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TRAVEL COST METHODS FOR ESTIMATING THE RECREATIONAL USE BENEFITS OF ARTIFICIAL MARINE HABITAT

J. Walter Milon

Abstract

The growing popularity of marine recreational fishing has created considerable interest in artificial marine habitat development to maintain and enhance coastal fishery stocks. This paper provides a comparative evaluation of travel cost methods to estimate recreational use benefits for new habitat site planning. Theoretical concerns about price and quality effects of substitute sites, corner solutions in site choice, and econometric estimation are considered. Results from a case study indicate that benefit estimates are influenced by the way these concerns are addressed, but relatively simple single site models can provide defensible estimates. Practical limitations on data collection and model estimation are also considered.

Key words: travel cost method, use benefits, recreational fishing, artificial habitat, limited dependent variables, discrete choice models.

The growing popularity of marine recreational fishing has generated considerable interest in ways to maintain and enhance coastal fishery stocks. In 1985, the total number of recreational fishing trips on the South Atlantic (Delaware to Florida) and Gulf of Mexico coasts exceeded 61 million trips, representing an increase of over 10 million trips from 1979 (the first year in which national recreational fishing statistics were collected) (National Marine Fisheries Service). This growth in the recreational demand for marine fishing has been accompanied by continuing development and conversion of coastal habitats that support marine fisheries. One way to augment the availability of fishery habitat and to recruit stocks for particular coastal areas is the deployment of artificial habitats. These habitats can be sea-bottom structures constructed from discarded materials (e.g., vessels and other transportation vehicles, or oil drilling platforms) or floating structures (either surface or mid-water) made from a variety of materials. Artificial habitats are generally believed to improve fishing by concentrating fishes and by increasing overall biomass production (Bohnsack and Sutherland).

Small-scale artificial habitat development has been practiced in the U.S for over a century (Stone). But, with the National Fishing Enhancement Act of 1984 (P.L. 98-623) and the subsequent National Artificial Reef Plan (U.S. Department of Commerce), artificial habitat development has been recognized as an important component of national coastal resource and fishery management. States in the southern U.S. have been especially active in artificial habitat development, and the effects of these public investments on sport angler and diver participation at artificial habitat sites have been well-documented (e.g., Ditton and Graefe; Liao and Cupka; Roberts and Thompson).

Despite the growing interest in artificial habitats, few researchers have attempted to identify the economic use benefits of new site development. This is an integral part of efficient site planning and evaluation that has been virtually ignored (Gordon and Ditton). The need for economic benefit estimation methods and results is particularly acute in the southern U.S. All states in the southern region now have active artificial habitat development programs (Sport Fishing Institute). In addition, the supply of "materials of opportunity" for artificial habitat is expanding rapidly. The U.S. Mineral Management Service estimates that a minimum of 100 oil

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and gas platforms in the Gulf of Mexico will be decommissioned annually after 1990, and the number increases to 200 per year after 2010 (National Research Council). Since the costs of removal for inshore disposal are high and usually irretrievable, these platforms are highly desirable inputs for new site development (Reggio).

The problem of estimating the use benefits of new recreation sites is a familiar one in the recreation economics literature. The first major innovations in modeling recreation demand using the travel cost method (TCM) involved new site development benefits (e.g., Burt and Brewer; Cicchetti et al.). Recent innovations with the TCM have refined and expanded the modeling framework to address specification problems related to the inclusion of substitute site prices, varying levels of quality at existing and new sites, and the type of activity participation behavior considered in the model. These are important issues in use benefit estimation for new artificial habitat since sites will most likely be developed adjacent to existing artificial and natural habitat sites, new sites will have different levels of fishing (diving) quality, and different user groups will benefit depending on the siting decision (e.g., offshore anglers versus inshore anglers).

This paper provides a comparative analysis of TCM models that can be used to estimate the use benefits of artificial habitat site development and presents the results from an application of these models for a new site off the Southeast Florida coast. First, the theoretical basis for site demand models and new site benefit estimation is considered in both single and multiple site frameworks. Prior developments and recent innovations within these TCM frameworks are discussed. Empirical results for the alternative TCM models are presented in the next section, and estimated use benefits from the models are reported. The paper concludes with a discussion of the advantages and disadvantages of the alternative models, focusing on problems of data collection, site quality specification, and the resources available to the analyst.

TRAVEL COST MODELS AND NEW SITE BENEFITS

The Single Site Framework

The simplest way to approach the problem of estimating the use benefits of a new artificial habitat site is with a single site TCM.[1] At the start of the recreation season, the n^{th} recreationist (sport angler or diver) chooses v_{1n} visits to the single site at travel cost p_{1n} given income m_n. The utility (U) maximization problem can be written as

$$(1)\ \text{MAX } U(v_{1n}, z_n), \quad \text{s.t. } p_n v_{1n} + z_n = m_n,$$

where z is the Hicksian composite good. A popular and convenient empirical representation of equation (1) which only requires that site 1 is separable from all other sites and recreation activities is the linear demand equation:

$$(2)\ v_{1n} = \alpha + \beta p_n + \gamma m_n,$$

where p and m have been normalized on the price of the composite good and α, β, and γ are parameters to be estimated. The travel cost may include a shadow cost for travel time if the individual has income-producing alternatives to the recreation trip, or the travel time may be a nonmonetary constraint on the site visitation decision (Bockstael et al.).

The use benefits of a new site, 2, that is "identical" to the existing site 1 are based on a price dominance rule for travel cost savings to each individual. This rule stipulates that the recreationist selects the site with the lowest travel cost, all other site characteristics being equal. Hanemann and Hausman have demonstrated that an exact compensating variation (CV) measure of the use benefits can be derived from the indirect utility function for a linear demand equation. For this application, the use benefits to the n^{th} recreationist are given by the formula:

$$(3)\ CV_n = \left(\frac{v_{2n}}{\gamma} + \frac{\beta}{\gamma^2}\right) - \exp[\gamma(p_{2n} - p_{1n})]\left(\frac{v_{1n}}{\gamma} + \frac{\beta}{\gamma^2}\right),$$

[1]This discussion assumes that the proper subject for welfare measurement is the individual recreationist. Although the TCM is commonly used with aggregate zonal data, this approach requires strong assumptions about homogeneity within travel zones and will yield biased measures of welfare changes (McConnell and Bockstael). The zonal approach is also not appropriate for "local" recreation sites for which a majority of users only travel short distances. In 1985, over 70 percent of marine fishing trips in the Southern region of the U.S. were from counties within 25 miles of the coast (National Marine Fisheries Service).

where v_2 is the predicted number of visits to the new site given the new travel cost, p_2. If site demand is income independent, the benefit estimating equation reduces to:

$$(4)\ CV_n = (.5(v_{2n})^2/\beta) - (.5(v_{1n})^2/\beta).$$

Comparable benefit formulas could be derived for other forms of the indirect utility/demand functions (Hanemann; Hausman).

This single site model is convenient, but two key procedural issues must be resolved before the model can be applied to estimate the expected benefits of a new artificial habitat site. First, the relevant sample group of recreationists to include in the data set must be defined. Suppose we are concerned only with sport anglers and one artificial reef site presently exists in the region. If data on angler visitation at the reef site are available, the critical issue is whether to estimate the demand equation (2) with or without those anglers who fish at other sites in the region but not at the existing artificial habitat site.[2] The decision to consume zero visits at the artificial habitat site is a "corner solution" to the recreationist's utility maximization problem which suggests a model of behavior such as

$$v_{1n} = d_n(\cdot) + \epsilon_n \text{ if } d_n(\cdot) + \epsilon_n > 0, \text{ and } v_{1n} = 0 \text{ otherwise,}$$

where $d_n(\cdot)$ is the demand function (2) evaluated for individual n and ϵ is the error term. Traditionally, users of the single site TCM have ignored the inherent data truncation problem and used non-zero values for the visits variable with ordinary least squares estimation. The truncation problem could be considered directly by including zero values and using appropriate estimation techniques such as Tobit (Maddala, 1983). Alternatively, each trip decision by an angler in the sample could be modeled as a discrete (binary) choice whether to visit the existing site using a probit analysis (Smith and Kaoru).[3] Unfortunately, there is very little in the literature to suggest how these specification decisions related to the single site model will influence the estimated benefits of a new site.

A second related but more difficult problem concerns the initial assumption of separability for site 1. The corner solution problem suggests that anglers may choose to visit another site, in this case a non-artificial habitat site, on any given fishing trip. Even if we assume (temporarily) that fishing quality (success rates) are the same at artificial and non-artificial habitat sites, the omission of substitute site travel costs suggests a specification error. This problem can be remedied by specifying a system of single site demand equations such as:

$$(5)\ v_{1n} = \alpha_1 + \beta_1 p_{1n} + \sum_{i=2}^{j} \beta_i p_{in} + \gamma_1 m_n,$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$v_{jn} = \alpha_j + \beta_j p_{jn} + \sum_{i=1}^{j-1} \beta_i p_{in} + \gamma_j m_n,$$

[2]The problem is sometimes described as sample selection bias (Ziemer et al.), but this term can be misleading. The immediate concern is situations where the sample frame has been properly developed from the potential user population (e.g., fishing license data for sport anglers), but some respondents participate at sites other than the target site. This differs from the situation where the user population is only sampled at the target site and zero visits cannot occur.

[3]Smith and Kaoru express the site choice decision problem in a random utility framework so that:

$$\text{Prob(visit)} = \text{Prob}(U_v + \epsilon_v \geq U_{nv} + \epsilon_{nv}),$$

where U is the systematic component of utility (v = visit, nv = not visit) from the single site and ϵ is the random component of utility. The probability of visiting the site can then be estimated with a probit analysis such as:

$$\text{Prob(visit)} = \text{Prob}(\epsilon_{nv} - \epsilon_v < \alpha' + \beta' p + \gamma' m),$$

where p and m are as defined above and α', β', and γ' are the estimated probit coefficients. Then the expected benefits of a new site could be estimated with the formula:

$$CV_n = ((\alpha' + \beta' p_{2n} + \gamma' m_n)/\beta') - ((\alpha' + \beta' p_{1n} + \gamma m_n)/\beta').$$

This model yields a per-trip benefit measure; a measure of total surplus comparable to equations (2) or (3) is the product of the per trip CV and the total number of trips for each angler.

where j is the number of sites with comparable quality in the region. Because it is possible that the site demand equations are mutually correlated, the system must be estimated as seemingly unrelated regression equations. Burt and Brewer and Cicchetti et al. have demonstrated how the estimated coefficients from equation system (5) can be used for a line integral calculation of new site benefits. However, Hof and King argue that the omitted variable problem can be solved simply by including substitute site prices in the single site equation, or

$$(6)\ v_{1n} = \alpha + \beta_1 p_{1n} + \sum_{i=2}^{j} \beta_i p_{in} + \gamma m_n.$$

The estimated coefficients from equation (6) can be used to estimate new site benefits. These estimated benefits will be equivalent to the estimated benefits from equation system (5) *if* the cross-price effects are symmetric.[4] While we would expect the differences between the two benefit estimation approaches to be consistent with expected error bounds (Randall and Stoll), again there is little evidence available in the travel cost literature to support or refute these expectations. Note, however, that this resolution of the omitted variable problem does not eliminate the first problem of truncation in the dependent variable.

The convenience of the single site model is appealing, but all the above specifications neglect quality differences between sites. As noted in the introduction, one of the expected advantages of artificial habitat sites is an improvement in fishing success rates. The expected quality differences with a new artificial habitat site cannot be considered directly in the single site model. This aspect of the problem can be addressed most effectively in a multi-site framework.[5]

The Multi-Site Framework

A straightforward extension of the utility maximization framework can be used to specify multiple site demand with substitute site price and quality dimensions. The utility maximization problem can be written with visitation as a function of site quality characteristics (q):

$$(7)\ \text{Max } U(v_{jn}(q_j), z_n),$$

$$\text{s.t. } \sum_j p_{jn} v_{jn}(q_j) + z_n = m_n.$$

One approximation to a demand equation from this problem can be described by assuming that the set of fishing (diving) sites 1,. . .,j in a region are separable from all other sites and recreation activities and that quality characteristics are additive. A linear demand system for the n sites can be defined as:

$$(8)\ v_{in} = \alpha_i + \beta_i p_{in} + \sum_j \beta_j p_{jn} + \gamma_i m_{in} + \delta_i q_i$$

$$\forall\, i = 1, \ldots, j;\ i \neq j,$$

where q_i represents quality at each site (for simplicity, only single dimensional). This model includes cross-price and own quality effects. It allows the analyst to specify the quality dimension of a new site and to account for existing substitutes. Unfortunately, the quality coefficient cannot be identified in this model unless the quality measure changes for each site. This requires time series data that are usually not available for fishing or diving activities in most coastal areas.[6]

An alternative specification that has been used extensively in TCM models of water

[4]Symmetry of the cross price effects for equation system (5) implies that the simple integral of equation (6) is equivalent to the line integral of the demand system. Hof and King show that the benefits for a new site could be estimated from equation (6) using the equation:

$$CV = \alpha(p_1' - p_1) + 1/2\,\beta[(p_1')^2 - (p_1)^2] + (p_1' - p_1)\left(\sum_{i=2}^{j} \beta_i p_i\right),$$

where p_1' denotes the travel cost to the new site.

[5]It could be argued that the demand system (5) includes quality differences through variations in the intercept and price coefficients across equations. At best, this is a very loose approach since it is not clear which site quality factors influence the demand equations. And the analyst must assume that quality at the new site is comparable to quality at one of the existing sites without specifying what quality actually means.

[6]The Marine Recreational Fishing Survey conducted annually by the U.S. National Marine Fisheries Service does provide time series data on visitation and fishing success rates. But the sample sizes for realistic levels of disaggregation (e.g., counties) are so small that the data are not useful for this problem.

quality improvement benefits (e.g., Smith et al.) is a restricted form of equation (8) given by:

(9) $v_{in} = \alpha + \beta\, p_{in} + \gamma m_n + \delta q_i \quad \forall\, i = 1, \ldots, j.$

This is a pooled site model in which the quality dimension can be identified if quality varies across sites. The estimated model coefficients can be used to predict new site visitation for a specific site location and quality level. And the expected benefits can be calculated using the formula given in equation (4).

The pooled multi-site TCM is a practical way to incorporate quality into new site benefit estimation, but the restrictions on equation (8) used to specify the pooled model are problematic. The pooled model neglects cross-price effects which may cause omitted variable bias as in the single site TCM. In addition, the intercept and the own-price/quality effects are the same across sites implying that all differences in site characteristics are captured in the price and quality measures. Finally, the pooled model does not provide a straightforward remedy for the corner solution problem. The analyst still must select the appropriate estimation procedure for the data. This is a serious problem in the multi-site context because it is unlikely that each individual will visit every site included in the region.

A conceptually different TCM that explicitly integrates both site substitution effects (price and quality) and accounts for the possibility of zero visits at certain sites is the multinomial logit (MNL) demand share model. This model has been used in recent studies of the benefits from new recreation site development (e.g., Morey; Stynes and Peterson). The behavioral assumptions employed in the demand share TCM differ from the traditional utility maximization model expressed in equations (1) and (7) above. It is assumed that the total number of fishing trips (choice occasions) are fixed ($\sum_j v_{jn} = \hat{v}_n$); the utility maximization problem is an allocation decision across the sites available in each angler's choice set for each choice occasion. Letting g represent the angler's decision to visit site j on the r^{th} choice occasion ($g_{jr} = 1$ if the j^{th} site is selected, 0 otherwise) and given the total trip constraint: $\sum_j \sum_r g_{jrn} = \hat{v}_n$, the utility maximization problem for a single choice occasion is

(10) $\text{Max } U(g_{jn}(q_j), z_n),$

$$\text{s.t. } \sum_j p_{jn} g_{jn} + z_n = m_n.$$

This demand share allocation problem can be restated in probabilistic choice form using McFadden's development of random utility theory. The probability that site i will be selected from the angler's choice set, C_n, can be expressed:

(11) $\text{Prob}_n(i) = \text{Prob}(U_{in} \geq U_{jn},\ \forall\, j \in C_n,\ i \neq j)$ or

(12) $= \text{Prob}[V(q_i, s_n) + \epsilon(q_i, s_n) \geq V(q_j s_n) + \epsilon(q_j, s_n),\ \forall\, i \neq j],$

where the systematic component of utility, V, is determined by the quality characteristics, q, of each site choice and the socioeconomic attributes (tastes), s, of each angler. The stochastic component, ϵ, is assumed to be independent and identically distributed and has the extreme value distribution.[7] The systematic component, V, can be defined as an indirect utility function; and the site choice constraints, travel cost and time, enter the function as negative site characteristics that reflect the disutility of these site costs to the recreationist.[8] Given these assumptions and assuming the indirect utility function is linear in the parameters, the probability of choosing site i can be written as the MNL model:

(13) $$\text{Prob}_n(i) = \frac{\exp(\beta_i p_i + \delta_i q_i + \gamma_i s_i)}{\sum_{j \in C_n} \exp(\beta_j p_j + \delta_j q_j + \gamma_j s_j)}.$$

[7] A more general specification could also be developed based on a generalized extreme value distribution of the random error. For a discussion on the implications of alternative error distributions in the random utility framework, see Ben-Akiva and Lerman (pp. 126–29).

[8] This discussion follows the traditional view that travel costs and travel time are opportunity costs to the recreationist. In certain types of recreational activities (e.g., time on the water to a fishing site), this assumption may not hold.

Once the coefficients for a MNL demand share model such as equation (13) have been estimated for a sample of anglers' site choice decisions over a fixed period of time (season, year), the model can be used to calculate the expected benefits of a new artificial habitat site for each angler in the sample. Following Small and Rosen's framework for welfare analysis with discrete choice models, the new site benefits can be calculated as:

$$(14)\ CV_n = 1/\beta[\ell n(\sum_j \exp(\beta_j p_j + \delta_j q_j)) - \ell n(\sum_{j'} \exp(\beta_j p_{j'} + \delta_j q_{j'}))],$$

where p_j, q_j are the initial matrices of price and quality characteristics defined in the choice set and $p_{j'}$, $q_{j'}$, are the new matrices of price and quality characteristics after the addition of the new site. This benefit measure is defined on a per-trip basis for each angler. The seasonal or annual benefits would be determined by multiplying the per trip benefits by the expected total number of trips during the period.[9]

Although the MNL TCM is a consistent utility-theoretic means to integrate site substitution effects and zero visit solutions in a multi-site framework, the model is limited by the independence of irrelevant alternatives (IIA) property. That is, the relative choice probabilities of two sites depend only on the utilities of the site choice set. The implication of the IIA property is that the site demand cross-elasticities are equal (constant elasticity of substitution). This restriction precludes the possibility of differential rates of substitution across sites which may lead to overestimates (underestimates) of the reallocation of trips to a new site from existing sites that are very dissimilar (similar) to the new site.

This restriction can be a serious problem in benefit estimation for new artificial habitat. To illustrate the problem, consider the situation of artificial habitat siting for states on the Gulf of Mexico. Because the gradient on the continental shelf is very flat and water depths are less than 30 feet within a few miles of shore, it is usually necessary to locate artificial habitat sites several miles (more than 5 nautical miles) offshore to minimize hazards to maritime shipping traffic and to comply with international treaties (U.S. Department of Commerce). This constraint on habitat siting suggests that offshore anglers as opposed to bay or near-shore anglers are more likely to benefit from a new habitat site. But the proximity to shore will be important since some near-shore anglers may go offshore if they perceive that success rates are higher at the new site than at near-shore sites. This situation suggests that offshore sites might be considered as one group of "similar" alternatives and near-shore sites as another group of "similar" alternatives. The angler's choice of sites can then be represented as a hierarchical choice from two or more groups of similar alternatives rather than as a choice from one group of alternatives as in the MNL TCM.

This hierarchical structure for the angler's site choice decision is depicted in Figure 1.

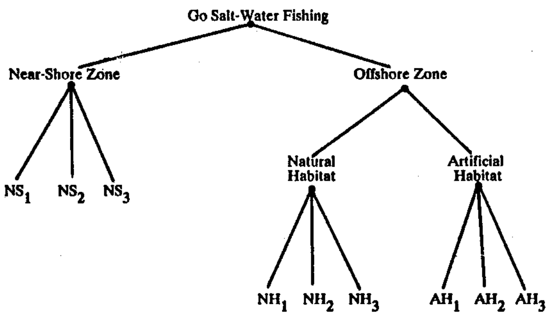

Figure 1. Hierarchic Choice Diagram for Fishing Site Selection. (For Simplicity, Only Three Site Alternatives Are Shown for Each Lower Branch.)

Given the decision to go salt-water fishing, the choice of offshore or near-shore zones provides a transition to the next decision node of artificial or natural habitat with the final node the choice of sites. Each transition node in the hierarchy is defined by the group of alternatives below the node and each transition is a progression toward groups of similar alternatives. The value of the alternatives

[9]It should be noted that the MNL demand share approach to new site benefit estimation is not fully consistent with utility maximization. Since the total number of trips decision is exogenous, the welfare effects are limited to trip reallocations across sites within a region. In coastal regions where a new artificial habitat site would not cause a major change in anglers' existing fishing choice site set, this constraint is not a serious limitation of the model. But if artificial habitats are used to rebuild a declining fishery or to develop a new fishery, this approach will underestimate new site benefits. Note, however, that this latter situation is also a serious problem in other multi-site TCMs because the site demand equations are based on *existing* site visitation patterns and the models do not explicitly consider anglers' decisions whether or not to participate in the regional fishery.

below each node is the "inclusive value" of the choice subset and can be measured by the formula:

$$(15)\quad I_J = \ln\Big(\sum_{j \in J} \exp(V_j)\Big),$$

where V is the systematic component of utility and J denotes a group of similar site alternatives included in the angler's choice set. The inclusive value concept can be incorporated into a discrete choice model using nested multinomial logit (NMNL) estimation. The first stage of a two (or more) stage estimation procedure can be written as:

$$(16)\quad P_n(j|k) = \frac{\exp(V(q_j, s_j))}{\sum_{j' \in J} \exp(V(q_{j'}, s_{j'}))},$$

which is a MNL analysis across all site choices conditional on the choice of inclusive site group k, $k \in K$. The second stage models the choice from groups of similar alternatives using the inclusive value and can be written:

$$(17)\quad P_n(k) = \frac{\exp(V(q_k, s_k) + I_k)}{\sum_{k' \in K} \exp(V(q_{k'}, s_{k'}) + I_k)}.$$

This stage can also be estimated using MNL analysis (Maddala, 1983). Appropriate functional forms for the indirect utility function V can be specified for each stage in the hierarchy.[10]

The estimated coefficients from the NMNL model can also be used to calculate the expected benefits of a new artificial habitat site with the formula:

$$(18)\quad CV_n = \frac{\Big[\Big(\sum_{k \in K_n} \exp(V_k^2(\cdot) + I_k^2)\Big) - \Big(\sum_{k \in K_n} \exp(V_k^1(\cdot) + I_k^1)\Big)\Big]}{\sum_{k \in K_n} \phi_n \exp V_k^2(\cdot) + I_k^2},$$

where V is the indirect utility function; the superscripts 1, 2 denote the sets of travel costs and site characteristics before and after the new site, respectively; and ϕ_n represents the compensated income effects for each individual. This is also a per-trip benefit measure which must be multiplied by the expected total trips to determine annual user benefits.

The preceding discussion has emphasized the theoretical advantages and disadvantages of alternative TCMs for new artificial habitat site benefit estimation. While these theoretical considerations are important, most often the choice of models will be limited by several practical considerations. The most serious concern is data on anglers' choices from sites in a coastal region. Panel data on anglers' site-specific choices are not collected in most state and national marine fishing surveys. Region-specific surveys could be developed, but these efforts are limited by the technical problem of defining specific marine fishing sites and the budget for the analysis. In addition, the analyst may not have the econometric expertise to implement the more complicated multi-site TCMs. Finally, and perhaps most important, coastal resource managers may be willing to sacrifice precision for expediency if they understand the confidence regions for new site benefits estimated from models that do not fully incorporate substitution effects and corner solutions. Thus, empirical evidence on the performance of single and multi-site TCMs and the differences in estimated benefits can serve as a useful guide to research and application for artificial habitat planning.

A CASE STUDY

In 1985 a study was conducted of anglers who participated in marine recreational fishing in southeast Florida. A sample was selected from boat registration files in Dade County using a general stratified sampling rule with proportional allocation by zip code. Mail survey questionnaires were sent in two waves of 1800 units at six month intervals. The overall response rate was 45 percent of which 887 respondents had taken 8,179 marine fishing trips during the 12-month sample period.

The Dade County area is a highly desirable setting for a study of anglers' demand for artificial marine habitat. Since 1971 the County has organized a well-publicized artificial habitat program in which seven major sites consisting of clustered derelict vessels have been developed. These sites are located along the continental shelf at depths of 90 feet or

[10]McFadden has demonstrated that a necessary condition for equation (17) to be consistent with random utility maximization is that the estimated coefficient for the inclusive value variable lies in the unit interval. A more complete discussion on specification and estimation of the NMNL model is available in Milon.

more. The sites are not marked by buoys, but Loran coordinates are readily available from several publications and all sites can be located using shore "line-ups." Electronic detection equipment such as Loran and depth finders can be helpful in locating sites.

The survey questionnaire solicited information on the number of trips taken by each angler to specific natural and artificial habitat sites during the prior six months, the launch site used, catch data at each site, descriptive characteristics about the angler's boat, and basic socioeconomic characteristics. Of the 887 respondent anglers, 248 had fished on at least one of the artificial habitat sites during the study period resulting in 2386 trips (choice occasions) to artificial habitat sites.[11] The trip data for the system of sites revealed that from the total observations of 1736 (7 sites × 248 anglers) for number of trips per angler to each site, 540 had non-zero values.

Trip travel costs were measured from respondents' estimated average (normal seas) fuel use per hour of running time and running speed using the formula:

$$TC_{in} = ((D_{il}/RS_n) \times BFM_n \times \$2.50),$$

where TC_{in} is the cost of a trip to the i^{th} site for angler n, D is the one-way distance to the i^{th} site from the l^{th} launch site, RS is the n^{th} angler's running speed (knots) per hour, BFM is the boat fuel mileage per hour, and $2.50 is the round-trip cost per gallon of fuel. The opportunity cost of travel time was also calculated based on reported annual income (wage rates).

Catch rates for each site were calculated from reported number and weight of all fish caught (kept or released) at a site. The mean and coefficient of variation of catch per unit effort (number of anglers times number of hours fished) were calculated. Preliminary tests of number and weight catch rates as indicators of site quality (success) showed that the weight measures consistently outperformed the number measures (in terms of the predictive power of the equation), hence the latter measures are not discussed further.

Other angler-specific boating equipment, attitudinal, and socioeconomic data were collected and used to construct alternative measures of taste variables that could influence habitat and site choice. A list of the variables used for this analysis is reported in Table 1.

TABLE 1. DEFINITION OF VARIABLES IN SINGLE AND MULTI-SITE TRAVEL COST MODELS

Variable	Explanation
v_{ni}	Number of trips by the n^{th} individual to the i^{th} fishing site, i = 1 in the single site models, i = 1,..., 7 in the pooled site and MNL models, and i = 1, . . ., 13 in the NMNL model.
TC-1, . . . , TC-7	Travel cost expenses for the n^{th} individual to each of the 7 artificial habitat sites – used in single site models.
TC_{ni}	Travel cost expenses for the n^{th} individual to the i^{th} fishing site – used in multi-site models.
PUEM	Mean pounds of fish (kept or released) per unit fishing effort for the i^{th} site.
PUECV	Coefficient of variation for pounds of fish per unit effort.
EQI	Index of boating equipment: Loran, depth-finder, fish-finder, and two-way radio (0–4).
EHP	Engine horsepower of angler's boat.
BL	Length of angler's boat.
MC	Membership in sport fishing club: 1 if member, 0 otherwise.
RAC	Angler's race: 1 if Hispanic, 0 otherwise.
OP	Angler's opinion of artificial habitat productivity relative to natural habitat (scalar value from 0 to 1 with 1 indicating strong opinion that artificial habitat is more productive).
YBL	Number of years of boating experience in local waters.
Y	Angler's annual income.
AGE	Angler's age.
ONC	Dummy variable constant for offshore natural habitat – used in the site selection level of the NMNL model.
OAC	Dummy variable constant for offshore artificial habitat – used in the site selection level of the NMNL model.
AHC	Dummy variable constant for artificial habitat – used in the habitat selection level of the NMNL model.
I1	Inclusive value for the habitat selection level of the NMNL model.
OC	Dummy variable constant for offshore sites – used in the offshore/inshore selection level of the NMNL model.
I2	Inclusive value for the offshore/inshore selection level of the NMNL model.

[11]Because the sample includes only local private boat anglers, a trip was defined as a fishing day. Trips to each site were allocated on the basis of the majority of a day's activity that took place at a specific site.

ESTIMATION AND RESULTS

To evaluate the performance and benefit estimates with alternative TCMs, data from the Dade County survey were analyzed using single and multi-site TCMs. For the single site models, visit data to the most centrally located artificial habitat site (hereafter Site 1) were used to estimate angler demand. Site 1 was used by 85 of the 248 artificial habitat users, and the site catch rates were typical of the other sites.

Three different estimation methods for a single-site TCM without substitute site prices were used. Ordinary least squares (OLS) is appropriate for the subset of anglers who used Site 1, but OLS will give biased parameter estimates if the data set includes artificial habitat users with zero visits (corner solutions) to Site 1. For this case a Tobit model can be estimated. Alternatively, if the 2386 trips to artificial habitat sites are analyzed as discrete choices whether to visit Site 1, the demand for Site 1 can be estimated as a probit model. Results with these three estimation methods using a linear specification of the single site demand equation are reported in Table 2. To facilitate comparisons of different models and for ease of exposition, a linear specification is used for all single and multi-site models reported.[12]

The estimated travel cost coefficients for the single site OLS and Tobit models have the expected negative sign, but neither coefficient is statistically significant.[13] The Tobit estimation procedure had a minor effect on the significance of the estimated coefficients, and the goodness-of-fit statistics are quite low in both models. On the other hand, the travel cost coefficient in the probit model has the expected sign and is highly significant as are most of the other explanatory variables. Income is not significant in any of the equations indicating that demand for Site 1 is income independent. The goodness-of-fit statistic for the probit model is reasonably good for a binary dependent variable model.

As discussed previously, travel costs to substitute sites should be included in a single site model to minimize omitted variable bias. Single site models with substitute site prices were estimated with OLS and a seemingly unrelated regression (SUR) procedure and are also reported in Table 2. Only the demand equation for Site 1 from the SUR system is reported here; the complete estimation results are available in Milon. The number of sites included in both models was reduced from seven to four based on the results from a mean square error test (Toro-Vizcarrondo and Wallace). Symmetry was not imposed on the SUR system.

Both the substitute site OLS and SUR models perform significantly better than the single site OLS and Tobit models. The own-price coefficients are negative and significant in both models, and the signs on the cross-price coefficients indicate that the included sites are substitutes for Site 1. This is not surprising since the three excluded sites were located the furthest distance from Site 1. The SUR procedure tended to reduce the significance level of the cross-price coefficients, but the other coefficients only changed slightly. Again, income was not significant. Although the own-price coefficient is smaller with the SUR procedure, it is not possible to conclude *a priori* how this result would change benefit estimates since the benefits integral also depends on cross-price effects (see footnote 4).

Adding substitute site prices in the single site demand equation makes the model more consistent with demand theory and improves the statistical performance. But theory also suggests that the inclusion of site quality variables and a more theoretically consistent estimation procedure with zero values for the dependent variable would improve performance. The first multi-site model estimated is a

[12]Semi-log and double-log functional form specifications were also estimated for the single site models. Specification tests using a Box-Cox likelihood ratio test statistic (Maddala, 1977) generally did not reject the linear form. The test statistic was also used for the single site with substitute prices model and the pooled site model with similar results. However, comparable functional form tests for the probit, SUR demand system, MNL, and NMNL models are not readily available. The linear form is used for all models considered in this analysis because it is the most common specification used in both single and multi-site models. In addition, since heteroskedasticity has been linked to functional form considerations in TCM models (Vaughan et al.), all regression models were tested for heteroskedasticity and the equations were adjusted wherever appropriate.

[13]Specifications which included the opportunity cost of travel time as monetary and nonmonetary constraints were also estimated for both the single and multi-site models. In all cases the addition of a monetary constraint (at 1.0, 0.5, and 0.25 fractions of the wage rate) did not improve the goodness-of-fit. In a few models, including time as a nonmonetary constraint did improve the estimation results. However, this was a minority and since the inclusion of a time variable limits the comparability of different models, all single and multi-site specifications are reported with the opportunity cost of time equal to zero.

pooled site equation with site catch rates (PUEM and PUECV) included. This equation is estimated with OLS for the 540 non-zero observations on the number of visits to each artificial habitat site, and the results are reported in Table 3. The pooled site equation was also estimated with a Tobit procedure for the full set of 1736 observations (zero values included), and the results are reported in Table 3.

The travel cost coefficient is highly significant in both the OLS and Tobit estimated equations although the Tobit reduced the absolute value of the coefficient. The quality variable coefficients are also smaller in the Tobit equation but are more significant. The positive sign for PUEM indicates that anglers' trip decisions are influenced by average site catch rates. The coefficient for PUECV suggests that anglers also prefer sites with greater variability in catch rates although the effect is less significant. As in the single site models, income and socioeconomic characteristics are not significant, but the boating equipment index is a significant determinant of site visitation. While the Tobit procedure tended to improve the significance of the explanatory variables, the increased variability in the dependent variable reduced the overall goodness-of-fit.

A multi-site MNL model was estimated by considering each of the 2386 trips to artificial habitat sites as discrete choices on which of the seven sites to select.[14] The results reported in Table 3 also support the hypothesis that site quality differences are important but

TABLE 2. ESTIMATED COEFFICIENTS FOR ALTERNATIVE SINGLE SITE TRAVEL COST MODELS AND ESTIMATION METHODS

Variable	Single Site w/o Substitutes			Single Site w/Substitutes	
	OLS	Tobit	Probit	OLS	SUR
Dependent Variable	$v_{n1} > 0$	$v_{n1} \geq 0$	$v_{n1}(0,1)^a$	$v_{n1} \geq 0$	$v_{n1} \geq 0$
Intercept	1.04 (0.42)^b	0.50 (0.72)	−1.25^e (10.98)	0.19 (0.29)	0.08 (0.13)
TC-1	−2.44 (0.53)	−1.43 (1.26)	−0.08^e (11.54)	−41.62^e (3.32)	−25.97^d (2.45)
TC-2	—	—	—	33.31^d (2.37)	16.49^c (1.65)
TC-3	—	—	—	5.92^d (1.97)	11.06^e (4.09)
TC-4	—	—	—	4.73^d (2.41)	1.02 (0.62)
EQI	1.16^c (1.71)	0.54^d (2.25)	0.11^e (3.16)	0.51^d (2.27)	0.51^d (2.27)
EHP	0.01 (0.98)	0.01 (0.62)	0.01^e (7.19)	−0.01 (0.06)	−0.01 (0.05)
MC	0.32 (0.15)	0.34 (0.42)	0.41^e (4.33)	0.56 (0.78)	0.59 (0.83)
RAC	0.13 (0.06)	0.26 (0.39)	0.02 (0.24)	0.33 (0.54)	0.55 (0.91)
Y	0.0001 (0.20)	0.0001 (0.25)	0.00006 (0.05)	0.0001 (0.10)	0.0001 (0.08)
Goodness-of-Fit	0.03^f	0.05^f	0.22^g	0.24^f	0.28^h
F-Statistic	1.99	2.76	—	11.93^e	—
Chi-Square Statistic	—	—	24.57^e	—	—
No. of observations	85	248	2386	248	248

[a]The dependent variable in the single site probit model is the log of the odds of choosing site 1.

[b]Absolute value of t-statistics in parentheses.

[c]Significant at the 10 percent level.

[d]Significant at the 5 percent level.

[e]Significant at the 1 percent level.

[f]Goodness-of-fit statistic is the adjusted coefficient of determination.

[g]Goodness-of-fit statistic is the adjusted log-likelihood ratio.

[h]Goodness-of-fit statistic is determined by regressing predicted values on actual data.

TABLE 3. ESTIMATED COEFFICIENTS FOR ALTERNATIVE MULTI-SITE TRAVEL COST MODELS AND ESTIMATION METHODS

Variable	Pooled Site OLS	Pooled Site Tobit	MNL	NMNL
Dependent Varaible	$v_{ni} > 0$	$v_{ni} \geq 0$	$v_{ni}(0,1)^a$	$v_{ni}(0,1)^a$
Intercept	8.94 (1.49)[b]	−9.53[e] (4.38)	—	—
TC_{ni}	−11.19[e] (4.52)	−7.38[e] (6.86)	−871.53[e] (15.30)	−308.52[e] (16.29)
PUEM	1.66[e] (6.99)	1.04[e] (9.22)	0.03 (1.55)	0.23[e] (17.15)
PUECV	0.82 (1.36)	0.55[d] (2.14)	0.89[e] (7.34)	0.51[e] (14.51)
ONC	—	—	—	−0.35[d] (3.10)
OAC	—	—	—	−0.23[d] (2.99)
AHC	—	—	—	−1.34[d] (3.50)
I1	—	—	—	0.23[e] (16.55)
EQI	1.34[e] (6.41)	0.67[e] (7.19)	—	0.42[e] (12.67)
MC	−2.69 (0.29)	0.19 (0.05)	—	0.11 (1.12)
RAC	4.12 (0.51)	0.58 (0.19)	—	0.49[e] (5.40)
Y	0.0001 (0.45)	0.0001 (0.38)	—	−0.01[e] (6.54)
YBL	—	—	—	−0.01[d] (2.25)
OP	—	—	—	1.67[e] (11.21)
OC	—	—	—	−2.35[e] (12.14)
I2	—	—	—	0.18[e] (14.17)
EHP	0.004 (1.09)	0.004[e] (3.43)	—	0.006[e] (15.25)
BL	—	—	—	0.03 (1.51)
AGE	—	—	—	−0.01[d] (2.11)
Goodness-of-Fit	0.30[f]	0.22[f]	0.08[g]	0.24[h]
F-Statistic	52.86[e]	69.71[e]	—	—
Chi-Square-Statistic	—	—	340.38[e]	2355.25[e]
No. of observations	540	1736	2386	8179

[a]The dependent variable in the MNL and NMNL model is the log of the odds of choosing site i (or higher level choices in the NMNL model).

[b]Absolute value of t-statistics in parentheses.

[c]Significant at the 10 percent level.

[d]Significant at the 5 percent level.

[e]Significant at the 1 percent level.

[f]Goodness-of-fit statistic is the adjusted coefficient of determination.

[g]Goodness-of-fit statistic is the adjusted log-likelihood ratio.

[h]Goodness-of-fit statistic is the adjusted log-likelihood ratio for the combined nested system.

the coefficient on PUEM is significant only at the 15 percent level. Since socioeconomic variables can be included in MNL models only as alternative-specific constants (Ben-Akiva and Lerman, pp. 114–17) and there is no *a priori* reason to differentiate any of the seven sites, socioeconomic characteristics are not considered in this model. Although the price and quality variable are significant, the model's goodness-of-fit is relatively low.

The final multi-site model considered is a NMNL in which the decision structure described in Figure 1 was estimated for the 8179 trips taken by the total sample of 887 anglers. In the construction of this model, the artificial habitat sites are grouped as one set of offshore site alternatives and natural habitat sites are grouped as the other offshore alternative. Bay and shallow reef natural habitat sites make up the near-shore alternative. The determinants of choice at each transition node in the model can be represented as the sequence:

(a) Choice of site = $C_1(TC_{ni}$, PUEM, PUECV, ONC, OAC),

(b) Choice of offshore habitat = C_2(AHC, I1,EQI,MC,RAC,Y,YBL,OP), and

(c) Choice of near-shore/offshore = C_3(OC, I2,EHP,BL,AGE),

where the variables are as defined in Table 1. The NMNL model is estimated by sequential estimation so that the preferences revealed by choices at the lowest level of the hierarchy can be used to compute inclusive values for subsequent decision levels (Ben-Akiva and Lerman, pp. 295–99).

The results reported in Table 3 strongly confirm the importance of price and quality effects in multi-site fishing choices. The negative signs on the offshore site group constants, ONC and OAC, indicate that, all else equal, anglers prefer near-shore sites. The inclusive value coefficients for the offshore habitat node and near-shore/offshore node are in the unit interval, and both are highly significant, which confirms the consistency of the model with random utility maximization. In addition, the socioeconomic variables RAC and Y, while not significant in the previous models of choice among artificial habitat sites, are significant in the choice between artificial and natural offshore habitat. The significance of these variables in the more comprehsensive NMNL model reflects the broader distribution of socioeconomic characteristics across the full sample and the importance of taste factors in determining habitat preferences. Preferences for specific sites within habitat groups were not influenced by these taste factors. In addition, the sign and significance of the user-specific variable EHP suggests that the investment cost of more powerful boats acts as a deterrent to offshore fishing. The goodness-of-fit for the combined model is reasonably good given the diverse characteristics of the fishing habitats considered and the numerous other factors that could influence site choice on any given trip.

To determine annual net use benefit estimates for a new artificial habitat site, a new site was fabricated which was located two nautical miles from the existing Site 1 and had catch rates (PUEM and PUECV) equal to the average of all seven artificial habitat sites. Travel costs to the new site were computed from each angler's most frequently used launch site, and individual angler benefits were calculated with the estimated coefficients for each model using the appropriate formulas discussed above. Since the income variable was insignificant in all models except the NMNL and fishing trip fuel expenses are small compared to angler's incomes, these benefit measures can be interpreted as each angler's annual compensating variation (WTP) for the new site. Results from these computations are reported in Table 4 as different measures of the location and variability of the benefits distribution.

Considering first the single-site models, all mean values are significantly different from zero, but there is considerable variability in the distribution of benefits estimated from each model. The probit model yields the highest mean value, but this estimate is a closer match to the more statistically robust models with substitute site prices (OLS and SUR) than to the weaker models without

[14]This model can be viewed as a generalization of the single site probit analysis where the choice set included only the decision whether to visit Site 1.

[15]This result differs from that reported by Smith and Kaoru who found that the probit model produced mean benefit estimates that were lower than those from a single site without substitutes model. However, it is difficult to evaluate their results since no information about the alternative model coefficients is provided and the models had different functional forms.

substitute prices (OLS and Tobit).[15] Mean values from the OLS and SUR substitute site models are quite similar confirming Hof and King's theoretical analysis. The variability measures reflect the heterogeneity among the sample of artificial habitat users. Clearly, some anglers would receive benefits from the new site that are considerably greater than the mean, while others would not benefit at all. This heterogeneity is an important dimension of use benefit analysis that is often neglected in reported results.

Mean values for the multi-site models are also significantly different from zero, but the median equals zero in three of the four models. While the latter result is somewhat disturbing if one believes that median values are preferred for welfare analysis (e.g., Kushman), this result should be considered an illustration of the general problem of defining a representative welfare measure for a diverse user group. The pooled site Tobit model yields the highest mean value which is very similar to the means from the single site with substitute prices models. The NMNL model yields the lowest mean benefit which is expected given that the NMNL calculation includes all 887 anglers in the sample, some of whom may only fish near-shore. In addition, the choice set in the NMNL model includes all artificial and natural habitat sites so that the addition of one new site is less important given the availability of substitute sites. These sample estimates can be extrapolated to the angler population by accounting for the different group of observations used with each model (Milon, pp. 56–60).

Finally, it should be noted that the estimated benefits from the multi-site models which incorporate site quality are not radically different from the single-site model results. This may be a product of assuming new site quality would be equal to the average of all existing sites. But it does suggest that location may be the dominant determinant of new site benefits (at least for new sites that are not atypical for the coastal area).

DISCUSSION AND CONCLUSIONS

Artificial habitats provide an innovative means for coastal resource managers to maintain and enhance fishery stocks for recreational users. As part of the new site planning

Table 4. Mean Distribution of Angler's Expected Annual Net Use Benefits for a New Site With Alternative Travel Cost Models

Model	Mean	Median	Std. Deviation	Lower Bound[a]	Upper Bound[a]
Single Site—OLS	\$ 7.41[c] (2.22)[b]	\$ 0.00	\$26.92	\$0.00	\$63.85
Single Site—Tobit[e]	7.91[d] (10.41)	4.03	11.96	0.00	36.47
Single Site—Probit	38.59[d] (30.24)	10.23	62.34	0.00	163.64
Single Site with Substitute Prices—OLS	20.55[d] (4.49)	6.09	72.58	0.00	91.01
Single Site with Substitute Prices—SUR	18.78[d] (5.04)	6.31	58.81	0.00	85.54
Pooled Site—OLS	9.57[d] (3.45)	0.00	64.49	0.00	25.19
Pooled Site—Tobit[e]	20.41[d] (2.92)	0.00	90.40	0.00	24.32
Multinomial Logit	6.15[d] (8.01)	0.00	31.55	0.00	27.55
Nested Multinomial Logit	1.80[d] (20.96)	1.07	2.32	0.00	5.91

[a]The lower and upper bounds of the distribution of individual angler's benefits are defined as the 5th and 95th percentile, respectively.

[b]Absolute value of the t-statistic for H_0: $\mu = 0$ using a one-tailed t-test are reported in parentheses.

[c]Significant at the 5 percent level.

[d]Significant at the 1 percent level.

[e]Benefit estimates with the tobit models are derived with the latent variable, potential visits, for all anglers in the sample (Maddala 1983, p. 160).

process, both single and multi-site TCM models are feasible tools for estimating the expected economic use benefits. The choice of a particular model will depend on several factors. First, the variety and number of marine habitats that already exist in the coastal area are important. Multi-site models are more appropriate for areas that already have artificial habitat sites and diverse types of natural habitat. Second, the significance of changes in fishing success as part of the site development plan is also relevant. Alternative material deployment configurations that could influence the type and catch rates of species caught (e.g., bottom-dwelling or surface-feeding fish) can be properly evaluated only in a multi-site model. Finally, one cannot overlook the fact that data collection and statistical estimation for multi-site models are more costly. The resource management agency and the analyst should consider the tradeoff between cost and the completeness of the TCM model in light of the extent to which use benefit information will influence the siting decision.

The results from this analysis provide information to guide the model selection decision. The multi-site models indicate that substitute site price and quality effects are important determinants of site choice. The poor performance of the single site without substitute prices OLS and Tobit models suggest that these models have limited usefulness in areas where substitution alternatives exist. However, adding substitute site prices to the single-site model does provide a relatively simple way to address this problem and yields results that are consistent with the more data-demanding SUR demand system. The NMNL model which incorporates substitution, quality, and corner solutions is statistically robust and offers the most comprehensive framework to evaluate the full range of substitution and quality effects across diverse habitats and types of anglers.

The estimated use benefits for the hypothetical new site from the alternative TCM models illustrate that there is considerable variability in the expected benefits for individual anglers. Moreover, this variability does not necessarily decrease with increasing complexity in the model. This suggests that, regardless of the model used, the choice of a statistical indicator (mean, mode, etc.) for the expected benefits to a "representative" angler could have a significant impact when the sample results are extrapolated to the population. Given the current state of the art in recreational demand modeling, prudence would suggest that the results from several TCM models and statistical indicators should be considered in the new site planning process.

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