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The Impact of Climate Change on Marine Recreational Fishing with Implications for the Social Cost of Carbon

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The Impact of Climate Change on Marine Recreational Fishing with Implications for the Social Cost of Carbon

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1. INTRODUCTION

The social cost of carbon (SCC) is an estimate of the economic damages from one metric ton of carbon dioxide emissions. Estimates of SCC for use in U.S. policy-making were developed by an interagency workgroup in 2009-10 (Greenstone, Kopits and Wolverton, 2013). The SCC for 2015 ranges from $12 to $61 depending on the discount rate. SCC was developed using the average of estimates from three integrated assessment models and includes impacts from the agricultural, health, and real estate sectors of the economy. Only one of the three models, the Dynamic Integrated Model for Climate and the Economy (DICE), includes nonmarket impacts. In revising the SCC estimates developed in 2009-10, the U.S. Environmental Protection Agency and U.S. Department of Energy hosted a workshop in 2011 to improve and update the SCC. One conclusion was “that there is very little existing research with which to develop the SCC for marine resources” (ICF International, 2011), including recreation.

Past research on the impact of climate change on outdoor recreational activities is relatively sparse. Early studies found that precipitation and temperature affects beach recreation activities (McConnell, 1977, Silberman and Klock, 1988). Mendelsohn and Markowski (1999) considered the effects of changes in temperature and precipitation on skiing and a wide range of summer outdoor recreational activities using state-level aggregate demand functions. Considering a range of climate scenarios, the authors found that rising temperatures and precipitation increase the aggregate economic value of some activities and decrease the aggregate economic value of others depending on how climate affects season lengths and demand for outdoor recreational activities. Loomis and Crespi (1999) took an approach similar to Mendelsohn and Markowski (1999). They considered the effects of temperature, precipitation, and other climate change impacts (e.g., beach length, wetland acres) on a wide range of outdoor recreational activities. Overall, they found that climate change is likely to have positive impacts on the aggregate economic value of outdoor recreation activities.

Several studies have focused on more narrow regions and outdoor recreational activities. Pendleton and Mendelsohn (1998) related the effects of temperature and precipitation to catch rates for trout and pan fish in the northeastern United States. Climate change is expected to decrease trout catch rates and increase pan fish catch rates. Using microdata, the authors found that fish catch rates influence fishing site location choice. Combining the effects of climate change on catch rates, the authors found that climate change would benefit freshwater fishing in the northeastern United States. Ahn et al. (2000) focused on trout fishing in the Southern Appalachian Mountain region of North Carolina. Using methods similar to Pendleton and Mendelsohn (1998) the authors found contrasting results. Climate change would reduce the economic value of trout fishing in this region. The contrast may be due to a lack of species-substitution possibilities in the model.

Two studies have used the temporal variation in temperature to estimate the effects of climate on recreation. Englin and Moeltner (2004) estimated weekly skiing and snowboarding trip demand models and integrate weekly weather conditions as a factor affecting demand. They find that temperature and precipitation affect the number of skiing and snowboarding days in expected ways. Carter and Letson (2009) use aggregate time series data to consider the effects of climate and effort on the harvest of red snapper.

The aforementioned studies used revealed preference methods. In contrast, Richardson and Loomis (2004) employed a stated preference approach to estimate the impacts of climate change on economic value for recreation at Rocky Mountain National Park. Richardson and Loomis’s hypothetical scenario explicitly considered 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. They found that climate change would have positive impacts on visitation at Rocky Mountain National Park.

These past studies on climate change and outdoor recreation have not included marine recreational fishing. Marine recreational fishing might be affected by air temperature and precipitation on the demand side as fishing seasons lengthen and fishing success increases with overcast days. Water temperature, precipitation, and ocean acidification could affect fish stocks and range on the supply side of the market. In this paper, we estimate a reduced form demand-side model to estimate the effects of temperature and precipitation on marine recreational fishing days. The data are from the National Survey of Wildlife-Associated Outdoor Recreation. We use the 1991, 1996, 2001, 2006 and 2011 survey data in an attempt to find spatial and temporal variation across states. We obtain estimates of the effects of demographic, recreational supply, and climate change variables on marine recreational fishing intensity across the U.S., and use this relationship to forecast changes in behavior with temperature and precipitation changes. To determine changes in economic value we simulate the effects of climate change on the intensity of participation with changes in U.S. average temperature developed from climate models. We use benefit transfer to estimate the welfare impacts of climate change on marine recreational fishing in the U.S. We find that the net effect is positive.

2. DATA

We use data from the National Survey of Fishing, Hunting, and Wildlife Association Recreation (FHWAR). The FHWAR is conducted roughly every five years and covers the entire U.S. population. The fishing participation questions from the screener questionnaire are:

> *Have you/Has name ever done any recreational fishing, including shellfishing?*
>
> *Did you/name do any recreational fishing last year; that is, during (the period January 1 to December 31,) [year]?*
>
> *During [year] how many days did you/name fish?*

Those respondents who participate in fishing are then asked to participate in the "sportspersons" survey. The saltwater fishing participation questions in the "sportspersons" survey are:

> *Did you do any recreational saltwater fishing in (state) from January 1, [year] to December 31, [year]? Saltwater fishing means fishing for finfish or shellfish in oceans, bays, sounds, and tidal waters of rivers and streams.*
>
> *In which state or states did you saltwater fish from January 1, 2006 to December 31, 2006?*
>
> *How many trips lasting a single day or multiple days did you take in or to (state) to go saltwater fishing?*
>
> *On how many days in (state) did you go saltwater fishing?*

Of your saltwater fishing days in (state), how many were for finfishing ONLY?

Variables are described in Table 1 and a data summary is presented, by survey year, in Table 2. The sample includes those who fished, hunted or watched wildlife during the past year. All of the regression analyses use weights provided by the FHWAR so that the sample is representative of the population. We focus our empirical analysis on the number of days fished (including shellfishing) within the state of residence. This represents 83% of all days fished. Participation rates vary from a high of 35% in 1991 to a low of 18% in 1996. This large decrease may be the result of differences in data collection in the 1991 survey (see supplemental Appendix C of the 2011 Report by the U.S. Department of the Interior, 2012). The number of days fished, including nonparticipants, ranges from 2.89 days in 1991 to 2.01 days in 1996.

Table 1. Variable Descriptions

Variable	Label
Participation	1 if respondent did any recreational saltwater fishing in home state during the past year
Days	Number of days saltwater fishing in home state
Personal Income	Personal income in thousands
Household Income	Household income in thousands
Missing Income	1 if respondent did not answer the income question
Age	Respondent age
Education	Number of years schooling
Married	1 if the respondent is married
White	1 if the respondent is white
Male	1 if the respondent is male
Gulf of Mexico	1 if the respondent resides in Texas, Louisiana, Mississippi, Alabama or Florida
South Atlantic	1 if the respondent resides in Florida, Georgia, South Carolina or North Carolina
Pacific Coast	1 if the respondent resides in California, Oregon or Washington
Mid-Atlantic	1 if the respondent resides in Virginia, Maryland, Delaware, New Jersey or New York
Northeast	1 if the respondent residents in Connecticut, Rhode Island, Massachusetts, New Hampshire or Maine
California	1 if the respondent lives in California
Coastline	Miles of coastline in the respondent's home state in hundreds

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The selection of independent variables is informed by recreation participation literature (Deyak and Smith, 1978, Hay and McConnell, 1979, Caswell and McConnell, 1980, Miller and Hay, 1981, Hay and McConnell, 1984, Rockel and Kealy, 1991). The factors that are proposed to affect participation in each of these activities are the standard demographic variables, regional recreation supply variables (e.g., miles of state coastline), average state-level temperature, and state-level precipitation.

Table 2. Data Summary

	1991		1996		2001		2006		2011	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Participation	0.35	0.48	0.18	0.39	0.24	0.43	0.21	0.41	0.22	0.42
Days	2.89	10.19	2.01	10.04	2.4	9.7	2.4	10.7	2.74	12.06
Days (if participation=1)	8.22	15.81	11.42	19.01	10.47	18.28	12.03	19.85	12.67	21.91
Personal Income/a	39.54	20.47	32.85	25.81						
Household Income/a					53.51	30.39	61.55	30.33	58.02	30.97
Missing Income	0.09	0.29	0.17	0.38	0.23	0.43	0.13	0.35	0.23	0.43
Age	38.93	15.05	42.63	16.02	42.56	15.38	43.93	15.64	46.66	16.65
Education	13.06	2.71	13.44	2.83	13.43	2.7	13.46	2.75	13.85	2.7
Married	0.67	0.47	0.64	0.49	0.67	0.47	0.66	0.48	0.62	0.49
White	0.91	0.29	0.86	0.36	0.87	0.33	0.86	0.34	0.84	0.36
Male	0.75	0.44	0.64	0.49	0.68	0.47	0.67	0.48	0.67	0.48
Gulf of Mexico	0.33	0.47	0.34	0.48	0.35	0.48	0.35	0.48	0.34	0.48
South Atlantic	0.22	0.42	0.24	0.44	0.25	0.44	0.27	0.45	0.25	0.44
Mid-Atlantic	0.2	0.41	0.22	0.43	0.21	0.41	0.21	0.41	0.22	0.42
Northeast	0.13	0.34	0.06	0.24	0.06	0.23	0.06	0.24	0.06	0.24
Pacific Coast	0.21	0.41	0.24	0.44	0.24	0.43	0.22	0.42	0.22	0.42
California	0.13	0.34	0.16	0.37	0.15	0.36	0.14	0.34	0.14	0.35
Coastline	3.8	3.99	4.21	4.13	4.18	4.1	4.11	4.1	4.05	4.07
Sample Size	9286		9515		10,894		10,016		5188	

a/ Sample size is for those with non-missing income.

Personal income was collected in the 1991 and 1996 surveys and is coded at the midpoint of income ranges. Average personal income is $40,000 in 1991 and $33,000 in 1996. Household income was collected in 2001, 2006 and 2011 and is coded at the midpoint of income ranges. Average household income is $54,000, $62,000 and $58,000 in 2001, 2006, and 2011. A substantial number of respondents did not report personal or household income. For the data analysis we include a missing income dummy variable for these respondents and set their income equal to zero. This strategy for dealing with item non-response with income leads to similar results when compared to a model that imputes missing income with the mean of the income variables (results available upon request).

Age is the respondent's age in years and education is the number of years schooling. Married, white, and male are equal to one if the respondent is married, white, and male. Average age ranges from 39 in 1991 to 47 in 2011. The number of years schooling is between 13 and 14 in each survey year. The sample ranges from 84% white in 2011 to 91% white in 1991.

About 33% of the sample resides in a Gulf of Mexico state (Texas, Louisiana, Mississippi, Alabama, or Florida) and about 25% resides in a south Atlantic state (Florida, Georgia, South Carolina, or North Carolina). Between 20% and 22% reside in the mid-Atlantic (Virginia, Maryland, Delaware, New Jersey or New York). Six percent reside in the Northeast (Connecticut, Rhode Island, Massachusetts, New Hampshire, or Maine) for years 1996, 2001, 2006 and 2011, and 13% reside in the Northeast in 1991. Between 21% and 24% reside on the Pacific Coast (California, Oregon, or Washington). The only recreation supply variable included is miles of coastline in the respondent's home state (measured in hundreds). The state average is between 380 and 421 miles. State-level temperature and precipitation data are obtained from NOAA (https://www.ncdc.noaa.gov/). State-level average temperature and precipitation data are presented in the supplemental content.

3. MODEL

Since recreation days are integers and there is overdispersion (i.e., the variance is greater than the mean), we analyze the data with the negative binomial count data model (Haab and McConnell, 2002):

$$\Pr(d_i) = \frac{\Gamma\left(d_i + \frac{1}{\alpha}\right)}{\Gamma(d_i + 1)\Gamma\left(\frac{1}{\alpha}\right)} \left(\frac{\frac{1}{\alpha}}{\frac{1}{\alpha} + \lambda_i}\right)^{\frac{1}{\alpha}} \left(\frac{\lambda_i}{\frac{1}{\alpha} + \lambda_i}\right)^{d_i}$$

where d is fishing days, α is the overdispersion parameter and $i = 1, \ldots, n$. The mean number of fishing days is $E(d_i) = \lambda_i = e^{\beta' x_i}$ where β is a parameter vector and x_i is a vector of independent variables. The variance of fishing days is $\sigma^2(d_i) = \lambda_i(1 + \alpha\lambda_i)$. If $\alpha = 0$ then there is no overdispersion and the Poisson count data model is appropriate.

With the negative binomial model, days fished can be interpreted with the semi-log functional form, $\ln(d) = \beta' x$, which is approximately the percentage change in days on the left-hand side of the model. We approximate the relationship between the dependent variable and key independent variables, temperature, and precipitation (z), as $\Delta d/d = \gamma z$. Rearranging allows for a forecast of the change in the number of fishing days temperature and precipitation, as $\Delta d = \gamma \Delta z \times d$.

4. RESULTS

The negative binomial fishing intensity model is presented in Table 3 (next page). The overdispersion parameter is statistically significant, indicating that the negative binomial model is appropriate. Each additional degree F increase in temperature increases the number of fishing days by 6%. Each additional inch of rain increases fishing days by 9%. We include dummy variables for the survey years. Consistent with the univariate data, days fished is lower in each year following 1991. The effect of income on days fished is positive and statistically significant. The coefficient implies an income elasticity of 0.32. We control for personal income relative to household income and find no differences. Those respondents who do not report their income fish 20% more days. Older respondents fish more days with about 5% more days for each decade of age. White respondents fish 19% fewer days and males fish 70% more days. Education and marital status do not effect fishing days.

Table 3. Determinants of Marine Recreational Fishing

	Negative Binomial Participation - Days Fished		
	Coeff.	**S.E.**	**t-stat**
Intercept	-3.562	0.395	-9.03
Temperature	0.057	0.007	8.11
Precipitation	0.087	0.021	4.14
Year96	-0.322	0.053	-6.09
Year01	-0.381	0.07	-5.48
Year10	-0.472	0.074	-6.42
Year11	-0.223	0.087	-2.57
Income	0.008	0.001	9.6
Income x Year91 & Year96	-0.002	0.001	-1.56
Missing Income	0.199	0.059	3.39
Age	0.005	0.001	4.33
Education	-0.006	0.007	-0.77
Married	-0.015	0.038	-0.39
White	-0.188	0.051	-3.7
Male	0.702	0.036	19.29
Coastline	0.176	0.01	18.37
BP oil spill	-0.181	0.11	-1.65
Gulf of Mexico	-0.865	0.142	-6.1
South Atlantic	-0.941	0.12	-7.88
Mid-Atlantic	0.407	0.072	5.67
Northeast	0.405	0.088	4.63
California	-1.732	0.153	-11.29
α	11.707	0.14	83.61
Sample Size	44,899		
Log likelihood	-56,405		

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The coefficient on miles of coastline, a measure of recreation supply, is positive and statistically significant and indicates that each 100 miles of coast within the state increases fishing days by 18%. Respondents in the Gulf of Mexico region, the South Atlantic, and California fish fewer in-state days than those in the Northwest Pacific region (Oregon and Washington). Respondents in the Mid-Atlantic and Northeast fish more in-state days than those in the Northwest Pacific region. A variable measuring the effects of the BP oil spill (Gulf of Mexico x Year11) is not statistically different from zero.

We pursue an approach for climate forecasts similar to Mendelsohn and Markowksi (1999) and Loomis and Crespi (1999), who simulate the effects of a 2.5C increase in temperature and a 7% increase in precipitation based on Intergovernmental Panel on Climate Change (IPCC) central estimates for the year 2060. We consider a range of temperature (4ºF to 11ºF) based on a range of climate models and carbon dioxide emission scenarios projected through the year 2100 (Karl et al., 2009). Karl et al. (2009) project that the Northeast and Pacific Northwest regions will become wetter in the winter and spring and California, Gulf of Mexico and the South Atlantic will be drier. In order to compare our results with previous research, we consider the 7% precipitation increase used by Mendelsohn and Markowksi (1999) and Loomis and Crespi (1999). The average monthly precipitation across the five years of survey data is 3.63 inches.

We use the standard errors on the negative binomial temperature coefficient to produce a 95% confidence interval for the change in days. We use a use value per person per day estimate to estimate the welfare change of temperature increases. Rosenberger (2014) reports the simple mean use value (consumer surplus) per day across 139 saltwater fishing studies as $109 (2010 dollars). In Table 4 (next page) we report this simulation. As the temperature change rises from 4ºF to 11ºF the change in the number of saltwater fishing days rises from 19 million to 52 million (from a baseline of 82 million, see Table 4). The annual welfare change rises from $2.1 billion to $5.7 billion as the temperature change rises from 4ºF to 11ºF. The effect of a 7% increase in precipitation is smaller, increasing marine recreational fishing by 1.8 million days and annual welfare by $198 million.

Table 4. Impacts of Temperature Change (in millions of dollars)

		95% confidence interval			95% confidence interval	
Temp increase	**Days**	**Low**	**High**	**Welfare change**	**Low**	**High**
4º	19	14	23	2,067	1,567	2,567
5º	24	18	29	2,584	1,959	3,208
6º	28	21	35	3,100	2,351	3,850
7º	33	25	41	3,617	2,743	4,492
8º	38	29	47	4,134	3,135	5,133
9º	43	32	53	4,651	3,526	5,775
10º	47	36	59	5,167	3,918	6,417
11º	52	39	65	5,684	4,310	7,058

Note: Consumer surplus is $109.39 (Rosenberger, 2014).

CONCLUSIONS

In this paper we have estimated climate change effects on marine recreational fishing in the United States. Considering a 4.5ºF temperature change and a 7% precipitation change, we estimate that saltwater fishing days will increase by 27% with an annual welfare change of $2.5 billion. In comparison, Loomis and Crespi (1999), who do not include marine recreational fishing, estimated that a 2.5ºC (4.5ºF) temperature change and a 7% precipitation change would lead to a $3.9 billion welfare change for a large number of outdoor recreation activities. If these estimates are additive and inclusive, marine recreational fishing accounts for about 39% of the positive impacts of outdoor recreation from climate change. This suggests that excluding saltwater fishing from SCC estimates is economically significant and could have implications for the accurate estimation of the social cost of carbon. While these estimates are suggestive they are only preliminary. Our simple model does not account for other (potentially mitigating) factors such as the availability of fishery resources due to changes in fisheries ecology (e.g., salinity), recreational fishing effort, changes in coastline due to sea level rise, and socioeconomic factors. Further research is needed to account for these effects.

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