site-frequency recreation demand models," Chapter 7 in Preference Data for Environmental Valuation: Combining Revealed and Stated Approaches, eds: Whitehead JC, Haab TC, Huang JC: Routledge
Lazarus ED, McNamara DE, Smith MD, Gopalakrishnan S, Murray AB (2011) Emergent behavior in a coupled economic and coastline model for beach nourishment *Nonlinear Processes in Geophysics* 18: 989-99
Lew DK, Larson DM (2008) Valuing a beach day with a repeated nested logit model of participation, site choice, and stochastic time value. *Marine Resource Economics* 23 (3): 233-25
McConnell KE (2011) Joint estimation of stated and revealed welfare measures: The conceptual basis," Chapter 2 in Preference Data for Environmental Valuation: Combining Revealed and Stated Approaches, eds: Whitehead JC, Haab TC, Huang JC: Routledge
NcNamara DE, Gopalakrishnan S, Smith MD, Murray AB (2015) Climate adaptation and policy-induced inflation of coastal property value. *PLOS One* (May 25) DOI:10.1371/journal.pone.0121278
McNamara DE, Keeler AG (2013) A coupled physical and economic model of the response of coastal real estate to climate risk. *Nature Climate Change* 3: 559-562
McNamara DE, Murray AB, Smith MD (2011) Coastal sustainability depends on how economic and coastline responses to climate change affect each other. *Geophysical Research Letters* doi.org/10.1029/2011GL047207
Mullin M, Smith MD, McNamara DE (2018) Paying to save the beach: effects of local finance decisions on coastal management. *Climatic Change* doi.org/10.1007/s10584-018-2191-5
Oh CO, Dixon AW, Mjelde JW, Draper J (2008) Valuing visitors' economic benefits of public beach access points. *Ocean and Coastal Management* 51 (12): 847-53
Parsons GR, Chen Z, Hidrue MK, Standing N, Lilley J (2013) Valuing beach width for recreational use: Combining revealed and stated preference data. *Marine Resource Economics* 28(3): 221-41
Pendleton L, Mohn C, Vaughn RK, King P, Zoulas JG (2012) Size matters: The economic value of beach erosion and nourishment in southern California. *Contemporary Economic Policy* 30 (2): 223-37
Phaneuf DJ, Kling CL, Herriges JA (2000) Estimation and welfare calculations in a generalized corner solution model with an application to recreation demand. *Review of Economics and Statistics* 82: 83-92

Pompe J (2008) The effect of gated community on property and beach amenity valuation. *Land Economics* 83(4): 423-33
Ranson M (2012) What are the welfare costs of shoreline loss? Housing market evidence from a discontinuity matching design. Discussion Paper 2012-07, Cambridge, MA: Belfer Center for Science and International Affairs
Ready RC, Champ PA, Lawton JL (2010) Using respondent uncertainty to mitigate hypothetical bias in a stated choice experiment. *Land Economics* 86: 363-81
Riggs SR, Ames DV (2003) Drowning The North Carolina Coast: Sea-Level Rise and Estuarine Dynamics, North Carolina Sea Grant
Shivlani MP, Letson D, Theis M (2003) Visitor preferences for public beach amenities in south Florida. *Coastal Management* 31: 367-85.
Slott JM, M.D. Smith, and A.B. Murray, 2008. Synergies between Adjacent Beach-Nourishing Communities in a Morpho-Economic Coupled Coastline Model, *Coastal Management* 36: 374-391.
Smith MD, McNamara D, Slott JM, Murray AB (2009) Beach nourishment as a dynamic capital accumulation problem. *Journal of Environmental Economics and Management* 58(1): 58-71
Speybroek J, Bonte D, Courtens W, Gheskiere T, Grootaert P, Maelfait JP, Maths M, Provoost S, Sabbe K, Stienen EWM, Van Lancker V, Vincx M, Degraer S (2006) Beach nourishment: An ecologically sound coastal defence alternative? A review. *Aquatic Conservation: Marine and Freshwater Systems* 16: 419–35.
Whitehead JC (2005) Environmental risk and averting behavior: Predictive validity of revealed and stated preference data. *Environmental and Resource Economics*, 32(2): 301-16
Whitehead JC, Haab TC, Huang JC (2000) Measuring recreation benefits of quality improvements with revealed and stated behavior data. *Resource and Energy Economics* 22: 339-54
Whitehead JC, Haab TC, Huang JC (2011) Preference Data for Environmental Valuation: Combining Revealed and Stated Approaches, editors: Routledge
Whitehead JC, Dumas CF, Herstine J, Hill J, Buerger B (2008) Valuing beach access and width with revealed and stated preference data. *Marine Resource Economics* 23(2): 119-35
Whitehead JC, Phaneuf D, Dumas CF, Herstine J, Hill J, Buerger B (2010) Convergent validity of revealed and stated recreation behavior with quality change: A comparison of multiple and single site demands. *Environmental & Resource Economics* 45: 91-112
Williams, ZC, McNamara DE, Smith MD, Murray AB, Gopalakrishnan S (2013) Coupled economic-coastline modeling with suckers and free riders. *Journal of Geophysical Research: Earth Surface* 118(2): 887-99

Table 1: Details of Beach Erosion Management Alternatives

Beach Erosion Management Scenarios	Description of Policy
Beach Replenishment	Public funding for replenishment of North Carolina beaches. This policy will improve beach width, providing for improved recreation, storm protection, and ecological habitat.
Shoreline Armoring (with replenishment)	Public funding for shoreline armoring in conjunction with replenishment of North Carolina beaches. This policy will protect oceanfront development and improve beach width, providing for improved recreation, storm protection, and ecological habitat.
Coastal Retreat	Public funding for coastal retreat along North Carolina beaches. This policy will provide funds for relocating building and infrastructure, which will improve beach width, providing for improved recreation, storm protection and ecological habitat.
Status Quo	No state program - coastal communities would pursue limited beach nourishment and continued erosion. Overall coastal beach width would continue to decline, leading to loss of beach area for recreation and tourism and loss of natural beach habitat.

Table 2: Experimental Design for Contingent Valuation Study

		Environmental Impacts	
		Minimal	*Negative*
Beach Width	*Wide*	I. Wide beaches (e.g., 50 foot increase); minimal environmental impacts associated with management strategy	II. Wide beaches (e.g., 50 foot increase); negative environmental impacts associated with management strategy
	Wider	III. Wider beaches (e.g., 150 foot increase); minimal environmental impacts associated with management strategy	IV. Wider beaches (e.g., 150 foot increase); negative environmental impacts associated with management strategy

Table 3 Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
beach_visitor	0.822	-	0	1
rp_trips	2.085	3.732	0	30
travel_cost	266.647	128.706	0	728.647
Beach Characteristics				
beachwidth (m)	57.279	10.469	30.89	95
beachlength (m)	22,438.33	10,190.53	6350	88,700
parking_area (m^2/km)	1231.21	401.591	0	2033.784
access_km (points/km)	2.908	1.213	0.011	5.811
ferry_only	0.0526	0.147	0	1
Management/ CV Factors				
favor_nourishment	0.466	-	0	1
favor_armor	0.462	-	0	1
favor_retreat	0.447	-	0	1
favor_statusquo	0.163	-	0	1
tax	54.955	39.042	4	114
vote (=1 for "Yes")	0.256	-	0	1
support_referendum	0.712	-	0	1
share_policymakers	0.676	-	0	1
survey_consequences	0.542	-	0	1
understand_survey	0.780	-	0	1
confidence_policymakers	0.542	-	0	1
Respondent Characteristics				
male	0.425	-	0	1
hh_size	2.332	1.103	1	10
children	0.350	0.810	0	8
white	0.866	-	0	1
h_school	0.067	-	0	1
college	0.355	-	0	1
grad	0.319	-	0	1
env	0.0748	-	0	1
inc ($1,000s)	77.792	59.209	0	312.392
liberal	0.172	-	0	1
moderate	0.390	-	0	1
conservative	0.345	-	0	1
vote2012	0.864	-	0	1

N = 936 observations

Table 4. Joint Estimation of Trip Demands and WTP

Variable	Specification 1 (No NUV) Parameter Estimate	Specification 1 (No NUV) Std. Error	Specification 2 (Exponential NUV) Parameter Estimate	Specification 2 (Exponential NUV) Std. Error	Specification 3 (Linear NUV) Parameter Estimate	Specification 3 (Linear NUV) Std. Error
Constant	-15.104***	1.153	-15.042***	1.148	-15.245***	1.143
Price	-0.005***	0.000	-0.005***	0.000	-0.005***	0.000
Ln(Income)	0.289***	0.070	0.285***	0.070	0.300***	0.069
Ln(BeachWidth)	0.053***	0.020	0.047*	0.024	0.077***	0.032
Ln(BeachLength)	1.264***	0.084	1.265***	0.084	1.256***	0.084
ParkArea	-0.018	0.016	-0.018	0.016	-0.018	0.016
Access Points	0.410***	0.065	0.410***	0.065	0.407***	0.065
Ferry	0.781***	0.264	0.788***	0.264	0.761***	0.265
$\sigma(\epsilon)$	0.708***	0.038	0.708***	0.038	0.707***	0.038
$\sigma(\nu)$	133.024***	14.579	124.117***	14.764	140.149***	22.050
ρ	0.171**	0.073	0.184**	0.075	0.175***	0.076
Constant			-0.106***[a]	0.047	-0.081	0.074
Armor			-0.101*[a]	0.057	-0.029	0.035
Retreat			0.096**[a]	0.047	0.062	0.057
Enviro			0.145***[a]	0.051	0.080	0.070
Armor*Enviro			0.079[a]	0.071	0.037	0.046
Retreat*Enviro			-0.054[a]	0.062	-0.035	0.043
Children			0.029*[a]	0.016	0.013	0.013
Male			0.035[a]	0.027	0.019	0.021
Log Likelihood	-1732.3		-1702.85		-1704.04	

*** statistically significant at 1% chance of Type I error; ** 5%; * 10%
[a] Multiply coefficients and their corresponding standard errors by 10^{-4}
N = 936 observations

Table 5: WTP for Coastal Erosion Management

	Specification 1 (No NUV)	Specification 2 (Exponential NUV)	Specification 3 (Linear NUV)
Mean WTP	\$10.03	\$7.914	\$0.1988
	(3.880)[a]	(1.869)[b]	(1.930)[b]
Mean WTP per Meter	\$0.3506	\$0.2459	\$0.0075
	(0.135)[a]	(0.057)[b]	(0.054)[b]
Median WTP	\$5.643	\$10.70	\$9.3470
	(2.229)[a]	(2.645)[b]	(2.420)[b]
Median WTP per Meter	\$0.2327	\$0.4773	\$0.3839
	(0.0939)[a]	(0.1104)[b]	(0.074)[b]

[a]Standard errors obtained by delta method; [b] Standard errors obtained by bootstrap