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Abstract: Nonmarket valuation of climate change and ocean acidification impacts to marine resources

John Whitehead
Department of Economics
Appalachian State University

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Introduction

The purpose of this abstract is to describe existing methods of estimating the economic values for avoiding the climate change impacts to marine resources. In the first section I describe the available methods. In the next section I review the literature focused on recreation values associated with climate change. In the third section I consider a conceptual model for valuing climate change impacts to marine resources. In the fourth section I consider future research needs.

Methods

Estimating the nonmarket values of climate change impacts to marine resources first requires consideration of the type of impacts. Market values are the changes in outputs and inputs associated with a resource reallocation and are valued with market prices. Nonmarket values are those that accrue above and beyond market values and are variously called consumer surplus, compensating surplus, equivalent surplus, willingness to pay and willingness to accept. The total economic value is the sum of all nonmarket values.

Estimation of the total economic value for marine resources is complex. Consider coral reefs which can provide recreation and tourism values, amenity values, fishery habitat values and biodiversity values (Figure 1). The main categories of nonmarket values include direct use values, indirect use values and nonuse values. Direct use values are those that arise from on-site enjoyment of a natural resource. Direct use values that are generated by marine resources are primarily recreational and tourism values. In Figure 1, individuals can enjoy recreational diving on the coral reef ecosystem and gain direct use values. Indirect use values are those that are enjoyed on-site as a by-product of coral reefs. For example, fish stocks are enhanced by coral reef protection and anglers enjoy coral reef protection indirectly through improved catch rates. Nonuse values are those values that arise without on-site enjoyment. Nonuse values may be motivated by altruism, bequests or an environmental ethic.

Both revealed and stated preference methods can be used to estimate direct and indirect nonmarket use values. The most advantageous revealed preference nonmarket valuation method for outdoor recreational modeling is the travel cost method. The travel cost method exploits the empirical relationship between outdoor recreation trips and site selection and the travel cost required to reach recreation sites. The most basic finding is that the further the distance the less likely the recreation site will be selected and the fewer the number of trips.

Stated preference methods include the contingent behavior, contingent valuation and attribute-based choice experiment (i.e., conjoint analysis) methods. The contingent valuation method could be used by asking survey respondents for their willingness to pay to prevent climate change to recreation resources. The contingent behavior method could be used by asking survey respondents for hypothetical changes in visitation behavior (i.e., trips) with changes in climate related variables. Attribute-based choice experiments can be used by asking survey respondents about changes in visitation behavior (i.e., site selection) with changes in climate related variables.

Both revealed and stated preference methods have limitations when valuing the impacts of long term climate change. Revealed preference methods are constrained by current spatial variations in temperature and other measures of climate change impacts. Forecasts of the impacts of temperature change beyond current experience are possible but the range and types of behavior change are constrained by the model and existing behaviors. Stated preference methods are limited in that the measured behavior is hypothetical and subject to potential biases. One approach for resolving these weaknesses is the combination and joint estimation of revealed and stated preference data. Joint estimation allows the behavior change to range beyond historical experience with the stated preference data while grounding the hypothetical data in revealed preferences.

Stated preference methods must be used to estimate nonuse values. The contingent valuation method can be used to ask survey respondents about their willingness to pay for climate change policy that would change the characteristics of marine resources. One problem with the contingent valuation method in this context is that it is most effectively employed to estimate total economic values. Willingness to pay for climate change policy could also capture marine resource values, coastal values, terrestrial values and others. Attribute-based choice experiments can also be used to estimate nonuse values. Respondents are typically led through a series of policy choices with varying characteristics of the policy. In the case of coral reef valuation, these characteristics could include changes in the ecosystem, fish stocks and other impacts with and without opportunities for recreation. Simulation methods can then be used to estimate nonuse values.

Literature on Outdoor Recreation and Climate Change

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 Markowsi (1999) considered the effects of changes in temperature and precipitation on a wide range of outdoor recreational activities using state-level aggregate demand functions. Considering a range of climate scenarios, the authors found that increased temperature and precipitation increase the aggregate economic value of some activities and decreases the aggregate economic value of others. Loomis and Crespi (1999) took an approach similar to Mendelsohn and Markowsi (1999) but used microdata. 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. Based on their 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. More recently, 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.

All of the previous 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' 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.

A Conceptual Model

There are a number of relationships that need to be modeled to estimate a marine rsources damage function (Figure 2).[1] First, a simple model of the effect of carbon dioxide emissions on ocean acidification is needed. The simple model should be able to abstract away from the biophysical complexities and allow focus on the endpoints that are important for anthropogenic valuation. For example, a description of how carbon dioxide emissions affect seawater variables and other weather-related variables important to recreation (e.g., ambient temperature, precipitation) is needed. Considering the example of coral reef ecosystems, let this relationship be expressed as equations (1) and (2):

(1) $S = f(CO2)$
(2) $W = f(CO2)$

where *S* represents seawater variables (e.g., temperature, chemistry), *W* represents weather-related climate change variables (e.g., ambient temperature, precipitation) and *CO2* represents carbon dioxide. In Figure 2 this relationship is represented by the arrows labeled (1) and (2).

[1] Note that this model is what is understood by an economist with no training in climate science.

Next, a biophysical description of the effect of seawater and other climate variables on coral reef ecosystems and fish stocks (e.g., range shifts, habitat loss, and prey availability) is needed.

(3) $CR = f(S, W)$
(4) $FS = f(S, W, CR)$

where *CR* is coral reef ecosystem and *FS* is fish stocks. In Figure 2 these relationships are represented by the arrows labeled (3) and (4). Note that fish stocks are affected by seawater variables and other climate variables directly and indirectly through coral reef ecosystems.

Next, behavioral models could be estimated with revealed preference methods such as the travel cost method:

(5) $RD = f(p, y, CR)$
(6) $RF = f(p, y, FS)$

where *RD* is recreational diving, *RF* is recreational fishing, *p* is the access cost of each activity (e.g., travel cost) and *y* is income. In Figure 2 these are illustrated by the arrows labeled (5) and (6). The link between carbon dioxide emissions and recreational behavior can be found by substituting equations (1) and (2) into (3) and substituting equations (1), (2) and (3) into equation (4). Then equation (3) would be substituted into equation (5) and equation (4) would be substituted into equation (6). The reduced form behavioral models are:

(5') $RD = f\big(p, y, S, W, CR(S, W)\big)$
(6') $RF = f(p, y, S, W, FS(S, W, CR))$

To estimate recreational impacts from climate on marine recreational behavior in a revealed preference study, one would follow the methods employed in previous studies. Considering the conceptual framework developed by Shaw and Loomis (2008), one would estimate the relationship between the direct effects of climate change (e.g., temperature, precipitation, climate variability), the indirect effects (e.g., fish stocks and composition) and the effects on outdoor recreational behavior and economic value. Data with spatial variation in the climate change variables is required.

In particular, consider the random utility model version of the revealed preference 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., temperature, precipitation, catch rates). If anglers make fishing site selections based on these characteristics, then the existing relationship between site characteristics and fishing site selection can be used to simulate the impact of climate change. This model could then be linked to models of visitation frequency to estimate the aggregate impacts of climate change on marine recreation behavior. Stated preference recreation scenarios can be designed to elicit hypothetical behavior data to supplement the revealed preference data in a joint estimation framework.

The simple biophysical descriptions represented by equations (1), (2), (3) and (4) could be used to design stated preference recreation scenarios for estimation of use values and policy scenarios for estimation of nonuse values. First, nonuse values must be conceptually defined. Economists use the utility function to conceptualize the relationship between consumption and welfare (i.e., happiness). Considering the example above:

(7) $U = U(X, RD, RF, CR, FS, U^a U^b)$

where *U* is the utility of an individual, *X* represents market goods, U^a represents the utility of individual *a* (i.e., altruism) and U^b represents the utility of individual *b* (i.e., bequests to future generations). Changes in *RD* and *RF* that affect utility represent behavior that generates use values. Changes in *CR* and *FS* generate nonuse values motivated by an environmental ethic. Changes in U^a and U^b generate nonuse values motived by altruism and bequests to future generations. These relationships are represented by the arrows labeled (7) in Figure 2.

Substitution of equation (7) for individuals *a* and *b* leads to a reduced form utility function which can be maximized subject to a budget constraint to find the indirect utility function:

(8) $v = v(p, y, CR, FS)$

Use and nonuse values can be conceptually defined using equation (8). The total economic value of a change in coral reef ecosystems from the baseline level to a degraded state (*CR*', *FS*') is:

(9) $v(p, y - TEV, CR, FS) = v(p, y, CR', FS')$

where TEV is the total economic value, the amount of income that must be taken from the individual in order to maintain utility at a level equal to that with full income but a degraded environment. Total economic value is the sum of use value and nonuse value, TEV = UV + NUV, where nonuse value is:

(10) $v(p^*, y - NUV, CR, FS) = v(p^*, y, CR', FS')$

where *p** is the price at which the quantity of recreation demanded is equal to zero. The residual difference between TEV and NUV is equal to the sum of the use values from equations (5') and (6'). Contingent valuation or attribute-based choice experiment scenarios can be described to convey the information included in equations (1) – (10) and obtain estimates of total economic values and nonuse values for the impacts of climate change on marine resources. Joint estimation with recreation demand functions (5') and (6') can be used to decompose total economic value into use value and nonuse value and further calibrate the model.

Future Research

Future research must be conducted to determine how the biophysical models could be integrated with the economic models. To my knowledge there are no good examples in the literature.[2] Important gaps and uncertainties in our knowledge regarding the economic impact of changes in fisheries and coral reef ecosystems due to climate change are the lack of empirical relationships described above. One of the next steps to improving how nonmarket impacts to marine ecosystem service impacts are handled in an integrated assessment modeling framework is to gather the necessary revealed preference and stated preference data and estimate the relationships described above. The accuracy of transfers of these damage functions across regions and over long periods of time is an open question, requiring validity studies. Research examining these relationships would be most fruitful. In the interim, investigation of benefit transfer methods with existing estimates of coral reef recreation and recreational fishing values would allow preliminary estimation of these damage functions.

[2] Note that I still have a stack of papers to read and have not yet exhausted my literature search abilities.

Figure 1. Nonmarket Economic Values

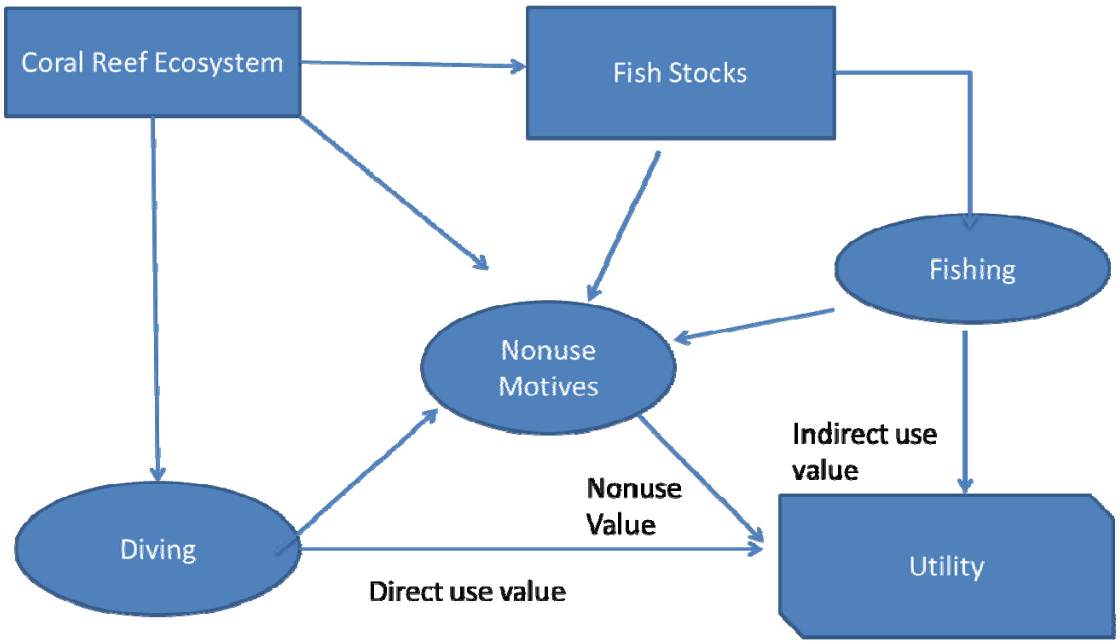
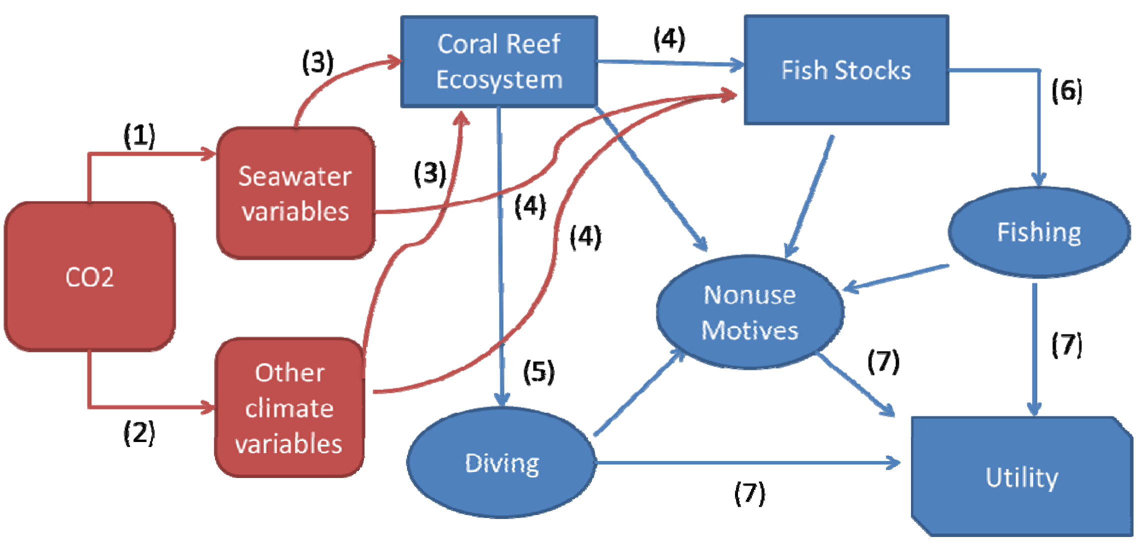


Figure 2. Climate Change and Nonmarket Economic Values



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