Measuring the Economic Effects of Sea Level Rise on Beach Recreation[1]

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Abstract. We develop estimates of the economic effects of climate change-induced sea level rise on recreation at seventeen southern North Carolina beaches. We estimate the relationship between recreation behavior and beach width and simulate the effects of sea level rise on recreation site choice and trip frequency. We find that reductions in beach width due to increased erosion from sea-level rise negatively affect the number and value of beach recreation trips. For beach goers who only take day trips, we estimate that four percent of recreation value is lost in 2030 and 11 percent is lost in 2080. For those who take both day and overnight trips, 16 percent and 34 percent of recreation value is lost in 2030 and 2080, respectively. The present value of the lost recreation value through 2080 assuming no increase in population or income is $9 billion, $4 billion and $722 million with 0 percent, 2 percent and 7 percent discount rates. With expected increases in population and income the present value of the lost recreation value is $29 billion, $11 billion and $2 billion with 0 percent, 2 percent and 7 percent discount rates.
Key Words: coastal recreation, travel cost method, climate change, sea level rise

Introduction

Fueled by preferences for living in coastal locations, the population along the U.S. coast has grown more than double the national growth rate in the last few decades. Rapid economic growth in the coastal zone has resulted in more valuable coastal property. However, climate change threatens to increase the intensity of coastal storms and raise sea level at least 0.18 to 0.59 meters over the next century creating potential problems for the coastal economy (Intergovernmental Panel on Climate Change 2007). In this paper we estimate the economic effects of sea level rise on the beach recreation sector of the coastal economy. This research offers an integration of geospatial data and economic models of the coastal economy.

With one of the fastest population growths in the nation and building development pressures in coastal areas, North Carolina is especially vulnerable to climate-change induced sea level rise. Coastal tourism is an important economic sector in this relatively poor region of the state. Given the barrier island roads and highways that act as barricades for a mobile beach, sea-level rise is expected to result in significant changes in beach width negatively impacting the land that currently hosts beach cottages and beach recreation opportunities. Beach nourishment (i.e. adding sand from offshore sources) can be used to mitigate the damages to property values and coastal recreation and tourism due to sea-level rise but this option is costly (Jones and Mangun 2001). Trembanis, Pilkey and Valverde (1999) estimate that the cost of nourishing all 138 miles of North Carolina shoreline is $831 million every 10 years (2004 dollars).

There has been little previous research examining the impacts of climate change on recreation. Early microeconomic studies find that precipitation and temperature

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impacts beach recreation activities (McConnell, 1977, Silberman and Klock, 1988). More recently, Englin and Moeltner (2004) find that temperature and precipitation affects the number of skiing and snowboarding days.

Two studies have related the observed effects of temperature and precipitation on outdoor recreation activities and used these results to model future impacts on the net economic benefits of climate change. This research finds that the net benefits of climate change on outdoor recreation may be positive for many recreational activities. Mendelsohn and Markowsi (1999) consider the effects of changes in temperature and rainfall on boating, camping, fishing, hunting, skiing and wildlife viewing using statewide aggregate demand functions. Considering a range of climate scenarios, the authors find that increased temperature and precipitation increases the aggregate willingness-to-pay of hunting, freshwater fishing and boating and decreases the aggregate willingness-to-pay of camping, skiing and wildlife viewing. The net effects of climate change on aggregate willingness-to-pay are positive.

Loomis and Crespi (1999) take an approach similar to Mendelsohn and Markowsi (1999) but use more disaggregate data. They consider the effects of temperature and precipitation on beach recreation, reservoir recreation, stream recreation, downhill and cross-country skiing, waterfowl hunting, bird viewing and forest recreation. Overall, they also find that climate change will have positive effects on the aggregate willingness-to-pay of outdoor recreation activities. In particular, they consider the impacts of sea level rise on beach recreation and waterfowl hunting. For beach recreation they use the positive relationship between beach length and the number of beach days per month to assess the loss of beaches. However, the joint effects of increased temperature, increased

precipitation and beach loss leads to an overall positive economic effect. For waterfowl hunting they use the relationship between wetland acres and waterfowl hunting participation and find a negative economic effect with sea level rise.

In contrast to the previous studies that use revealed preference data, Richardson and Loomis (2004) employ a stated preference approach to estimate the impacts of climate change on willingness-to-pay for recreation at Rocky Mountain National Park. Stated preference surveys ask outdoor recreation participants for their willingness-to-pay for climate change or for their hypothetical changes in visitation behavior with changes in climate. Richardson and Loomis' hypothetical scenario explicitly considers the direct effects of climate, temperature and precipitation, and the indirect effects of temperature and precipitation on other environmental factors such as vegetation composition and wildlife populations. Using visitor data, they find that climate change would also have positive effects on visitation at the Rocky Mountain National Park.

Stated preference and revealed preference methods can both be used to estimate the effects of sea level rise on recreation behavior. Stated preference surveys would ask beach goers for their willingness-to-pay to avoid a narrow beach or for their hypothetical changes in visitation behavior with changes in beach width. Since sea level rise is a long term process, hypothetical questions may be problematic due to a lack of realism or immediacy. Revealed preference data is also problematic since long-term behavior is forecast with economic models. However, Loomis and Richardson (2006) compare the stated preference visitation estimates to revealed preference estimates and find evidence of convergent validity of both the revealed preference and stated preference data.

In contrast to these previous studies we consider another aspect of climate change,

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the physical environment and its response, and estimate the effects of sea level rise on beach width and the resulting recreation effects. Considering the conceptual framework developed by Shaw and Loomis (2008) we estimate the indirect relationship between climate change and effects on outdoor recreation and benefits. We exploit the relationship between existing beach width and beach trips and simulate (1) the effects of sea level rise on beach width and (2) the effects of changes in beach width on recreation behavior. Due to data limitations we do not consider the direct effects of climate change, such as temperature, precipitation and climate variability, or other indirect effects of climate change, such as changes in fish species and stocks, on beach recreation.

Using beach recreation data collected during 2005 at seventeen North Carolina beaches, a recreation demand model is estimated. Information from a geospatial analysis is used to measure potential reductions in beach width and identify beach recreation sites that will potentially become unavailable with sea-level rise. The recreation demand model is used to simulate the effects of reductions in beach width and site closure on recreation behavior at these locations and the resulting reallocation of beach recreation trips and costs.

Site Description and Shoreline Impacts

North Carolina's coastal plain is one of several large coastal systems around the world threatened by rising sea level (Moorhead and Brinson 1995, Titus and Richman 2001). Over 5000 km^2 of land are below 1-m elevation and rates of sea level rise are approximately double the global average due to local isostatic subsidence (Douglas and Peltier 2002, Poulter and Halpin, 2008). In the southern coastal region of the state, rates of sea level rise are up to 0.32 meters per century. Continued and projected sea level rise

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is expected to significantly impact natural and economic systems with estimates anywhere between 0.3 to 1.1 meters likely according to Church et al. (2001).

Seventeen beaches along the southern coastal region were identified as major tourism destinations and selected for analysis of changing erosion rates with sea level rise (Figure 1). The study area includes beaches in five southern North Carolina counties. Bogue Banks, a barrier island, is located in Carteret County, and encompasses a twenty-four mile stretch of beach communities. Topsail Island, a barrier island, is located in both Pender and Onslow Counties and encompasses a twenty-two mile stretch of beach communities. New Hanover County encompasses a thirteen mile stretch of beach communities and lies between Pender and Brunswick County. The Brunswick County Beaches are located between the Cape Fear River and the South Carolina border and encompass a twenty-four mile stretch of beach communities.

Data on beach width, length and usage were obtained from the U.S. Army Corps of Engineers. For each beach, the ocean-side vegetation line (where dune vegetation ends and unvegetated beach begins) was digitized into a Geographic Information System from U.S. Department of Agriculture National Air Inventory Program's photographs. When possible, digitized vegetation line data were used from the North Carolina Division of Coastal Management datasets. To calculate the erosion rate for each beach we used erosion rate transect data provided by the U.S. Geological Survey. These data consist of long and short-term erosion rates measured directly from aerial photograph time sequences. Each transect extends from the ocean toward the estuary and with attributes describing erosion. A series of these transects run north to south and capture any spatial variation in the rates of erosion that exist along the shoreline. Transects (separated by

approximately 100 meters) are intersected with the vegetation line for a beach to obtain erosion rates. The erosion attributes for each transect are then partitioned according to each beach providing a range of erosion estimates.

Nourishment of beaches has been significant in coastal North Carolina which resulted in positive erosion rates for some beaches. We identified beaches that had been nourished anytime prior to 1997 using data from the Program for Developed Shorelines (http://psds.wcu.edu). The erosion rate for these beaches was removed from our analysis. To estimate historic erosion rates for nourished beaches we used the overall mean erosion rate from all the erosion estimates from non-nourished beaches. This overall mean was used to project changes in erosion from climate change.

Due to uncertainty in modeling shoreline response to global change (Cooper and Pilkey 2005, Slott et al. forthcoming), we developed a range of percent increases in historic erosion rates that are most likely in the future with climate change. The historic erosion rates are adjusted by these percentages and used for projecting future shoreline change. Two endpoints are used to project changes in beach width, the year 2030 and 2080 (with a low, mid, and high scenario for each year). The annual erosion rate is multiplied by the number of years to determine beach width lost, and this figure is subtracted from the beach widths provided by the U.S. Army Corps of Engineers. The resulting economic analysis is not sensitive to the width scenario so we focus on the midrange erosion scenario (Table 1). The average beach width in 2003 is 130 feet. The minimum beach width is 80 feet (Caswell Beach) and the maximum width is 400 feet (Fort Fisher). We project that all of the beaches will lose 50 feet of width by 2030. We project that by 2080 14 of the 17 beaches will have eroded to the road so that beach

recreation is not feasible. At that time Wrightsville Beach only has 3 feet of width, Carolina Beach has 28 feet and Fort Fisher has 243 feet.

We make a number of assumptions that affect the accuracy of this analysis. These assumptions include using a constant rate of erosion for the entire coastline of North Carolina, assuming that barrier island migration will not occur, that nourishment will not occur, and that the baseline erosion rate is accurate. In addition, near-term human modification of beaches (i.e. shoreline hardening and bulkheading) could have a significantly greater effect on sediment supply and erosion dynamics than climate change. However, shoreline hardening is not currently a policy option in North Carolina.

Since our beach width estimates are an average over miles of beach there is potential for measurement error. We assume that the measurement error is not correlated with the true beach width and is not correlated with other variables in the model. Under these conditions any measurement error in beach width will not bias our results. Also, the data limit our ability to consider other geological and behavioral factors. For example, we do not consider the effects of new beach recreation sites created by littoral drift of sand or beach retreat.

Another assumption is the lack of adaptation in terms of beach nourishment. Each of the beaches that we consider is bordered inland by highways and roads. We assume that beach erosion proceeds to the highway or road and, at that point, the sandy beach has vanished. This assumption allows us to estimate the maximum loss of recreation values that might be expected.

Beach characteristic data other than beach width are beach length, the number of parking spaces, the number of public access points and water salinity (Table 2). Average

beach length, beach access points and parking spaces are found using various U.S. Army Corps of Engineers project books. Salinity data was collected from the North Carolina Department of Environment and Natural Resources.

Beach Recreation Data

The target survey population was chosen based on the results of an on-site survey conducted during the summer of 2003 at the study area beaches (Herstine et al. 2005). One finding from the on-site survey is that majority of day users, 73 percent, traveled 120 miles or less to get to the beach. For this study, day users are defined as those who leave their home, enjoy the beach and return home afterwards without spending the night. Overnight users spend at least one night away from home. Locals are those who live within walking or biking distance of the beach.

A telephone survey of beachgoers was administered by the Survey Research Laboratory at the University of North Carolina at Wilmington. Survey Sampling, Inc. provided telephone numbers within the study area. The telephone survey was conducted during May 2004. The telephone survey response rate was 52 percent. Of the telephone survey respondents 1509 stated that they had considered going to an oceanfront beach in North Carolina during 2003. Of this number, 1186 (79 percent) actually took an oceanfront beach trip to the North Carolina coast. Of these, 79 percent took an oceanfront beach trip to the southern North Carolina beaches. Approximately 80 percent of the respondents stated that 2003 was a typical year in terms of their oceanfront beach trips to the southern North Carolina coast. Of those who reported that 2003 was not a typical year, 75 percent would normally have taken more trips. Of all respondents who took at least one trip to the southern North Carolina coast, 96 percent planned to take at least one

oceanfront beach trip to this area in 2004. After deleting cases with missing trip information, missing income, missing distance or distance beyond the study site the remaining sample size is 632.

The telephone survey elicited information on whether respondents took day trips only or a mix of day and overnight trips. Two-hundred twenty eight respondents took only day trips. Four hundred and four respondents took both day and overnight trips. There exists a variety of approaches to overnight trips (Parsons 2003). One concern is that the willingness to pay for the recreation trip or a characteristic of the trip may be biased with multiple purpose trips. The bias may be positive if the beach trip is a minor reason for taking the overnight trip. For example, vacationers may spend more time at an amusement park or shopping than at the beach. Since we are unable to distinguish between day trips and overnight trips for this sub-sample, we estimate separate models for (1) day trippers and (2) day and overnight trippers. In the day and overnight trippers model we assume that beach recreation is the primary purpose of the trip and attribute all of the willingness-to-pay to that purpose; however, estimating separate models for day trippers (only) and day/overnight trippers allows willingness-to-pay to differ across the two types of recreation households.

Beach trip data was elicited by asking respondents who had actually taken oceanfront beach trips to the North Carolina coast in 2003 how many of their oceanfront beach trips were to the southern North Carolina coast from the Beaufort/Morehead City area in Carteret County to the South Carolina border. The most popular beaches for day trippers are Atlantic Beach, North Topsail Beach, Wrightsville Beach and Carolina Beach (Table 3). The most popular beaches for day and overnight trippers are Atlantic Beach,

Emerald Isle, Wrightsville Beach and Carolina Beach.

The average annual number of trips is 22 for day trippers and 11 for day and overnight trippers (Table 4). We did not gather information about the number of days spent at the beach so that we must aggregate over the number of trips and not days. Otherwise, the subsamples are similar. The average number of children is less than one, 68% of the sample is married, 40% is male and 90% is white. The average age is 44 and the average number of years schooling is 13. The average household income is $57 thousand for day trippers and $61 thousand for day and overnight trippers.

Empirical Model

Climate change-induced sea level rise will have negative impacts on beach recreation and beach recreation-dependent communities. Sea level rise exacerbates coastal erosion and can eventually eliminate a recreation site. Estimation of economic benefits (i.e., willingness to pay) from demand curves is relatively straightforward if market data exists. Without market data, a number of methodologies have been developed to estimate willingness-to-pay for environmental non-market goods. The travel cost method is a revealed preference approach that is most often used to estimate the benefits of outdoor recreation. The travel cost method begins with the insight that the major cost of outdoor recreation is the travel and time costs incurred to get to the recreation site. Since individuals reside at varying distances from the recreation site, the variation in distance and the number of trips taken are used to estimate a demand curve for the recreation site. The demand curve is then used to derive the willingness-to-pay associated with using the site. With data on appropriate demand curve shift variables (i.e., independent variables such as beach width), changes in willingness-to-pay associated

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with changes in the shift variables (i.e., changes in beach width) can be derived.

We use the random utility site-selection model version of the travel cost method. In this model, it is assumed that individuals choose recreation sites based on tradeoffs among trip costs and site characteristics (e.g., beach width). Combined with trip frequency models we estimate the potential change in the economic value per beach trip and the potential change in the number of beach trips due to reductions in beach width arising from sea level rise.

Consider an individual who considers a set of j recreation sites. The individual utility from the trip is decreasing in trip cost and increasing in trip quality

(1) $u_i = v_i(y - c_i, q_i) + \varepsilon_i$

where u is the individual utility function, v is the nonstochastic portion of the utility function, y is the per-trip recreation budget, c is the trip cost, q is a vector of site qualities, ε is the error term, and i is a member of s recreation sites, $s = 1, \ldots, i, \ldots J,$ where J is the total number of sites. The random utility model assumes that the individual chooses the site that gives the highest utility

(2) $\pi_i = \Pr(v_i + \varepsilon_i > v_s + \varepsilon_s \ \ \forall \, s \neq i)$

where π_i is the probability that site i is chosen. If the error terms are independent and identically distributed extreme value variates then the conditional logit site selection model results. The conditional logit model restricts the choices according to the assumption of the independence of irrelevant alternatives (IIA). The IIA restriction forces the relative probabilities of any two choices to be independent of other changes in the choice set.

The nested logit model relaxes the IIA assumption. The nested logit site selection

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model assumes that recreation sites in the same nest are better substitutes than recreation sites in other nests. Choice probabilities for recreation sites within the same nest are still governed by the IIA assumption. Consider a two-level nested model. The site choice involves a choice among M groups of sites or nests, $m = 1, \dots, M$. Within each nest is a set of J_m sites, $j = 1, \dots, J_m$. When the nest chosen, n, is an element in M and the site choice, i, is an element in J_n and the error term is distributed as generalized extreme value the site selection probability is:

$$(3) \qquad \pi_{ni} = \frac{e^{v_{ni}/\theta}\left[\sum_{j=1}^{J_n} e^{v_{nj}/\theta}\right]^{\theta-1}}{\sum_{m=1}^{M}\left[\sum_{j=1}^{J_m} e^{v_{mj}/\theta}\right]^{\theta}}$$

where the numerator of the probability is the product of the utility resulting from the choice of nest n and site i and the summation of the utilities over sites within the chosen nest n. The denominator of the probability is the product of the summation over the utilities of all sites within each nest summed over all nests. The dissimilarity parameter, $0 \leq \theta \leq 1$, measures the degree of similarity of the sites within the nest. As the dissimilarity parameter approaches zero the alternatives within each nest become less similar to each other when compared to sites in other nests. If the dissimilarity parameter is equal to one, the nested logit model collapses to the conditional logit model where $M \times J_m = J$.

Welfare analysis is conducted with the site selection model by, first, specifying a functional form for the site utilities. It is typical to specify the utility function as linear

$$(4) \qquad \begin{aligned} v_{ni}(y - c_{ni}, q_{ni}) &= \alpha(y - c_{ni}) + \beta' q_{ni} \\ &= \alpha y - \alpha c_{ni} + \beta' q_{ni} \\ &= -\alpha c_{ni} + \beta' q_{ni} \end{aligned}$$

where α is the marginal utility of income. Since αy is a constant it will not affect the probabilities of site choice and can be dropped from the utility function.

The next step is to recognize that the inclusive value is the expected maximum utility from the cost and quality characteristics of the sites. The inclusive value, IV, is measured as the natural log of the summation of the nest-site choice utilities

$$
\begin{aligned}
IV(c,q;\alpha,\beta) &= \ln\left(\sum_{m=1}^{M}\left[\sum_{j=1}^{J_m} e^{v_{mj}/\theta}\right]^{\theta} \right) \\
&= \ln\left(\sum_{m=1}^{M}\left[\sum_{j=1}^{J_m} e^{(-\alpha c_{mj}+\beta' q_{mj})/\theta}\right]^{\theta} \right)
\end{aligned}
$$

(5)

Haab and McConnell show that the willingness-to-pay, WTP, for a quality change (e.g., changes in beach width) can be measured as

(6) $$ WTP(\Delta q) = \frac{\beta_k \Delta q_{k|ni}}{\alpha} $$

where q_k is one element of the q vector at site i in nest n. Willingness to pay for the elimination of a recreation site from the choice set (e.g., beach erosion that eliminates the sandy beach) is

(7) $$ WTP(j\,|\,m) = \frac{\ln\left[(1-\Pr(j\,|\,m))^{\theta}\Pr(m)+(1-\Pr(m))\right]}{\alpha} $$

where $\Pr(i\,|\,n)$ is the unconditional probability of choosing site i given that nest n is chosen and $\Pr(n)$ is the unconditional probability of choosing nest n. Willingness to pay for elimination of a entire nest is

(8) $$ WTP(m) = \frac{\ln(1-\Pr(m))}{\alpha} $$

since $\Pr(j\,|\,m)=1$ when the entire nest of sites is eliminated. Haab and McConnell show that the value of eliminating the entire nest is greater than the sum of the value of all of the individual sites within the nest. The intuition is that, losing each site within a nest is less valuable because a number of good substitutes remain available within the nest. Therefore, the value of the whole is greater than the sum of its parts.

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These welfare measures apply for each choice occasion, in other words, trips taken by the individuals in the sample. If the number of trips taken is unaffected by the changes in beach width, then the total willingness to pay is equal to the product of the per trip willingness to pay and the average number of recreation trips, $\bar{x}$.

If the number of trips taken is affected by the changes in cost and/or quality then the appropriate measure of aggregate welfare must be adjusted by the change in trips. There are several methods of linking the trip frequency model with the site selection model (Herriges, Kling and Phaneuf, 1999), we choose the original approach that includes the inclusive parameter as a variable in the trip frequency model (Bockstael, Hanemann and Kling, 1987)

(9) $x = x\big[IV(c,q;\alpha,\beta),y,z\big]$

where $x[\cdot]$ is a trip frequency model and z is a vector of individual characteristics that affect trip frequency. These models are typically estimated with count (i.e, integer) data models such as the Poisson or negative binomial models (Haab and McConnell 2002, Parsons 2003). Parsons, Jakus and Tomasi (1999) find that the linked model generates results similar to a repeated choice logit model and, while it is not utility theoretic, it is a useful first-order approximation of demand.

Trips under various welfare scenarios can be simulated by substitution of quality change into the trip frequency model:

(10) $x(\Delta q) = x\big[IV(c,\Delta q;\alpha,\beta),y,z\big]$

Given the willingness-to-pay for quality change and sites and trip changes, the total willingness-to-pay of a quality change is

(11) $TWTP(\Delta q) = \sum_{m=1}^{M} \sum_{j=1}^{J_m} \big(\big[\bar{x}_{mj}(\Delta q)\big] WTP(\Delta q) + \big[\bar{x}_{mj} - \bar{x}_{mj}(\Delta q)\big] WTP(j \mid m) \big)$

The first component of the willingness-to-pay is the product of the average number of trips taken with the quality change and the value of the quality change. The second component of the willingness-to-pay is the product of the difference in trips and the willingness to pay for a trip to a particular site. Total willingness-to-pay is then summed over the number trips.

Empirical Results

The site selection model is specified so that beach goers first choose a distinct subset of beaches, either a barrier island or coastal county, and then choose the particular beach to visit within the county. The beach site selection decision depends on travel costs and the beach site characteristics. Travel distances and time between each survey respondent's home zip code and the zip code of the population center of each beach county are calculated using the ZIPFIP correction for "great circle" distances (Hellerstein et al. 1993). Travel time is calculated by dividing distance by 50 miles per hour. The cost per mile is $0.37, the national average automobile driving cost for 2003 including only variable costs and no fixed costs as reported by the American Automobile Association (AAA Personal communication, 2005). Thirty-three percent of the wage rate is used to value leisure time for each respondent. The round-trip travel cost is

$p = (2 \times c \times d) + (\theta w \times [2 \times d / mph])$ where c is cost per mile, d is one-way distance, θ is the fraction of the wage rate, w, and mph is miles per hour. The average travel cost across all trip choice occasions is $95 ($n = 17$ beaches $\times$ 228 cases = 3876) for day trippers and $138 ($n = 17$ beaches $\times$ 404 cases = 6868) for day/overnight trippers.

The nested logit demand models are estimated with the full information maximum likelihood routine in the NLOGIT econometric software (Greene 2002). The results

indicate that beach goers behave as expected with respect to trip costs and beach width (Table 5). Both day trippers and day/overnight trippers choose beaches that have lower travel costs (i.e., are closer to home) and have wider beaches. Other results are that beach goers are less likely to choose beaches that have greater water salinity and state parks. Beach goers are more likely to choose sites with ample parking. Since the number of parking spaces is positively correlated with the number of access points and beach length, it is not too surprising that the coefficients on these two variables are negative and statistically significant. The coefficient on the inclusive value is statistically different from zero and one in both models which indicates the county-site choice is an appropriate nesting structure.

The trip frequency models include socioeconomic variables along with the inclusive value from the nested random utility model as independent variables (Table 6). The dependent variable is the number of beach trips summed across the 17 beaches. The number of beach trips increases with the inclusive value for nonlocal trips in the day trippers sample and for all trips in the day/overnight trippers sample. In other words, since beach site quality variables do not vary across respondents, those with lower travel costs take more trips. For day trippers, white beach goers with more children and higher incomes take more trips. For day/overnight trippers, those with higher incomes take more trips.

Household Willingness-to-pay

We use the nested logit and trip frequency models to simulate the effects of changes in beach. We consider 2030 and 2080 scenarios for day trips and day/overnight trips. Considering equation (12) we estimate two components of household willingness-

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to-pay. The first is the willingness-to-pay to avoid the change in beach width as the difference in trips and the willingness-to-pay to avoid the decrease in beach width per trip. The second component is the willingness-to-pay to avoid beach site loss due to elimination of the beach.

Since we assume that beach width changes uniformly along the coast, the proportion of trips to each of the beaches does not change from baseline conditions for day trippers in 2030 (Table 7). The baseline trips fall, but only slightly, with a 50 foot reduction in beach width. Willingness-to-pay to avoid a 50 foot decrease in beach width is almost $2 per trip. Multiplying the willingness to pay by the predicted number of trips at each site and summing gives an estimate of the willingness-to-pay to avoid a decrease in beach width of $43 for each beachgoer. The reduction in beach trips is also a component of the cost of sea level rise. Summing the product of the willingness-to-pay for each beach recreation site and the reduction in the number of trips to that site across sites gives an estimate of the willingness-to-pay to avoid reduced beach trips. In 2030, the willingness-to-pay is only $0.27 for each day tripper.

In 2080 sea level rise is predicted to eliminate 14 of the 17 beach recreation sites, therefore the proportion of trips to each of the beaches changes from baseline conditions. Wrightsville Beach trips rise from 20 percent to 66 percent, Carolina Beach trips rise from 6 percent to 23 percent and Fort Fisher trips rise from 3 percent to 11 percent. Note that the predicted beach width at Wrightsville Beach is only 3 feet in 2080. It may seem unrealistic for 66 percent of all beach trips to be congregated on a beach only one yard wide. Another concern is the impact of congestion on beach trips. Since Wrightsville Beach is a popular beach, the model allocates a large number of trips to a narrow strip of

sand (20 percent to 66 percent), which would drastically increase congestion and reduce the value of each beach trip. Finally, at the erosion rates used to estimate reductions in beach widths, Wrightsville Beach will be eliminated from the choice set in less than 2 years beyond 2080.

Since the basic nested random utility model can not readily accommodate these details, we pursue the analysis with the assumption that Wrightsville Beach is no longer part of the recreation choice set in 2080 (i.e., it is completely eroded). We assume that in 2080 sea level rise eliminates 15 of the 17 beach recreation sites and the simulated proportion of trips to each of the beaches changes based on these conditions. Wrightsville Beach trips fall to 0 percent, Carolina Beach trips rise from 6 percent to 68 percent and Fort Fisher trips rise from 3 percent to 32 percent.

Without Wrightsville Beach in the choice set the number of beach trips falls by more than 5 trips for each day tripper. Willingness-to-pay to avoid the decrease in beach width is between $5/trip and $6/trip for the two remaining beaches. Multiplying the willingness to pay per trip by the predicted number of trips at each site and summing gives an estimate of the willingness-to-pay to avoid a decrease in beach width of $102 for each beach goer. Summing the product of the willingness-to-pay for each beach recreation site, calculated at the county level, and the reduction in the number of trips to that site across sites gives the willingness-to-pay to avoid reduced beach trips due to loss of site access. In 2080 the willingness-to-pay to avoid a decrease in beach width is $63 for each beach goer.

The baseline number of trips falls by more than 10 percent with sea level rise in 2030 for day/overnight trippers. Willingness-to-pay to avoid a 50 foot decrease in beach

width is $11 per trip. Aggregated over all trips with the decrease in beach width at each site, the willingness-to-pay to avoid a decrease in beach width is $102 for each day/overnight tripper. In 2030, the willingness-to-pay to avoid the slight reduction in beach trips due to reduced width is only $0.85 for each day/overnight tripper.

In 2080 for day/overnight trippers Carolina Beach trips rise from 8 percent to 76 percent and Fort Fisher trips rise from 3 percent to 24 percent assuming that Wrightsville Beach is no longer a viable recreation site. The number of beach trips fall by over 4 trips for each day/overnight tripper. Willingness-to-pay to avoid the decrease in beach width is between $32/trip and $34/trip for the two remaining beaches. Multiplying the willingness-to-pay per trip by the predicted number of trips at each site and summing gives an estimate of the willingness to pay to avoid a decrease in beach width of $195 for each beachgoer. In 2080, the willingness to pay to avoid the reduction in beach trips is $34 for each beachgoer.

Aggregate Willingness-to-pay

Aggregation of trips and willingness-to-pay across the population in 2030 and 2080 is conducted assuming (1) no change in population and income (Table 8) and (2) increases in population and income (Table 9). Smith (2006) estimates that the North Carolina population will increase by 50 percent from 2000 to 2030 and increase by 100 percent from 2000 to 2080. Increases in population increase the size of the recreation market. Smith (2006) also estimates that North Carolina per capita personal income will increase by 52 percent from 2004 to 2030 and increase by 217 percent from 2004 to 2080. Income increases may increase the number of recreation trips taken and the percentage of the population that engages in beach recreation (see Appendix).

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Considering that 64 percent of the general population contacted in the telephone survey participated in some form of beach trip, we estimate that 23 percent of the general population are day trippers and 41 percent are day/overnight trippers. With increases in population and income we forecast beach recreation participation at 37 percent and 55 percent for day and day/overnight trippers in 2030 and 54 percent and 70 percent in 2080.

The 2000 population of the study region is 1.58 million households. Applying the percentage of recreation participants to the population gives an estimate of the number of beach going households in the study region. In 2003 there are about 365 thousand day trippers and 646 thousand day/overnight trippers. Since the southern North Carolina beaches might reach capacity with increases in recreation demand and decreases in supply, especially in 2080, we estimate the economic effects of sea level rise with and without changes in recreation participation. We estimate the number of day trippers increases to 875 thousand in 2030 and 1.7 million in 2080 as both population and participation rates increase. The number of day/overnight trippers increases to 1.3 million in 2030 and 2.2 million in 2080 with increases in population and participation.

The product of the beach trip households and annual trips is an estimate of the total number of beach trips. We assume that annual trips remains constant at 9 million and 7 million for day and day/overnight trippers. With increased population and income the number of day trips increases to 21 million in 2030 and 40 million in 2080. The number of day/overnight trips increases to 14 million in 2030 and 23 million in 2080 with increased population and income. Considering the large number of trips and the limited space on the beach, congestion would be a significant problem.

The household willingness-to-pay for a beach trip is approximated by assuming

that all of the beach sites represent 99% of the beach recreation opportunities for each household. This assumption likely overstates the aggregate baseline value of beach recreation but understates the estimate of the percentage change in beach recreation value due to sea level rise. Since our aim is to estimate the change in beach recreation value we proceed with the conservative assumption.

Taking the product of aggregate beach trips and household willingness-to-pay for a beach trip, the annual value of southern North Carolina beaches is $477 million for day trippers and $445 million for day/overnight trippers in 2003. With an increase in the total number of trips due to population and income aggregate willingness-to-pay rises to $1 billion in 2030 and $2 billion in 2080 for day trippers. For day/overnight trippers, aggregate willingness-to-pay for beach trips rises to $905 million in 2030 and $1.5 billion in 2080.

Aggregating the household willingness-to-pay values gives an estimate of the aggregate welfare cost of a decrease in beach width of $16 million and $66 million for day and day/overnight trippers in 2030. In 2080 the welfare cost is $37 million and $125 million for day and day/overnight trippers in 2030. Taking into account potential increases in population and income, the estimated aggregate welfare costs of a decrease in beach width are larger. The aggregate welfare cost of a decrease in beach width is $38 million and $135 million for day and day/overnight trippers in 2030. In 2080 the welfare cost is $172 and $430 million.

Another component of the aggregate welfare cost of sea level rise is the value of beach trips not taken due to a lower quality beach. Taking the product of the difference in beach trips and the value of beach trips provides this estimate. Assuming no change in

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population or income, aggregate willingness-to-pay to avoid the decrease in beach trips is $5 million and $6 million for day and day/overnight trippers in 2030 and $15 million and $25 million for day and day/overnight trippers in 2080. With increasing population and income, aggregate willingness-to-pay to avoid the decrease in beach trips is $12 million and $13 million for day and day/overnight trippers in 2030 and $70 million and $85 million for day and day/overnight trippers in 2080.

The total willingness-to-pay to avoid the decrease in beach width is the sum of the value of the reduction in trip quality and the value of the trips not taken. Assuming no changes in population or income, the total willingness-to-pay to avoid the decrease in beach width is $21 million and $73 million for day and day/overnight trippers in 2030 and $52 million and $151 million for day and day/overnight trippers in 2080. The total welfare cost for all beach goers is $93 million in 2030 and $203 million in 2080. With increasing population and income, the total willingness-to-pay to avoid the decrease in beach width is $49 million and $148 million for day and day/overnight trippers in 2030 and $242 million and $515 million for day and day/overnight trippers in 2080. The total welfare cost for all beach goers is $197 million in 2030 and $757 million in 2080.

Taking the quotient of the total willingness-to-pay to avoid the decrease in beach width and the baseline annual value of beach trips provides an estimate of the percentage change in beach recreation value due to sea level rise. For day trippers, four percent of recreation value is lost in 2030 and 11 percent is lost in 2080. For day and overnight trippers, 16 percent and 34 percent of recreation value is lost in 2030 and 2080, respectively. These percentages hold with increases in population and income since the baseline value and the WTP to avoid the decrease in beach width grow at the same rate.

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The estimates above are annual welfare costs (i.e., annual aggregate willingness-to-pay to avoid the decrease in beach width). The present value of the welfare costs are estimated by assuming the impacts are equal to zero in 2004 and increase linearly to 2080. Using a 0 percent discount rate, the present value of the welfare costs of sea level rise from 2005 to 2080 assuming no increase in population or income is $9 billion. Assuming increases in population and income leads to a present value of the welfare costs of $27 billion. Using a 2 percent discount rate, the present value of the welfare costs assuming no increase in population or income is $3.5 billion. Assuming increases in population and income leads to a present value of the welfare costs of $10 billion. Using a 7 percent discount rate, the present value of the welfare costs assuming no increase in population or income is $711 million. Assuming increases in population and income leads to a present value of the welfare costs of $2 billion.

Conclusions

Current scientific research shows that global sea level is expected to continue to rise significantly over the next century (Rahmstorf 2007, IPCC 2007). The relatively dense development and abundant economic activity along the North Carolina coastline is vulnerable to risk of coastal flooding, shoreline erosion and storm damages. In this paper we estimate the relationship between sea level rise, outdoor recreation and economic costs of the business as usual climate change policy option. We find that narrowing of beaches due to sea level rise negatively affects the number of beach trips and the value of beach trips. For beach goers who only take day trips, we estimate that the annual lost recreation value is between four percent and 16 percent in 2030 and between 11 percent and 34 percent in 2080. The present value of the lost recreation value through 2080

ranges from $9 billion to $722 million as the discount rate ranges from 0 percent to 7 percent. With expected increases in population and income the present value of the lost recreation value is significantly higher. Increased congestion at eroding beaches, especially in 2080, will lead to lower quality and therefore lower values of ongoing beach trips. This factor causes the recreation costs of sea level rise to be underestimated in this study.

Several caveats are in order. First, a potential impact of sea-level rise is its negative effect on participation. Beachgoers may choose another recreation activity as congestion increases (e.g., in 2030) and as beach capacity constraints are reached (e.g., in 2080). Second, due to data limitations we do not consider the direct effects of climate change, such as temperature, precipitation and climate variability, or other indirect effects of climate change, such as changes in fish species and stocks, on beach recreation. Third, analysis of events in the far distant future is subject to much uncertainty. Our uncertainty arises in the rudimentary participation modeling. We make forecasts of future beach trips based on increases in population and income but ignore demographic change. For example, recreation participation is typically higher for those between 25 and 64 years of age. If the population ages during the next 25 and 75 years, recreation participation rates will fall. Future research could consider the sensitivity of our results to these issues. Also, further application of recreation demand models to beach recreation in other regions would illuminate some additional costs of climate change induced sea level rise.

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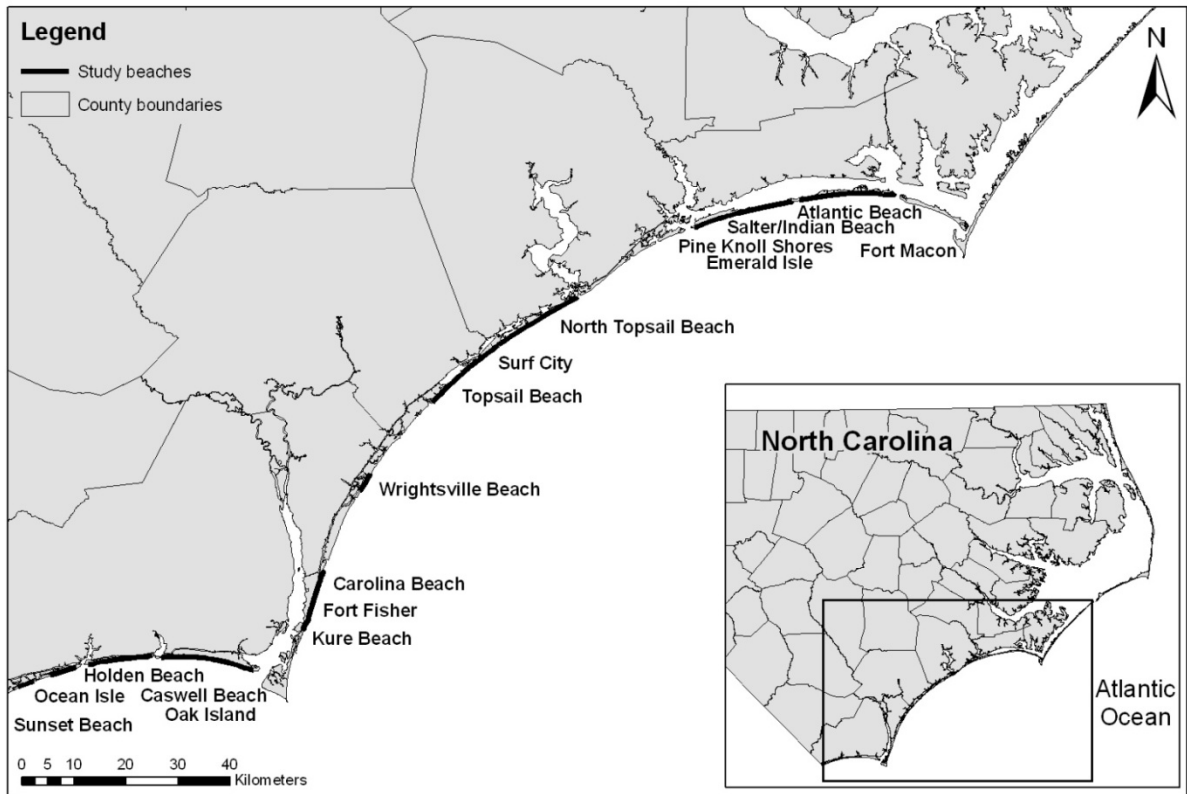
Figure 1. Southern North Carolina Beaches

Table 1. Average and Projected Beach Widths

County	Beach	2003	2030	2080
Carteret	Fort Macon	90	40	0
Carteret	Atlantic Beach	135	85	0
Carteret	Pine Knoll Shores	110	60	0
Carteret	Indian Beach / Salter Path	90	40	0
Carteret	Emerald Isle	130	80	0
Onslow-Pender	North Topsail Beach	82	32	0
Onslow-Pender	Surf City	90	40	0
Onslow-Pender	Topsail Beach	110	60	0
New Hanover	Wrightsville Beach	160	110	3
New Hanover	Carolina Beach	185	135	28
New Hanover	Kure Beach	130	80	0
New Hanover	Fort Fisher	400	350	243
Brunswick	Caswell Beach	80	30	0
Brunswick	Oak Island	120	70	0
Brunswick	Holden Beach	90	40	0
Brunswick	Ocean Isle Beach	85	35	0
Brunswick	Sunset Beach	115	65	0

Table 2. Beach Characteristics

County	Beach	Salinity	Public Access	Parking Spaces	State Park
Carteret	Fort Macon	31.87	2	602	1
Carteret	Atlantic Beach	32.17	19	662	0
Carteret	Pine Knoll Shores	32.61	6	195	0
Carteret	Indian Beach/Salter Path	31.92	2	131	0
Carteret	Emerald Isle	32.74	69	550	0
Onslow-Pender	North Topsail Beach	35.89	42	929	0
Onslow-Pender	Surf City	36.02	36	272	0
Onslow-Pender	Topsail Beach	36.13	37	234	0
New Hanover	Wrightsville Beach	36.19	45	1479	0
New Hanover	Carolina Beach	35.16	26	452	0
New Hanover	Kure Beach	34.83	20	223	0
New Hanover	Fort Fisher	35.08	2	240	1
Brunswick	Caswell Beach	31.05	12	103	0
Brunswick	Oak Island	33.31	66	821	0
Brunswick	Holden Beach	34.57	21	200	0
Brunswick	Ocean Isle Beach	35.04	28	341	0
Brunswick	Sunset Beach	34.61	34	260	0

Table 3. Percentage of Trips across Beaches

County	Beach	Day Trippers	Day/Overnight Trippers
Carteret	Fort Macon	4.23	1.19
Carteret	Atlantic Beach	10.30	15.48
Carteret	Pine Knoll Shores	3.87	2.08
Carteret	Indian Beach / Salter Path	1.76	1.45
Carteret	Emerald Isle	9.56	14.24
Onslow-Pender	North Topsail Beach	11.48	4.81
Onslow-Pender	Surf City	3.17	5.00
Onslow-Pender	Topsail Beach	3.55	7.87
New Hanover	Wrightsville Beach	15.29	23.13
New Hanover	Carolina Beach	15.51	11.88
New Hanover	Kure Beach	2.27	1.56
New Hanover	Fort Fisher	1.92	1.87
Brunswick	Caswell Beach	2.79	0.37
Brunswick	Oak Island	1.78	1.98
Brunswick	Holden Beach	1.90	3.39
Brunswick	Ocean Isle Beach	8.10	3.04
Brunswick	Sunset Beach	2.53	0.68

Table 4. Socioeconomic Variables

	Day Trippers		Day/Overnight Trippers	
	Mean	Std.Dev.	Mean	Std.Dev.
Trips	21.89	47.11	10.60	21.55
Children	0.72	1.02	0.77	1.06
Married	0.68	0.47	0.68	0.47
Male	0.40	0.49	0.40	0.49
White	0.89	0.32	0.90	0.30
Age	44.42	15.49	43.22	15.11
Education	12.99	1.97	13.19	2.03
Income	57.41	26.13	60.69	27.81
Cases	228		404	

Table 5. Nested Random Utility Site Selection Models

	Day Trippers		Day/Overnight Trippers	
	Coeff.	t-ratio	Coeff.	t-ratio
Travel Cost	-0.083	-28.14	-0.071	-23.50
Beach Width	0.003	8.59	0.015	17.55
Salinity	-0.126	-9.44	-0.137	-8.50
Beach Access	-0.007	-5.06	-0.003	-1.72
State Park	-0.818	-9.55	-3.906	-16.34
Parking Spaces	0.001	23.49	0.001	17.71
Beach Length	-0.026	-2.91	0.010	0.80
IV	0.883	24.17	0.842	21.24
Log-Likelihood	-9621.44		-8915.49	
R2	0.32		0.26	
Cases	228		404	

Table 6. Negative Binomial Trip Frequency Models

	Day Trippers		Day/Overnight Trippers	
	Coeff.	t-ratio	Coeff.	t-ratio
Constant	2.18	3.21	3.34	6.68
Children	0.37	4.05	0.05	0.83
Married	-0.11	-0.43	-0.21	-1.44
Male	-0.18	-1.02	-0.10	-0.85
White	0.67	2.26	-0.08	-0.42
Age	0.00	0.62	-0.01	-1.33
Education	-0.02	-0.43	-0.02	-0.72
Income	0.01	1.80	0.02	6.48
IV x local	-0.04	-0.84	0.15	8.83
IV x nonlocal	0.09	3.79		
Alpha	1.51	11.79	1.14	14.48
Cases	228		404	

Table 7. Change in Value with Sea Level Rise

Trips	Day Trippers		Day/Overnight Trippers	
	2030	2080	2030	2080
Baseline	23.58	23.58	10.62	10.60
Decrease in Beach Width	23.11	18.31	9.44	6.05
Willingness-to-pay to avoid decrease in width				
Per trip	1.86	0.67	10.77	3.85
Total	42.99	102.49	101.65	194.62
Willingness-to-pay to avoid lost beach trips				
Per Trip	7.83	42.75	8.46	48.00
Total	0.27	63.27	0.85	33.78

Table 8. Impacts of Climate Change Induced Sea Level Rise on Beach Recreation: Current Income and Population (in millions)

	2030		2080	
	Day Trippers	Day/Overnight Trippers	Day Trippers	Day/Overnight Trippers
Beach going households	0.36	0.65	0.36	0.65
Annual trips	8.60	6.88	8.60	6.88
Annual trips with decrease in beach width	7.82	6.10	7.37	4.70
Aggregate Beach Trip Value	$67.35	$58.24	$67.35	$58.24
Aggregate WTP to avoid decrease in beach width per trip	$14.54	$65.66	$41.74	$153.36
Aggregate WTP to avoid decrease in beach trips	$6.14	$6.67	$9.68	$18.48
Aggregate WTP to avoid a decrease in beach width	$20.68	$72.33	$51.42	$171.85

Table 9. Impacts of Climate Change Induced Sea Level Rise on Beach Recreation: Increased Income and Population (in millions)

	2030		2080	
	Day Trippers	Day/Overnight Trippers	Day Trippers	Day/Overnight Trippers
Beach going households	0.88	1.31	1.69	2.21
Annual trips	20.64	14.00	39.90	23.50
Annual trips with decrease in beach width	18.76	12.40	34.16	16.05
Aggregate Beach Trip Value	$161.58	$118.46	$312.40	$198.85
Aggregate WTP to avoid decrease in beach width per trip	$34.88	$133.55	$193.60	$523.64
Aggregate WTP to avoid decrease in beach trips	$14.73	$13.57	$44.91	$63.11
Aggregate WTP to avoid a decrease in beach width	$49.62	$147.12	$238.51	$586.75

Appendix: Effects of Income Change on Beach Recreation Participation and Trips

An estimate of the increase in the percentage of the population that takes beach trips is obtained from analysis of the National Survey on Recreation and the Environment (NSRE) (1999-2001) data. The sample is 1086 North Carolina residents. The dependent variable is whether the respondent took an ocean beach trip. Independent variables are respondent characteristics. A probit model is used to estimate the determinants of beach recreation participation.

Beach recreation participation increases with income and education (Table A-1). Participation decreases with age. Whites are more likely to participate. The marginal effect of the independent variable on the dependent variable is the change in the probability of participation from a one unit change in the independent variable. For each $10,000 increase in income, recreation participation increases by 2 percent. The marginal effect can be used to forecast changes in beach recreation participation with the caveat that the probit model is nonlinear and the marginal effects are most accurate for small changes in the independent variables. Forecasts for nonmarginal changes in independent variables should only be considered first order approximations.

We also use the trip frequency model to predict the number of trips with an increase in sample income and find unrealistically high trip estimates (e.g., we predict that some households go to the beach every day with increased income). Therefore, we assume that the household average number of annual trips is constrained by time and equal to the household average number of annual trips in 2003. This assumption likely causes our welfare cost estimates to be underestimated.

Table A-1. Probit Model of Beach Trip Participation

	Coeff.	t-ratio	Marginal Effect	Means
ONE	-1.287	-4.26		
HHNUM	0.039	0.71	0.015	2.63
OVER16	0.044	0.60	0.017	1.09
UNDER6	0.044	0.50	0.017	0.25
INCOME	0.004	2.61	0.002	33.52
WHITE	0.396	3.82	0.153	0.81
EDUC2	0.073	4.24	0.029	13.38
MALE	-0.021	-0.26	-0.008	0.41
AGE	-0.008	-3.28	-0.003	45.99
MISSINC	-0.049	-0.43	-0.019	0.40
MISSEDUC	0.920	1.77	0.335	0.01
C2	98.98			
Cases	1086			
Percent Beachgoers	0.48			