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*Research Article*

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# Assessing Climate Change Threats to the Marine Environment: An Application of the Ordered Logit Model

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**ABSTRACT**

This study explores saltwater anglers' perceptions of climate change threats to the marine environment, drawing on data from the 2013 National Saltwater Angler Survey. A multi-attribute framework is employed, and an ordered logit model is used to analyze responses captured on a Likert-type scale, which measures the perceived threat on a continuum from low to high. The empirical findings indicate that demographic factors, such as age, gender, income, education level, and geographic region, significantly shape anglers' concerns regarding climate change impacts on marine ecosystems. Older anglers, for example, may perceive the threat differently compared to younger ones, while regional variations highlight diverse environmental awareness across the country. These results offer valuable insights into how saltwater anglers view marine environmental risks linked to climate change. The findings provide a foundation for designing more targeted marine fisheries management and communication campaigns that address specific demographic groups' concerns about climate-driven environmental changes.

**Keywords:** Climate Change Threats, Marine Environment, Saltwater Angler, Ordered Logit Model

## Introduction

Marine ecosystems provide an array of vital ecological goods and services, from supporting fisheries to maintaining biodiversity and regulating the climate. Their sustainability is crucial for the well-being of human societies. Recognizing this importance, the U.S. National Ocean Policy marks a pivotal step toward better stewardship of ocean and coastal areas. In line with these efforts, the National Oceanic and Atmospheric Administration (NOAA) Fisheries introduced the National Saltwater Recreational Fisheries Policy in 2015, which offers guidance to ensure the sustainability and longevity of recreational saltwater fisheries.

A 2013 report by NOAA Fisheries highlights the diverse threats perceived by saltwater anglers. Notably, 88% identified overfishing in commercial fisheries as a severe or moderate threat, 86% pointed to industrial pollution, and 79% expressed concern over habitat degradation. In contrast, fewer anglers viewed alternative energy development (67%) and shipping activities (51%) as significant threats [1].

As the global population grows and environmental conditions worsen, exacerbated by climate change, understanding the complex interplay between human actions and marine ecosystems becomes imperative. Marine ecosystems face a wide range of threats, from the loss of biodiversity and habitats to overfishing, pollution, offshore wind development, invasive species, and the far-reaching impacts of climate change [2-7].

Climate change driven by anthropogenic activities such as fossil fuel combustion and deforestation, alongside natural phenomena like volcanic eruptions has been extensively studied for its atmospheric effects. However, its impact on marine ecosystems has garnered less attention. As marine environments become increasingly vulnerable, understanding how stakeholders, particularly saltwater anglers, perceive these threats is critical.

Lotze et al. offer valuable insights into public perceptions of marine threats, attitudes toward mitigation, and behavioral responses [8]. Public surveys have consistently shown that climate change is widely viewed as a pressing issue [9-18]. Despite this growing concern, there is a lack of focused research on how saltwater anglers perceive the specific impacts of climate change on marine environments.

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This study aims to fill that gap by exploring saltwater anglers' perceptions of climate change as a threat to marine ecosystems using a multi-attribute framework. By analyzing the factors that shape their views, including age, income, education, and region, this study provides baseline data that will help marine fisheries managers tailor more effective strategies. Understanding these perceptions can inform future policies, foster public support, and better equip stakeholders to mitigate the impacts of climate change on marine environments.

## Materials and Methods

### Data

The data used in this study was derived from the 2013 National Saltwater Angler Survey, a comprehensive dataset developed by NOAA Fisheries and conducted by CIC Research [1]. The survey specifically targeted saltwater anglers aged 16 and older, who had participated in saltwater fishing at least once in their lifetime, with the goal of capturing insights into their fishing participation, preferences, and environmental attitudes. Conducted across six key U.S. regions the North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, West Coast, and Alaska the survey aimed to reflect the diverse perspectives of saltwater anglers on a range of marine issues.

Respondents were asked to evaluate various potential threats to the marine environment, including climate change (CLIMATE), using a Likert-type scale. The scale ranged from 0, signifying 'not a threat at all,' to 3, representing a 'severe threat.' This study specifically focuses on analyzing the qualitative choice properties of climate change as a perceived threat to the marine environment, based on data from 7,303 saltwater anglers who provided complete information on their climate change perceptions. By focusing on this substantial sample, the study aims to shed light on the underlying demographic and regional factors that may shape saltwater anglers' views on the impact of climate change on marine ecosystems.

### Ordered Logit Model

When the dependent variable has more than two categories with a meaningful, ordered progression where each category represents a level of intensity or importance higher than the previous one the appropriate econometric technique to employ is the ordered logit model [19]. This model is grounded in the principles of random utility maximization, a robust theoretical framework for decision-making analysis developed by McFadden [20]. The ordered logit model is particularly useful when analyzing ordinal data, such as responses on a Likert-type scale.

In neoclassical economics, utility represents the satisfaction or benefit an individual derives from a combination of goods and services. Utility is maximized subject to constraints like income and prices, and it is influenced by both personal characteristics and environmental conditions. This relationship can be represented mathematically as:

$$U = x'\beta + \varepsilon \quad (1)$$

where U denotes utility, x is a vector of explanatory variables, β is a vector of coefficients, and ε is the error term. Utility is composed of both deterministic components, represented by x'β, and a stochastic error term ε [20].

Given the ordinal nature of Likert-type data, the ordered logit model is the appropriate choice for analyzing the relationship between explanatory variables and ordered outcomes. The ordered logit model is a latent variable model that describes the data-generating process for a dependent variable measured on a Likert-type scale. Let yi* represent the latent variable for individual i, where i = 1, …, n:

$$yi^* = xi'\beta + \varepsilon i \quad \text{with } \varepsilon i \sim N(0, \sigma^2) \quad (2)$$

Here, εi is normally distributed with a mean of 0 and variance $\sigma^2$. The latent variable yi* given the vector xi, also follow a normal distribution: $yi^*|xi \sim N(xi'\beta, \sigma^2)$, where the expected value of yi* is $E[yi^*] = xi'\beta$.

However, what is observed is not the latent variable yi* itself, but rather the category yi that individual i falls into. These categories are defined by threshold values (or cut points) μj, where j = 1, 2, …, J. The observed choice yi is:

$$y_i = \begin{cases} 1 & \text{if} \quad y_i^* \le \mu_1 \\ 2 & \text{if} \quad \mu_1 < y_i^* \le \mu_2 \\ 3 & \text{if} \quad \mu_2 < y_i^* \le \mu_3 \\ \vdots & \vdots \\ J & \text{if} \quad \mu_{J-1} < y_i^* \end{cases} \quad (3)$$

The probability that individual *i* chooses alternative *j* is given by

$$P_{ij} = P(y_i = j|x_i) = \begin{cases} F\left(\frac{\mu_1 - x_i\beta}{\sigma}\right) & \text{for} \quad j = 1 \\ F\left(\frac{\mu_2 - x_i\beta}{\sigma}\right) - F\left(\frac{\mu_1 - x_i\beta}{\sigma}\right) & \text{for} \quad j = 2 \\ F\left(\frac{\mu_3 - x_i\beta}{\sigma}\right) - F\left(\frac{\mu_2 - x_i\beta}{\sigma}\right) & \text{for} \quad j = 3 \\ \vdots & \vdots \\ 1 - F\left(\frac{\mu_{J-1} - x_i\beta}{\sigma}\right) & \text{for} \quad j = J \end{cases} \quad (4)$$

where F(.) represents the cumulative standard logistic distribution function. A key aspect of the ordered logit model is predicting choice probabilities P(y = j | x) for specific values of x, as well as analyzing the marginal effects of an independent variable xk on the choice probabilities. Assuming μ1 = 0 and σ = 1, the marginal effects can be expressed as:

$$\frac{\partial P(y=1|x)}{\partial x_k} = -f(x\beta)\beta_k$$

$$\frac{\partial P(y=2|x)}{\partial x_k} = [f(x\beta) - f(\mu_2 - x\beta)]\beta_k$$

$$\frac{\partial P(y=3|x)}{\partial x_k} = [f(\mu_2 - x\beta) - f(\mu_3 - x\beta)]\beta_k$$

$$\vdots$$

$$\frac{\partial P(y=J|x)}{\partial x_k} = f(\mu_{J-1} - x\beta)\beta_k \quad (5)$$

where f(.) is the standard logistic density function. Estimation of the ordered logit model is carried out using maximum likelihood (ML) methods. The log likelihood function is given by:

$$\log L = \sum_{i=1}^{n}\sum_{j=1}^{J} d_{ij} \log(P_{ij}) \quad (6)$$

where $d_{ij} = 1$ if individual i chooses alternative j, and $d_{ij} = 0$ otherwise. The parameters β and μ are estimated by maximizing the log likelihood function, subject to the constraints $\mu_1 < u_2 < \ldots < \mu_{J-1}$. The maximum likelihood estimators β^ and μ^ are consistent, asymptotically efficient, and normally distributed [21,22].

## Results

### Profile Analysis

The Chi-square test revealed statistically significant differences in the gender composition of respondents regarding their perceptions of climate change as a threat to the marine environment ($\chi^2 = 27.449$, df = 3, $p < 0.001$). This result suggested that men and women differed notably in how they assessed the severity of climate change's impact on marine ecosystems. Specifically, the analysis showed that female respondents were more likely to categorize climate change as a 'moderate threat' or 'severe threat,' reflecting greater concern for its environmental implications. In contrast, male respondents were more inclined to downplay its severity, with a higher tendency to classify climate change as 'not a threat at all' or 'not a very severe threat' (see Table 1). These gender-based differences in risk perception may point to broader social, cultural, or experiential factors influencing how individuals assess environmental threats.

**Table 1: Gender Composition of Saltwater Anglers Responding Climate Change Threats to Marine Environment**

| Gender | Not a threat at all | Not a very severe threat | Moderate threat | Severe threat | Total |
|---|---|---|---|---|---|
| Male | 1025 (87.7%) | 1842 (84.9%) | 2081 (81.8%) | 1157 (81.5%) | 6105 (83.6%) |
| Female | 144 (12.3%) | 328 (15.1%) | 464 (18.2%) | 262 (18.5%) | 1198 (16.4%) |
| Total | 1169 | 2170 | 2545 | 1419 | 7303 |

% within CLIMATE in parentheses

The analysis revealed statistically significant differences in the educational levels of saltwater anglers concerning their perceptions of climate change as a threat to the marine environment ($\chi^2 = 49.4041$, df = 12, $p < 0.001$). The results indicated that respondents with higher and more advanced educational attainment were more likely to view climate change as a 'severe threat' to marine ecosystems. Those holding college degrees or higher tended to express greater concern about the potential impact of climate change, in contrast to respondents with lower levels of education, who were less likely to categorize it as a severe environmental threat. This suggested that education plays a key role in shaping individuals' environmental awareness and understanding of climate change risks (refer to Table 2). These findings underscored the importance of educational outreach and public awareness initiatives in promoting informed attitudes toward marine environmental issues.

**Table 2: Education Composition of Saltwater Anglers Responding Climate Change Threats to Marine Environment**

| Educational Level | Not a threat at all | Not a very severe threat | Moderate threat | Severe threat | Total |
|---|---|---|---|---|---|
| 12th Grade or less | 66 (5.6%) | 148 (6.8%) | 217 (8.5%) | 119 (8.4%) | 550 (7.5%) |
| High school graduate or GED | 256 (21.9%) | 516 (23.8%) | 613 (24.1%) | 312 (22.0%) | 1697 (23.2%) |
| Associate or technical school degree or college coursework | 328 (28.1%) | 709 (32.7%) | 751 (29.5%) | 396 (27.9%) | 2184 (29.9%) |
| Bachelor's degree | 321 (27.5%) | 487 (22.4%) | 571 (22.4%) | 317 (22.3%) | 1696 (23.2%) |
| Advanced, professional, or doctoral degree or coursework | 198 (16.9%) | 310 (14.3%) | 393 (15.4%) | 275 (19.4%) | 1176 (16.1%) |
| Total | 1169 | 2170 | 2545 | 1419 | 7303 |

% within CLIMATE in parentheses

The analysis also revealed statistically significant differences in perceptions of climate change among saltwater anglers based on household total annual income ($\chi^2 = 79.256$, df = 21, $p < 0.001$). Specifically, respondents with lower household incomes were more inclined to categorize climate change as a 'moderate threat' or 'severe threat' to the marine environment. In contrast, those from higher-income households were more likely to downplay its significance, perceiving it as 'not a threat at all' or 'not a very severe threat.' These findings suggested that socioeconomic factors may influence how individuals assess environmental risks, with income levels potentially shaping access to information, personal experiences with environmental changes, or varying priorities in addressing broader societal issues (refer to Table 3). This income-based divergence in perceptions highlights the need for tailored communication and policy strategies to ensure that climate change messaging resonates across different economic groups, particularly in promoting the sustainable management of marine resources.

**Table 3: Income Composition of Saltwater Anglers Responding Climate Change Threats to Marine Environment**

| Income Level | Not a threat at all | Not a very severe threat | Moderate threat | Severe threat | Total |
|---|---|---|---|---|---|
| Less than $20,000 | 46 (3.9%) | 118 (5.4%) | 164 (6.4%) | 111 (7.8%) | 439 (6.0%) |
| $20,000-$39,999 | 130 (11.1%) | 255 (11.8%) | 359 (14.1%) | 207 (14.6%) | 951 (13.0% |
| $40,000-$59,999 | 161 (13.8%) | 372 (17.1%) | 426 (16.7%) | 224 (15.8%) | 1183 (16.2%) |
| $60,000-$79,999 | 187 (16.0%) | 328 (15.1%) | 388 (15.2%) | 257 (18.1%) | 1160 (15.9%) |
| $80,000-$99,999 | 179 (15.3%) | 322 (14.8%) | 408 (16.0%) | 181 (12.8%) | 1090 (14.9%) |
| $100,000-$149,999 | 255 (21.8%) | 446 (20.6%) | 452 (17.8%) | 258 (18.2%) | 1411 (19.3%) |
| $150,000-$199,999 | 104 (8.9%) | 139 (6.4%) | 171 (6.7%) | 98 (6.9%) | 512 (7.0%) |
| $200,000 or more | 107 (9.2%) | 190 (8.8%) | 177 (7.0%) | 83 (5.8%) | 557 (7.6%) |
| Total | 1169 | 2170 | 2545 | 1419 | 7303 |

% within CLIMATE in parentheses

Statistically significant differences were observed among saltwater anglers across all six regions ($\chi^2 = 153.763$; df =

15; $p < 0.001$). Notably, anglers in the Gulf of Mexico region exhibited a tendency to perceive climate change as either 'not a threat at all' or 'not a very severe threat.' In contrast, anglers in the North Atlantic, Mid-Atlantic, and South Atlantic regions were more inclined to view climate change as a 'moderate threat' or 'severe threat' to the marine environment. This disparity in perception highlights the regional variations in attitudes toward climate change among saltwater anglers, suggesting that local ecological, economic, and social factors may influence these views. For a more detailed breakdown of the responses by region, refer to Table 4.

**Table 4: Region Composition of Saltwater Anglers Responding Climate Change Threats to Marine Environment**

| Gender | Not a threat at all | Not a very severe threat | Moderate threat | Severe threat | Total |
|---|---|---|---|---|---|
| Alaska | 27 (2.3%) | 47 (2.2%) | 57 (2.2%) | 45 (3.2%) | 176 (2.4%) |
| West Coast | 189 (16.2%) | 324 (14.9%) | 375 (14.7%) | 213 (15.0%) | 1101 (15.1%) |
| North Atlantic | 115 (9.8%) | 255 (11.8%) | 381 (15.0%) | 258 (18.2%) | 1009 (13.8%) |
| Mid-Atlantic | 192 (16.4%) | 460 (21.2%) | 622 (24.4%) | 357 (25.2%) | 1631 (22.3%) |
| South Atlantic | 270 (23.1%) | 519 (23.9%) | 577 (22.7%) | 301 (21.2%) | 1667 (22.8%) |
| Gulf of Mexico | 376 (32.2%) | 565 (26.0%) | 533 (20.9%) | 245 (17.3%) | 1719 (23.5%) |
| Total | 1169 | 2170 | 2545 | 1419 | 7303 |

% within CLIMATE in parentheses

**Ordered Logit Analysis**

In the context of the multi-attribute framework, while the true level of utility remains unobservable, the self-reported level of choice is measurable and provides valuable insights. In this study, the dependent variable consisted of four ordered values: 0 (not a threat at all), 1 (not a very severe threat), 2 (moderate threat), and 3 (severe threat). This scale effectively captures a spectrum of individual self-reported preferences regarding the perceived threat of climate change to the marine environment. The definitions of the variables used in the ordered logit model are detailed in Table 5, which outlines how each variable is operationalized for analysis. Notably, the variable CLIMATE was specifically designed to accommodate the ordinal nature of the dependent variable within the ordered logit model employed in this research [21,22]. By utilizing this approach, the study aims to reveal underlying patterns and preferences among participants, enhancing our understanding of how different factors may influence perceptions of climate change threats in the marine context.

**Table 5: Variable Definition for Ordered Logit Model**

| Variable | Variable Description |
|---|---|
| CLIMATE | = 0 (Not A Threat At All) |
| CLIMATE | = 1 (Not A Very Severe Threat) |
| CLIMATE | = 2 (Moderate Threat) |
| CLIMATE | = 3 (Severe Threat) |
| Age | Age in Year (2013) |
| $Age^2$ | Age Squared |
| Female | 1 if Female; 0 if Male |
| Silent[a] | 1 if Silent (~ 1945); 0 otherwise |
| Boomer | 1 if Baby Boomer (1946 ~ 1964); 0 otherwise |
| GenX | 1 if Generation X (1965 ~ 1980); 0 otherwise |
| Millen | 1 if Millennial (1981 ~); 0 otherwise |
| LowInc[b] | 1 if Income < $59,999; 0 otherwise |
| MidInc | 1 if $60,000 ≤ Income ≤ $99,999; 0 otherwise |
| HighInc | 1 if Income > $100,000; 0 otherwise |
| GenEdu[c] | 1 if College Coursework or Less; 0 otherwise |
| College | 1 if Bachelor Degree; 0 otherwise |
| Advanced | 1 if Advanced, Professional, or Doctoral Degree or Coursework; 0 otherwise |
| Alaska | 1 if Region is Alaska; 0 otherwise |
| WCoast | 1 if Region is West Coast; 0 otherwise |
| NAtlant | 1 if Region is North Atlantic; 0 otherwise |
| MAtlant | 1 if Region is Mid-Atlantic; 0 otherwise |
| SAtlant[d] | 1 if Region is South Atlantic; 0 otherwise |
| Gulf | 1 if Region is Gulf of Mexico; 0 otherwise |

[a]Silent is the base; [b]LowInc is the base; [c]GenEdu is the base; [d]SAtlant is the base.

The empirical estimation of the ordered logit model using maximum likelihood estimation ensures several large sample properties, including consistency, efficiency, normality of parameter estimates, and the validity of significance tests. While the coefficient estimates obtained through this analysis do not allow for direct interpretation concerning the probabilities of the outcome variable (CLIMATE), they do indicate the direction and magnitude of influence on these probabilities. Therefore, it becomes essential to interpret the calculated changes in probabilities, referred to as marginal effects. Marginal effects provide a more intuitive understanding of how variations in independent variables impact the likelihood of respondents perceiving climate change as a specific level of threat to the marine environment [21,22]. By analyzing these marginal effects, researchers can derive meaningful insights into the underlying dynamics of the ordered logit model, enabling a clearer interpretation of the relationship between factors influencing perceptions of climate change threats.

Using Stata SE 16, all estimated coefficients in the ordered logit model including Age, $Age^2$, Female, Boomer, GenX, MidInc, HighInc, Advanced, Alaska, NAtlant, MAtlant, and Gulf were statistically significant at the 1%, 5%, or 10% levels, except for the variables Millen, College, and WCoast, which were not statistically significant. The chi-square statistic of 256.75 indicated a strong goodness of fit for the model, suggesting that it effectively explains the variability in the outcome variable. Additionally, collinearity diagnostics based on condition indexes revealed that collinearity among the independent variables was not statistically significant, reinforcing the reliability of the model's estimates.

The results indicated that being female is associated with a greater concern about climate change, consistent with findings from previous studies [11,12,18]. Likewise, higher levels of education were linked to increased concern about climate change, aligning with earlier research outcomes that highlight the influence of educational attainment on environmental awareness.

For the variable Age, the ordered log-odds estimate reflects the change in expected CLIMATE for a one-unit increase in age, holding other variables constant. Specifically, a one-unit increase in age corresponds to a -0.0364 unit decrease in the ordered log-odds of being classified in a higher CLIMATE category. In terms of the significant variable Female, the ordered log-odds estimate compares females to males regarding expected CLIMATE while controlling for other variables. As a result, females had a 0.3225 higher ordered logit of being in a higher CLIMATE category compared to males.

Regarding the significant variable HighInc, the comparison of high-income households to non-high-income households indicated a -0.3754 lower ordered logit for high-income households to fall into a higher CLIMATE category than their non-high-income counterparts. Additionally, for regional variables such as Gulf, MAtlant, and NAtlant, comparisons were made between specific regions and non-specific regions concerning expected CLIMATE, while holding other variables constant. For example, the ordered logit for the Gulf region being classified in a higher CLIMATE category was -0.3285 lower than that of non-Gulf regions.

In terms of odds ratios, the significant variable Boomer serves as an illustrative example. The proportional odds ratio compares boomers to non-boomers in relation to CLIMATE, controlling for other variables. The odds of being classified as high CLIMATE versus the combined categories of middle and low CLIMATE were 1.3537 times lower for non-boomers compared to boomers, assuming other variables remained constant. Similarly, the odds of the combined categories of high and middle CLIMATE versus low CLIMATE were also 1.3537 times lower for boomers compared to non-boomers, underscoring the nuanced differences in climate change perceptions across age groups.

**Table 6: Variable Estimation for Ordered Logit Model**

| Variable | Coefficient | Odds Ratio | Std. Err. | P > \|Z\| |
|---|---|---|---|---|
| Age | -0.0364 | 0.9643 | 0.0181 | 0.044 |
| $Age^2$ | 0.0004 | 1.0004 | 0.0002 | 0.029 |
| Female | 0.3225 | 1.3805 | 0.5805 | 0.000 |
| Boomer | 0.3028 | 1.3537 | 0.1074 | 0.005 |
| GenX | 0.3799 | 1.4621 | 0.1562 | 0.015 |
| Millen | 0.2066 | 1.2294 | 0.2263 | 0.360 |
| MidInc | -0.1555 | 0.8560 | 0.0532 | 0.003 |
| HighInc | -0.3754 | 0.6870 | 0.0564 | 0.000 |
| College | 0.0073 | 1.0073 | 0.0541 | 0.893 |
| Advanced | 0.2580 | 1.2943 | 0.0642 | 0.000 |
| Alaska | 0.2765 | 1.3185 | 0.1468 | 0.060 |
| WCoast | 0.0854 | 1.0891 | 0.0712 | 0.230 |
| NAtlant | 0.4878 | 1.6287 | 0.0729 | 0.000 |
| MAtlant | 0.3505 | 1.4198 | 0.0634 | 0.000 |
| Gulf | -0.3285 | 0.7200 | 0.0624 | 0.000 |
| $\mu_1$ | -2.2684 | 0.5181 | Log Likelihood = -9654.4316 | |
| $\mu_2$ | -0.7467 | 0.5174 | LR $Chi^2$ (14) = 256.75 | |
| $\mu_3$ | 0.8863 | 0.5175 | Prob > $Chi^2$ = 0.000 | |
| | | | Pseudo $R^2$ = 0.0131 | |

The marginal effects, calculated at the mean values of the model covariates, derived from Stata's margins command may exhibit signs that are opposite to those of their corresponding coefficients in the ordered logit model. This phenomenon occurs because an increase in an independent variable shifts the distribution of the dependent variable to the right, while the coefficients and threshold estimates remain unchanged [22]. As a result, interpreting marginal effects becomes crucial for understanding the practical implications of the model.

The marginal effects of the independent variables reflect the change in the probability of choosing a specific level of CLIMATE if the independent variables change by one unit, while all other variables are held constant. For instance, a one-unit increase in the variable Advanced, from its mean, is expected to decrease the probability of responding 'not a threat at all' by 3.18 percent, assuming all other variables remain unchanged in the ordered logit model. Conversely, for a one-unit increase in HighInc from its mean, the probability of evaluating climate change as "not a threat at all" among saltwater anglers is anticipated to increase by 5.13 percent (refer to Table 7).

These marginal effects underscore the nuanced relationships between independent variables and perceptions of climate change threats. Understanding how these probabilities shift with changes in individual factors can provide valuable insights for policymakers and stakeholders seeking to address concerns about climate change in the marine environment. By examining these effects in greater detail, researchers can better identify key drivers of public perception and tailor interventions to mitigate potential threats.

**Table 7: Marginal Effects for Ordered Logit Model**

| Variable | Not a threat at all | Not a very severe threat | Moderate threat | Severe threat |
|---|---|---|---|---|
| Age | 0.0048** (0.0024) | 0.0043** (0.0021) | -0.0035** (0.0017) | -0.0056** (0.0028) |
| $Age^2$ | -0.00005** (0.00002) | -0.00004** (0.00002) | 0.00003** (0.00002) | 0.00005** (0.00002) |
| Female | -0.0392*** (0.0066) | -0.0397*** (0.0075) | 0.0262*** (0.0040) | 0.0527*** (0.0101) |
| Boomer | -0.0399*** (0.0143) | -0.0351*** (0.0123) | 0.0289*** (0.0103) | 0.0461*** (0.0163) |
| GenX | -0.0465*** (0.0179) | -0.0464** (0.0197) | 0.0313*** (0.0108) | 0.0617** (0.0269) |
| Millen | -0.0256 (0.0265) | -0.0252 (0.0285) | 0.0176 (0.0168) | 0.0332 (0.0381) |

| | | | | |
|---|---|---|---|---|
| MidInc | 0.0208*** (0.0073) | 0.0178*** (0.0060) | -0.0153*** (0.0054) | -0.0233*** (0.0079) |
| HighInc | 0.0513*** (0.0081) | 0.0420*** (0.0061) | -0.0380*** (0.0061) | -0.0553*** (0.0080) |
| College | -0.0010 (0.0071) | -0.0009 (0.0064) | 0.0007 (0.0051) | 0.0011 (0.0083) |
| Advanced | -0.0318*** (0.0075) | -0.0315*** (0.0082) | 0.0217*** (0.0047) | 0.0416*** (0.0109) |
| Alaska | -0.0330** (0.0159) | -0.0344* (0.0191) | 0.0216** (0.0089) | 0.0458* (0.0262) |
| WCoast | -0.0110 (0.0090) | -0.0102 (0.0086) | 0.0078 (0.0063) | 0.0133 (0.0113) |
| NAtlant | -0.0565*** (0.0075) | -0.0612*** (0.0096) | 0.0349*** (0.0038) | 0.0829*** (0.0136) |
| MAtlant | -0.0430*** (0.0073) | -0.0429*** (0.0081) | 0.0289*** (0.0046) | 0.0569*** (0.0109) |
| Gulf | 0.0457*** (0.0092) | 0.0361*** (0.0064) | -0.0342*** (0.0071) | -0.0476*** (0.0086) |

Note: Single, double, and triple asterisks (*) denote significance at the 10%, 5%, 1% level, respectively. Standard errors in parentheses.

Consequently, the predicted probabilities for the outcome variable (CLIMATE) were estimated across different perception categories as follows: 15.51% for individuals who perceived climate change as 'not a threat at all', 30.16% for those who viewed it as 'not a very severe threat', 35.47% for respondents identifying it as a 'moderate threat', and 18.85% for those considering it a 'severe threat'. These estimates reflect the likelihood of respondents selecting each category while holding all other variables constant at their mean values.

This distribution highlights the varied perceptions of climate change threats among the participants, indicating a significant proportion (35.47%) classify it as a 'moderate threat, ' which could be interpreted as a critical threshold for policymakers and environmental advocates. Understanding these predicted probabilities allows for a more nuanced approach in addressing climate change communications and interventions. By targeting the perceptions of individuals within these categories, stakeholders can develop tailored strategies to enhance awareness and encourage proactive measures in response to climate-related challenges.

**Discussion and Conclusions**

Saltwater recreational fishing occupies a central role in American culture, offering not only a beloved pastime but also a crucial aspect of social, cultural, and economic activities throughout the country. The significance of this activity extends beyond mere recreation, as it is intertwined with community identity, regional economies, and environmental stewardship. Understanding the concerns of saltwater anglers regarding marine environmental threats is essential for implementing effective marine fisheries programs that support ecosystem-based management in the United States. Among these threats, the pervasive influence of climate change on the marine environment requires urgent and sustained attention, especially given the profound and potentially irreversible impacts it may have on fish populations, habitats, and fishing communities.

This study utilized cross-sectional data extracted from the 2013 National Saltwater Angler Survey, encompassing a diverse sample of 7,303 saltwater anglers. By employing a qualitative choice analysis within a multi-attribute framework, we were able to comprehensively assess the perceptions of anglers regarding climate change threats to the marine environment. The empirical findings highlighted that several factors including age, gender, income levels, education, and geographical region significantly influenced the self-reported preferences of saltwater anglers regarding the threats posed by climate change.

The findings revealed that demographic characteristics play a crucial role in shaping perceptions of climate change among saltwater anglers. For instance, younger anglers and those with higher levels of education tended to express greater concern about climate change threats, suggesting a potential generational divide in environmental awareness. These insights underscored the importance of tailoring communication strategies to different demographic groups to effectively engage them in discussions about climate change and marine conservation. In particular, outreach efforts targeting younger and more educated anglers could be instrumental in fostering a sense of environmental responsibility and activism.

Through the empirical analysis of the ordered logit model, this study demonstrated a robust approach to evaluating the diverse concerns of saltwater anglers regarding climate change. The use of a multi-attribute framework allowed for a more nuanced understanding of perceptions, going beyond traditional Likert-type scales. This methodological advancement not only provides a clearer picture of anglers' concerns but also challenges the conventional notion of an 'average' angler, revealing the complexity and variability of opinions within this community.

Moreover, this research contributes to the existing empirical literature by updating and testing the well-established multi-attribute framework for assessing self-selection levels concerning climate change threats. The insights gained from this analysis can be instrumental in informing future studies and policy initiatives aimed at enhancing the resilience of marine ecosystems. By recognizing and addressing the unique concerns of various socio-demographic groups, researchers and practitioners can develop more effective conservation strategies that resonate with the values and priorities of saltwater anglers.

The results of this study provided baseline information that is essential for marine fisheries managers in developing targeted strategies to address the specific concerns of saltwater anglers. Understanding the perceived threats from climate change is crucial for garnering public support and guiding policy decisions. By integrating anglers' perspectives into the decision-making process, fisheries managers can foster a sense of ownership and responsibility among stakeholders, leading to more sustainable fishing practices and enhanced marine conservation efforts.

Additionally, the findings underscored the need for enhanced education and outreach initiatives aimed at increasing awareness of climate change impacts on marine ecosystems. By equipping saltwater anglers with the knowledge and tools necessary to understand and address these challenges, stakeholders can create a more informed public that actively participates in conservation

efforts. Engaging anglers in collaborative decision-making processes can also help build community resilience and foster adaptive strategies to cope with the uncertainties posed by climate change.

In conclusion, this research highlights the urgent need for ongoing dialogue and engagement with saltwater anglers to address their concerns and enhance the resilience of marine ecosystems in the face of climate change. By prioritizing the voices of those directly impacted by these environmental shifts, policymakers can create more inclusive and effective strategies that resonate with the values and priorities of the fishing community. Ultimately, fostering a collaborative relationship between anglers, fisheries managers, and environmental advocates will be crucial in ensuring the sustainability of marine resources for future generations.

**References**


1. Brinson AA, Wallmo K. Attitudes and Preferences of Saltwater Recreational Anglers: Report from the 2013 National Saltwater Angler Survey, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-135. 2013. 1: 45.
2. Beatley T. Protecting biodiversity in coastal environments: introduction and overview. Coastal Management. 1991. 19: 1-19.
3. Norse EA. A river that flows to the sea: marine biological diversity movement. Oceanography. 1996. 9: 5-9.
4. Snelgrove PVR. Getting to the bottom of marine biodiversity: sedimentary habitats. BioScience. 1999. 49: 129-138.
5. Beddington JR, Agnew DJ, Clark CW. Current problems in the management of marine fisheries. Science. 2007. 316: 1713-1716.
6. Derraik JGB. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin. 2002. 44: 842-852.
7. Acheson J. Attitudes toward offshore wind power in the midcoast region of Maine. Marine Policy Review. 2012. 21: 42-55.
8. Lotzea HK, Guesta H, O'Learyc J, Tudad A, Wallaceb D. Public perceptions of marine threats and protection from around the world. Ocean and Coastal Management. 2018. 152: 14-22.
9. Kellstedt PM, Zahran S, Vedlitz A. Personal Efficacy, the Information Environment, and Attitudes Toward Global Warming and Climate Change in the United States. Risk Analysis. 2008. 28: 113-126.
10. Scruggs L, Benegal S. Declining public concern about climate change: can we blame the great recession? Global Environmental Change. 2012. 22: 505-515.
11. Kvaløy B, Finseraas H, Listhaug O. The publics' concern for global warming: a cross-national study of 47 countries. Journal of Peace Research. 2012. 49: 11-22.
12. Franzen A, Vogl D. Two decades of measuring environmental attitudes: a comparative analysis of 33 countries. Global Environmental Change. 2013. 23: 1001-1008.
13. Carlton SJ, Jacobson SK. Climate change and coastal environmental risk perceptions in Florida. Journal of Environmental Management. 2013. 130: 32-39.
14. Capstick S, Whitmarsh L, Poortinga W, Pidgeon N, Upham P. International trends in public perceptions of climate change over the past quarter century. WIREs Climate Change. 2015. 6: 35-61.
15. Egan PJ, Mullin M. Climate Change: US Public Opinion. Annual Review of Political Science. 2017. 20: 209-27.
16. Wang J, Kim S. Analysis of the Impact of Values and Perception on Climate Change Skepticism and Its Implication for Public Policy. Climate. 2018. 99: 1-28.
17. Jellason NP, Baines R N, Conway JS, Ogbaga CC. Climate Change Perceptions and Attitudes to Smallholder Adaptation in Northwestern Nigerian Drylands. Social Sciences. 2019. 31: 1-20.
18. Arikan G, Günay D. Public attitudes towards climate change: a cross-country analysis. The British Journal of Politics and International Relations. 2021. 23: 158-174.
19. McKelvey RD, Zavoina W. A statistical model for the analysis of ordinal level dependent variables. Journal of Mathematical Sociology. 1975. 4: 103-120.
20. McFadden D. Econometric Models of Probabilistic Choice. In Structural Analysis of Discrete Data with Econometric Applications, eds. Manski CF and McFadden D. Cambridge MA: The MIT Press. 1981. 198-272.
21. Maddala GS. Models with self-selectivity. In Limited-Dependent and Qualitative Variables in Econometrics, Maddala GS, New York: Cambridge University Press. 1983. 257-291.
22. Greene WH. Econometric analysis, Sixth edition. Upper Saddle River, NJ: Prentice Hall. 2008.